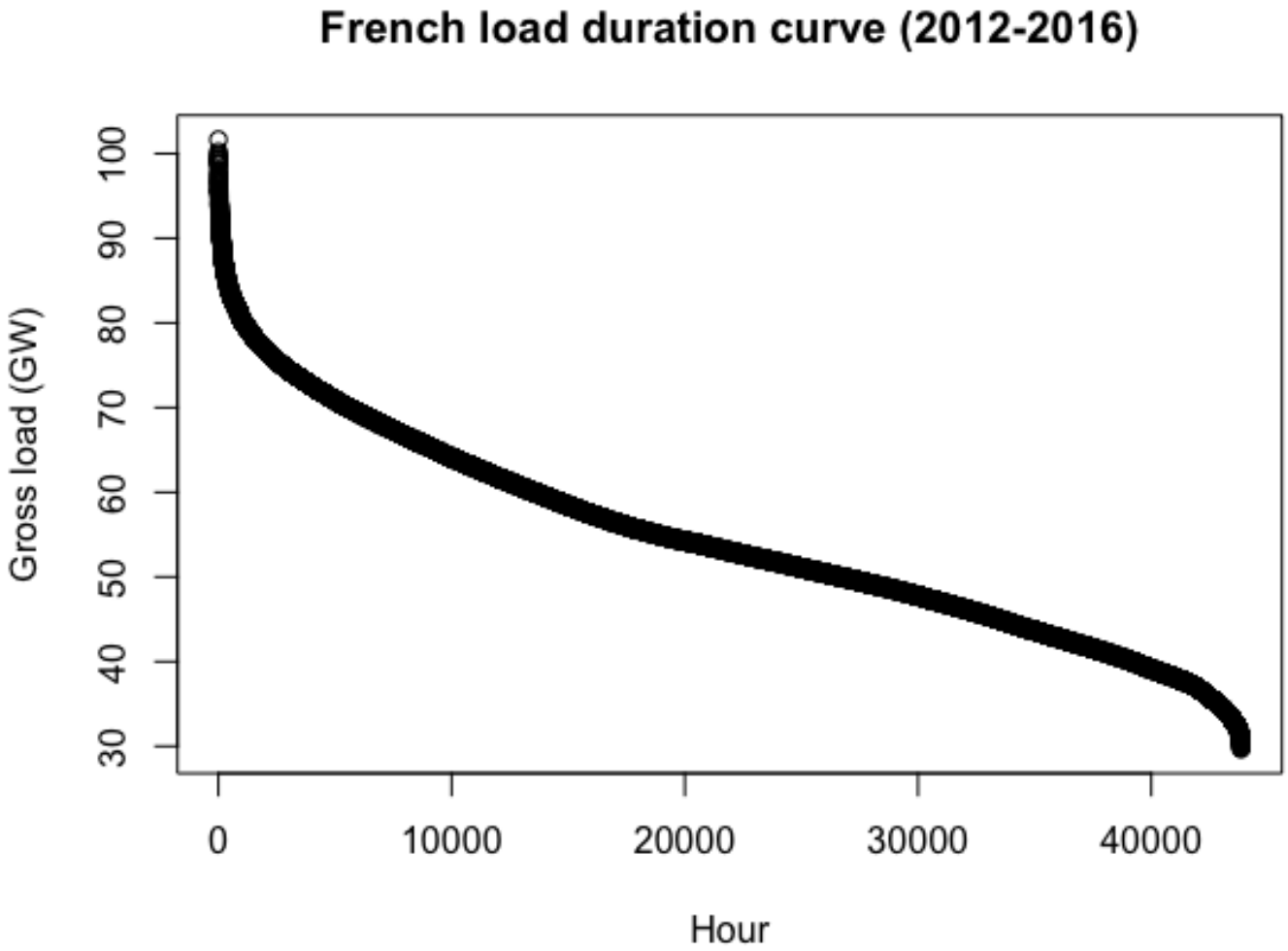
Ensuring Capacity Adequacy in Liberalised Electricity Markets

Nicolas Astier and Xavier Lambin

Twelfth Conference on the Economics of Energy and Climate (TSE)

The capacity adequacy problem



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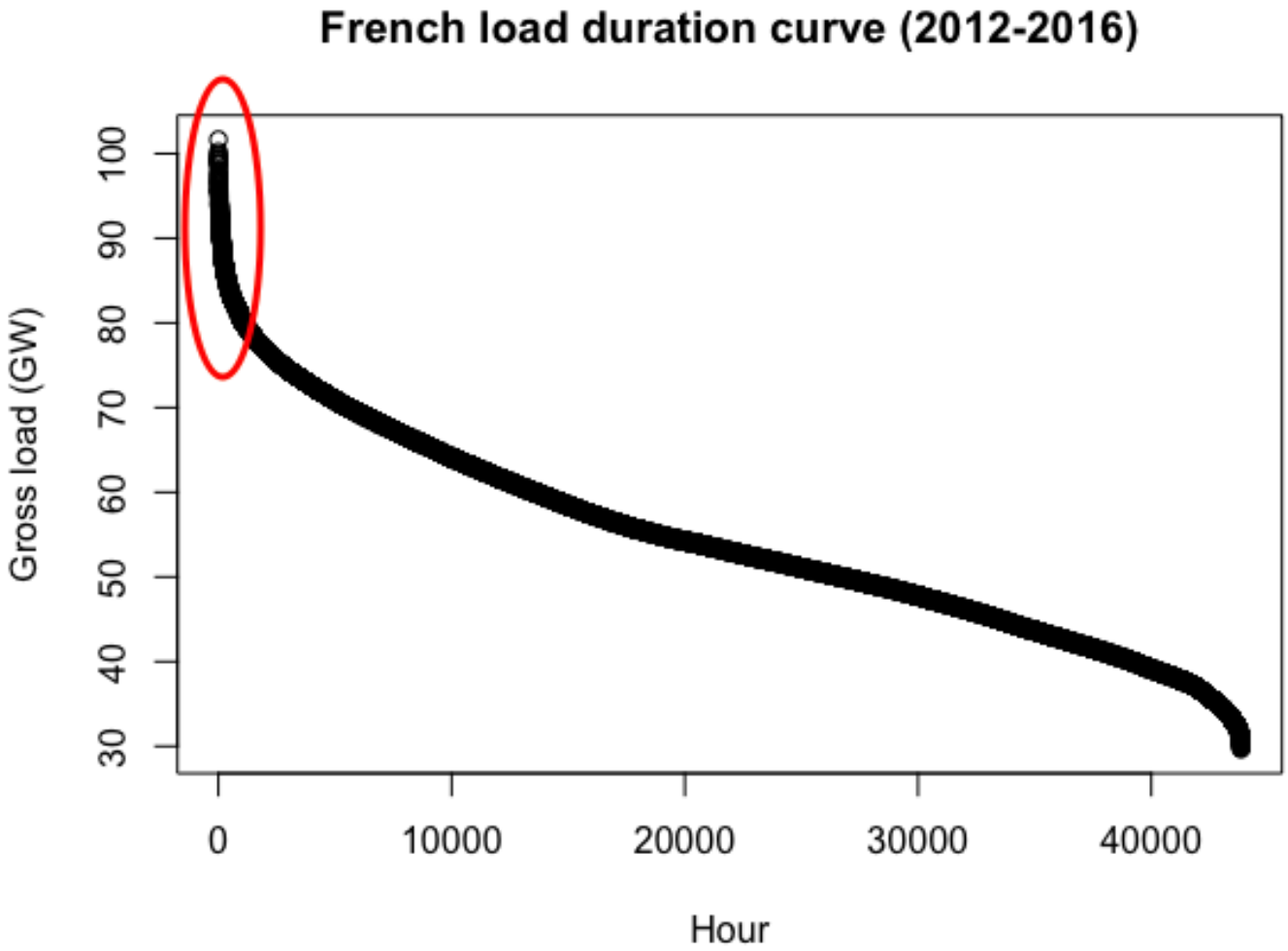
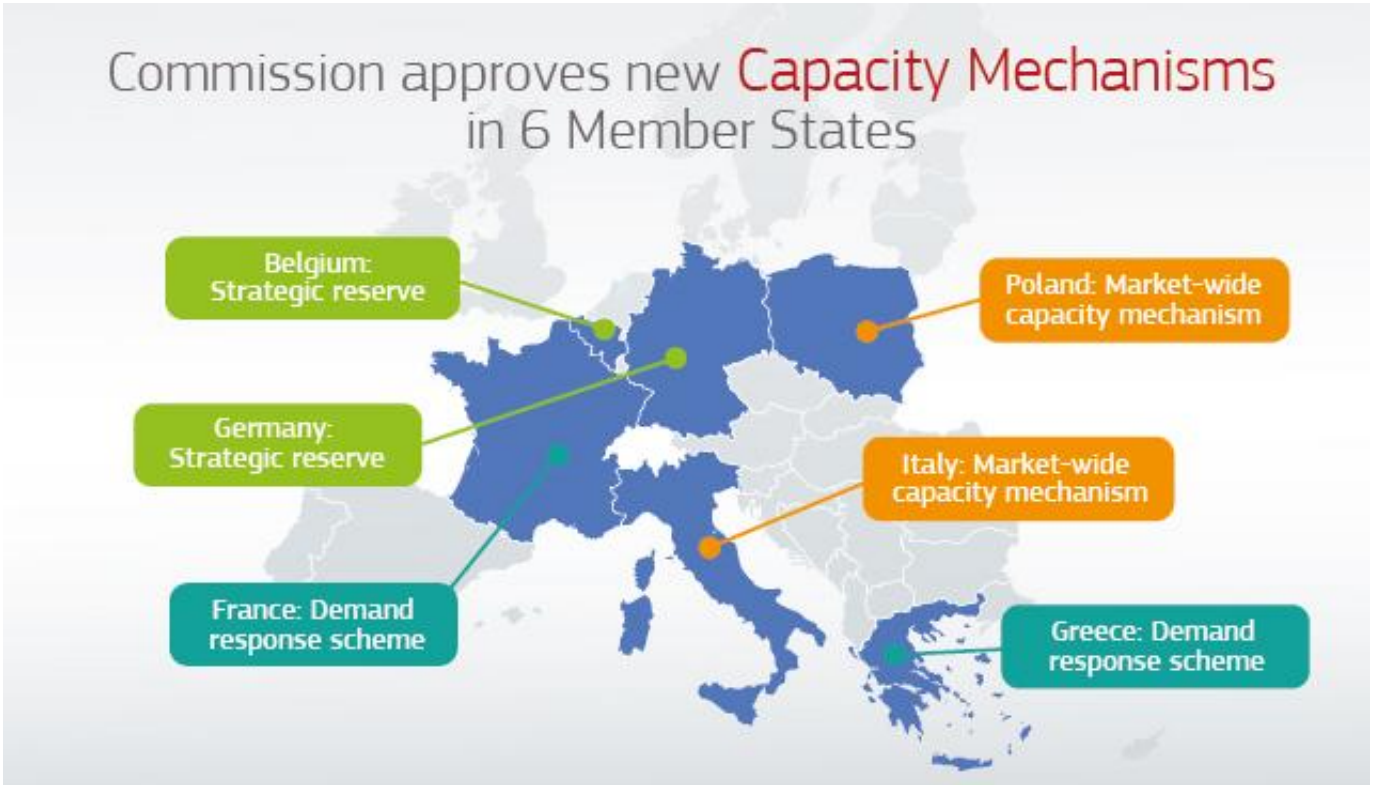


Capacity adequacy mechanisms are mushrooming

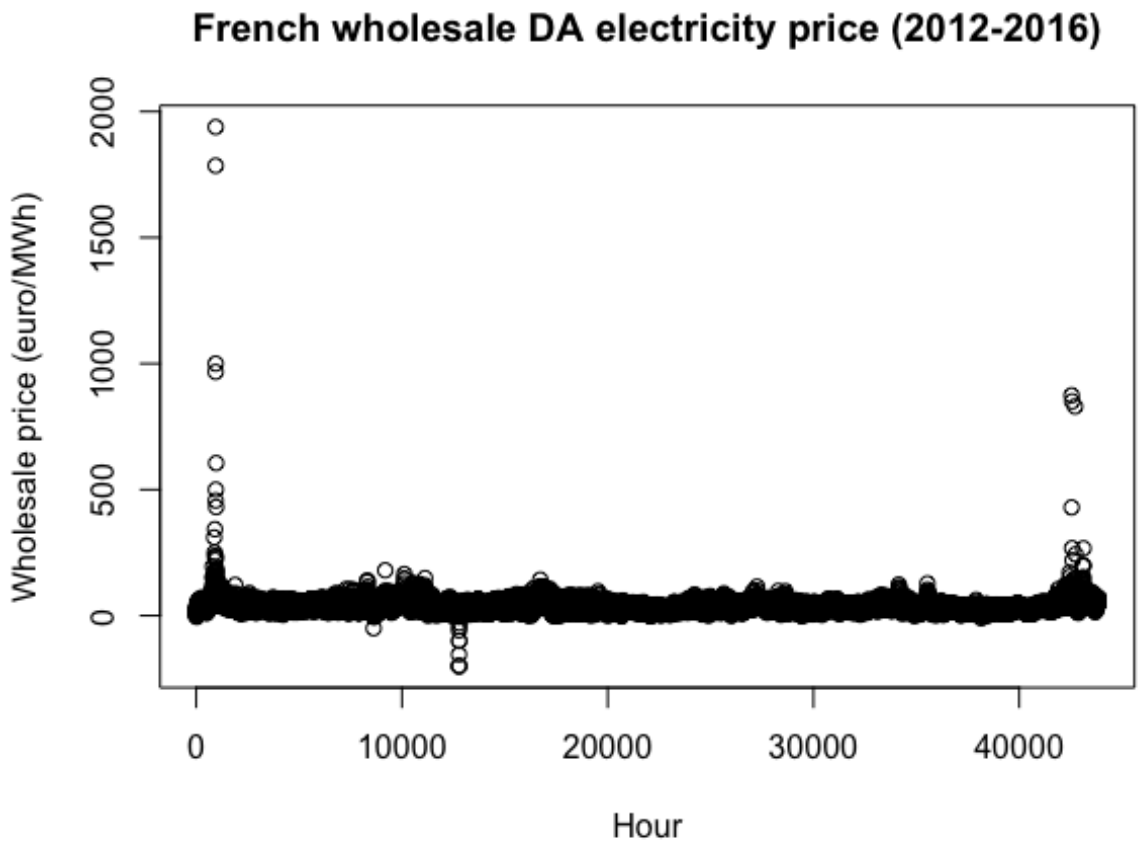
European Commission - Press release

State aid: Commission approves six electricity capacity mechanisms to ensure security of supply in Belgium, France, Germany, Greece, Italy and Poland

Brussels, 7 February 2018



Price spikes attract political attention



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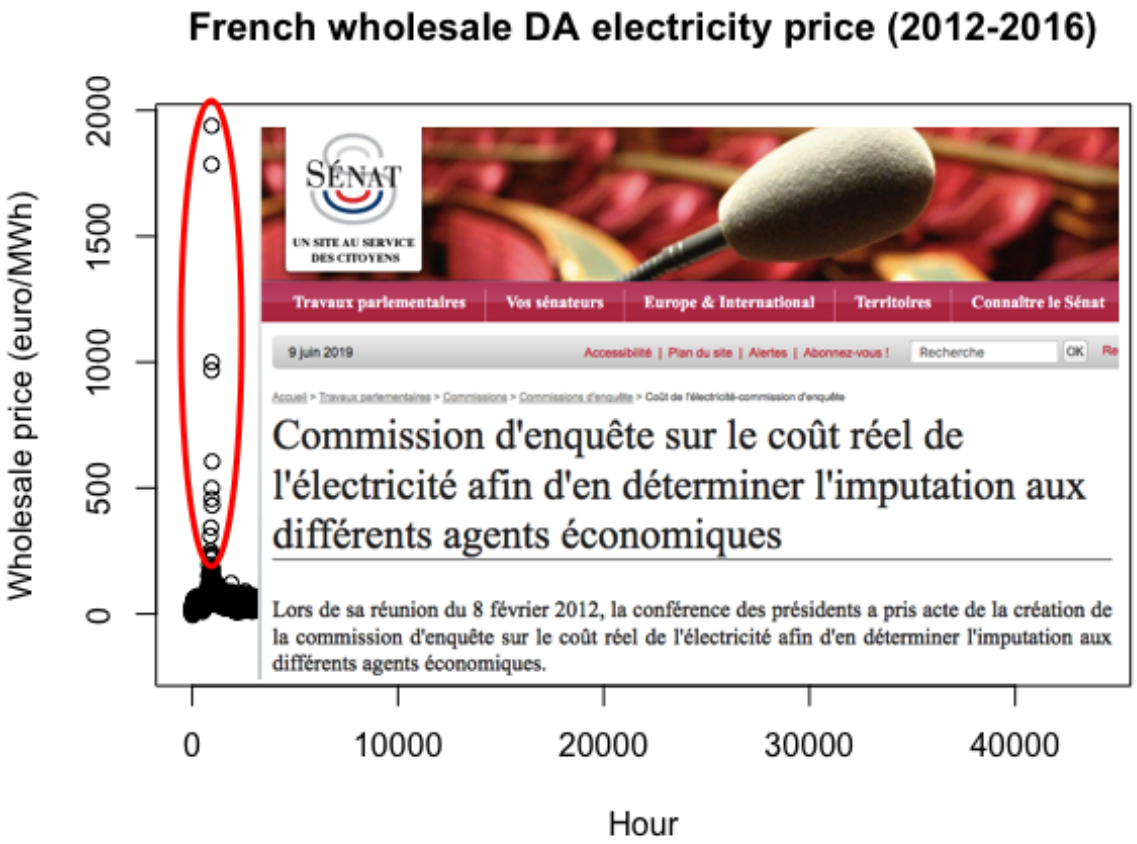

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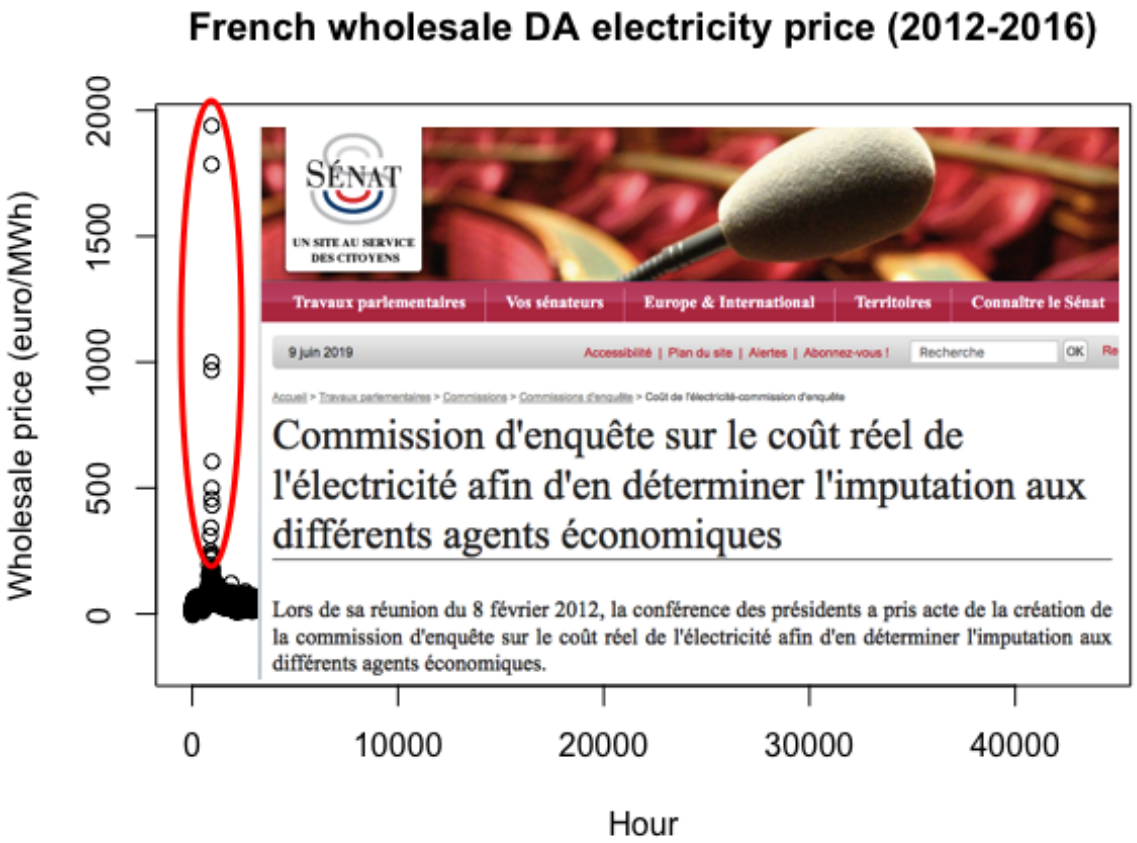

"*[Price] caps and automatic mitigation protocols that constrain idealized free trading and market signals have been implemented in order to curb market power abuse and* **politically unacceptable price spikes** (Oren, 2005).

This paper

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- We show that both demand- and supply-side adequacy mechanisms can be described within a **common analytical framework**.
- We note that, under typically made assumptions, optimal investment signals can be restored by making the marginal costs during peak states either **explicit** or **implicit**.
- While implicit mechanisms are likely to face less political opposition, they are unfortunately more vulnerable to various inefficiencies.

Outline

Background

Demand-side mechanisms:

- **Priority service:**
  e.g. Marchand (1974) ; Tschirhart and Jen (1979) ; Chao et al. (1987) ; Chao and Wilson (1987) ; Wilson (1989).
- **Demand response:**
  e.g. Chao (2010) ; Hogan (2010) ; Chao and DePillis (2013) ; Astier and Léautier (2016) ; Lambin (2017).

Supply-side mechanisms:

- **Capacity Remuneration Mechanisms:**
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Although there are other rationales for the implementation of capacity adequacy mechanisms, we focus here on a situation where a **price cap** is enforced in the wholesale market.

Contributions

1. Models of capacity adequacy mechanisms most often study a single-side of the market, making **strong assumptions on the other side of the market** for the sake of simplicity.

   $\Rightarrow$ we formalize capacity adequacy mechanisms under a **common analytical framework**. This allows to clarify to what extent can capacity adequacy mechanisms be implemented on both the demand and the supply side while still having a good chance of restoring the first-best outcome.

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   $\Rightarrow$ we formalize capacity adequacy mechanisms under a **common analytical framework**. This allows to clarify to what extent can capacity adequacy mechanisms be implemented on both the demand and the supply side while still having a good chance of restoring the first-best outcome.

2. We also highlight the **distinction between implicit and explicit mechanisms**, depending on whether contractual arrangements make it necessary or not to compute supply marginal costs above the price cap.

   $\Rightarrow$ the higher political acceptability of implicit mechanisms is shown to be very likely to come at the cost of inefficiencies.

First-best benchmark

- We start from a first-best situation in which the structure and level of long-term assets is optimal. The would-be price in state t in denoted $p^*(t)$.

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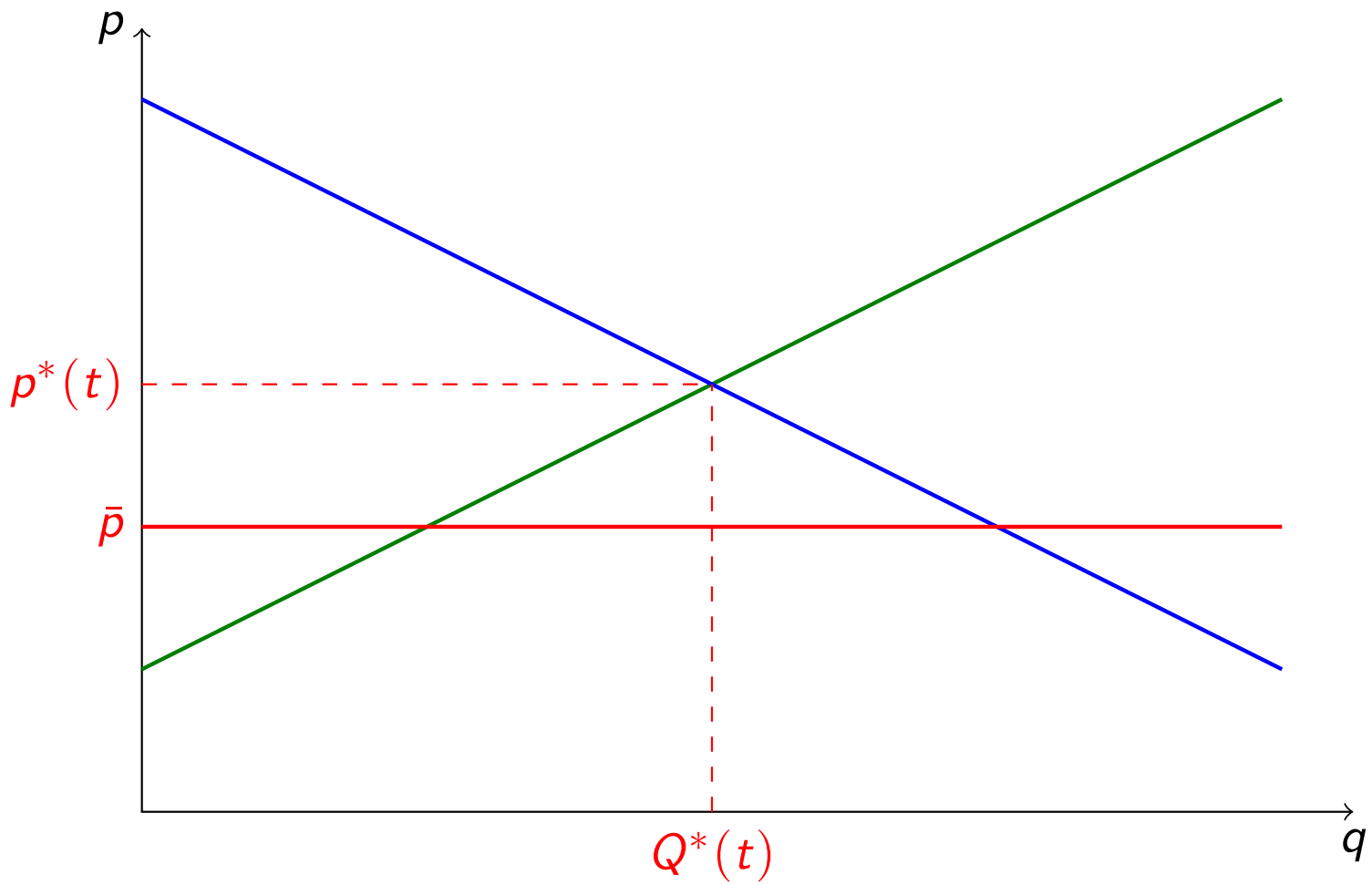
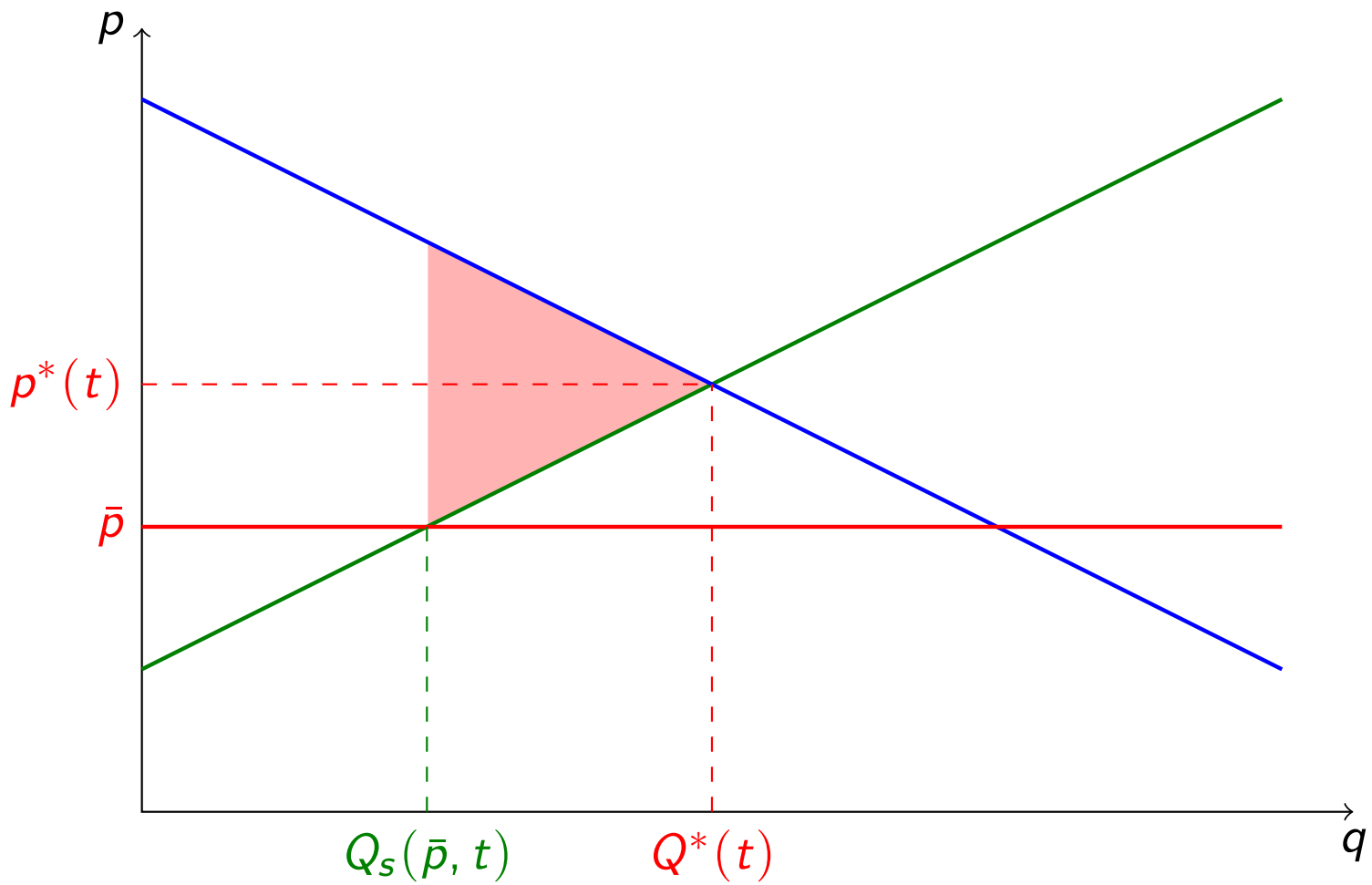
  - **Off-peak states** are such that $p^*(t) \leq \bar{p}$;
  - **Peak states** are such that $p^*(t) > \bar{p}$.

Capacity adequacy mechanisms and short-term efficiency



Capacity adequacy mechanisms and short-term efficiency



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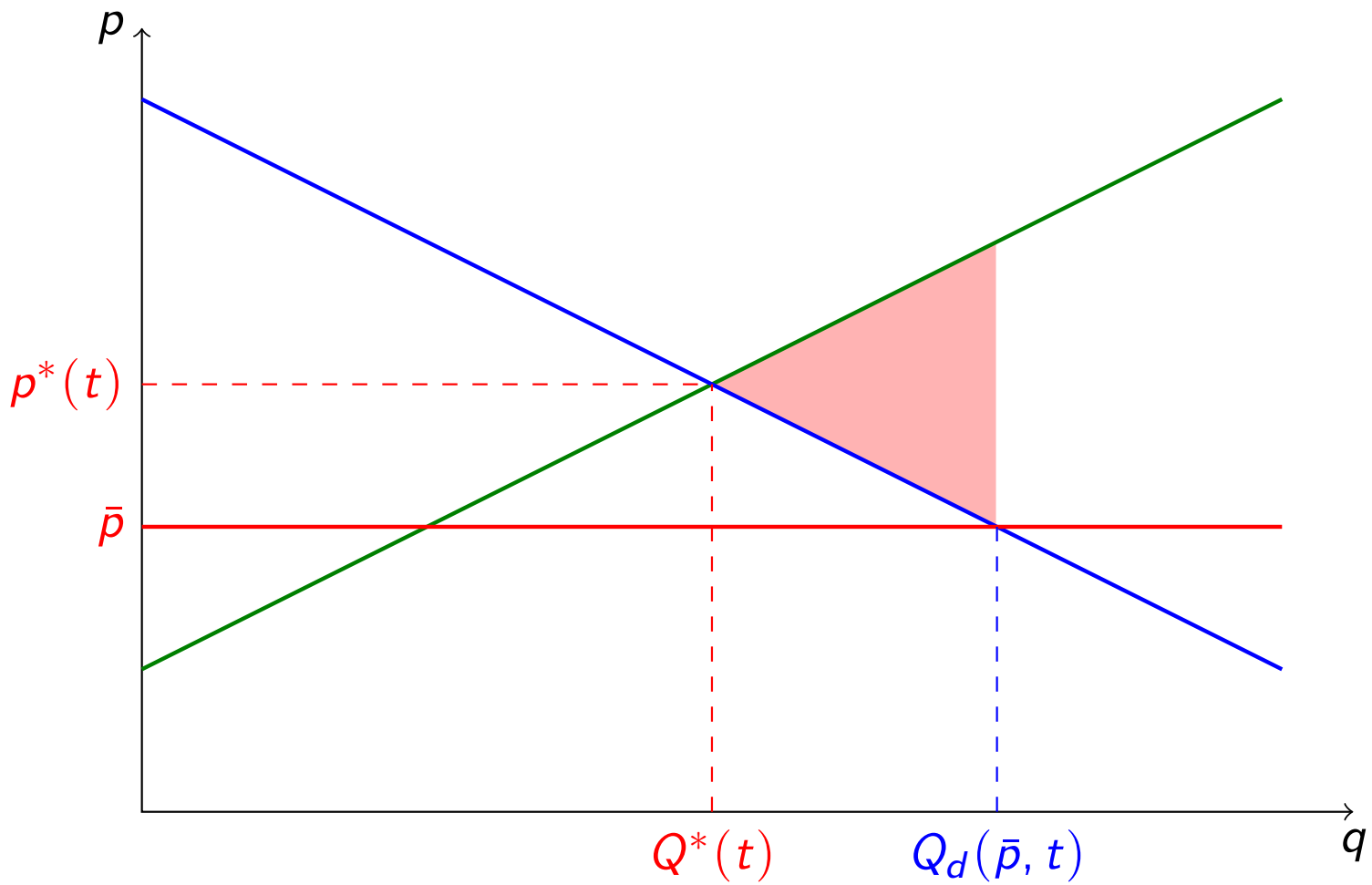

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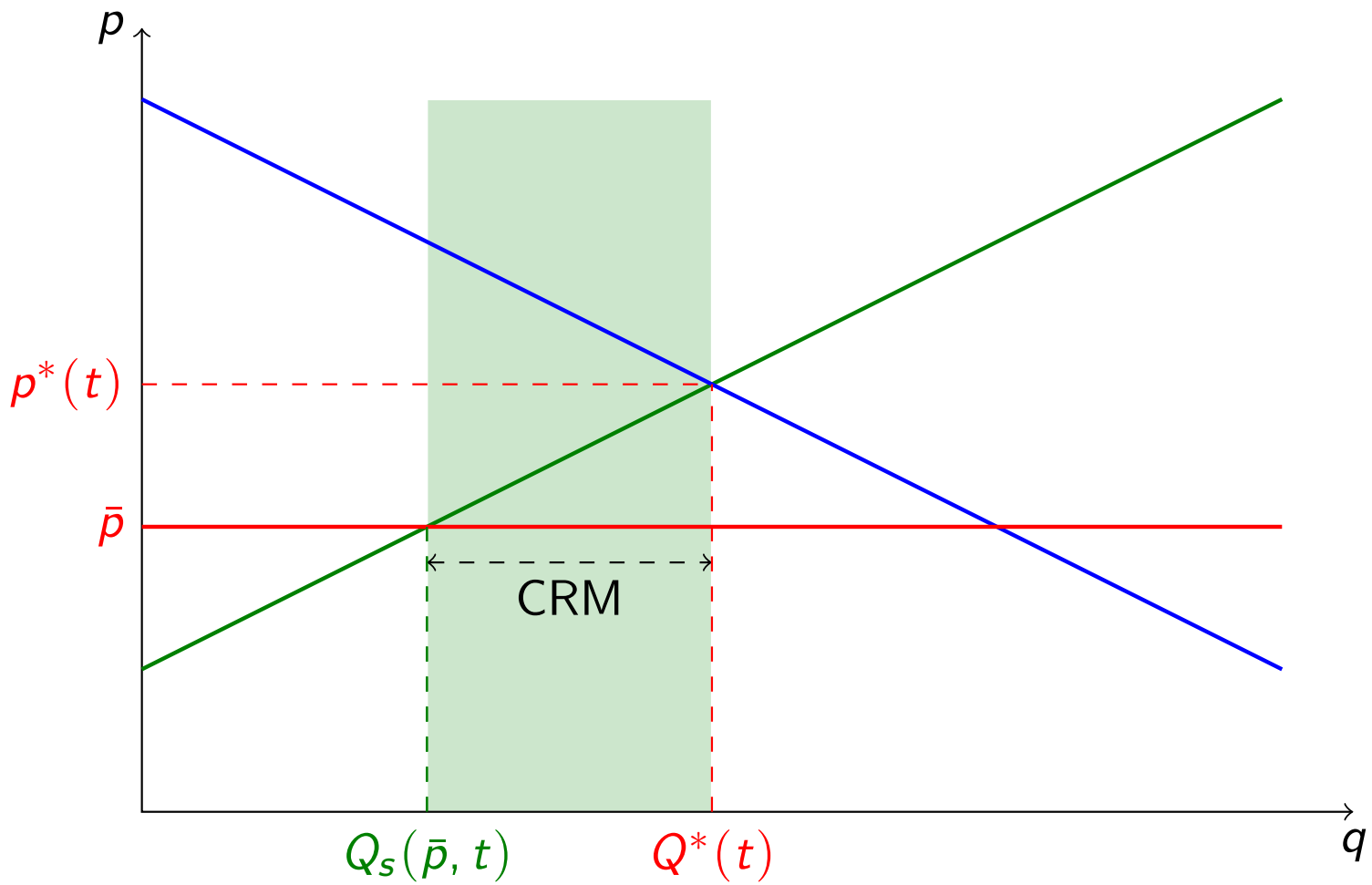

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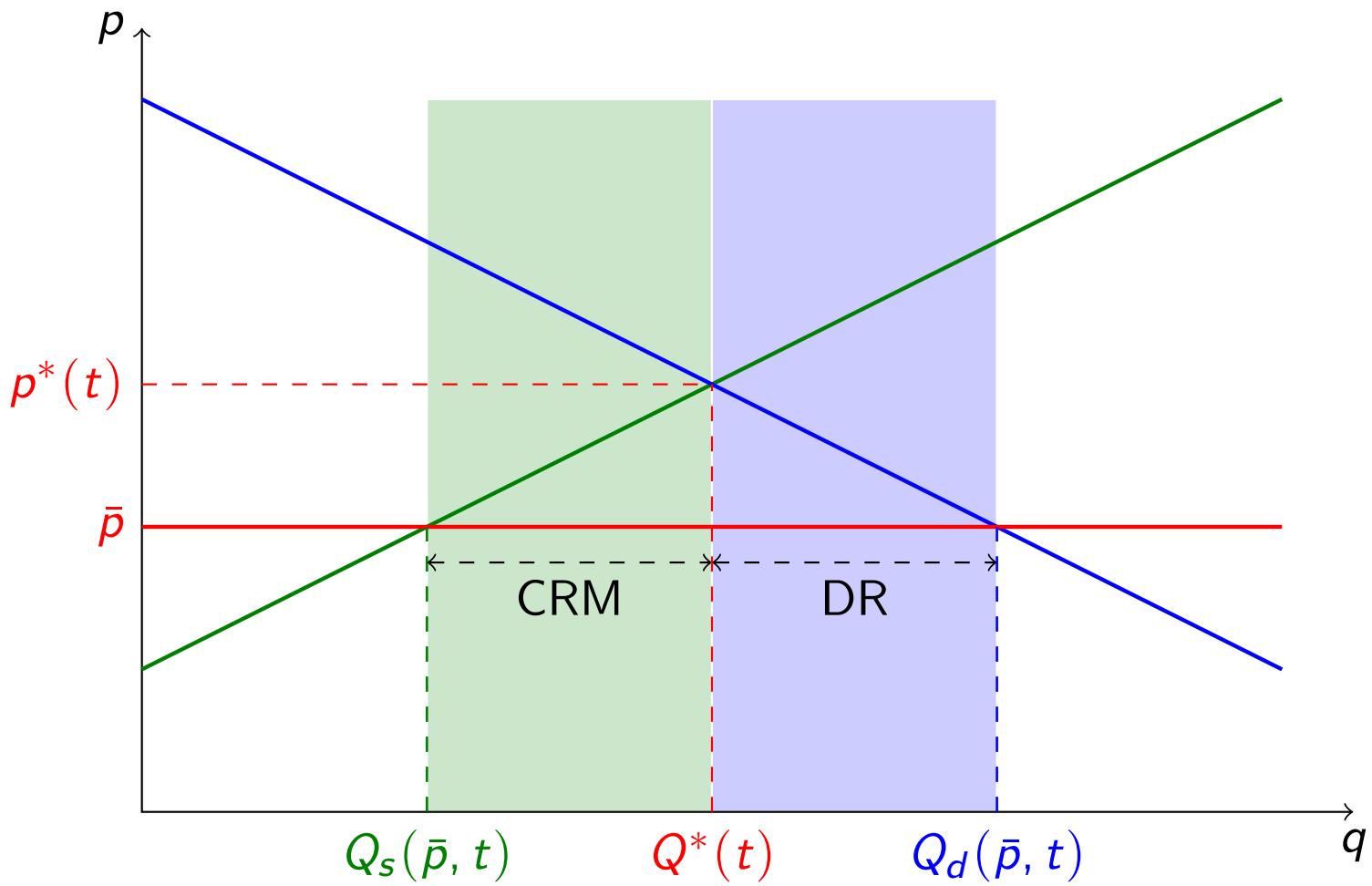

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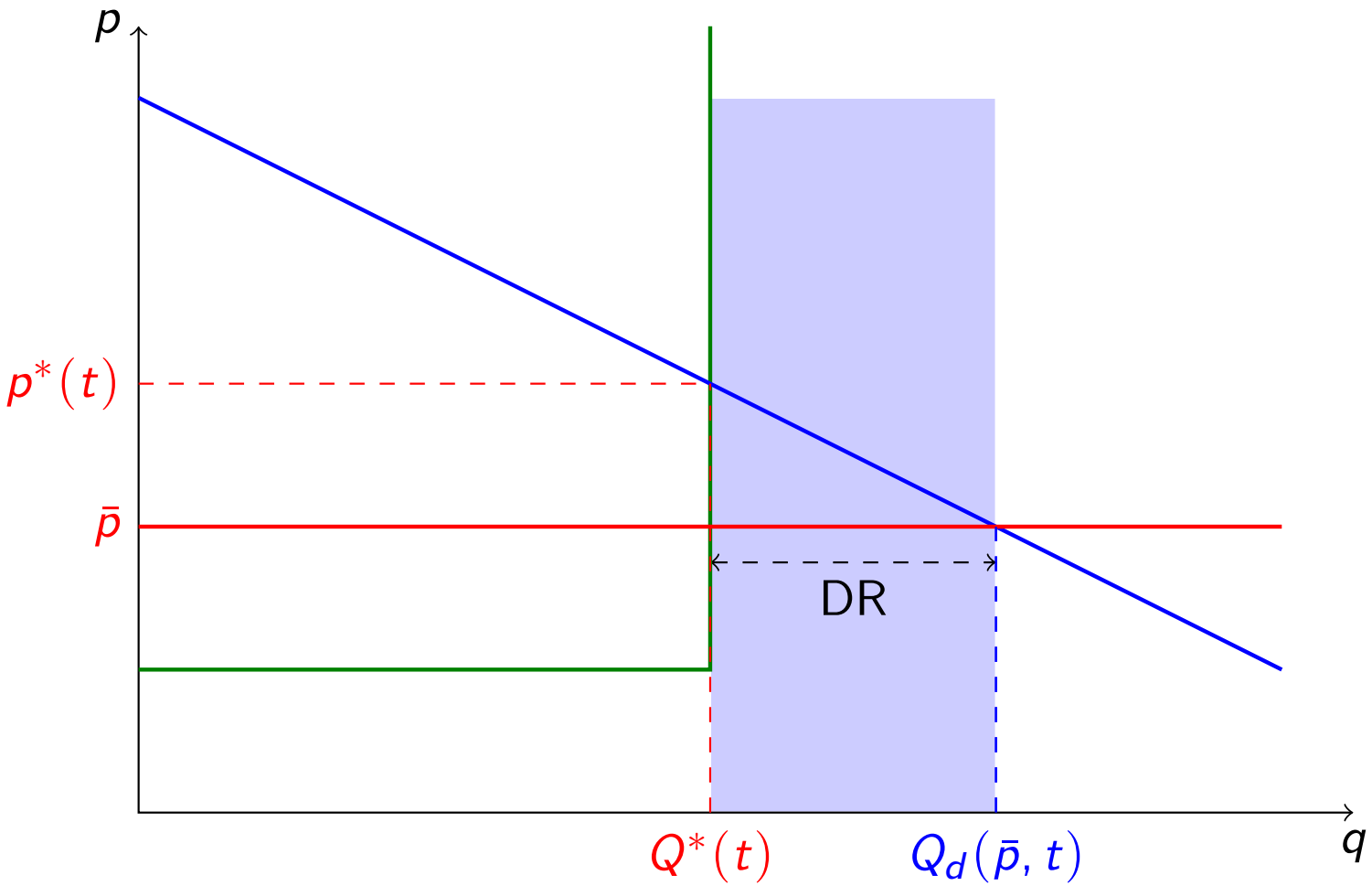


Canonical models found in the literature (1/2)

Models of capacity adequacy mechanisms usually assume that:

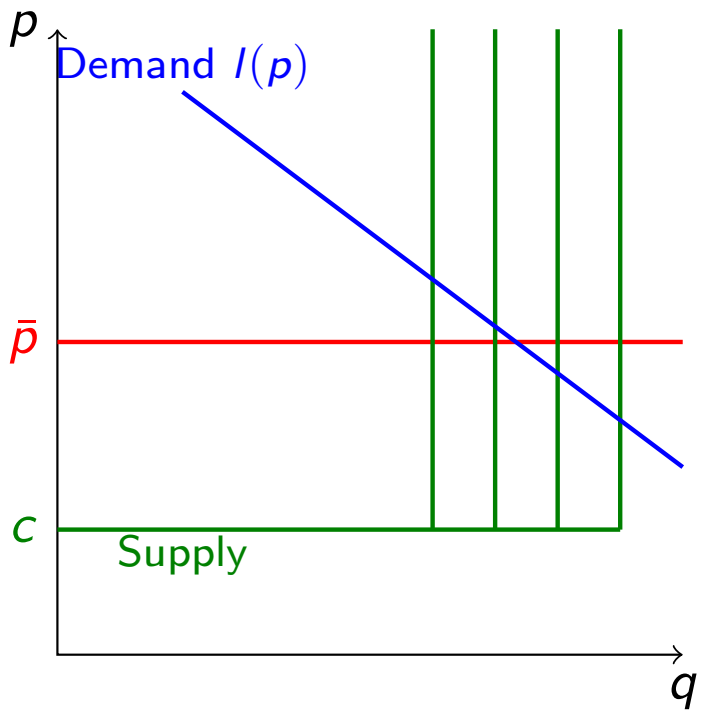
- One side of the market is exogenous, but its level varies with the state of the world t;
- The other side is elastic, agents having a type θ following a *state-independent* distribution $f(.)$;
- Agents' type allow to define a price-elastic demand/supply curve $l(p)$, which is state-independent in the region of interest.

Variable	Demand-side mechanism	Supply-side mechanism
$Z(t)$	available supply	demand level
θ	willingness-to-pay	marginal cost
$l(p)$	$1 - F(p)$	$F(p)$
Examples	Chao and Wilson (1987)	Cramton et al. (2013)

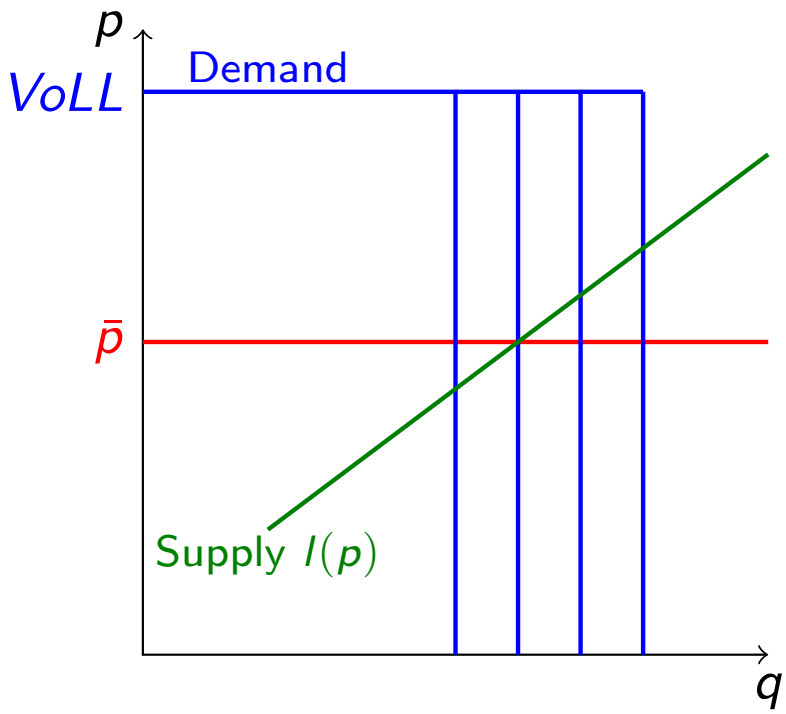
Table: Ingredients of canonical capacity adequacy mechanisms

Canonical models found in the literature (2/2)

Demand-side mechanism



Supply-side mechanism



Long-term investment incentives and missing money

The revenue shortfall for a producer that supplies (resp. the undercharge for a customer who consumes) 1 unit of electricity in *all* states of the world is:

$$MM(\bar{p}) \equiv \mathbb{E}_t \left[(p^*(t) - \bar{p})^+ \right]$$

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However, for types that consume/produce only during a fraction of peak states, this missing money transfer is reduced to:

- $\pi_C(\theta) \equiv \mathbb{E}_t \left[(p^*(t) - \bar{p})^+ \mathbf{1}_{p^*(t)<\theta} \right]$ for a consumer;
- $\pi_P(\theta) \equiv -\mathbb{E}_t \left[(p^*(t) - \bar{p})^+ \mathbf{1}_{p^*(t)>\theta} \right]$ for a producer.

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In particular, we have that:

$$\pi_C(\theta) = MM(\bar{p}) + \pi_P(\theta)$$

$\Rightarrow$ there exists a **formal analogy between DR and CRM payments in canonical capacity adequacy models**.

Taxonomy of capacity adequacy mechanisms (1/2)

Because of the partial recovery of $\pi_C(\theta)$ or $\pi_P(\theta)$ by intermediary types, two broad categories of capacity adequacy mechanisms may be envisioned:

- **Explicit designs:** make the full transfer $MM(\bar{p})$ *ex ante* and then implement state-dependent penalties/rewards $(p^*(t) - \bar{p})^+$ *ex post*;
- **Implicit designs:** make right away the transfers $\pi_C(\theta)$ or $\pi_P(\theta)$, assuming one can elicit *ex ante* which consumers to serve and which plants to switch on *ex post*.

Taxonomy of capacity adequacy mechanisms (2/2)

Type	Stage	Supply-side mechanisms	Demand-side mechanisms
Implicit Designs	*Ex ante*	Producers receive $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+ \mathbf{1}_{\theta<p^*(t)}\right]$	Consumers pay $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+ \mathbf{1}_{\theta>p^*(t)}\right]$
	Ex post	Consumers/SO switch on the plant whenever $p^*(t)>\theta$	Producers/SO shed the load whenever $p^*(t)>\theta$
Explicit Designs	*Ex ante*	Producers receive $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+\right]$	Consumers pay $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+\right]$
	Ex post	Producers pay $(p^*(t)-\bar{p})^+$ if they don't produce, and thus they pay in expectation: $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+ \mathbf{1}_{\theta>p^*(t)}\right]$	Consumers receive $(p^*(t)-\bar{p})^+$ if they don't consume, and thus they pay in expectation: $\mathbb{E}_t\left[(p^*(t)-\bar{p})^+ \mathbf{1}_{\theta<p^*(t)}\right]$

Table: Taxonomy of capacity adequacy mechanisms (producers and consumers are assumed to have a unit demand/supply)

Schematically corresponds to strategic reserves (top-left), reliability options (bottom-left), priority service (top-right) and demand response (bottom-right).

Implicit mechanisms need not reveal high social marginal costs

If $H(.)$ denotes the cdf of first-best prices, one may rewrite payments:

$$\pi_c(\theta) = \int_{\bar{p}}^{\theta} (H(\theta) - H(p))\, dp \text{ and } \pi_p(\theta) = \pi_c(\theta) - MM(\bar{p})$$

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Because H may be interpreted as a probability, **implicit designs may make transfers based on activation periods**, without requiring to disclose underlying social marginal costs.

$\Rightarrow$ **The very same political motivations that drove the enforcement of a price cap are thus likely to favor implicit mechanisms.**

Sweeping prices under the carpet

- Under implicit mechanisms, because $p^*(t)$ **is no longer observed**, strong assumptions are needed to come out with an elicitation mechanism that enables an efficient use of power plants and/or rationing of demand.

- More precisely, implicit mechanisms seek to **elicit an absolute monetary value ex ante** (WTP or marginal cost of supply) – which is a cardinal notion – so as to be able **to determine a ranking of activation ex post** (curtailment or reserve activation) – which is an ordinal notion.
  $\Rightarrow$ the function mapping the monetary value to the ranking must thus remain as stable as possible during the time elapsed between the signature of the contract and its execution.

- In particular, the assumptions of **unit demand** and of **known and state-independent types** are needed for implicit mechanisms to restore a first-best outcome.

Example limits of implicit mechanisms

State-dependent volumes:

$$\pi_c(\theta, q(.)) = \mathbb{E}_t\left[(p^*(t) - \bar{p})^+ \mathbf{1}_{p^*(t)\leq\theta}\right]\mathbb{E}_t\left[q(t)\right] + H(\theta)\underbrace{\mathrm{Cov}\left((p^*(t) - \bar{p})^+, q(t) \mid p^*(t) \leq \theta\right)}_{\text{Type-specific derating factor}}$$

1. Under **complete information**, the sole use of activation periods does not restore the first-best outcome;
2. Under **incomplete information**, probability of activation/service is no more sufficient to screen types.

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Incomplete ex ante information on type:

$$DWL = \left|\int_{\mathbb{E}[\theta]}^{\theta}(\theta - p)dH(p)\right|$$

$\Rightarrow$ implicit mechanisms cannot use *ex post* information.

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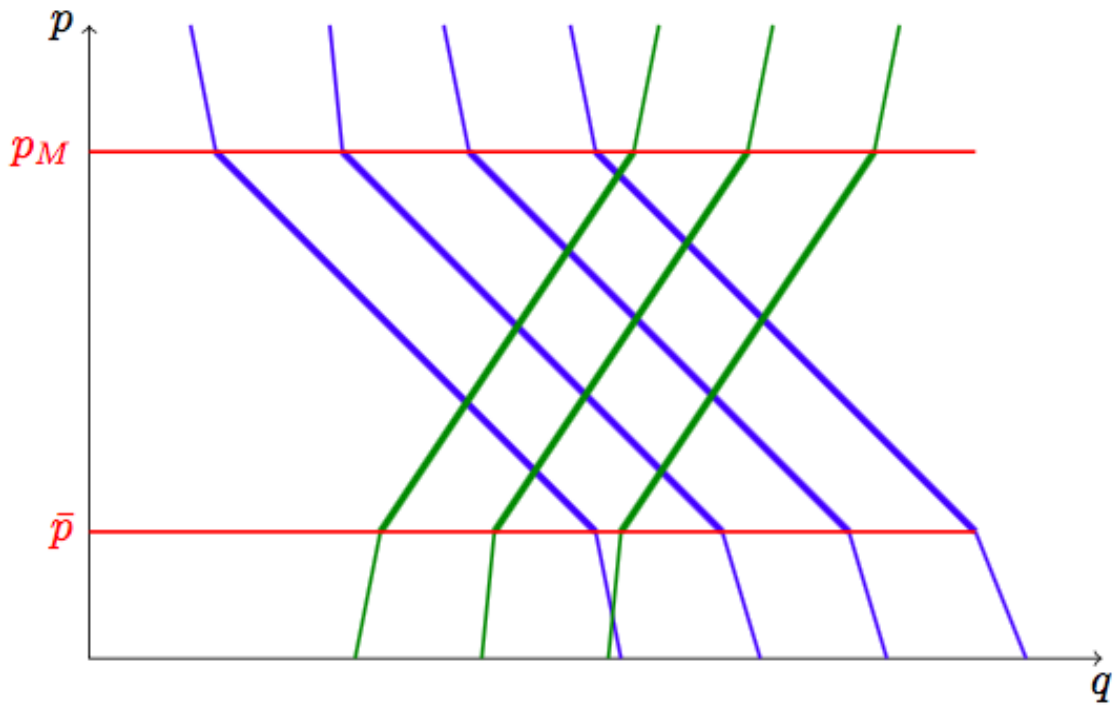

Figure: An extension of the canonical model robust to double-sided uncertainties

Policy implications

- Electricity markets where an exogenous **price cap** is enforced face the challenges of restoring both short-term allocative efficiency and long-term investment incentives.
- Under canonical capacity adequacy models, optimal investment signals can be restored by making the marginal costs during peak states either **explicit** or **implicit**.
- While implicit mechanisms are likely to face less political opposition, they are unfortunately more vulnerable to various inefficiencies.

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- Under canonical capacity adequacy models, optimal investment signals can be restored by making the marginal costs during peak states either **explicit** or **implicit**.
- While implicit mechanisms are likely to face less political opposition, they are unfortunately more vulnerable to various inefficiencies.
- If they are to be used nonetheless, our very simple framework would suggest to:
  1. set the price cap higher than the marginal cost of the most expensive plant;
  2. careful investigate the limits of canonical capacity adequacy mechanisms when applied to the demand-side of the considered market.

Thank you for your attention!