Investing in electricity production under a reliability options scheme

Fulvio Fontini, Tiziano Vargiolu, Dimitrios Zormpas

University of Padova

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CRMs and ROs

- Should we stimulate investments in electricity production and if yes how?
- Energy-only markets (no intervention).
- Capacity Remuneration mechanisms (intervention).

CRMs and ROs (cont.)

- Reliability Options are about to be implemented in Italy.
- Contracts between the system operator and a power producer.
- The power plant receives ex-ante a flow of payments.
- In return, a price cap is imposed.

Our work

- Are ROs effective, i.e., able to foster investments?
- What is the impact on the investment value?

Methodology: The Real Options Approach

- According to the Real Options Approach, when contemplating an investment characterized by **uncertainty** and **irreversibility**, the **ability to delay** the investment is valuable.
- Investments in power production are characterized by uncertainty (e.g. volatile prices and production costs) and irreversibility (e.g. the mere construction of a power plant).

The basic set-up

- A potential investor is contemplating investing in a power plant.
- The investment cost associated with the project is $I > 0$.
- The market price is P_t and is assumed to be fluctuating over time according to the following gBM:

$$\frac{dP_t}{P_t} = \alpha dt + \sigma dW_t \text{ with } P_0 = P$$

- α is the drift, σ is the instantaneous volatility, P is the starting point of the process and W_t is a standard Wiener process.

The basic set-up (cont.)

- The production cost of electricity is assumed to be constant and equal to $c \geq 0$
- The instantaneous profit flow is $\pi_t = P_t - c$.
- Also i) risk-neutral potential investor, ii) $r > \alpha$, iii) once launched, the project runs forever.
- The problem that the potential investor needs to solve has to do with the choice of the **optimal investment timing**.

The investment problem in the absence of ROs

- The operating value of the power plant is:

$$V\left(P_t\right) = \frac{P_t}{r-\alpha} - \frac{c}{r}$$

- The potential investor has the option to invest in the power plant and get $V\left(P_t\right)$ by spending I.
- The value of the option to invest is:

$$F\left(P_t\right) = \max\left\{V\left(P_t\right) - I, \frac{1}{1+rdt}E_t\left[F\left(P_t + dP_t\right)\right]\right\}$$

The investment problem in the absence of ROs (cont.)

For $P < P_T$ we obtain:

$$P_T = \frac{\beta_1}{\beta_1 - 1}(r - \alpha)\left(\frac{c}{r} + I\right)$$

and consequently,

$$F(P_t) = \left(\frac{P_T}{r-\alpha} - \frac{c}{r} - I\right)\left(\frac{P}{P_T}\right)^{\beta_1}$$

where $\beta_{1,2} = \frac{1}{2} - \frac{\alpha}{\sigma^2} \pm \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}}$ with $\beta_1 > 1$, $\beta_2 < 0$.

The investment problem in the presence of ROs

- The profit function is not $\pi_t = P_t - c$ anymore but:

$$\begin{aligned} \overline{\pi}_t &= \min\{P_t, K\} - (c - m) \\ &= \min\{P_t, K\} - n \end{aligned}$$

- $K\,(> 0)$ is the price cap that the RO poses.
- $m\,(> 0)$ is a fixed periodic payment.
- $n = c - m$

The investment problem in the presence of ROs (cont.)

The operating value of the project in this case is:

$$\overline{V}\left(P_t\right)=\begin{cases} AP_t^{\beta_1}+\frac{P_t}{r-\alpha}-\frac{n}{r} & \text{for } P_t\leq K \\ BP_t^{\beta_2}+\frac{K-n}{r} & \text{for } P_t>K \end{cases}$$

where

$$\begin{aligned} A &= -\frac{r-\beta_2\alpha}{\left(r-\alpha\right)\left(\beta_1-\beta_2\right)r}K^{1-\beta_1}<0 \\ B &= -\frac{r-\beta_1\alpha}{\left(r-\alpha\right)\left(\beta_1-\beta_2\right)r}K^{1-\beta_2}<0 \end{aligned}$$

- $AP_t^{\beta_1}$ and $BP_t^{\beta_2}$ represent the obligation of the power plant to cash K when $P_t>K$, and P_t otherwise $\left(P_t\leq K\right)$.

The investment problem in the presence of ROs (cont.)

The value of the option to invest is as before:

$$\overline{F}\left(P_t\right) = \max\left\{\overline{V}\left(P_t\right) - I, \frac{1}{1+rdt} E_t\left[\overline{F}\left(P_t + dP_t\right)\right]\right\}$$

The investment problem in the presence of ROs (cont.)

Since the investment threshold can be higher or lower that K, we consider two possible cases:

1. K is larger than, or at most equal to, the optimal investment threshold.
2. K is smaller than the optimal investment threshold.

Case 1 (the investment threshold is smaller than the price cap)

Provided that $K \geq \frac{\beta_1}{\beta_1 - 1}(r-\alpha)\left(\frac{n}{r}+I\right)$ we have:

$$
\begin{aligned}
P_T^* &= \frac{\beta_1}{\beta_1 - 1}(r-\alpha)\left(\frac{n}{r}+I\right) \\
\overline{F}(P_t) &= \left(AP_T^{*\beta_1} + \frac{P_T^*}{r-\alpha} - \frac{n}{r} - I\right)\left(\frac{P}{P_T^*}\right)^{\beta_1}
\end{aligned}
$$

Case 1 (the investment threshold is smaller than the price cap) (cont.)

Note that:

- $P_T^* < P_T$
- Unsurprisingly $\frac{\partial P_T^*}{\partial m} < 0$, $\frac{\partial \overline{F}(P_t)}{\partial m} > 0$, $\frac{\partial \overline{F}(P_t)}{\partial K} > 0$.
- For a given m, we can obtain $\overline{F}(P_t) = F(P_t)$ by choosing

$$\hat{K} = \left(\frac{(\beta_1 - 1)\tilde{A} P_T^{*\beta_1}}{\left(\frac{n}{r} + I\right) - \left(\frac{c}{r} + I\right)\left(\frac{P_T^*}{P_T}\right)^{\beta_1}} \right)^{\frac{1}{\beta_1 - 1}}.$$

Case 2 (the investment threshold is larger than the price cap)

Provided that $K \in \left(Ir + n, \frac{\beta_1}{\beta_1 - 1} (r - \alpha) \left(I + \frac{n}{r} \right) \right)$ we have:

$$
\begin{aligned}
P_T^{**} &= \left[\frac{1}{B} \frac{\beta_1}{\beta_1 - \beta_2} \left(I - \frac{K - n}{r} \right) \right]^{\frac{1}{\beta_2}} \\
\overline{F}(P_t) &= \left(B P_T^{**\beta_2} + \frac{K - n}{r} - I \right) \left(\frac{P}{P_T^{**}} \right)^{\beta_1}
\end{aligned}
$$

Case 2 (the investment threshold is larger than the price cap) (cont.)

- P_T^{**} can be larger, smaller or exactly equal to P_T.
- For a given K, $\tilde{m} = c + rI - K + K\frac{r-\beta_1\alpha}{(r-\alpha)\beta_1}\left(\frac{P_T}{K}\right)^{\beta_2}$ guarantees $P_T^{**} = P_T$.
- Also, $\frac{\partial P_T^{**}}{\partial K} < 0$, $\frac{\partial P_T^{**}}{\partial m} < 0$, $\frac{\partial \overline{F}(P_t)}{\partial m} > 0$, $\frac{\partial \overline{F}(P_t)}{\partial K} > 0$
- For a given K, a periodic flow $\hat{m}$ such that $\left(I - \frac{K-(c-\hat{m})}{r}\right)\frac{\beta_2}{\beta_1-\beta_2} = \left(\frac{c}{r} + I\right)\frac{1}{\beta_1-1}\left(\frac{P_T^{**}(\hat{m})}{P_T}\right)^{\beta_1}$, guarantees $F(P_t) = \overline{F}(P_t)$.

Summing up

- The policy maker can use the ROs as investment stimuli.
- However, certain conditions need to hold for this to be the case.
- This depends on the constraints (budget, technical, political etc.) that the policy maker faces.

What's next?

- Can we stimulate investments while keeping a balanced budget?
- Relax the gBM assumption.
- Allow for a price cap that reflects the economic fundamentals of the energy sector, i.e., K stochastic or endogenous.
- Allow for mothballing when the price falls below the unit cost.