The Option Value of Capacity Remuneration Mechanisms: a Comparison of Different Technologies

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Introduction

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- The theory claims that optimal load shedding occurs when the NPV of the loss-of-load equals the discounted cost of investments in new capacity (energy-only markets).
- Market only (Exp NPV of supermarg. profit) vs. CRM (Market failures: insufficient markets to hedge risk, price caps, dynamic policy inconsistency etc.)

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- Problem: capacity investments are a dynamic process; their value depend on the evolution of costs and values, which are uncertain.
- Even if the investment in capacity allows obtaining *security of supply*, it fixes the technology that a given system relies on (investments are stranded costs) and foregoes technological improvements.
- The analytical framework to evaluate the value of investments that includes the value of flexibility is the Real Option analysis.

Introduction

An investor who invest in capacity under a CRM sells a bundle of call options to the SO: obtains ex ante a remuneration, but foregoes the possibility to gain the difference between the VOLL and the marginal cost whenever the system is short of capacity.

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1. What is the option value of the investments in capacity financed by a CRM?
2. Is the value of the investment increased or reduced when including the OV compared with the NPV?
3. How can we compare the value of the investment across different technologies when there is technological uncertainty?

The framework/1

Our assumptions:

- Investment in capacity through a CRM allows reaching *security of supply*: no evaluation of effectiveness, only efficiency is studies. This allows normalizing w.r.t. quantity and focusing on values.

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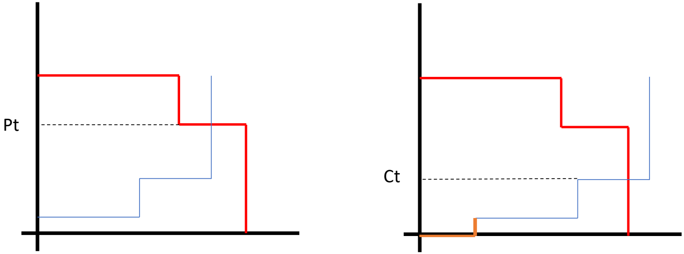
- Investment in capacity through a CRM allows reaching *security of supply*: no evaluation of effectiveness, only efficiency is studies. This allows normalizing w.r.t. quantity and focusing on values.
- A CRM allows avoiding price spikes (VOLL) $\rightarrow$ prices are set by marginal cost of marginal technology (C_t). The effect in the market is capping (de facto) power prices and profits, switching it to ex ante fixed remuneration. Examples: Reliability Options (make this apparent) but also capacity payments or strategic reserves.

The framework/2



The framework/3

Suppose there is uncertainty on power prices (P_t) and on the cost of the marginal technology (C_t). Assume they are both GBM with drift:

$$\frac{dP_t}{P_t} = \mu_P P_t dt + \sigma_P P_t dW_t^P \tag{1}$$

$$\frac{dC_t}{C_t} = \mu_c C_t dt + \sigma_c C_t dW_t^C \tag{3}$$

μ_P and μ_c are drifts; σ_P and σ_C are the volatility parameters, and dW_t^P and dW_t^C are Wiener processes.

The framework/4

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1. on the (marginal) cost of the marginal technology;
2. on the marginal cost of its own power production;
3. on becoming itself the marginal plant.

In order to tackle this problem, we consider four different types of investments:

The framework/5

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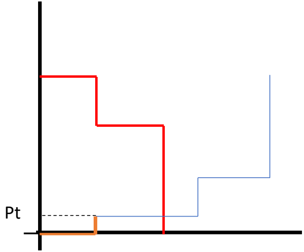
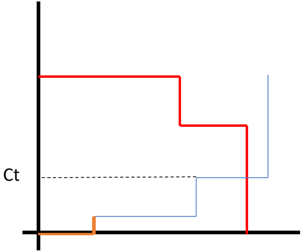
3. A capacity with fixed (cheap) marginal cost but no technological evolution (eg: nuclear - or coal with CCS).
4. A capacity with random cost and (full uncertainty) (eg: DSR).

Model 1 - Battery storage coupled with RES production

There is no cost of generating power.





Model 1 - Battery storage coupled with RES production

The instantaneous profit for a investor in the Battery is:

$$\begin{aligned}\pi_t^c &= k + P_t - \max(P_t - C_t,\ 0)\\ &= \begin{cases} k + C_t \ \textit{if} \ P_t \geq C_t \\ k + P_t \ \textit{if} \ P_t < C_t \end{cases}\\ &= k + \min(P_t,\ C_t)\end{aligned}$$

Model 1 - Battery storage coupled with RES production

The value of the investment is:

$$
\begin{aligned}
V(P_t, C_t) &= E_t\left[\int_t^{\infty} \pi^c(P_s, C_s)e^{-r(s-t)}ds\right] \\
&= \frac{k}{r} + E_t\left[\int_t^{\infty} \min(P_t,\ C_t)e^{-r(s-t)}ds\right]
\end{aligned}
$$

Model 1 - Battery storage coupled with RES production

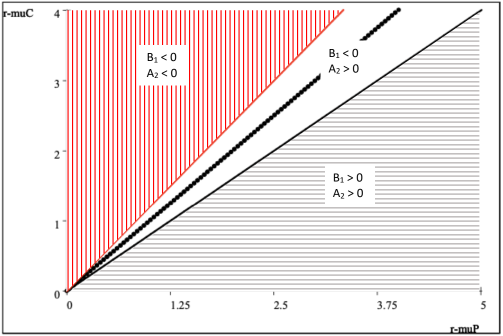
Solving the PDEs, we get:

$$V(P,C) = \begin{cases} V^1(P,C) = \frac{k}{r} + \frac{P}{r-\mu_P} + B_1 C^{1+\beta_2} P^{-\beta_2} & \text{for} \quad P < C \\ V^2(P,C) = \frac{k}{r} + \frac{C}{r-\mu_C} + A_2 C^{1+\beta_1} P^{-\beta_1} & \text{for} \quad P \geq C \end{cases}$$

Model 1 - Battery storage coupled with RES production

$B_1 \cdot \Delta_1$ and $A_2 \cdot \Delta_2$ are the OV of the investment. They can be negative or positive, depending on μ_P and μ_C. Thus, the OV might increase or reduce the investment compared to the NPV. If: $\mu_P = \mu_C = 0 \rightarrow A_2 = B_1 < 0$. This means that investments are undertaken under lower fixed costs: $I = V(P, C) < I^*$, where $I^* = NPV$ is the 'accounting' equilibrium condition. However, this depends on how μ_C and μ_P evolve overtime.

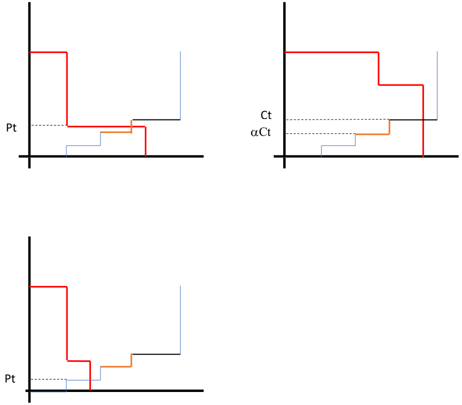
Model 1 - Battery storage coupled with RES production



If $\mu_C >> \mu_P \rightarrow B_2 > 0$ and $A_1 > 0$: investments cost more than the NPV (or the equilibrium k needs to be higher).

Model 2 - Efficient CCGT

There is a cost of generating power B_t but the plant is always more efficient than the marginal one: $B_t = \alpha C_t$, $\alpha \in (0, 1)$.



Model 2 - Efficient CCGT

The instantaneous profits are:

$$\pi_t^c = \begin{cases} k + C_t - \alpha C_t & \text{if } P_t \geq C_t \\ k + P_t - \alpha C_t & \text{if } \alpha C_t < P_t < C_t \\ k & \text{if } P_t < \alpha C_t \end{cases}$$

$$\pi_t^c = k + \min(P_t,\ C_t) - \alpha C_t$$

Model 2 - Efficient CCGT

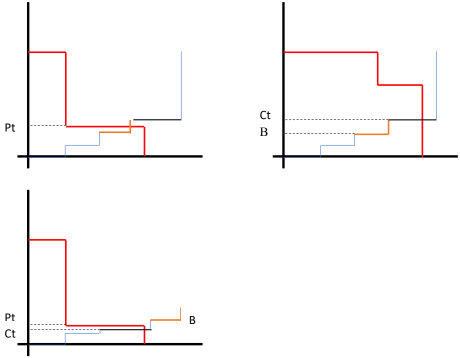
The value function $V(P, C)$ is:

$$\begin{cases} V^1(P,C) & = \frac{k-\alpha C}{r} + \frac{C}{r-\mu_C} + B_1 C^{1+\beta_2} P^{-\beta_2} \text{ for } 1 \\ V^2(P,C) & = \frac{k-\alpha C}{r} + \frac{P}{r-\mu_P} + A_2 C^{1+\beta_1} P^{-\beta_1} + B_2 C^{1+\beta_2} P^{-\beta_2} \quad \text{for } 2 \\ V^3(P,C) & = \frac{k}{r} + A_3 C^{1+\beta_1} P^{-\beta_1} \quad \text{for } 3 \end{cases}$$

$1 = P_t \geq C_t$; $2 = \alpha C_t < P_t < C_t$; $3 = P_t < \alpha C_t$.

Model 3 - Nuclear

Uncertain technological and cost evolution. B is constant, however, the capacity might become the marginal plant.



Model 3 - Nuclear

$$\pi_t^c = \begin{cases} k + C_t - B & \text{if } P_t \geq C_t \\ k + P_t - B & \text{if } B < P_t < C_t \\ k & \text{if } P_t \leq B \cup B > C_t \end{cases}$$

$$\pi_t^c = k + \max\{\min(P_t,\ C_t) - B, 0\}$$

Model 4 - DSR. random cost and random marginal technology

Full uncertainty. Assumption: uncorrelated GBM, $P_t - B_t$ and $C_t - B_t$ are ABM

$$\pi_t^c = \begin{cases} k + C_t - B_t & \text{if } P_t \geq C_t \\ k + P_t - B_t & \text{if } B_t < P_t < C_t \\ k & \text{if } P_t < B_t \cup B_t \geq C_t \end{cases}$$

$$\pi_t^c = k + \max\{\min(P_t - B_t,\ C_t - B_t), 0\}$$