# A Primer on Capacity Mechanisms

**Natalia Fabra**
Universidad Carlos III de Madrid and CEPR

FUNCAS, April 2018

# Introduction

**Electricity markets at a cross-road**:

- Deployment of renewables needed for the low-carbon transition
- Renewables depress market prices
- Reduce profitability and increase risk of conventional technologies
- Weak-demand response + non-storability: back-up?

# Introduction

**Electricity markets at a cross-road**:

- Deployment of renewables needed for the low-carbon transition
- Renewables depress market prices
- Reduce profitability and increase risk of conventional technologies
- Weak-demand response + non-storability: back-up?

**Renewables are not the problem...**

- Energy-only markets pay a uniform price to all MWhs
- Unpriced externalities:
  - environmental externalities, reliability, flexibility, etc.
- Because of no free entry, market power rents

# Today's focus

Are the current arrangements well suited
to induce adequate investments?

February 2010, **Ofgem**:

*"There is a need for unprecedented levels of investment to be sustained over many years in difficult financial conditions and against a background of increased risk and uncertainty...Ofgem does not consider that leaving the current arrangements unaltered is in the interests of consumers."*

# Today's focus

Energy-only market fails in providing adequate investment

**Need, effect and design** of capacity mechanisms

# Today's focus

Energy-only market fails in providing adequate investment

**Need, effect and design** of capacity mechanisms

**Issues:**

- How do capacity payments affect energy markets?
- What is the optimal capacity target?
- And the optimal policy to achieve it?
- Should all plants receive capacity payments, or only the new ones?
- What if there is market power in the capacity market?
- Auctioning capacity payments while mitigating mkt power?

# Investment Incentives and Market Power

Fundamental interaction: investment and market power

- market power determines rents for investors...
- ....but also affects marginal incentives

# Investment Incentives and Market Power

Fundamental interaction: investment and market power

- market power determines rents for investors...
- ....but also affects marginal incentives

Understanding the trade-off is key for....

- diagnosing market failures
- designing regulatory and market-based instruments

# Investment Incentives and Market Power

Fundamental interaction: investment and market power

- market power determines rents for investors...
- ....but also affects marginal incentives

Understanding the trade-off is key for....

- diagnosing market failures
- designing regulatory and market-based instruments

**Scarcity pricing** leaves free-way to **market power**

**Capacity payments** needed to **restore missing money without introducing market power**

# Roadmap

- Model description
- Benchmarks:
  - welfare maximizing capacity
  - the energy-only market paradigm
- Equilibrium investment
- Capacity mechanisms
- Further issues:
  - new vs old capacity
  - market power in the capacity market
  - reliability options
- Conclusions

# Model Ingredients

- $n$ firms compete to generate electricity
- Zero production costs up to the firm's capacity, $k_i$, $i = 1, ..., n$
- Unit cost of capacity, $c > 0$
- Demand $\theta$ is uniformly distributed on $[0, 1]$
- Demand is price- inelastic; prices capped at $P$
- Consumers receive gross utility $v \geq P$ per unit consumed

# First-Best Capacity

- Expected welfare as a function of aggregate capacity $K$,

$$W = v\left(\int_0^K \theta d\theta + \int_K^1 K d\theta\right) - cK$$

# First-Best Capacity

- Expected welfare as a function of aggregate capacity $K$,

$$W = v\left(\int_0^K \theta d\theta + \int_K^1 K d\theta\right) - cK$$

- Trade-off: value of extra consumption ($v$) versus investment cost ($c$)

$$K^{FB} = \frac{v - c}{v} < 1$$

# First-Best Capacity if Blackouts are Possible

- Probability of a system blackouts: $\gamma$

$$W = v\left(\int_0^K \theta d\theta + (1-\gamma)\int_K^1 K d\theta\right) - cK$$

# First-Best Capacity if Blackouts are Possible

- Probability of a system blackouts: $\gamma$

$$W = v\left(\int_0^K \theta d\theta + (1-\gamma)\int_K^1 K d\theta\right) - cK$$

- Optimal capacity goes up:

$$K^{FB} > \frac{v-c}{v}$$

- Full insurance against blackouts ($K^{FB} = 1$) if $\gamma$ very high

# Energy-only Market Paradigm

1. free entry $\Rightarrow$ zero profits
2. no market power $\Rightarrow$ prices=MC if excess capacity

# Energy-only Market Paradigm

1. free entry ⇒ zero profits
2. no market power ⇒ prices=MC if excess capacity

- Profits = scarcity rents minus investment costs = 0

$$\pi_i = P \int_{nk}^{1} k d\theta - ck = 0$$

# Energy-only Market Paradigm

1. free entry ⇒ zero profits
2. no market power ⇒ prices=MC if excess capacity

- Profits = scarcity rents minus investment costs = 0

$$\pi_i = P \int_{nk}^{1} k d\theta - ck = 0$$

$$K^* = \frac{P - c}{P} \leq K^{FB}$$

# Energy-only Market Paradigm

1. free entry $\Rightarrow$ zero profits
2. no market power $\Rightarrow$ prices=MC if excess capacity

- Profits = scarcity rents minus investment costs = 0

$$\pi_i = P \int_{nk}^{1} k d\theta - ck = 0$$

$$K^* = \frac{P-c}{P} \leq K^{FB}$$

# Energy-only Market Paradigm

**Claims of the energy-only paradigm:**

- Price caps create under-investment
- Removing price caps $\Rightarrow$ efficient investment; consumers better off

# Energy-only Market Paradigm

**Claims of the energy-only paradigm:**

- Price caps create under-investment
- Removing price caps $\Rightarrow$ efficient investment; consumers better off

**However...**

- Sub-optimal investment if blackouts are possible
- Because of market power and no free entry:
  - Efficiency cannot be achieved by removing price-caps
  - Removing price caps gives rise to market power
  - Market power reduces consumer surplus and distorts efficiency

# Investment Model under Market Power

**Dominant firm-fringe model:**

- all firms but one bid at marginal cost (fringe)
- firm 1 maximizes profits over residual demand

# Investment Model under Market Power

**Dominant firm-fringe model:**

- all firms but one bid at marginal cost (fringe)
- firm 1 maximizes profits over residual demand
- Energy market profits for firm 1:

$$\pi_1 = P \int_{k_F}^{k_F + k_1} [\theta - k_F] \, d\theta + P \int_{k_F + k_1}^{1} k_1 \, d\theta - c k_1$$

# Equilibrium outcomes

- **Dominant firm**: only benefits from capacity expansions when $\theta > K$

$$K^* = \frac{P - c}{P} \leq K^{FB}$$

# Equilibrium outcomes

- **Dominant firm**: only benefits from capacity expansions when $\theta > K$

$$K^* = \frac{P - c}{P} \leq K^{FB}$$

- Welfare max. is price-caps removed $P^* = v$ [* with *caveats*]

# Equilibrium outcomes

- **Dominant firm**: only benefits from capacity expansions when $\theta > K$

$$K^* = \frac{P - c}{P} \leq K^{FB}$$

- Welfare max. is price-caps removed $P^* = v$ [* with *caveats*]
- Profits = market power rents (scarcity rents = investment costs)

# Equilibrium outcomes

- **Dominant firm**: only benefits from capacity expansions when $\theta > K$

$$K^* = \frac{P - c}{P} \leq K^{FB}$$

- Welfare max. is price-caps removed $P^* = v$ [* with *caveats*]
- Profits = market power rents (scarcity rents = investment costs)
- Consumer surplus max. with binding price caps, $P^* < v$
  - trade-off greater consumption vs higher prices

# Capacity Mechanisms

- Capacity payments: pay $sk$ regardless of firms' production
  - **price regulation:** regulator sets $s$ and investors choose $K$
  - **quantity regulation:** regulator chooses $K$, and market sets $s$

# Capacity Mechanisms

- Capacity payments: pay $sk$ regardless of firms' production
  - **price regulation:** regulator sets $s$ and investors choose $K$
  - **quantity regulation:** regulator chooses $K$, and market sets $s$
- To induce desired investments in capacity,

$$K^* = \frac{P - (c - s)}{P} \Rightarrow s = c - (1 - K^*)\, P$$

- To induce $K^*$, pay firms investment costs net of scarcity rents

# Capacity Mechanisms

- Capacity payments: pay $sk$ regardless of firms' production
  - **price regulation:** regulator sets $s$ and investors choose $K$
  - **quantity regulation:** regulator chooses $K$, and market sets $s$
- To induce desired investments in capacity,

$$K^* = \frac{P - (c - s)}{P} \Rightarrow s = c - (1 - K^*) P$$

- To induce $K^*$, pay firms investment costs net of scarcity rents
- $s = 0$ when $P = v$ (i.e., no price cap)
- $s = c$ when $P = 0$ (prices capped at MC)

# The optimal policy: price-caps and capacity payments

**Optimal capacity payment for a given price-cap**

- For given $P$, consumer surplus is maximized at some $s^*$ :
  - The lower $P$, the higher $s^*$

# The optimal policy: price-caps and capacity payments

**Optimal capacity payment for a given price-cap**

- For given $P$, consumer surplus is maximized at some $s^*$ :
  - The lower $P$, the higher $s^*$
  - If no price caps ($P = v$), charge a *capacity fee* $s^* < 0$
  - the energy-only market paradigm is sub-optimal ($P = v; \ s = 0$)

# The optimal policy: price-caps and capacity payments

**Optimal capacity payment for a given price-cap**

- For given $P$, consumer surplus is maximized at some $s^*$ :
  - The lower $P$, the higher $s^*$
  - If no price caps ($P = v$), charge a *capacity fee* $s^* < 0$
  - the energy-only market paradigm is sub-optimal ($P = v;\ s = 0$)

**Optimal capacity payment and price-cap**

- Optimal policy: $s^* = c$ and $P = 0$
- [Auctions to overcome *asymmetric info*]

**Capacity payments** needed to **restore missing money without introducing market power**

# Support for all or only for the new capacity?

- Support to new capacity only
  - examples: strategic reserves, tenders for new capacity
- Support to new and old capacity
  - examples: capacity markets, decentralized obligation schemes

# Support for all or only for the new capacity?

- Support to new capacity only
  - examples: strategic reserves, tenders for new capacity
- Support to new and old capacity
  - examples: capacity markets, decentralized obligation schemes
- **Aggregate capacity is the same** under both mechanisms
  - investment depends on marginal profits, not on profit levels

# Support for all or only for the new capacity?

- Support to new capacity only
  - examples: strategic reserves, tenders for new capacity
- Support to new and old capacity
  - examples: capacity markets, decentralized obligation schemes
- **Aggregate capacity is the same** under both mechanisms
  - investment depends on marginal profits, not on profit levels
- Consumers better off when only new capacity receives support
  - Regulator chooses higher $s \Rightarrow$ capacity closer $K^{FB}$
  - Old capacity loses profits but profit loss $<$ capacity payments

# Capacity markets might be subject to market power

- Market power in the capacity market $\Rightarrow$ higher capacity price:

$$s = c - (1 - K)\,P + \left[P\frac{n}{n-1}\left(\frac{K}{n} - k_1\right)\right]$$

**Impact of market power on regulator's choices:**

- Optimal capacity is lower
- Consumers worse off (price increase + capacity reduction)

# Auctioning Reliability Options

- Option price ($s$) and strike price ($f$)
  - Regulator chooses $f$ and $s$ is determined through an auction
- Consumers pay $s$ in exchange of option to buy electricity at $f$

# Auctioning Reliability Options

- Option price ($s$) and strike price ($f$)
  - Regulator chooses $f$ and $s$ is determined through an auction
- Consumers pay $s$ in exchange of option to buy electricity at $f$
- Firms' profits:

$$\pi = \begin{cases} pq - (c - s)\,k & \text{if} \quad p \leq f \\ fk - (c - s)\,k - p\,(k - q) & \text{if} \quad p \geq f \end{cases}$$

# Auctioning Reliability Options

- Option price ($s$) and strike price ($f$)
  - Regulator chooses $f$ and $s$ is determined through an auction
- Consumers pay $s$ in exchange of option to buy electricity at $f$
- Firms' profits:

$$\pi = \begin{cases} pq - (c - s)\,k & \text{if} \quad p \leq f \\ fk - (c - s)\,k - p\,(k - q) & \text{if} \quad p \geq f \end{cases}$$

- Market power is mitigated:
  - $f$ acts as a plant-specific price-cap
  - optimal to set $f = 0$ at marginal cost
- Availability incentivized:
  - $-p\,(k - q)$ acts as endogenous penalty for not being available

# Conclusions

- Scarcity pricing induces inefficiencies
  - Removing price caps gives free-way to market power
  - Plus unpriced externality: reduce blackouts
- Max. consumer surplus: price caps + capacity payments

# Conclusions

- Scarcity pricing induces inefficiencies
  - Removing price caps gives free-way to market power
  - Plus unpriced externality: reduce blackouts
- Max. consumer surplus: price caps + capacity payments

**Further issues:**

- Capacity payments only to new capacity
- Capacity markets vulnerable to market power
- Auctions of new back-up capacity through reliability options
  - strike prices close to MC to mitigate market power

# ¡Muchas gracias!

preguntas? comentarios?

natalia.fabra@uc3m.es

eco.uc3m.es/nfabra