Right and duty: Investment risk under different renewable energy support policies

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Overview

Most renewable energy projects require some form of public support in the form of a regulated tariff. These projects face risk due to the uncertainty of both future electricity prices and the amount of energy produced, which ultimately depends primarily on weather conditions. These regulated tariffs usually consist of some form of guarantee, either on the price received per MWh supplied or on the return on investment per MW installed. This support reduces the investor's risk, which is then assumed by the regulator. However, most of these policies not only grant the investor the right to receive a guaranteed payment, but also limit its potential benefits (i.e. impose an obligation). We propose a model with analytical solutions in which, taking into account the randomness of the market price as well as that of the energy production, we quantify the risk removed under different types of regulations and the importance of both the right and the obligation that the policy entails in each case. Finally, we apply the model to the case of Spain, which has undergone numerous changes in its green energy support system in recent years. Our results indicate that years ago, under most of these schemes, the obligation imposed was negligible compared to the right received. By contrast, in the current context of high electricity prices and increasingly competitive renewable energy sources, the obligation assumed in this trade-off becomes more important, which may cause the support to become a liability.

Regardless of whether the incentive is set by a government or by an auction, we can categorize them according to the payment mechanism involved. We distinguish two general types of "fixed" payment mechanisms, which we refer to as fixed-price (FP) and fixed-revenue (FR). Under an FP system, a fixed price is set for each MWh of electricity delivered. If the market price is lower than the guaranteed price, the producer receives a premium equal to the difference between these prices; if it is higher, the producer must pay the difference back to the regulator. Under this system, the producer's (regulator's) revenues (costs) are subject to the uncertainty of production levels. Under an FR system, the supplier receives a fixed payment regardless of the amount of electricity produced and the price of electricity. Thus, the generator sells all of its electricity at the market price, and the regulator then pays the difference between the market revenue and the level of fixed revenue specified in the contract. This system removes 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 or market prices. There are also different more flexible schemes that, in addition to guaranteeing a minimum price, allow for some potential benefit from market prices above a certain threshold. For example, a Shared-Upside (SU) is a mechanism where the investor receives a minimum price if the market price of electricity falls below this floor. If, on the other hand, the market price exceeds the floor, the investor and the regulator share the excess remuneration according to a predefined rule.

Methods

Real option pricing techniques are an appropriate tool for analyzing the investment decision process in renewable energy, as they allow investment opportunities to be priced as a function of their volatility (Lee and Shih, 2010). For example, Haar and Haar (2017) propose to use option theory to model Feed-in Tariff subsidies as European put options in order to quantify the value of the risk transferred from the investor to the regulator.

Suppose that the regulation under discussion offers the investor at time $t = 0$ the right to trade the electricity produced at time T for at least a revenue Rev_R, which in general depends on the total production in that period ($Rev_R = Rev_R(X_T)$). We define the value of the right (R) provided by the regulation as the expected value of the discounted payoffs that the right provides, taking into account the probability of the market not reaching the guaranteed revenue: $R(T) = \mathbb{E}_0[e^{-rT}\left(Rev_R - X_T S_T\right)^+]$, where r is the constant discount rate, $\mathbb{E}_0$ is the conditional expectation operator given the information at $t = 0$, and where we use the standard notation $z^+ \equiv \max\{0,z\}$. Now suppose that the regulation obliges the investor at time $t = 0$ to trade the electricity produced at time T for a maximum revenue Rev_O, which again generally depends on the total production in that period ($Rev_O = Rev_O(X_T)$). We define the value of the obligation (O) imposed by the regulation as the expected value of the discounted amount that the investor must give up under the policy, taking into account the likelihood that the market will exceed the allowed cap: $O(T) = \mathbb{E}_0[e^{-rT}(X_T S_T - Rev_O)^+]$. We propose to model the value of the support policy (V) as the difference between these two quantities: $V = R - O$.

For a given renewable technology, we model both the Volume Weighted Average Price of electricity and the annual electricity production during a given period (t), say a year, as two Geometric Brownian Motion stochastic processes S_t and X_t, respectively. The dynamics are described by:

$$\begin{cases} dS_t = \mu_S S_t dt + \sigma_S S_t dW_t^S \\ dX_t = \mu_X X_t dt + \sigma_X X_t dW_t^X \\ \rho = corr(dW_t^S, dW_t^X) \end{cases}$$

where both Brownian motions are correlated with correlation parameter ρ. σ_S and σ_X are the volatilities of each process, and μ_S and μ_X are the drifts denoting the growth rate of S_t and X_t respectively.

Finally, under each support mechanism, the risk exposure is of a different nature. Using the obtained results, we can design different types of incentives in such a way that the assumed risk under each scheme is identical, and therefore, the regulator is indifferent between offering one or the other to the supplier. Assuming that two incentives of different types A and B, with a set of retributive parameters Ω_A and Ω_B respectively, are offered with a duration of T_f years. Then, both regulations will have an identical value if

$$\sum_{T=1}^{T_f} V_A(T, \Omega_A) = \sum_{T=1}^{T_f} V_B(T, \Omega_B)$$

Results

First, we use stochastic calculus methods to obtain analytical solutions for support policies consisting of fixed-price, fixed-revenue, and shared-upside payment mechanisms. Second, we apply the theoretical model presented to the case of Spain, which has undergone significant changes in its green energy support policy and has implemented the three different incentive mechanisms we have discussed. We focus on the two main renewable technologies in Spain: wind and solar photovoltaic (PV), and analyze two different periods. First, in 2013, when there was a transition from the *Feed-in Tariff* system (fixed-price mechanism) to the Rate of Return (fixed-revenue) due to the high regulatory costs that the former system entailed (Ciarreta et al., 2014). Second, in 2021, when the old projects were under the *Rate of Return* regulation, while the new projects were implemented under the *Renewable Energy Economic Regime* regulation, which, consists of a shared-upside mechanism awarded in an auction.

The application of the model to the specific case of wind and solar PV power in Spain shows that years ago the obligation imposed was negligible compared to the right received, but in a context of high electricity prices and increasingly competitive renewables (Neuhoff et al., 2022), the obligation assumed becomes more important in this trade-off, which may cause the support scheme to become a liability. This may have a number of important consequences, especially for new investments yet to be made in future auctions. As the incentives were too generous years ago, changes in support policies were introduced to reduce the regulatory costs of these instruments. Today, however, the situation is reversed. Not only have investment incentives been reduced, but there is now a strong disincentive to invest.

Conclusions

The risk faced by an investor in renewable energy technologies that are highly dependent on weather conditions, such as solar and wind, is not only due to the price of electricity, but also to the fact that production is uncertain. Therefore, it may not be sufficient to use real option theory to study the value of a renewable energy support policy by considering the market price of electricity as the only source of uncertainty. We contribute to the literature with an analytical model to estimate the investment risk removed under different types of renewable energy policies and the importance of both the right and the obligation that the policy entails, taking into account both the randomness of the market price, the randomness of energy production, and the correlation between them. The developed methodology allows for a direct comparison of different incentive schemes, each having a different nature of risk exposure. In addition, our model can be applied to both administratively imposed and competitively auctioned support schemes. Furthermore, our model allows, given the characteristics of one of the incentive mechanisms (prices, duration, etc.), to determine the design under another scheme so that the regulatory value of both schemes is identical. The proposed *Incentive Equivalence Proposition* opens the question of the optimality of incentive schemes under different criteria and proves to be a useful tool in the design of support mechanisms for renewable energy.

We show how our analytical model can provide valuable insights into the evaluation of renewable energy support policies. We believe that it is necessary to continue studying the impact of excessive discouragement of investment in renewable energy in different dimensions, such as in the energy transition agenda, the impact on markets, or the potential disruption of investor behavior regarding future deployment. In this study, we apply the proposed model to the specific case of Spain at different relevant moments in its green energy support policy. However, our methodology could be applied to any electricity market facing or about to face similar challenges in terms of green energy regulation.

References

- Ciarreta, A., Espinosa, M. P., & Pizarro-Irizar, C. (2014). *Switching from feed-in tariffs to a Tradable Green Certificate market*. In The Interrelationship Between Financial and Energy Markets (pp. 261-280). Springer, Berlin, Heidelberg.
- Haar, L. N., Haar, L. (2017). *An option analysis of the European Union renewable energy support mechanisms*. Economics of Energy & Environmental Policy, 6(1), 131-148.
- Lee, S.C. and Shih, L.H. (2010). *Renewable energy policy evaluation using real option model - The case of Taiwan.* Energy Economics, 32(1), S67-S78.
- Neuhoff, K., May, N., & Richstein, J. C. (2022). *Financing renewables in the age of falling technology costs.* Resource and Energy Economics, *70*, 101330.