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The price of wind power generation in Iberia and the merit-order effect

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ABSTRACT

Renewable energy generation depresses electricity spot prices, which is often used as argument to justify incentives provided to renewables. In the so-called "merit-order effect", renewable power reduces the load available for conventional power and displaces higher marginal cost generation out of the market. In this study, we estimate the value of the "merit-order effect" due to wind power generation in the Iberian market, in the period between 1st January 2008 and 31st October 2016. This value, representing consumers' potential cost savings, is compared with the direct costs of the financial incentives in Portugal and in Spain.

The accumulated "merit-order effect" amount is estimated to be 26.1 billion €, whilst the total values for the financial incentives reported is 23.9 billion €. The value of the "merit-order effect" explains the existing lower returns by conventional generation and might have additional impacts on future RES projects, subject to normal electricity market risks.

Keywords:

Merit-order effect;
Wind power;
Renewables financial incentives;

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1. Introduction

Electricity spot markets rank electrical energy suppliers through the so-called "merit-order" of generators, depending on their marginal costs. Renewable energy source electricity generation (henceforth referred to as RES-E), having high capital costs and small operational costs, generate as much electrical energy as the applicable renewable resource available, depressing electricity spot prices significantly [1].

The changes in the European electricity systems are profound and ongoing. New challenges arise from the high level penetration of RES-E, both in the technical sense and in the market design, due to the known RES-E intermittency and non-dispatchability [2].

Simultaneously, electricity markets in Europe are being restructured in face of a number of European policies intending to guarantee the supply of electricity, reduce costs, foster competition, ensure security of supply and protect the environment [3]. Alongside, unbundling and privatisation of the electricity supply industry has been achieved in most of the EU Member States, together with the creation of independent national regulatory agencies, and introducing competition at the different market levels [4]. Energy-only markets remunerate electrical energy, based on the traded volume and price. Therefore, increasing RES-E create a depression in spot electricity prices, due to the "merit-order effect" of zero marginal cost bidding, and diminishes the available load for the remaining non-zero bidding technologies [5].

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Lower spot electricity prices are often used as argument to justify incentives provided to renewables; however, a number of challenges are created related with failure of investment signals, capital cost recovery and other market design issues. Additionally, in most cases, savings are not appropriated by consumers due to the pass through of renewable incentives in electricity bills. In the so called "merit-order effect", renewable power bids shift the aggregated supply curve to the right, reducing the load available for conventional power (the "residual load") and displacing high marginal cost generation out of the merit-order [6–8]. Therefore, the electricity wholesale market fails to provide incentives to sustain adequate generation capacity, the "missing money problem". This "missing money problem" not only impacts conventional generation, but also renewables, if fully integrated in the spot electricity market and exposed to market risks. There is a financial transfer from the wholesale market through the "merit-order effect" to end-consumer savings. However, end-consumers bear the costs of RES-E financial support mechanisms through additional tax or directly in the electricity bill [6, 9–12]. Currently, most of the RES-E projects are financed through some kind of support mechanisms, such as, investment subsidies, tax credits, low interest loans, feed-in tariffs or feed-in premia (for a more comprehensive list and description of the support mechanisms used, the reader can refer to [13–16]).

In this study, we estimate the value of the "merit-order effect" due to wind power generation in the Iberian electricity market between the 1st of January 2008 and 31st of October 2016 and compare this value, which represents consumers' potential cost savings, with the direct costs of the financial support mechanisms for RES-E. The computation of the "merit-order effect" is done by estimating the new clearance price and energy quantities that would be achieved in the wholesale electricity market in the absence of wind power. Our methodology is based on real bids and on a simple clearing price calculation, whilst Sensfuß et al. [6] used simulated spot electricity prices through an agent-based model and Felder [7] just established a methodology to calculate the "merit-order effect". Moreover, our calculation was made for Iberia as an integrated spot electricity market for a time span of almost 8 years. Ultimately, the goal is to verify if the amounts transferred from the wholesale electricity market are adequate to finance the RES-E support mechanisms.

In Section 2 we present a literature review, followed by the data and methods used in this study in Section 3. The results obtained and associated analysis is presented in Section 4 and a brief conclusion can be found in Section 5.

2. Literature review

2.1. The rising importance of RES-E

The impact of RES-E financial support on end-consumer electricity prices has been evaluated in several studies without any common conclusions. For example, in Australia, Gerardi and Nidras [17] found that the RES-E financial support decreased retail electricity prices, whilst Roam Consulting [18] calculated an increase of 5% in 2015. For some European Member States, Silva and Cerqueira [10] estimated that an increase of 1% in RES-E share of demand would increase 1 to 1.8% end-consumers' electricity price. For Spain, Costa-Campi and Trujillo-Baute [19] found that, at an aggregate level, an increase of about 9% in total production under the FIT system leads to a fall of 2.61% in the wholesale price and an increase of 4.35% in the FIT cost, which results in a 0.042% increase in the average retail price of final industrial consumers.

Europe's ambitious target of 20% renewable energy sources in 2020 (or 33% renewable energy sources for electricity) prompted several member states to propose highly attractive support mechanisms. Denmark, Germany, Portugal, Spain, Italy, Ireland, and Belgium, for example, have seen their share of renewable energy sources, mainly in wind and solar, increase drastically in a few years.

Among all renewable energy sources, wind and solar were the ones subject to the strongest research and development, based on clusters established in some regions of Europe. All these efforts required financial instruments like feed-in tariffs, feed-in premia, fiscal incentives, tax exemptions and other [14, 20–22]. These financial instruments provided an initial incentive to invest in non-mature RES-E technologies.

One of the most successful examples of RES-E incentive policies can be found in Denmark, where a partnership between public and private institutions was established [23]. After a strong energy policy shift, Denmark managed to reach 20% RES-E share in 2008 [24, 25]. Since then, RES-E share in Denmark continued to rise, reaching, in 2015, 41.4% of wind power and 13.8% of essentially biomass. This level of RES-E is possible due to the cross-border interconnections that allow electricity trading in the Nord Pool and smooths production profiles.

In Iberia, both Portugal and Spain had an outstanding increase in wind power, whilst, in spite of the existing solar potential in Portugal, only Spain developed significantly solar power. Moreover, hydropower generation share is historically high in Iberia. In Germany, the "*Energiewende*" policy prescribed the end of nuclear power and the growth of RES-E to replace fossil generation. In result, Germany has currently the largest wind and solar power in Europe with 40.5 GW and 38.2 GW of installed capacity, respectively [26].

With the recent technology developments, wind and solar power became mature. With decreasing investment costs, the existing financial instruments became obsolete. Furthermore, the financial burden of RES-E incentives is significant and policies are being reviewed throughout Europe. In Germany and Spain, for example, actions were already taken to reduce RES-E financial support [27, 28].

2.2. The Merit-order effect

Electricity trading in Europe is currently based on several types of markets: exchanges or spot markets, bilateral and over-the-counter markets, ancillary services markets, and retail markets [29]. Presently, electricity exchanges in Europe trade volumes of electricity at a clearing price, matching supply and demand. All market agents bidding lower than the clearing price, trade their bidding volumes at that price. These exchanges have day-ahead sessions for each of the day period (usually for each of the 24 hours) and intraday sessions to provide a first level for the electrical system balance. The electricity market price clearance is done for a specific geographical area, which depends not only on national borders, but also in some cases on internal transmission capacity, reflecting electricity flow constraints and allowing for distinct price signals in each area (e.g. Sweden with four bidding areas). In Europe, spot electricity markets bidding areas are then joined through a market coupling/splitting mechanism, where bidding areas with lower prices export electricity to markets with higher prices through the interconnections. If the interconnection capacity is large enough to accommodate the exported electricity flows (without congestion), then the price is the same in both markets, otherwise market splitting occurs and two regional market prices are cleared [30].

On the supply side, the so-called "merit-order" of generators depends on marginal costs of each market agent bidding in the spot electricity market. These marginal costs of market agents depend mainly on the generation technology in their electricity production portfolio and related operational costs [31]. Each generating plant operational cost presents several components like fuel, variable consumables, variable maintenance, emissions and transmission costs. Generally, in the bottom of the supply curve one can find market agents bidding electricity produced with low marginal cost technologies, like nuclear or hydro. This is the also the case of renewable generation technologies with high capital costs and small operational costs, which will produce as much electrical energy as the applicable renewable resource available [22]. Therefore, electricity spot prices are significantly dependent on the available renewable electrical energy in the market, given that renewable power comes first in the merit-order, lowering spot electricity prices and potentially causing zero, or even negative, price periods in the case when demand is fully covered [7, 32, 33].

Confirmation of the above is obtained through the analysis of data extracted from the Iberian electricity spot market (OMIE), from the 1st of July 2008 to the 15th of March 2014, where the volume of bids at zero price is found to be positively correlated with the available RES-E power generation (correlation factor of 0.733 with a 95% confidence interval [0.728, 0.737]), as seen in Figure 1. Clearly, the spot electricity price is also correlated with the volume of bids at zero price; however, negatively (correlation factor of –0.413 with a 95% confidence interval [–0.420, –0.406]), with significant amount of market periods with zero spot electricity price (Figure 2), confirming the statements of several authors [7, 32, 34].

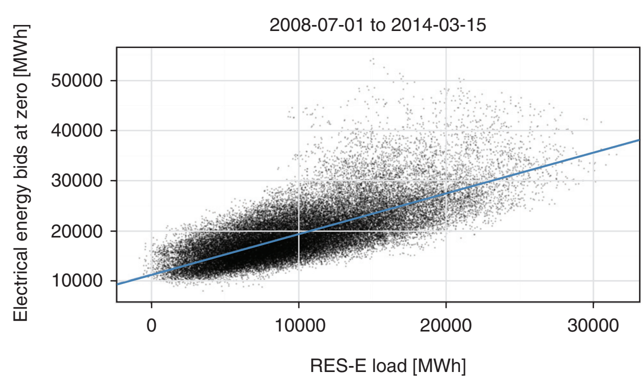

Figure 1: OMIE electrical energy bids at zero [35] vs. renewable power generation [29, 36, 37]

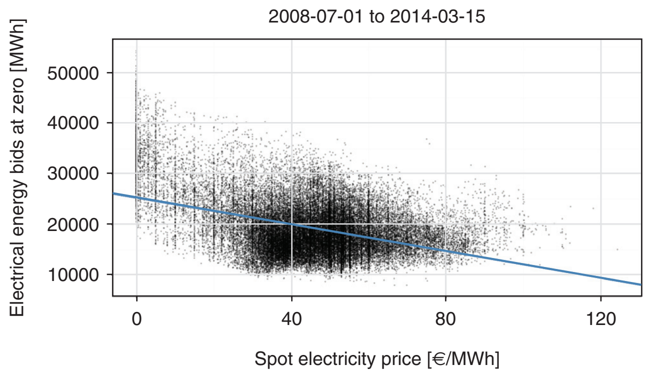

Figure 2: OMIE electrical energy bids at zero vs. spot electricity price [29, 35]

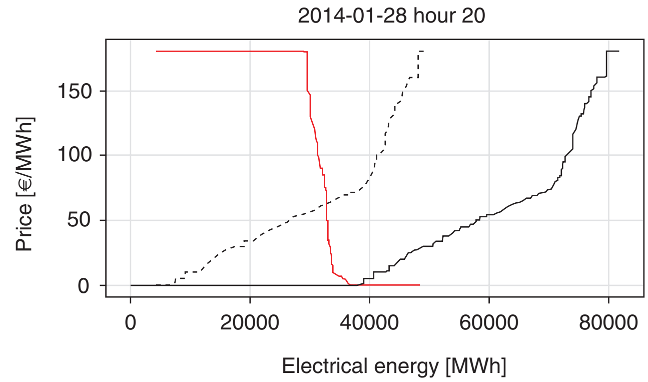

Figure 3: OMIE aggregated demand and supply curves (with RESE bids - solid and without RES-E bids - dashed) [29, 35]

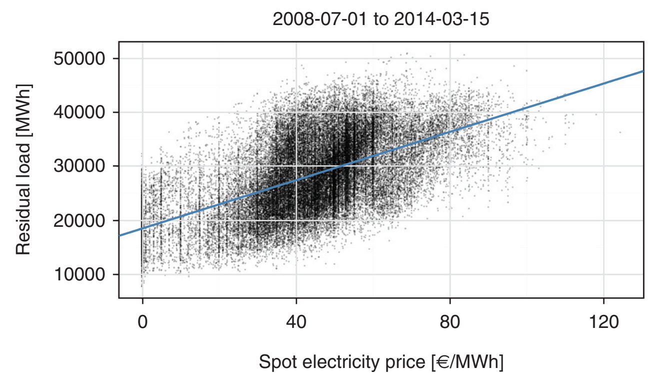

Figure 4: OMIE residual electrical energy vs. spot electricity price [29, 35]

Renewable power bids shift the aggregated supply curve to the right and displace high marginal cost generation out of the merit-order. This, as abovementioned, is the so-called "merit-order effect", causing a reduction in the spot electricity price and reducing the load available for conventional power, or the so-called "residual load" [6–8]. The residual load is positively correlated with the spot electricity price (correlation factor of 0.553 with a 95% confidence interval [0.547, 0.559]), as observed for the OMIE in Figure 4. Figure 3 shows the aggregated supply and demand plot for the hour with the highest RES-E generated in Iberia in the considered data sample extracted from the OMIE (28th January 2014, hour 20). Considering the aggregated supply curves with, and without RES-E bids, it is possible to compute the merit-order effect, which for this hour alone amounted to 2.1 million Euros.

Felder (2011) actually stated that by providing incentives to "out-of-market" technologies, such as most renewables, spot electricity prices would fall to zero. Lower spot electricity prices are often used to justify the incentives provided to RES-E; however, they create a number of challenges related with the investment signals and capital cost recovery. Additionally, wealth fails to shift from producers to consumers [6, 9, 11], as in most cases, savings are not obtained by consumers due to the inclusion of renewable incentives in their electricity bills.

Additional concerns and challenges of high generation shares of RES-E are reported both in the technical sense and in the market design [29]. On the technical sense, it is possible to list the following: generation variability and uncertainty, adequate transmission capacity, flexibility and standby of dispatchable generation, electrical system regulation and frequency control, demand-side response, RES-E curtailment, energy storage, adequate transmission grid and cross-border interconnections [38–41]. Concerning the market design, one can enumerate electricity market integration, cost allocation of transmission grid and cross-border interconnections, intraday and reserve power markets, RES-E financial support schemes and capacity support mechanisms [2, 40, 42, 43].

Vis-à-vis market design, the reduced residual load and the depressed spot electricity prices, along with the technical challenges and costs of peaking conventional thermal power plants, are currently stressing utilities income [44]. The failure of the market to provide signals to investors for adequate generation capacity levels is the so called "missing money problem". This "missing money problem" not only impacts conventional generation, but might also affect RES-E market integration, if exposed to normal market risks. The development of RES-E to comply with the increasing EU targets (45% RES-E generation share by 2030), might only be viable if market design is carefully assessed and financial incentives kept, notwithstanding reasonable levels depending on technology maturity.

2.3. The challenge of market integration

With the incentives provided coming to an end or reduced substantially, the renewables integration in the electricity market and their subsequent exposure to market risks becomes a prominent issue. It is unanimous throughout the literature that flexibility is the key to obtain an efficient electricity market with high levels of renewable generation. In the literature several strategies to achieve this flexibility are proposed: implementation of a premium system to allow RES-E to recover investment; implement demand-side response; develop storage technologies; integrate spot, balancing and ancillary electricity markets; improve grid flexibility through reinforcing transmission and distribution networks; flexible and efficient generation mix; capacity guarantee mechanisms; subsidies for electrification of transport and heating [29, 33]. Policy makers should tailor the mix of strategies that fits best each regional specificity.

3. Data & methods

Real bid data was extracted for electricity offers and demand from the OMIE website [35], from the 1st of January 2008 until the 31st of October 2016. Furthermore, wind power generation was obtained from Redes Energéticas Nacionais [36] and Red Eléctrica de España [37], for the same period.

A new equilibrium for electricity price and quantity that would be achieved in the wholesale Iberian electricity market in the absence of wind power is estimated to obtain the “merit-order effect”. Figure 6 illustrates this in a stylised way where we can observe the difference in supply curves, with and without wind power electricity, solid and dashed lines respectively. Without wind power generation, the supply curve shifts to the left, causing an increase of the market clearing price. The consumer surplus is thus increased with higher wind power in the wholesale electricity marginal market and the “merit order effect” is the difference between both consumer surpluses, with and without wind power.

A simplified clearing price algorithm, without considering interconnection congestion, market splitting or grid constraints, is used to re-calculate the spot electricity market quantities and price. This algorithm is used to calculate a simplified clearing price with all the bids extracted from the OMIE electricity spot exchange. This initial clearing price is then compared with a second clearing price, considering the absence of wind power, therefore a higher price depending on the amount of wind power bids found in each particular hour. This simplified algorithm might present some limitations, namely the calculated price does not follow the algorithm used in the OMIE, therefore, clearing prices will certainly be different from the obtained in the real spot market. In fact, the restrictions imposed in the real spot price calculation increase the price in relation to the simple matching of supply and demand bids (Figure 5). Nevertheless, given that our objective is to find price and energy quantity relative differences, the assumed simplification may be acceptable.

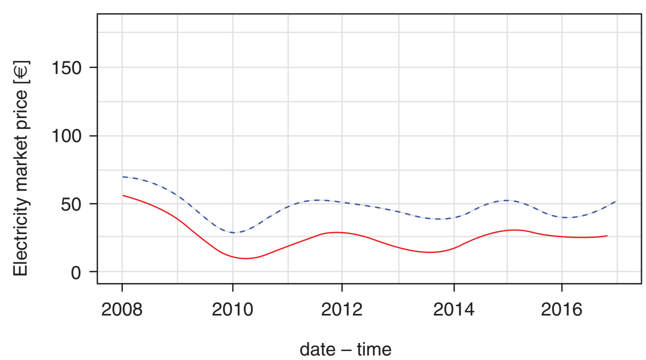

Figure 5: Electricity spot prices (simple clearing – solid and OMIE algorithm – dashed)

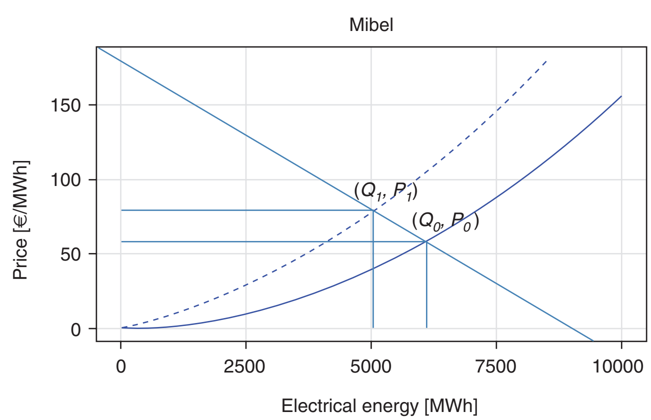

Figure 6: Aggregated demand and supply curves (with wind power – solid and without wind power – dashed)

The "merit-order effect" is then calculated for each hour of the considered data sample, following Felder, (2011) and Sensfuß et al., (2008) through the following equation:

$$merit\ order\ effect = \sum_{hour} (P_1 - P_0)Q_1 + \frac{1}{2}(P_1 - P_0)(Q_0 - Q_1) \quad (1)$$

where, (Q_0, P_0) is the estimation of the initial market equilibrium energy and price with all market bids (thus, including wind power) and (Q_1, P_1) the estimation of the new market equilibrium energy and price considering all market bids with the exception of wind power bids (thus, without wind power). Consequently, a consumer surplus difference is calculated (the reader should bear in mind that these consumers are wholesale market agents, e.g. electricity retailers or big industrial consumers).

The financial cost of wind power financial incentives is also computed and then compared with the "merit-order effect". The annual average wind power financial incentives in Portugal and in Spain are inhere used. These incentives are calculated based on the annual total amount paid to wind power divided by the total wind generation. Therefore, the estimation of the amounts spent in wind power financial incentives in each hour, is calculated based on the hourly wind power generation in each country, multiplied by the annual average values for the financial incentives (Table 1). The incentives are reported by each country energy regulatory agency, i.e., ERSE in the Portuguese case [45] and CNMC in the case of Spain [46].

4. Analysis and Results

The estimation of the "merit-order effect" was made for each hour of the considered data sample. This is illustrated in Figure 7 where it is observed that the calculated clearing price without the wind power bids is higher than the one calculated with all the bids. An expected negative

Table 1: Wind power average financial incentives in Euros/MWh [45, 46]

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Portugal	94.70	93.70	91.60	93.50	96.60	93.90	93.46	94.11	96.28
Spain	100.41	80.09	78.01	87.38	84.83	77.23	58.95	70.7	53.45

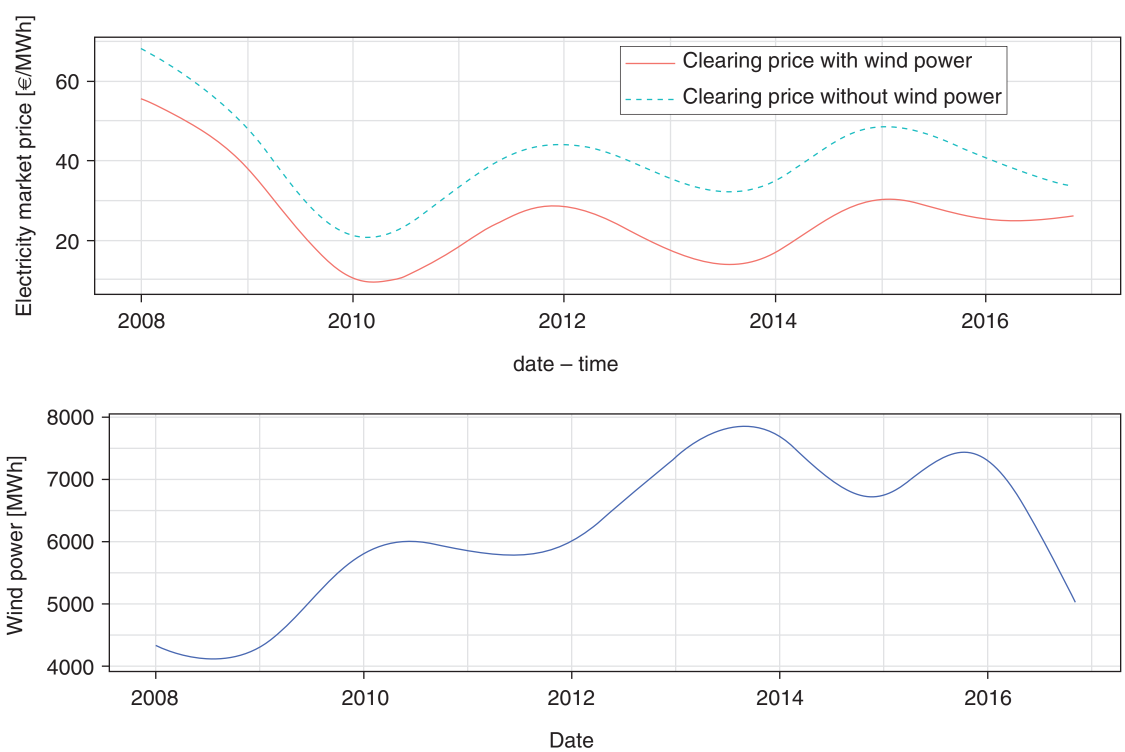

Figure 7: Electricity market clearing prices with and without wind power

correlation between the "merit-order effect" and the residual load (in our study the residual load is assumed to be the load without wind power) was confirmed (Figure 8), supporting the "merit-order effect" theory. This is corroborated by the positive correlation found between the "merit-order effect" and wind power (Figure 9).

By adding all the discounted "merit-order effect" of the hours considered in the sample, the accumulated "merit-order effect" amount is estimated to be 26.1 billion € (annual amounts are presented in Table 2). All amounts were discounted back to the year 2008 using the 3 months Euribor interest rate (daily rates obtained from Datastream [47]). The value of the "merit-order effect" represents the increasing wholesale consumer surplus and explains the decreasing returns by conventional generation. The decreasing returns obtained by wholesale electricity suppliers may also impact future RES projects, which might be subject to normal electricity market risks.

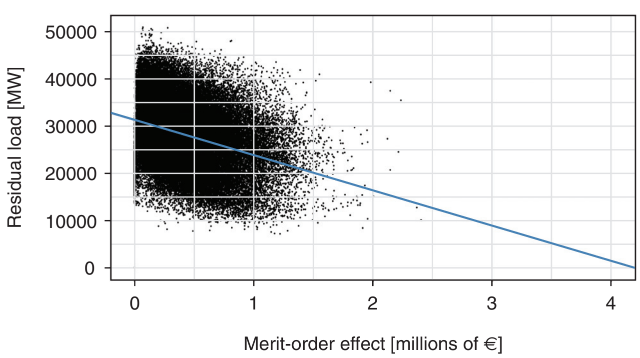

Figure 8: Merit-order effect vs. Residual load

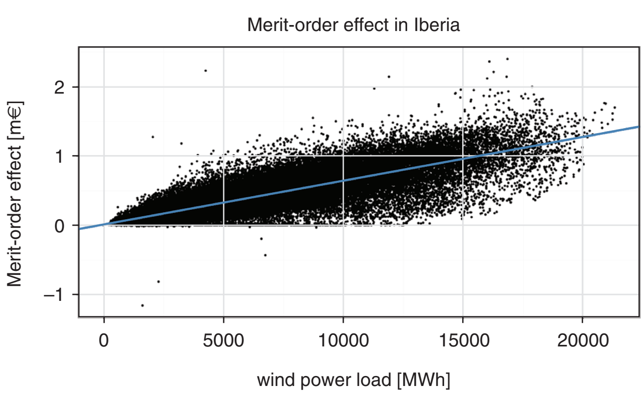

Figure 9: Wind power load vs. "merit-order effect"

The increasing surplus observed in the wholesale electricity market does not necessarily mean that the retail end-consumers obtain savings. In this study, the amount of wind power financial incentives throughout the considered sample period is estimated to be 23.9 billion €, which is lower than the calculated "merit-order effect".

This result is confirmed by previous similar analysis conducted in the literature, in particular, with respect to Spain [19, 48, 49], with respect to Germany [6] and to several EU countries [10].

5. Conclusion

The lower wholesale electricity prices are used quite often as argument in favour of RES-E. In fact, the "merit-order effect" created by renewable generation and associated lower spot electricity prices, is often used to justify the incentives provided and according to the results obtained, the value estimated for the financial incentives is lower than the merit-order effect. However, in most cases, savings are not obtained by end consumers due to the inclusion of general RES costs in electricity bills [6, 9–11]. Additionally, a number of challenges are created related with the failure of investment signals and capital cost recovery, causing the so called "missing money problem". The missing money problem not only impacts conventional generation, but also renewables, if integrated in the spot electricity market and exposed to normal market risks. Without financial support and with the depressed short-term marginal pricing from an "energy-only" market, capital cost recovery would be problematic. Thus, investment in renewables can be at risk, depending on the continued existence of financial incentives. Additionally, end-consumers have to support the additional costs created by the incentives to wind power and renewables in general.

In this study, we conducted the analysis considering the fully integrated Iberian electricity system and not Portugal and Spain separately. Also, this article constitutes a longer-term analysis than those currently available in the literature, which is an important aspect to consider as RES-E incentives promote producers' investments with long term contracts, having financial

Table 2 – Annual calculated merit-order effect [million Euros 2008]

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Merit-order effect	2920	2127	2617	2627	3182	3974	3616	3198	1901

implications to the electricity market. It is demonstrated that the wholesale consumer surplus increase is higher than the financial incentives provided to wind power generation. A proper market design would transmit these benefits to end-consumers.

However, the existing electricity market design is not providing the necessary signals to investors, creating an uncertain future with respect to adequate available generation capacity. Policy makers have to address this issue adequately, either by prolonging financial incentives to renewables (in spite of the recognized maturity), capacity payments to dispatchable power generation, or by any other design change to provide adequate signals for existing and new generation capacity, renewable or not. Debate is ongoing between all stakeholders and needs to be completed, otherwise a supply capacity shortage can be reached in the near future, endangering the required security of supply.

Aknowledgements

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