CHAIRE EUROPEAN ELECTRICITY MARKETS
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CEEM RESEARCH SEMINAR

Université Paris Dauphine, PSL

Information Value In Capacity Market Designs

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Motivation

Security of supply problem

Electricity:

- Non economically storable
- Inelastic demand
- Individual willingness to pay unknown

⇒ **How to ensure that enough capacity is available to avoid non discriminatory rationing?**

Proposed solution: CRMs

Capacity markets:

- Act on behalf on end-consumers
- Procure firm capacity to meet the (centrally defined) reliability target
- Remunerate firm capacity for its security of supply service

⇒ **End-consumer see their SoS improved**

⇒ **Capacity owners receive additional revenues**

Motivation

	What is the product	How is the volume determined	Who is responsible for procurement
Strategic Reserve	Physical Capacity (sub-set of generation only)	Central Authority sets volume	Central Authority (sub-set of generation only)
Ex Ante Capacity Obligation	Physical Capacity	Central Authority sets volume	LSEs or other individual entities
Ex Post Capacity Obligation	Physical Capacity	LSEs determined volume with *ex post* verification by Central Authority based on predetermined procedure and parameters	LSEs or other individual entities
Capacity Auction	Physical Capacity	Central Authority sets volume	Central Authority
Reliability Options	Financial Instrument	Central Authority sets volume	Central Authority
Capacity Payment	Physical Capacity	Central Authority sets price, volume determined by market	Central Authority
Capacity Subscription	Physical Capacity	Customers determine volume based on their preferences for uninterrupted supply and the price of capacity	Customers, directly and through intermediaries

Figure 1: Common grouping and terminology according to CIGRE 2016

1. Existing literature often compares the different kinds of CRMs (Keles et al. 2016; Cepeda and Finon 2011; Léautier 2017)
2. However, implementation features greatly affect performance (Mastropietro et al. 2016)

In capacity markets, the regulator has to define (amongst other):

- Who procures the capacity
- How uncertainty on future scarcity conditions should affect the actors

Motivation

Two kind of capacity markets:

- Centralized markets:

  The System Operator (SO) buys all the required capacities on behalf of end-consumers.

- Decentralized markets:

  Retailers buy capacities by themselves on behalf of their consumers.

The first capacity markets were decentralized (PJM, MISO); such market organization has been abandoned to the benefit of centralized ones (current PJM).

Motivation

Two kind of requirements in decentralized capacity markets:

- Ex-ante requirements:

  The forecast of capacity needs is binding: retailers requirements correspond to their share of peak demand (Example: Former MISO, Former PJM).

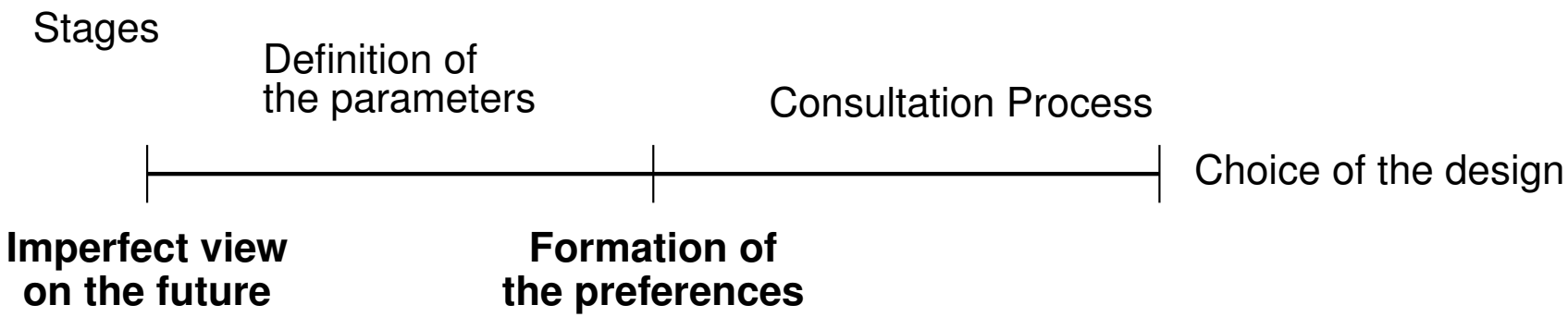
- Ex-post requirements:

  Retailers requirements are not bound by the forecast of capacity needs. Retailers' actual peak demand define their requirements (example: France)

In forward capacity markets, this resumes to risk allocation: ex-ante requirements isolate retailers from risk realization while ex-post requirements make them liable.

Motivation

What are the actors preferences in term of design taking into account the uncertainty and the market organization?



The model

Adapting the Cournot Model in Roy et al. 2019, we consider an oligopsony model *a la Cournot* in which the regulator defines how the capacity buyers are affected by uncertainty.

Assumptions:

- n homogeneous buyers.
- Uncertain linear demand with two equally possible states of the world:

$$D^{-1}(Q) = Z - aQ$$

  with $Z \in \{z_l, z_h\},\ z_h > z_l$, the only uncertainty being left.

- The public authority sends a public signal $s \in \{s_l, s_h\}$ about Z
- Continuous supply curve with a continuum of heterogeneous capacity owners:

$$F(Q)$$

  being the price of a capacity unit if Q units are bought.

Graphical Example

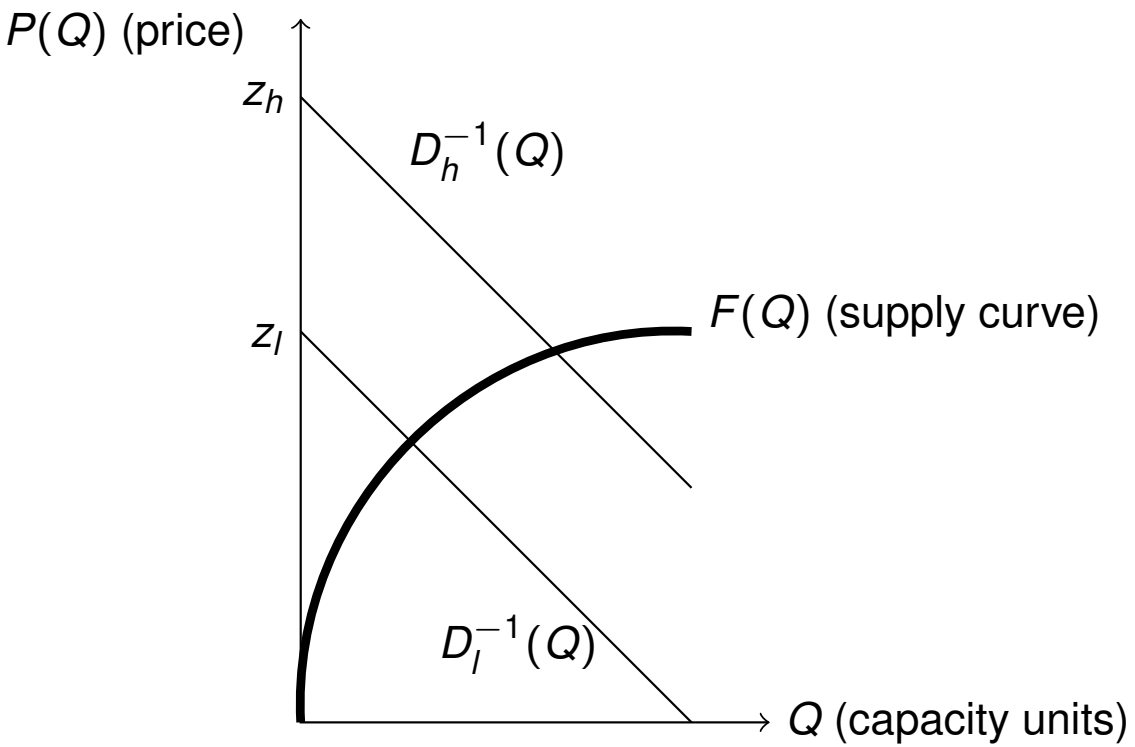


Figure 2: Graphical example - Uncertain linear demand with two possible states h and l (two possible intercepts z_h and z_l), and a concave supply curve

The Signal

Regulator $\longrightarrow$	System Operator $\longrightarrow$	Capacity Buyers
decides the value of λ	*sends the public signal*	*buy capacities w.r.t. the signal and λ*

Table 1: Actors in the market: by which channel the design affects the buyers

From the System Operator, all the capacity buyers observe the same binary signal of preciseness λ, $s \in \{s_l, s_h\}$ about Z:

$$\lambda = \mathbb{P}(s_l|z_l) = \mathbb{P}(s_h|z_h)$$

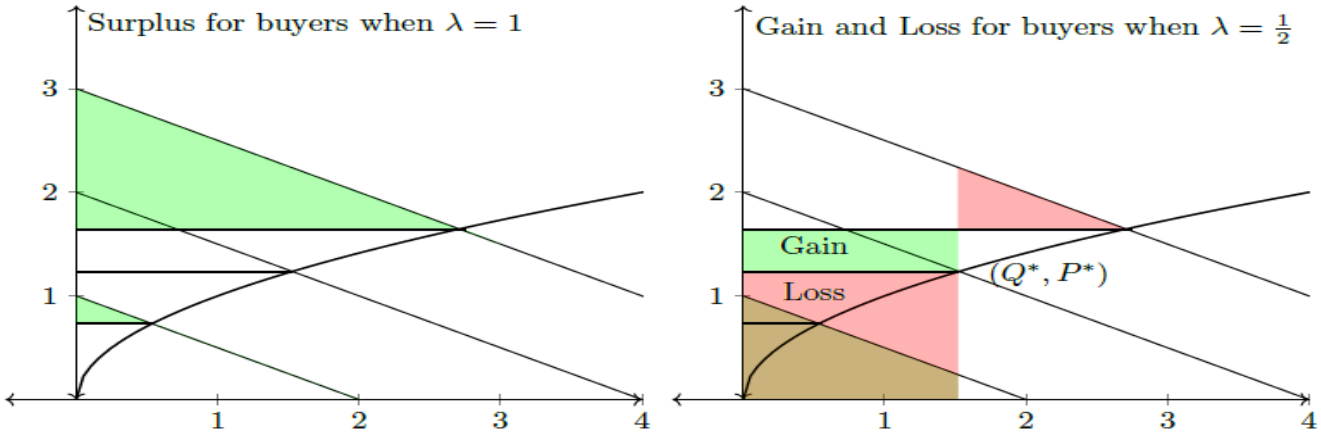
The two extreme cases, $\lambda = \frac{1}{2}$ and $\lambda = 1$ corresponds to the two kind of requirements:

signal preciseness	expected state of the world	requirements
$\lambda = 1$	z_h if s_h z_l if s_l	Fully regulated ex-ante requirements
$1 > \lambda > \frac{1}{2}$	$z_h > \lambda z_h + (1-\lambda) z_l > z_l$ if s_h $z_h > (1-\lambda) z_h + \lambda z_l > z_l$ if s_l	Partial hedging
$\lambda = \frac{1}{2}$	$\frac{1}{2} z_h + \frac{1}{2} z_l$ in any case	Ex-post requirements without hedging

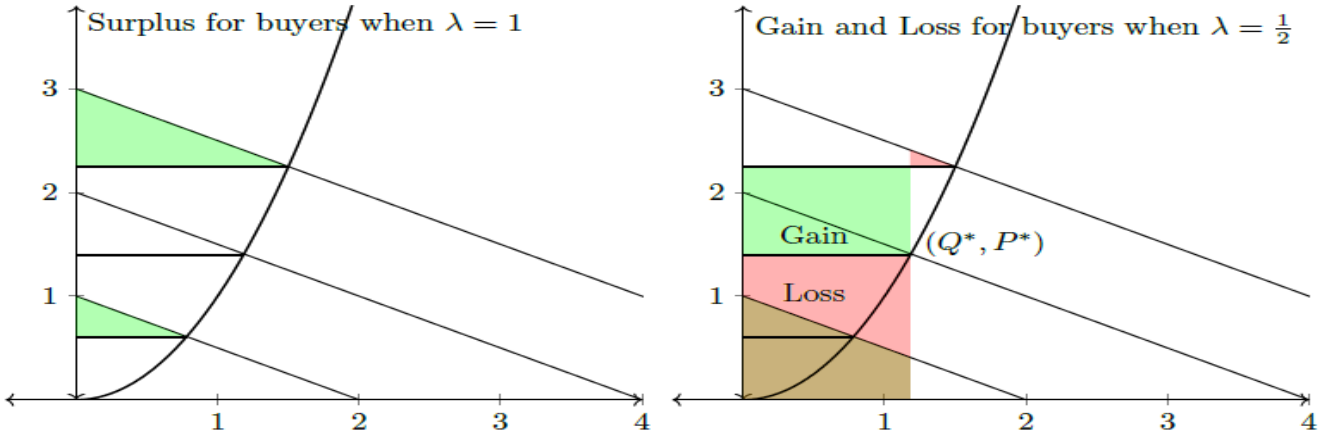
Table 2: How requirements are stylized in the model

Model

$n = \infty$:



Graphical concave example - Buyers' Surplus



Graphical convex example - Buyers' Surplus

The Preferences - Traditional Criteria

How does the regulator choose the value of λ? Which criteria can be used?

- Buyers' surplus: $\max_{\lambda} S(Q) = \max_{\lambda} \int_0^Q D^{-1}(x) - F(Q) \, \mathrm{d}\, x$
- Owners' surplus: $\max_{\lambda} \Pi(Q) = \max_{\lambda} \int_0^Q F(Q) - F(x) \, \mathrm{d}\, x$
- Welfare: $\max_{\lambda} W(Q) = \max_{\lambda} (S(Q) + \Pi(Q))$.

The Preferences

Problem: Heterogeneity of the sellers can generate potential conflict

Example

A design can maximize:

1. The mean price
2. The number of owners able to sell their capacity

The Preferences - Majority Winning criterion (Owners)

1. **If there is an agreement between the owners** (case where the expected price is increasing in λ): Same preference as for the profit

2. **If there is a disagreement between the owners** (case where the expected price is increasing in λ):

   majority winning criterion:

$$L(Q) = \underbrace{\int_{\hat{b}(Q)}^{F(Q(S_h;\lambda=1))} F^{-1\prime}(b_i)db_i}_{\text{Preference for } \lambda=1} - \underbrace{\int_{0}^{\hat{b}(Q)} F^{-1\prime}(b_i)db_i}_{\text{Preference for } \lambda=\frac{1}{2}}$$

   $\hat{b}$ being the bid for which the owner is indifferent between the two designs.

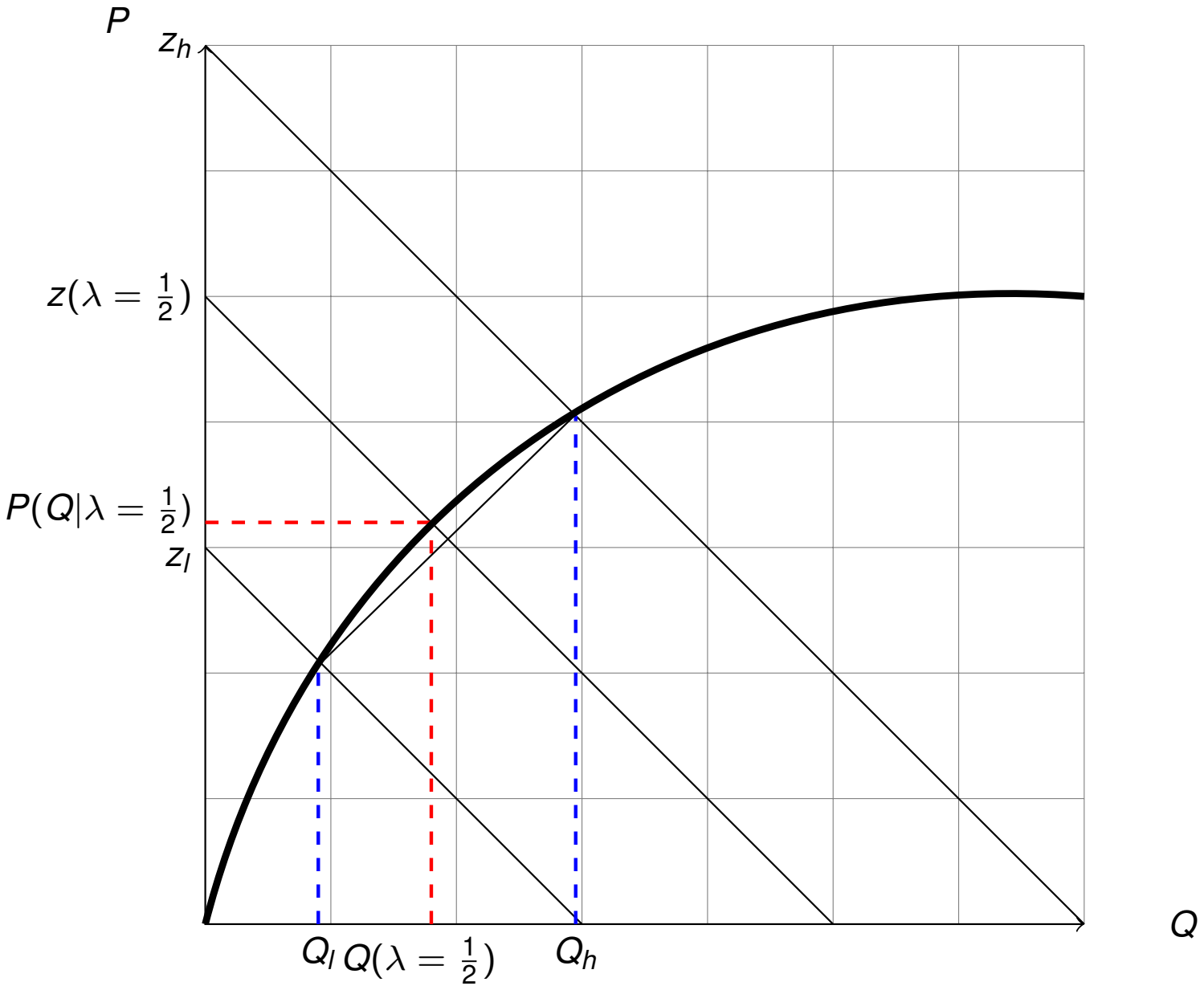


Figure 3: Graphical example - concave supply curve

The Equilibrium

We have a standard **Cournot Equilibrium** condition:

Marginal Revenue = Marginal Cost

$\Rightarrow$ Capacity buyers use their market power to reduce the market parice (through under procurement).

To give economic intuition, we express our results with respect to the Markup (MUP) buyers exert to reduce the price with respect to the competitive case.

$$MUP(q^*, n) = \frac{\partial F(nq^*)}{\partial q} q^*$$

Value of Information

When n is large enough, preferences can be characterized with respect to the curvature of the bid function:

		$F'' < 0$	$F'' > 0$
Welfare		$\lambda_W = 1$	
Buyers' Surplus		$\lambda_S = 1$	$\lambda_S = \frac{1}{2}$
Owners' Profit		$\lambda_P = \frac{1}{2}$	$\lambda_P = 1$
Majority Winning	if $L(Q) > 0$	$\lambda_C = 1$	
	if $L(Q) < 0$	$\lambda_C = \frac{1}{2}$	$\lambda_C = 1$

Table 3: Maximizing precision for n large enough

The value of information

When the number of retailers is limited, capacity buyers become strategic and consensus can emerge:

- $n = 1 \Rightarrow$ A monopsony prefers $\lambda = 1$.
- When n>1, we have 4 distinct thresholds depending on the shape of the markup
  - When the markup is increasing rapidly in quantities: capacity owners prefer no information
  - When the markup is decreasing rapidly in quantities: capacity buyers prefer no information

$MUP''(Q)$		$\underline{\rho}$	ρ	$\bar{\rho}$	$\bar{\bar{\rho}}$	
Welfare		$\lambda_W = 1$	$\lambda_W = 1$	$\lambda_W = 1$	$\lambda_W = 1$	$\lambda_W = \frac{1}{2}$
Buyers' Surplus		$\lambda_S = \frac{1}{2}$	$\lambda_S = 1$	$\lambda_S = 1$	$\lambda_S = 1$	$\lambda_S = 1$
Owners' Profit		$\lambda_P = 1$	$\lambda_P = 1$	$\lambda_P = 1$	$\lambda_P = \frac{1}{2}$	$\lambda_P = \frac{1}{2}$
Majority Winning	if $L(Q) > 0$	$\lambda_C = 1$	$\lambda_C = 1$	$\lambda_C = 1$	$\lambda_C = 1$	$\lambda_C = 1$
	if $L(Q) < 0$			$\lambda_C = \frac{1}{2}$	$\lambda_C = \frac{1}{2}$	$\lambda_C = \frac{1}{2}$

Table 4: Maximizing precision for $n > 1$

$$\rho = \frac{F''}{F'}(MUP' + an) \qquad \bar{\rho} = \rho + \left(\frac{MC'}{Q}\right) \qquad \underline{\rho} = \bar{\rho} - \frac{MC'^2}{QF'(n-1)} \qquad \bar{\bar{\rho}} = \bar{\rho} + \frac{MC'^2}{QF'}$$

With $MC'(Q^*) = F''(Q^*)Q^* + (n+1)F'(Q^*) + na$

Data: Germany 2010

Supply-side assumptions: competitive behavior (missing money)

- Merit order according to He et al. 2013
- Spot prices from EPEX Spot
- Fixed costs from Villavicencio 2017
- Supply curve smoothed through splines: $Max(-\pi; 0)$

Demand-side assumptions: market designs shape the demand curve

- Targets (central signal): Entso-e maximum demand for 2010, IEA reasonable reserve margins (15-20%)
  $Q_i \in \{79.9, 87.1, 100.1, 104.5\}$
- Slope (opportunity cost): UK and NYISO demand curves used as benchmark
  $a \in \{5, 10, 20, 50\}$
- Level of competition: European Commission 2014 (Major retailers, households retailers and all retailers)
  $n \in \{4, 65, \infty\}$

Data

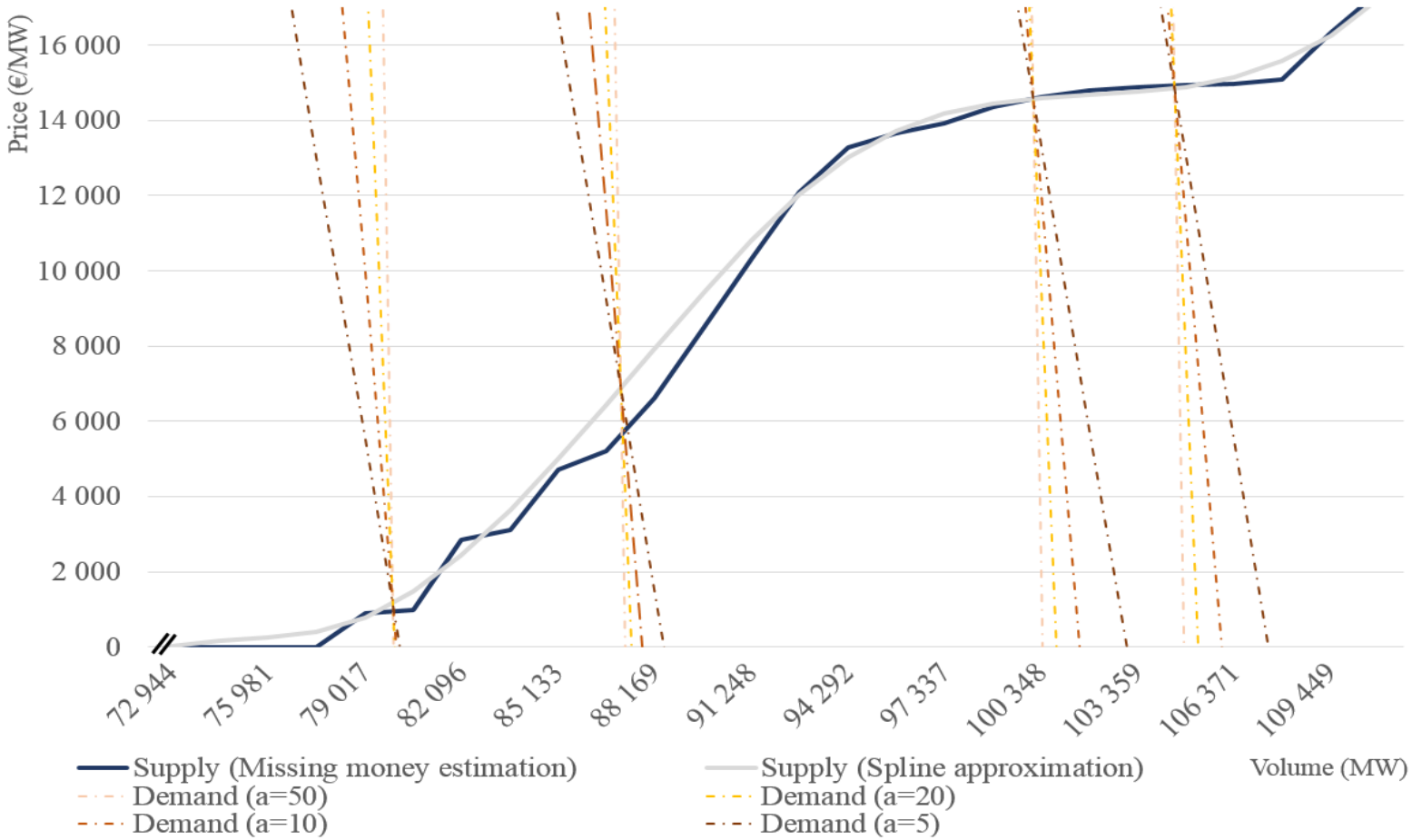


Figure 4: Estimated supply and demand curves (no uncertainty) for Germany 2010

Results

		$Q_1^t = 79.9$ GW	$Q_2^t = 87.1$ GW	$Q_3^t = 100.1$ GW	$Q_4^t = 104.5$ GW
$n = \infty$	$\forall a$	Demand side	Demand side	Supply side	Demand side
$n = 65$	$a = 50$	None	None	Supply side	None
	$a = 20$	None	None	Supply side	None
	$a = 10$	Demand side	None	Supply side	None
	$a = 5$	Demand side	None	Supply side	None
$n = 4$	$a = 50$	None	None	Supply side	None
	$a = 20$	None	None	Supply side	None
	$a = 10$	None	None	Supply side	None
	$a = 5$	None	None	Supply side	None

Table 5: Sensitivity of the form of disagreement to the slope, the competitive equilibrium and the competition

Results

1. Antagonism between market players increases with n
2. Increasing the opportunity cost a reduces retailers' strategic behavior (the level of non compliance penalty does matter): see Q_1^t
3. The shape of the supply curve is the main driver of preferences
   - All the actors prefer the maximal preciseness (i.e. ex ante requirements) when the supply curve is "regular".
   - When the supply curve's form is changing, one type of actors may disagree with full information disclosure.
4. Disagreement between capacity owners is empirically improbable
   - The total capacity procured is large compared to the size of the uncertainty: the preference of the capacity owners who always sell dominates the majority winning
   - The interval in which the price decreases in information while the profit is still increasing is reduced

Conclusion

With perfect competition ($n \Rightarrow \infty$), choosing between ex-ante and ex-post requirements resumes in favoring one or the other market player

With the strategic capacity buyers:

- In perfect knowledge of surpluses, a regulator might still prefer disclose imperfect information (ex-post requirements) to curb retailers' market power
  $\Rightarrow$ Requires the supply curve to increase rapidly (ex: new entry)
- In imperfect knowledge of surpluses, a regulator might want to uncover actors preferences through public consultation
- We introduce the notion of Majority Winning in this context: public consultations are used in order to collect information (preferences) from the actors.
- Sellers can disagree between each others, making the preferences expressed through public consultation less informative

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