Quantifying the value of reduced investment risk under different green energy support policies

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Overview

Although there exist many support schemes to promote green energy penetration worldwide, Feed-in Tariff (FiT) schemes have become the preferred renewable energy support mechanism in many markets. The benchmark is the fixed-FiT scheme, a mechanism allowing Renewable Energy Sources for electricity (RES-e) producers to sell electricity at a guaranteed fixed price per generated MWh. FiT subsidies for renewable energy penetration have been of the foremost importance, and they may still play a role as long as they are carefully crafted. Indeed, by the end of 2020 many countries worldwide had a FiT in place as a support policy for RES-e development. Nevertheless, their main drawback is the huge cost they usually involve for the regulator, especially if they are not properly designed. This is the main reason why some countries have already abandoned the FiT system and introduced new schemes based on auctions (Ciarreta et al., 2014). In many auction systems, bids are made for a return on investment of renewable plants (i.e. Rate of Return (RoR) regulation), and the electricity generator's income is fixed according to the reasonable profitability set in the auction, regardless of the amount generated and the market price of electricity.

In this context, real option pricing techniques are an appropriate tool to analyze the RES-e investment decision process, since they allow to assess investment opportunities as a function of their volatility (Lee and Shih, 2010). In particular, Haar and Haar (2017) propose using option theory to model FiT subsidies as European put options in order to quantify the value of the risk that is transferred from the investor to the regulator. According to Haar and Haar (2017), the risk accepted by the regulator, which is ultimately transferred to the rest of the society, could be hypothetically hedged by purchasing a strip of put options (the right to sell) with strike prices equal to the FiT price.

In this paper, we argue that the risk faced by an investor in renewable energy is not only due to the price of electricity but also to the fact that the amount of electricity produced is uncertain, especially for technologies that are heavily dependent on weather conditions, such as solar and wind. For this reason, we extend the previous literature using option theory to estimate the value of the investment risk removed by a RES-e subsidy, considering both the randomness of the market price as well as that of the amount of electricity generated. We contribute a methodology for pricing energy subsidies that models jointly market prices and generation as correlated stochastic processes.

Since under FiT the price per MWh produced is guaranteed, the producer's revenues (and for the same reason the generator's costs) are subject to uncertainty in the number of units generated. On the other hand, under the RoR system, a fixed return is guaranteed, thus eliminating the risk of lower than expected revenues due to poor generation. However, it also eliminates the possibility of higher potential revenues due to higher than expected generation. Therefore, our methodology allows us to compare the value of these two important incentive systems taking into account all these considerations regarding the different risks involved and the risk-sharing under each scheme.

Finally, we present an application where we compare the performance of the FiT scheme and the RoR regulation in the Spanish electricity market, which transitioned from the former system to the latter in 2013.

Methods

For a given renewable technology, we model both the Volume Weighted Average Price (VWAP) of electricity and the amount of generation during a given period, say a year, as stochastic processes S_t and X_t respectively. Long-term electricity prices have been modeled as Geometric Brownian Motion processes (GBM). We propose that the annual generation of RES-e technology can also be approximated as a GBM, as it seems reasonable to approximate it as a log-normally distributed variable. The risk-neutral dynamics of the problem are given by:

$$\begin{cases} dS_t = rS_t dt + \sigma_S S_t dW_t^S \\ dX_t = rX_t dt + \sigma_X X_t dW_t^X \\ dW_t^S dW_t^X = \rho\, dt \end{cases} \tag{1}$$

where W_t^S and W_t^X are two correlated Brownian motions with correlation parameter ρ, T is a fixed final time, r is the risk-free rate, and σ_S and σ_X are the volatilities of each process. The fundamental theorem of asset pricing implies that in a complete market a derivative's price at any initial time t is the discounted expected value of the payoff at future maturity time T under the risk-neutral measure.

Under the FiT scheme the generator has a guaranteed minimum price K_{FiT} per generated MWh. Thus, the payoff at maturity offered by the subsidy is given by the product of the annual generation (X_T) and the payoffs for each produced MWh $(K - S_T)^+$. Hence, the value of the subsidy at $t = 0$ is given by the expectation under the risk-neutral measure: $V_{FiT} = \mathbb{E}^{\mathbb{Q}}[e^{-rT} X_T (K_{FiT} - S_T)^+ \mid \mathscr{F}_0]$. On the other hand, under the RoR regulatory scheme, the generator has a guaranteed revenue (K_{RoR}), independent of both generation and market prices. Therefore, the payoff at maturity is given by $(K_{RoR} - S_T X_T)^+$. Thus, the value of the RoR subsidy at $t = 0$ is: $V_{RoR} = \mathbb{E}^{\mathbb{Q}}[e^{-rT}(K_{RoR} - S_T X_T)^+ \mid \mathscr{F}_0]$.

Results

Using stochastic calculus, we obtain the following closed-form solution for the FiT subsidy option with maturity *T*:

$$V_{FiT} = X_0 \left[K_{FiT}\Phi(-d_{FiT}) - S_0 e^{(r+\sigma_S\sigma_X\rho)T}\ \Phi(-d_{FiT} - \sigma_S\sqrt{T}\,) \right] \tag{2}$$

where Φ denotes the CDF of the standard normal distribution, and

$$d_{FiT} = \frac{\log\left(\frac{S_0}{K_{FiT}}\right) + \left(r + \sigma_S\sigma_X\rho - \frac{\sigma_S^2}{2}\right)T}{\sigma_S\sqrt{T}} \tag{3}$$

Similarly, we obtain the closed-form solution for the RoR scheme option with maturity *T*:

$$V_{RoR} = e^{-rT}\left[K_{RoR}\Phi(-d_{RoR}) - Y_0 e^{\mu_Y T}\ \Phi(-d_{RoR} - \sigma_Y\sqrt{T}\,) \right] \tag{4}$$

where $Y_0 = X_0 S_0$, $\mu_Y = 2r + \sigma_S\sigma_X\rho$, and $\sigma_Y = \sqrt{\sigma_S^2 + \sigma_X^2 + 2\sigma_S\sigma_X\rho}$.

$$d_{RoR} = \frac{\log\left(\frac{Y_0}{K_{RoR}}\right) + \left(\mu_Y - \frac{\sigma_Y^2}{2}\right)T}{\sigma_Y\sqrt{T}} \tag{5}$$

In addition, we perform a numerical simulation verifying that the obtained analytical solutions agree with a Monte Carlo valuation of the problem.

Finally, using the results obtained, we can design both types of incentives in such a way that their value is identical, and therefore, the regulator is indifferent between offering one or the other to the supplier. Assuming that both incentives are offered with a duration of T_F years, the total value of the subsidy will consist of a set of annual options with different maturity times over the horizon of T_F years. Therefore, both subsidies will have an identical value if:

$$\sum_{T=1}^{T_F} V_{FiT}(T, K_{FiT}) = \sum_{T=1}^{T_F} V_{RoR}(T, K_{RoR}) \tag{6}$$

For the empirical application, we use data from the Spanish market at the time when there was a transition between the two types of incentives.

Conclusions

The risk faced by an investor in RES-e technologies that are heavily dependent on weather conditions, such as solar and wind, is not only due to the price of electricity but also to the fact that the production is uncertain. Therefore, using option theory to study the value of a subsidy considering the market price of electricity as the only source of randomness may be insufficient.

We contribute to the literature with a model to estimate the value of the investment risk eliminated by a RES-e subsidy, considering both the randomness of the market price as well as that of the amount of electricity generated. We develop a methodology that prices energy subsidies by modeling prices and generation as correlated stochastic processes. Using fundamentals of real options theory and stochastic calculus, we are able to obtain closed-form solutions to the value of FiT and RoR subsidies. Furthermore, we perform a numerical simulation to verify that the obtained solutions agree with a Monte Carlo valuation of the problem. With the developed methodology, we can directly compare two different incentive systems, the FiT, under which a price per unit sold is guaranteed, and the RoR, under which a fixed level of profitability is guaranteed.

Subsequently, we present an empirical application of the proposed theoretical model for the case of Spain, where in the last decade, the FiT system was replaced by the RoR system in an attempt to decrease regulation costs. According to our preliminary results, the value of the subsidy offered under the FiT system by the Spanish government was considerably higher than that delivered under the RoR system. This finding is consistent with the fact that the Spanish government abandoned the FiT incentive mechanism for the RoR because the former (under the incentive level offered at the time) implied excessive costs to the regulator. Our methodology could be applied to any electricity market facing, or about to face, similar challenges in terms of RES-e regulation.

Finally, our methodology allows, given the features of one of the two incentive mechanisms (prices, duration, etc.), to determine the design of the other system so that the value of both schemes, when considered as options, is identical. This *Incentive Equivalence Result* in terms of option valuation opens up the question of the optimality of incentive schemes under different criteria.

References

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