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UNIVERSIDAD PONTIFICIA
ICAI

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master's Thesis:

EFFECTIVENESS OF THE FORWARD ELECTRICITY MARKET FOR HEDGING MARKET PRICE RISK IN A PHOTOVOLTAIC SOLAR PROJECT IN IBERIA

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Introduction and motivation

The deployment and connection of renewable energy plants is growing at a fast pace. One of the main objectives of the regulatory authorities is incentivizing the progressive substitution of thermal generation for renewables, with the target of reducing carbon emissions and transitioning to a cleaner electricity sector. However, the electricity generation has significant differences between the available technologies. Traditional thermal generation offers reliability, flexibility and controlable production with the tradeoff of unpredictable variable cost and high carbon emissions; whereas renewable energy plants offer cleaner, cheaper and inexhaustible, but uncertain and unmanageable production.

This transition to different technologies is bound to have great impact in the current electricity markets. Their different specificities of each technology influence their bidding strategy for the spot markets; echoing in the forward markets. Historically, electricity prices had a strong correlation with commodity prices, mainly natural gas and coal, because the optimal strategy for generation units in the electricity markets is bidding their variable costs, which in its majority were represented by the cost of the combustion of the mentioned energetic commodities. However, with the growing penetration of renewables, the paradigm is shifting towards an electric mix where clean technologies setting the marginal price is becoming increasingly common. It is important to mention that renewable energy sources have negligible variable costs (mainly O&M), as they do not have to internalize the cost of the fuel in its bids.

In this context, the uncertainty about the economic viability of renewable projects becomes evident. The greater penetration of renewables, although favorable for a progressive reduction in carbon emissions, jeopardizes the economic viability of renewable generation if not enough flexible demand enters the mix. This phenomenon has two causes. On one hand, renewable generation is not manageable, as it depends solely on the weather conditions at each moment. The market agents develop complex prediction models to forecast the production to send the bids to the market. However there is volume risk associated with the unability to control how favorable are the weather conditions for optimal production. On the other hand, as it has been mentioned, renewable plants do have negligible variable costs, therefore bidding very low prices. If the renewable generation that enters the mix is sufficient to cover for the demand at a given period, the marginal value of electricity ("marginal price") will be set by renewable technologies. This low marginal price is received by all generation that was cleared in the market auction to fit the demand, therefore poorly remunerating the production plants. Traditional microeconomics demonstrate that the optimal bidding strategy is the variable cost, as the infrastructure investments (fixed costs/CAPEX) would progressively be recovered by the surpluses received when a more expensive technology is marginal. However, if increasing homogeneous renewable generation enters the market it may be possible that fixed costs are not recovered as there is not enough periods where renewable plants perceive revenue surpluses.

The purpose of this thesis is to discuss the effectiveness of different forward contracts to hedge market price risk for renewable plants, offering greater predictability and therefore allowing more clean generation into the system without compromising its economic viability. The main focus will be into solar photovoltaic plants; as the Spanish NECP expects 60GW of PV capacity by 2030.

Forward contracts are agreements to buy or sell an asset at a predetermined future date for a price agreed upon today. In the electricity market, these contracts allow generators to lock in prices for future electricity production, providing revenue certainty and protecting against price fluctuations. Renewable generators can use forward contracts to hedge against price risk by ensuring a stable and predictable income stream. By locking in prices, generators can better plan and budget their operations, avoiding potential losses from falling prices and ensuring financial stability. Forward contracts are used as risk management tools for generators to participate effectively in the market, enabling them to secure their revenue despite market volatility.

In Spain and Portugal (the Iberian market), the responsible for the exchange of electricity derivatives is OMIP (Operador del Mercado Ibérico - Polo Portugués). OMIP and OMIClear (its clearinghouse) work together to create a robust trading environment. OMIP provides a regulated platform for trading futures and options, allowing participants to hedge against price volatility and manage risks effectively. The platform also enhances liquidity by using market makers, making it easier for participants to enter and exit positions and thus improving market efficiency. OMIClear complements OMIP's functions by managing collaterals and warranties, reducing counterparty risk, and ensuring the financial integrity of the market. OMIClear provides clearing and settlement services for all trades executed on OMIP, ensuring that transactions are completed securely. OMIClear also acts as a clearinghouse in OTC (Over-The-Counter) settlements provided that both parties are registered in OMIP.

One of the main advantages of using centralized exchanges, like OMIP, is the standardization of their products and contracts. Their most traded and liquid product is the Baseload Futures Contract, which represents an agreement between buyer and seller to exchange 1MW constantly for every hour of the whole period of the contract. The trade can be physical, if energy is physically delivered; or financial if the difference between spot and agreed price is settled for differences. However, this product may not be suitable enough for a generator whose production is not constant for each hour, like solar PV and wind, as there is some risk associated with the periods in which the plant is short production. During these periods, the generator is exposed to price risk as it needs to financially cover the difference between the agreed volume and its production, at the spot price. This phenomenon of imperfect hedging is called "Basis Risk" and it is present whenever the hedge is not perfectly taylored to the plant production. Other products listed in OMIP, such as Peak Futures Contract and Solar Futures Contract provide a fitter profile for renewable generators. The impact of Basis Risk in the revenues of a plant is very relevant, and will be discussed in detail in this thesis.

Objectives

Valuation of OMIP products for their effectiveness in hedging market price risk

OMIP is the iberian market for electricity derivatives. They offer various contracts for hedging electricity positions. The focus of the thesis will be valuating the potential reduction in the Value At Risk of a PV plant when hedging with the different products available, including Baseload, Solar and Peak. An in-depth statistical analysis will also be computed for Basis Risk, to compare the distribution of probability of systematic penalizations when using imperfect hedges. While a Pay-as-Produced contract would mitigate the Basis Risk, these products need to be traded OTC and are not part of OMIP's derivatives catalogue.

Back Testing and Scenario Comparison

When assesing the effectiveness of hedges, it is crutial to develop scenario comparisons and back-testing analysis. This means using past contract and spot market prices to evaluate what would have been the effects in terms of revenues and value at risk if a specific future product is contracted. It is important to understand that past performance do not imply future performance, and back testing is not an exact science. However, it provides a grasp of the deviations between expected performance and actual results.

Conclusions for Market Agents

The conclusions obtained by this thesis could be useful for PV Plants (and other renewable facilities) market agents, as energy management guidelines of the potential effects of hedging their positions with derivatives from OMIP. This thesis is focused in being practical, avoiding overcomplicated calculations and terms that are not relevant in the normal operation of the plants.

Estimate Work Plan

Week Starting	**Tasks**
January 8 / January 22	- Project Draft - Resource gathering and Annex A - Prepare first presentation
February 5 / February 26	- Problem description - Price simulations brief discussion
February 27 / March 4	- OMIP Products Description - Value At Risk comparison
March 5 / May 19	- Basis Risk Stochastic Simulation - Scenario Analysis
May 20 / June 3	- Conclusions and results
June 15 / End	- Prepare presentation - Check and correct typos and mistakes

Methodology

Estimation and Simulation of Photovoltaic Plant Generation Profile:

The first step involves estimating and simulating the generation profile of the renewable plant, by appling gaussian copulas and Montecarlo simulations to historical data. The simulations are used to ascertain the expected probability distribution of annual volume of energy asthat can be feasibly contracted for hedging purposes as well as the generation profiles for the set of simulations. Historic values of generation are preferred, but software simulations tools such as PVsyst are also reputable for reliable data for scenario generation.

Price Profile Simulation Using Monte Carlo Paths:

In a similar way, applying gaussian copulas to datasets of yearly price curves with Montecarlo simulations is used to generate coherent price scenarios. The approach will be to consider price curves forecasts of commercial providers as base curves, and generating a large dataset of price curves using the base curve and the historical volatility. To simplify, this thesis will not focus on the fundamentals behind the generation of price base curves, but the model will be robust enough to generate scenarios with any given price curve.

Study of Revenues and Value at Risk (VaR):

Having both the simulations for generation and prices, the distribution of estimated revenues can be easily calculated. The 5% Value at Risk (5% VaR) is a key metric in this study, defined as the difference between the revenues referred to the P50 case (median) and the 5th percentile, divided by the mean value. This metric estimates the maximum potential loss in revenue for a project over a specified period, given a certain confidence level. VaR provides a revenue threshold below which actual revenues are not expected to fall with a certain degree of confidence (e.g., 95% confidence) during the specified period. In other words, a 5% VaR indicates there is a 5% chance that the revenue loss will exceed the estimated VaR value over the considered time period.

Selection of Derivative Contracts for Study:

The study will select specific types of contracts from OMIP (such as baseload, solar, and peak) to analyze. The selection of these hedging types is based on their relevance and potential effectiveness for a photovoltaic solar project in the Iberian market.

Estimation of Revenues with Hedging Contracts:

For each simulation, an estimation of the revenues obtained from contracting the selected hedge will be carried out. This will facilitate the examination of the average revenue without hedge as well as the value at risk when under hedge; considering the systematic basis risk. This step is critical in evaluating the financial benefits of various hedging strategies.

Analysis of Basis Risk:

Basis Risk appears when the contract profile is not equal to the actual production of the plant. If the hedge does not fit perfectly the production of the plant (Pay-As-Produced), a component of systematic deviation appears in the revenues perceived. If the plant is short in periods where price is high, and long in periods where price is low; there will be a systematic penalization in the revenues perceived. The proper statistical analysis of Basis Risk, distinguising between hedged and unhedged revenues will be carried out, applying the Central Limit Theorem. Given enough simulations for price and production, the basis risk could be modeled as a normal distribution.

Comparison of Cases with and without Hedging; Back Testing and Sensitivity Analysis:

The final phase involves a comparative analysis of scenarios with and without hedging. This will include back testing to assess the performance of the hedging strategies against historical data. Additionally, a sensitivity analysis will be conducted with different price profiles and future quotations to understand the robustness of the selected hedging strategies under varying market conditions.

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