Market (In)efficiencies under Two-Way CfDs: An Empirical Analysis of UK Offshore Wind Farms

[Melita Van Steenberghe, UGent, +32476663703, melita.vansteenberghe@ugent.be]
[Marten Ovaere, UGent, marten.ovaere@ugent.be]

Overview

In July 2024, the European Union (EU) adopted the reform to the electricity market design to achieve climate neutrality by 2050. In this reform, the EU emphasizes the role of **two-way contract for difference (CfDs)** as a subsidy scheme in supporting the development of renewable energy power plants (European Commission, n.d.). CfDs provide price stability for renewable energy generators by guaranteeing a fixed "strike price" for electricity generated – reflecting the cost of investment. If the day-ahead (DA) electricity price is lower than the strike price, the government covers the difference. Conversely, if it is higher, the power plant returns the difference. This subsidy scheme reduces revenue volatility and encourages investment in clean energy technologies. However, it should also ensure that CfD generators operate and participate efficiently in the energy markets and react to market signals. In recent years, several EU Member States have already implemented CfD schemes to promote renewable energy development. The United Kingdom (UK), however, has been using CfD schemes since its Electricity Market Reform in 2014, making it an ideal case for studying the potential (in)efficiencies and providing guidance to EU Members States.

While there has been extensive research done on renewable support schemes studying the (in)efficiencies by means of (small-scale illustrations and large-scale) simulation and equilibrium models, recently recapitulated by Meus et al. (2021), to our knowledge, **there is no ex-post empirical evaluation of support mechanisms' (in)efficiencies in practice**, especially on CfDs. This paper studies and estimates the empirical importance of (in)efficiencies of the CfD subsidy scheme, both in the DA and imbalance energy market of offshore wind farms in the UK.

On the **DA market**, generators do not always offer the most efficient generation. One of the reasons for this inefficiency is the subsidy schemes that tend to lead to market distortions and influence generation. When a subsidy offered by the government is unrelated to the wholesale price, power plants will produce and inject energy into the market even when this goes against market price signals. To have an efficient energy market, it is important that power plants only supply energy when the market signals a need for energy. Suggesting that **generation should follow the market price signals to be efficient**, producing when demand is high and prices are positive, and curtailing when there is oversupply and prices become negative. However, generators with fixed support schemes (such as CfDs) may still benefit financially even with negative prices. To partially account for this, the UK implemented the **six-hour rule**, which states that when prices are negative for six or more consecutive hours, no CfD payment from the government will be made. This should create a strong incentive for curtailment.

On the **intraday and balancing markets**, CfDs can introduce significant distortions due to their reliance on the DA market prices and the actual electricity generation. Once the DA market auction closes, generators know their hourly CfD payment, which they then can consider as an opportunity cost. This can have significant implications for the intraday and the balancing markets. During **high-DA price periods** (DA price > strike price), CfDs can create an incentive for generators to curtail generation to avoid CfD payments, even when imbalance prices are positive. If the intraday or imbalance price drops below the DA price during high-DA price periods, it is rational for generators to curtail output and buy the electricity they previously sold at DA prices back on the intraday market to maximize revenues. Such behaviour could lead to a reduction in the available low-carbon and low-cost energy supply, potentially driving up intraday prices (Schlecht et al., 2024). During **low-DA price periods** (DA price < strike price), the situation reverses. Generators can incorporate the CfD payment into their optimal intraday bids, curtailing only when the imbalance price falls below the CfD payment - even when imbalance prices are zero or negative. This behaviour can lead to inefficient market bids that fall below their variable costs but also further reduce already low prices (Schlecht et al., 2024)

We study how CfD offshore wind farms in the UK respond to market signals under different price scenarios, including prolonged negative-price periods (six-hour rule) and the imbalance price. **Knowing the size of these (in)efficiencies is important for policymakers designing subsidy schemes that balance price-stability for renewables with efficient market participation.**

Methods

We analyse a panel dataset of offshore wind farms in the UK (2017-2024), incorporating hourly generation data on Balancing Mechanism Unit (BMU) level (Elexon, n.d.-a), day-ahead prices (LCCC, n.d.), and imbalance prices

(Elexon, n.d.-b). The dataset allows us to study both CfD and non-CfD offshore wind farms, such as those operating under renewable obligations (ROs). On average, we have 23.6 BMUs per year.

To estimate the difference in efficiency between offshore wind farms under different support mechanisms, we make use of state-of-the-art econometric approaches, including **multiple regression models**, **instrumental variable (IV)**, and **difference-in-differences (DiD)** methods. These methods together allow for the exploration of causal effects, with the regression model providing a baseline estimation, IV addressing potential endogeneity concerns by isolating exogenous variation, and DiD capturing differences in trends over time.

In the first part of our analysis, we examine how CfD offshore wind farms in the UK respond to the DA market price signal compared to RO offshore wind farms. Next, we examine their response during **prolonged negative-price periods** (six-hour rule). Specifically, we test whether generation significantly decreases during these 21 prolonged negative-price periods due to the loss of CfD payments compared to generation 12 hours before and after. Finally, we analyse the **balancing distortions**. During **high-DA price periods**, we study whether CfD generators curtail output even when imbalance prices are positive, and in **low-DA price periods**, we study whether CfD generators curtail output when imbalance prices are zero or negative.

Results

Our analysis reveals that both CfD and RO generators react very little to the **DA price**. This is expected as they obtain a fixed price for their generation, shielding them from market price volatility. However, using a **DiD approach**, CfD generators significantly decrease generation by 64.40 MW per BMU (p-value: 0.0010) when prices are negative for 6 hours or longer compared to RO generators. This finding aligns with the CfD contract in the UK, where generators lose their CfD payments in this event. However, despite this reduction in generation, CfD generators do not fully curtail generation to zero, while RO generators increase generation by 17.80 MW per BMU (p-value: 0.0000). These results are robust to changing the before and after period to 6,3 and 1 hour.

In the **balancing market**, we observe significant balancing distortions. The first balancing distortion occurs during **high-price periods** (DA price > strike price) and a positive imbalance price. We find that if the imbalance price is larger than the difference between the DA price and the strike price (1.32% of our dataset), CfD generators take advantage of the opportunity in the imbalance market and significantly reduce output by 42.37 MW per BMU (p-value: 0.0000), even when the market signals a need for electricity generation. By curtailing generation, they avoid the higher CfD payment and buy the generation back on the intraday market at a lower price, thereby lowering financial losses and increasing profitability. The second balancing distortion occurs **during low-price periods** (DA price < strike price) and a negative imbalance price. We find that if the imbalance price is lower than the difference between the DA price and the strike price (2.74% of our dataset), CfD generators significantly increase generation by 63.27 MW per BMU (p-value: 0.0003). This suggests that rather than curtailing generation when imbalance prices are zero or negative, they only curtail if the CfD payment no longer covers the negative imbalance price. This behaviour indicates that CfD generators incorporate the CfD payment into their optimal bids and thus ignore balancing market signals.

Conclusions

This study provides empirical evidence of the significant impact of CfD subsidy schemes on the behaviour of offshore wind farms in the UK. While CfD subsidies provide price stability and investment security for renewable energy generators, they also lead to inefficiencies in their respond to market signals in both the DA and the balancing market. Our results show the importance of refining CfD designs to minimize market distortions. Insights from our analysis can guide future policy reforms, particularly as the EU considers the broader adoption of CfD subsidy schemes.

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