Tailoring long-term contracts to unlock investment in utility-scale battery storage

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Overview

The energy transition requires massive and costly investments in low-carbon power generation and storage. The private sector, however, is increasingly reluctant to undertake the needed investments in these technologies. One of the main reasons is that electricity markets are incomplete: risk averse investors are facing growing risk factors, but are unable to exchange or mitigate these risks by lack of financial instruments. Emerging financial instruments (e.g. Contracts for Difference, Power Purchase Agreements, Reliability Options, etc.) allow the exchange of risk between market agents, and have been shown to efficiently foster investment in low-carbon generation. However, few studies analyse their impact on storage technologies deployment.

This paper first propose a classification of long-term contracts proposed in the existing literature along three main features : 1. the time window on which the contract is defined ; 2. the indexation of its price ; and 3. the indexation of its payoff. Both the price and the payoff can indeed be indexed on the market price risk and on the idiosyncratic risks of each agent, in order to transfer those risks among agents.

A stochastic, 2-stage partial equilibrium model is then proposed to assess the efficiency of different contracts to achieve the optimal capacity expansion program. We especially consider their impact on welfare and on storage investment. This allow to finally quantify how the 3 characteristics defined above impact the efficiency of a contract.

Methods

A stochastic, 2-stage partial equilibrium model is implemented on GAMS as a Mixed Complementarity Problem (MCP), equivalent to the Linear Programs of all agents, coupled by market equilibriums on the spot market (2^{nd} stage) and on the financial derivative market (1rst stage). All agents (including the electricity demand) are risk averse, endowed with a convex risk measure (linear combinations of Expectancy and CvaR). In a complete market, this equilibrium problem can be computed as a single optimization problem, with a market unique risk measure shared by all agents. Because we study an incomplete market, the equilibrium has to be decomposed in two subproblems and solved in a iterative way.

We apply this model to a stylized case study with four technologies : wind turbines, PV, thermal plants, and battery storage. The exogenous sources of risks are calibrated on the Spanish market : an inelastic load level, the renewable production profiles, and the total price of gas and CO2. The revenues are taken as those of a representative year, itself composed of several representatives days, in order to disentangle deterministic seasonality, short-term risks (on a given day) and long-term risks (on a year).

Results

For all technologies, we define first best contracts allowing to complete the market and achieve the optimal welfare. They are : 1. defined on all operating hours of the technology ; 2. offering a fixed payoff to the utility (such as baseload PPA) instead of indexing on some idiosyncratic risks (as for a pay-as-produced PPA) ; 3. asking a payment from the utility to the counterpart which is indexed on all idiosyncratic risks, in order to transfer all the risks.

This result is in line with the previous results of [Newbery 2023] and [Schlecht et al. 2024], where these contracts, called financial CfDs, are considered as the first best option to hedge renewables. However, this first best outcome could not be freely achieved in reality, because indexing the contract payment on idiosyncratic risks requires sharing the private information on those risks between both parties, which has a cost – not considered in our model.

If one restricts contracts to be only indexed on the public electricity market price, the 2nd best welfare can be achieved by hourly futures, traded for each hour of the day. In the case of storage contracts, as storage only faces risk on the electricity price, this second best contract is in fact the same as the first best contract. This departs from the intuition developed in [Schlecht et al. 2024], where financial CfDs were rather described as unsuited for battery storage.

Finally, we study how reducing the number of traded futures contracts affects welfare and capacity investments. In particular, we compare the efficiency of a limited number of peak and offpeak futures (such as the Mon-Sun Peak Futures that will be available in Spain from 24 February 2025) with the efficiency of quantile-based contracts, fixing the price of the X% most/less expensive hours in a day (as defined in).

Conclusions

Financial CfD are the best long-term contracts in theory, allowing an efficient risk trading that allow to complete the market and achieve its first best outcome. In general however, such contracts are hard to implement because of the cost required to measure and share information about the idiosyncratic risks of an asset.

We show that, because battery storage are not subject to any large idiosyncratic risk, this drawback does not apply to storage financial CfDs, allowing an easier implementation than for renewables - contrarily to the intuition developed in [Schlecht et al. 2024].

Finally, we show that such a contract is equivalent to a portfolio of hourly futures, traded for each hour of the day. And that in comparison, the Mon-Sun Peak Futures deployed in Spain from 24 February 2025 lacks of flexibility to allow a full hedging of battery storage revenues.

Future research could verify if, as in the standard general equilibrium model of Arrow-Debreu, this static risk trading of long-term securities is equivalent to a sequential trading of short-term Arrow securities.

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