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Mitigating wind exposure with zero-cost collar insurance

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ABSTRACT

Renewable energy generation worldwide has relied increasingly on wind farms where wind energy is transformed into electricity. On the other hand, electricity prices are uncertain and wind speeds are highly variable, which exposes the producer to risks. Typically wind power producers enter into long term fixed price contracts in order to hedge against energy price risk, but these contracts expose the wind farm to energy volume risk, as they require delivery of the full amount of energy contracted, even if energy production falls short due to low wind speeds. To mitigate this risk, wind producers can purchase insurance. This article proposes a zero-cost collar insurance and develop a stochastic model to determine the feasible range of wind strikes for both the wind farm and the insurer. The results indicate there is a set of possible strike combinations that meets the objectives of both parties.

1. Introduction

Wind energy is a growing and increasingly popular source of clean and renewable energy. In recent years [19], many countries have an emphasised the development and deployment of new and renewable energy sources to cope with their demands for clean energy, wind power energy being one of the core areas for these investments. Nonetheless, wind power generation ventures require significant capital expenditures in exchange for risky returns due to uncertainties in energy prices and wind regimes. In the absence of government subsidies, private investors must bear the full risks of these ventures, thus, some form or risk mitigation scheme is important for this class of investments.

According to Reuter et al. [26], renewable-based technologies such as wind energy suffer from uncertain loads depending on environmental conditions. Unlike hydro power, wind energy cannot be stored in reservoirs, and unlike thermal sources, wind regimes are highly variable and strongly seasonal. In addition, there are difficulties in predicting future wind conditions, and there are financial risks due to pool price volatility. In order to hedge against these risks, wind power producers can choose to sell the energy generated through forward contracts, which guarantee a fixed price for the life of the contract [4,9]. However, due to environmental seasonality, energy production can vary significantly throughout the years, exposing the producer to volume risk. If production falls below expected levels, the energy shortfall must be purchased from the pool at prevailing prices, exposing the producer to pool price variations. If the periods of generation deficit happen to occur when pool prices are high, the firm may be subject to financial losses. Therefore, it is important that the firm find ways to create mechanisms that can hedge it against this risk.

A widely used risk mitigating mechanism are insurance contracts, where in exchange for a pre-established premium, protection against undesirable outcomes can be purchased. Insurance contracts cover low-risk, high-probability events, and are an available option to mitigate risk [23]. Jin et al. [12] explains that the wind power industry has high risks and since insurance is an effective instrument to control risks, it can contribute to the healthy development of the industry. According to Pineda et al. [25], under an insurance contract the insurer receives a premium at the beginning of the contract period in exchange for a contingent liability over future energy shortfalls. The authors also analyze the impact of an insurance contract on the decisions of an electric energy producer if some units fail and conclude that insurance reduces the financial risk associated with the failures of the production units and allows the producer to sell a greater amount of energy in the futures market. A similar analysis is made by Jiang et al. [11] who conclude that insurance can be an attractive hedge contract against financial losses caused by forced

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outages. In a different line, Mills [22] states that if properly applied, energy insurance can potentially reduce the net cost of energy-saving projects by reducing the interest rates charged by lenders. Braun and Lai [5] analyzed energy firms and determined which risks can be covered by purchasing insurance. On the other hand, none of these papers address the issue of how one determines a feasible set of strikes for an insurance contract, and the best our knowledge, this is an innovation of this article.

This article proposes a special type of insurance contract, a zero-cost collar that contributes to mitigate low production risk and has the advantage of being costless to the investor. A collar is a derivatives contract where the firm can secure protection against low production volume by purchasing a put option on low wind speeds from the insurer, while on the other hand, the firm sells to this same insurer a call option that provides it the right to receive any excess revenues from production from high wind speed in excess of a pre-established level. A zero-cost collar is then a collar contract where both the put and the call option command the same premium, so that the contract becomes costless for the firm. Thus, a costless collar transaction provides the firm with the opportunity to hedge its volume risk without the burden of costs [20,3].

The key to designing an effective zero-collar contract is in selecting the range of wind strike levels where both the wind energy producer and the insurance firm are better off by entering into the contract. As the collar contract requires two strike values, all combinations of a lower bound wind strike level below which the insurance firm covers any energy shortfall the producer may have, and an upper bound wind strike level above which the excess energy goes to the insurer must be determined.

There is obviously a conflict of interest between the wind farm and the insurer. While a very low lower strike level is in the interest of the insurer, as it minimizes the potential payments it may have to make, it is ineffective in protecting the producer against low wind speeds. Similarly, a low upper strike level may provide the insurer with significant returns at the expense of the producer. On the other hand, a high lower strike level provides maximum protection for the producer, but may be costly to the insurer, while a high upper strike level minimizes the revenues the producer may be required to hand over to the insurer. Thus, while the producer is interested in high lower and upper strike levels, the insurer is interested in the opposite in both cases. Therefore, in order to find the strike levels, a stochastic model that takes into account the firm's risk aversion and the uncertainty associated with pool prices variations and possible energy shortfalls was run. According to [9], risk aversion affects the firm's optimal hedge, and if the forward price is less than the expected price, the hedge increases as the firm becomes more risk averse. The present model seeks to determine a set of upper and lower strike levels that provide sufficient protection for the producer considering it's risk attitudes, while at the same time, providing the required return for the insurer in a contract region where the insurance is possible at zero cost.

The main advantage of a zero-cost collar contract is that it provides protection for the energy producer with no upfront outlay of cash. While the particular pair of wind strike levels that both parties may choose will depend also on the bargaining power of the producer and insurer, the model determines the complete set pairs of acceptable lower and upper wind strike level that they will choose from.

The main result of this article is a set of contract possibilities which represent the feasible strikes points (lower wind, upper wind) in all contract periods. The final result (the particular combination of strike points that will be agreed upon) will depend on the bargaining power of each party. The results indicate a negative correlation between the values of the producer and the insurer. It can be noted that in the contract region, both parties are better off with the contract, but for each pair of strike levels one party is individually better off than the other. Therefore, it is important that each of these firms be aware of this information, as it helps increase their bargaining power.

The rest of this paper is structured as follows. After this introduction, in the next section the concept of a zero cost collar option contract is explained and the risk metric used to assess the insurance contract is introduced. Section 3 presents the stochastic model adopted to determine the contract region and next it is applied to the case of a wind farm in northeastern Brazil. Section 5 discusses the main results and in Section 6 some robustness tests are run. The conclusions are in Section 7.

2. The collar insurance option

A collar insurance is a financial derivative instrument that can be used to hedge firms against exogenous risks. In particular, a collar option involves buying an out-of-the-money call (or put depending on the hedger's needs) and selling an out-of-money put (or call) with the same expiration date [29]. If the proceeds from selling the put are offset by the option premium on the call such that no upfront cash is required, then this derivative is a zero-cost collar.

Fig. 1 illustrates a typical collar strategy. In this example, the lower and upper wind strike levels determine the bounds for the option exercise. If wind speeds are below the lower bound, such as in week 9, the insurance firm pays the energy producer any revenue shortfall incurred. Similarly, if wind speeds reach levels above the upper bound, as in week 41, the producer transfers any excess revenues to the insurer.

Mathematically, a collar option can be described as follows. Assume that the wind farm profits are represented by $\Pi(G|\omega) = P^*Y(G|\omega) - C(G|\omega)$, where G is the set of resources used in generation, ω is the observed wind speed, P is price, $Y(G|\omega)$ represents the production function and $C(G|\omega)$ is the cost function. Profits are determined from revenues $P^*Y(G|\omega)$ and the cost function $C(G|\omega)$. It is assumed that G is predetermined so that marginal profits can be measured relative to ω alone. Under this specification, $\Pi(G|\omega)$ is determined by the input set, but the ultimate measure of profits is conditional on the specific wind.

It is assumed that $Y(\cdot)$ is concave in ω while $C(\cdot)$ is convex in ω which implies that as wind increases $\frac{dY}{d\omega} > 0$ up to some point at which ω^* is optimal, $\frac{dY}{d\omega} = 0$, and then $\frac{dY}{d\omega} < 0$. This assumption guarantees that wind insurance does not apply to low wind conditions alone, but can also be applied to specific events of excessive wind. The convexity argument in the cost structure is justified by a symmetric argument. There will be some ω^* such that $\frac{dC}{d\omega} = 0$. For $\omega < \omega^*$ costs will be increasing as the costs associated with low wind increase and for $\omega > \omega^*$ costs associated with excess wind are incurred. Marginal profits are then equal to Equation (1).

$$\frac{\partial \Pi(G|\omega)}{\partial \omega} = P\frac{\partial Y(G|\omega)}{\partial \omega} - \frac{\partial C(G|\omega)}{\partial \omega} \tag{1}$$

This equation will be convex with $\frac{\partial \Pi(\cdot)}{\partial \omega} > 0$ for $\omega < \omega^*$, $\frac{\partial \Pi(\cdot)}{\partial \omega} = 0$ for $\omega = \omega^*$ or $\frac{\partial \Pi(\cdot)}{\partial \omega} < 0$ for $\omega > \omega^*$.

From the firms' perspective Π_{min} depicts a critical profit level which must be protected. Accordingly, the wind farm has three contract options: it can select a put option which would provide an indemnity if wind falls bellow ω_{lower}, a call option if wind exceeds ω_{upper}, or both (a collar). In general, the price of these contracts would be: