The Energy Transition and the Value of Capacity Remuneration Mechanisms

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Overview

In our paper we study the capacity remuneration value through a Capacity Remuneration Mechanism (CRM) depending on three possible different technologies that participate to the market. We shall see that these three types of capacities can be framed by means of a common theoretical framework, whose level of complexity increases as the uncertainty rises, move from the simplest scheme (Model 1) to the most complex one (Model 3). For these different technological provisions, we consider how to evaluate them focusing on their flexibility value; we first provide a theoretical framework and then sensitivity analysis results.

Methods

Model M1 - capacity supplied by Variable Renewable Energy (VRE) source: in the first model we have two sources of uncertainty, that we frame as stochastic variables: the day-ahead electricity price, P, and the price cap effect that we represent as a random variable depending on the marginal cost of the marginal technology C (for instance it could be the cost of the natural gas). The instantaneous revenues for the investment in the firm VRE capacity is therefore composed by two regimes: one for $P \geq C$ (price effect is not binding) and the second for $P < C$ (the price cap effect is binding). We assume that P and C are stochastic and follow a Geometric Brownian Motion (GBM). The static picture of the profit function can be extended to a dynamic setup in order to derive the value of the investment. We adopt a standard stochastic dynamic programming in order to obtain the value function when $P < C$ and when $P \geq C$. Finally, we impose some proper boundary conditions to calculate the Present Value, $V^{VRE}(P, C)$, in the two regimes. In both regimes the final value is composed by two parts: one is the expected discounted flow of profit if the value is bound to remain in that regime forever and the second one corresponds to the possibility, due to the existence of the CRM, that when the plant is under one regime it goes into the other one and vice versa (flexibility value).

Model 2: Efficient Combined Cycle Gas Turbine (CCGT) plant: in this case we consider a capacity provided by a power plant with a positive marginal generation cost (B). In this model we assume that the plant is always more efficient than the plant that will be the marginal one and that will determine the price cap effect, so its marginal costs are $B = \alpha C$, $\alpha \in (0, 1)$. Three possible cases for the instantaneous revenues emerge: 1) the price cap effect is binding ($P \geq C$), 2) the price cap effect is not binding but the electricity price is above the plant marginal cost ($\alpha C < P < C$) and finally 3) the electricity price is below the plant marginal cost ($P < \alpha C$). In this latter case, we suppose that the plant can avoid selling energy in the power market at no cost.

Following the same procedure as before, we can calculate the value function $V^{CCGT}(P, C)$ in the three regimes. Differently from the previous value function, there are now two flexibility values for $V_2^{CCGT}(P, C)$, since there are two possibilities when the plant is in that case: the electricity price can rise making the price cap effect binding, i.e., entering into case one; the electricity price falls below the marginal cost of the efficient CCGT, i.e., entering into case three.

Model 3: Coal Power Plant: in the most general model we assume that also B is stochastic and follow a GBM. There can be an inversion in the merit order such that the investment considered become the marginal technology and might be affected by the price cap effect. As before three regimes arise for the revenues: 1) when the price cap is binding ($P \geq C > B$), 2) when it is not binding and the plant is active ($C > P > B$), which means that the revenues accruing from selling the electricity are higher than the own power generation costs, and 3) when the plant is off. The latter case however can arise for two reasons, namely, because the revenues deriving from the power prices would be lower than the cost of power generation ($B \geq C$ and $(C - B) < (P - B)$), as before, or because the price cap itself changes and is being set by the own marginal cost ($B \geq P$ and $(P - B) < (C - B)$). We then calculate $V^{coal}(P, C, B)$ in the four cases emerged.

Results

We provide some sensitivity analysis of the constants that determine the flexibility value and the Present Value of Model 1, 2 and 3. Both constants of Model 1 show negative values. It means that in both regime 1 and regime 2 the Present Value, V^{VRE}, decrease in the presence of CRM framework. While for Model 2, as we expected, constant of the first regime and one of the constant of the second regime are negative while constant of the third regime and the second constant of the second regime are positive. Then we study the Present Value of Model 1 and 2 in relation to the drift terms of P and C and to the volatility terms of P and C. Results show that V^{VRE} and V^{CCGT} are a convex curves and are positively correlated with the both drift terms. While both V^{VRE} and V^{CCGT} are concave functions and it are negatively correlated with both volatility terms. The main difference between V^{VRE} and V^{CCGT} in these sensitivity analysis is that the Present Value of Model 1 is lower than ones of Model 2 due to the fact that now there are generation costs that decrease the firm revenues. Finally, we study how V^{coal} change in relation to the drift parameter of B and the volatility of B in all four regimes. The Present Value in the first, second and third regime display a similar path: V^{coal} is positively correlated with the its volatility parameter while is negatively correlated with its drift. In addition, in all plots the Present Value tends to stabilize asymptotically around a given value (negative for regime 1, 2 and 3). Therefore, positive effects of sigma are higher for low values of mu.

Conclusions

The aim of this paper is to investigate the value of the investments in capacity financed by a Capacity Remuneration Mechanism, by adopting a stochastic approach. In Model 1 we provide an analytical framework for a capacity provided by VRE coupled an efficient Energy Storage System; in Model 2 for a thermal efficient capacity, i.e. a CCGT power plant that at the time of the investment is more efficient than the marginal power plant and; in Model 3 a brown capacity, i.e. a coal power plant. Finally, in the last part we studied the sensitivity of the constants and the sensitivity of all Present Values.