



CHAIRE EUROPEAN
ELECTRICITY MARKETS
Fondation Paris-Dauphine

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A Survey on Electricity Market Design

Modeling Behaviors in Capacity Markets

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Introduction

1

Short discussion on capacity markets

2

Why do we need a general framework based on behavior to assess the effectiveness of actual capacity markets ?

3

From a general economic point of view, how can we analyze price formation in markets ?

4

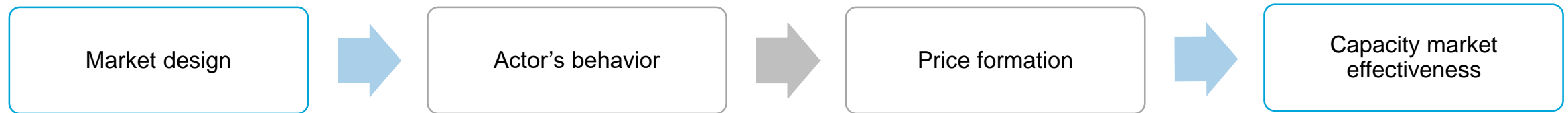
What does the literature say on price formation and behaviors in capacity markets ?

- *What is so special about capacity markets?*
- *Risk issues*
- *Industrial decisions*
- *Market rules*
- *Asymmetries issues*
- *Auction theory and capacity market*
- *Demand*

Context of this study


This study originates from the literature survey made for my thesis

The thesis aims at understanding possible implications of different market designs on capacity market effectiveness, which implies understanding **how market design impact price formation on capacity markets**



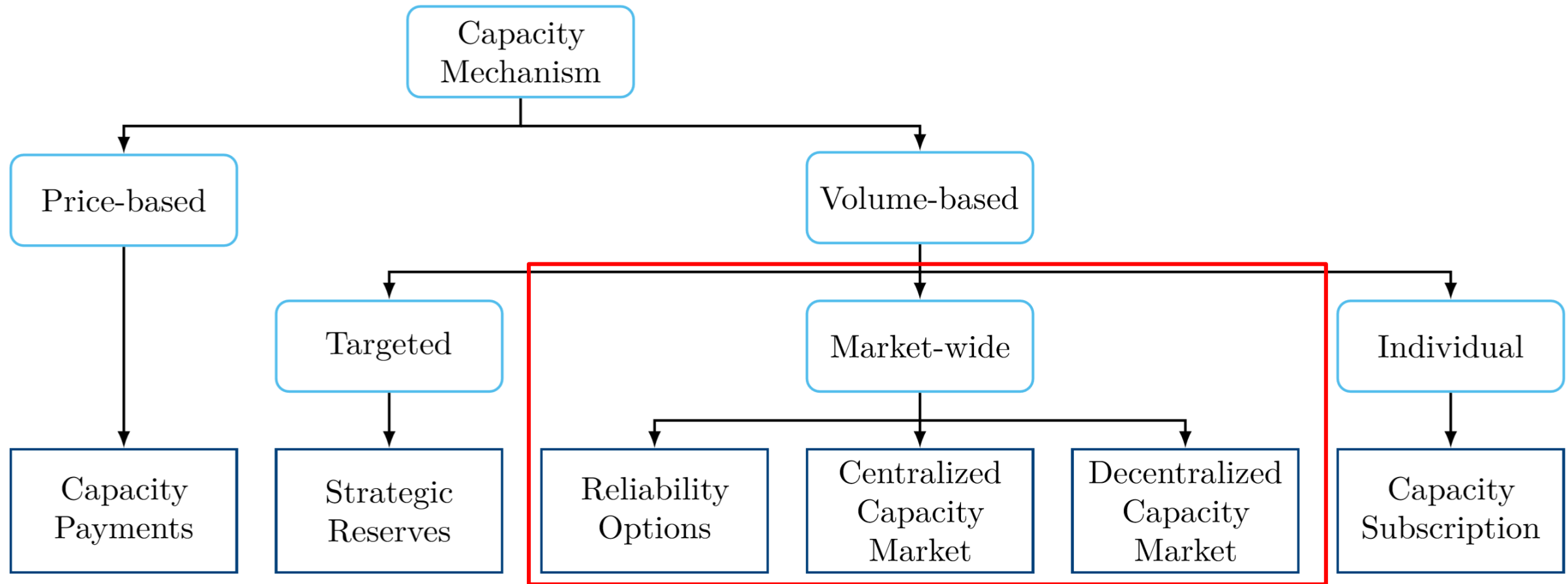
Objectives of this study

- What are the different models used to treat specific issues in capacity markets ?
- What is the actual outcome of such models ?
- **Create a benchmark on how we can model actors' behavior in capacity markets**
- **What has not yet been addressed in the capacity market literature?**



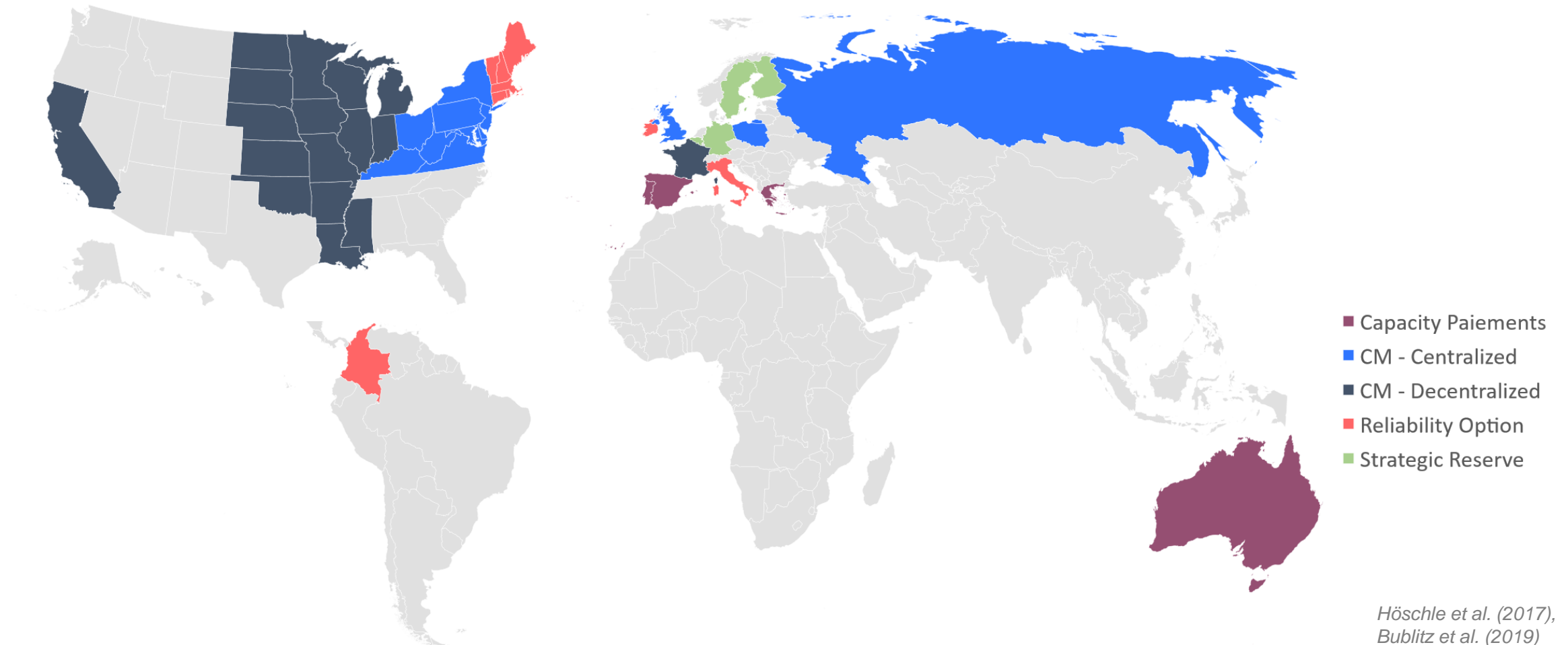
This work raises more questions than it solves, but it provides a solid foundation for answers

Capacity remuneration in practice

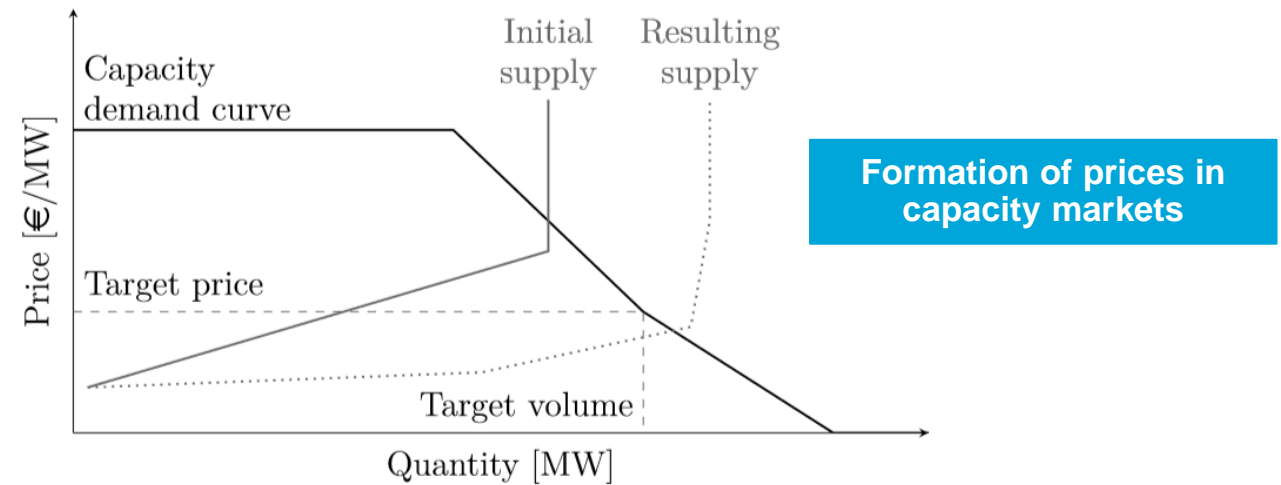
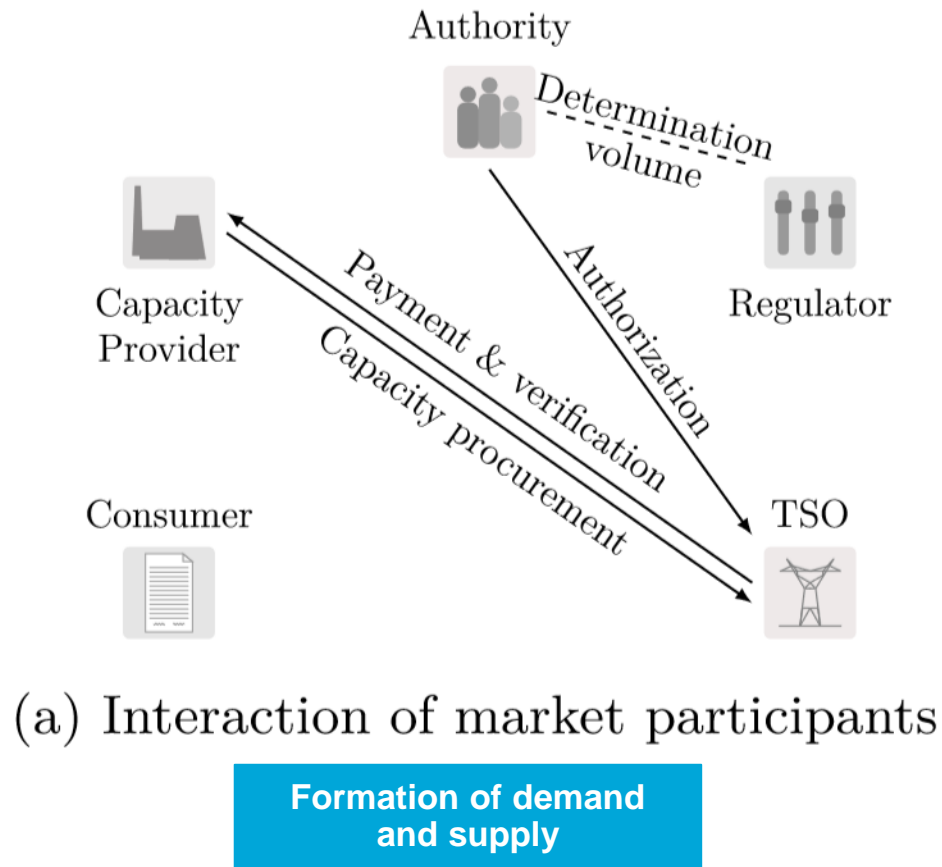


Höschle et al. (2017)

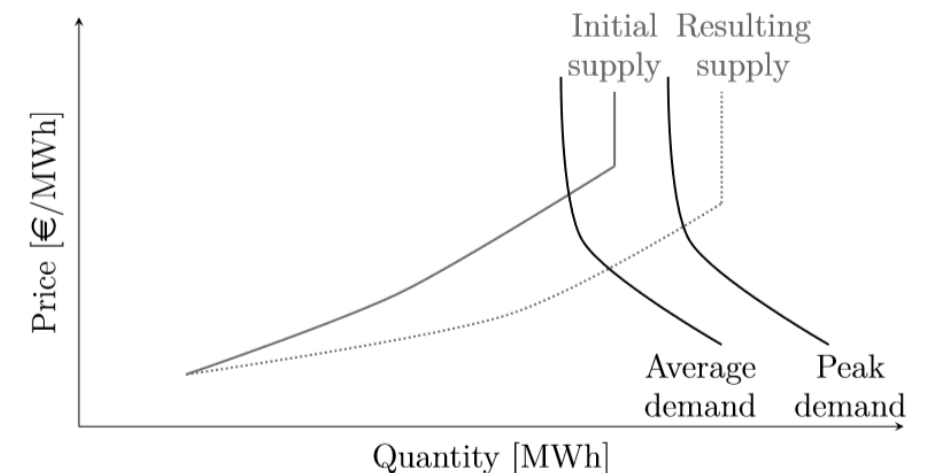
Real world application



How capacity markets are supposed to work ?



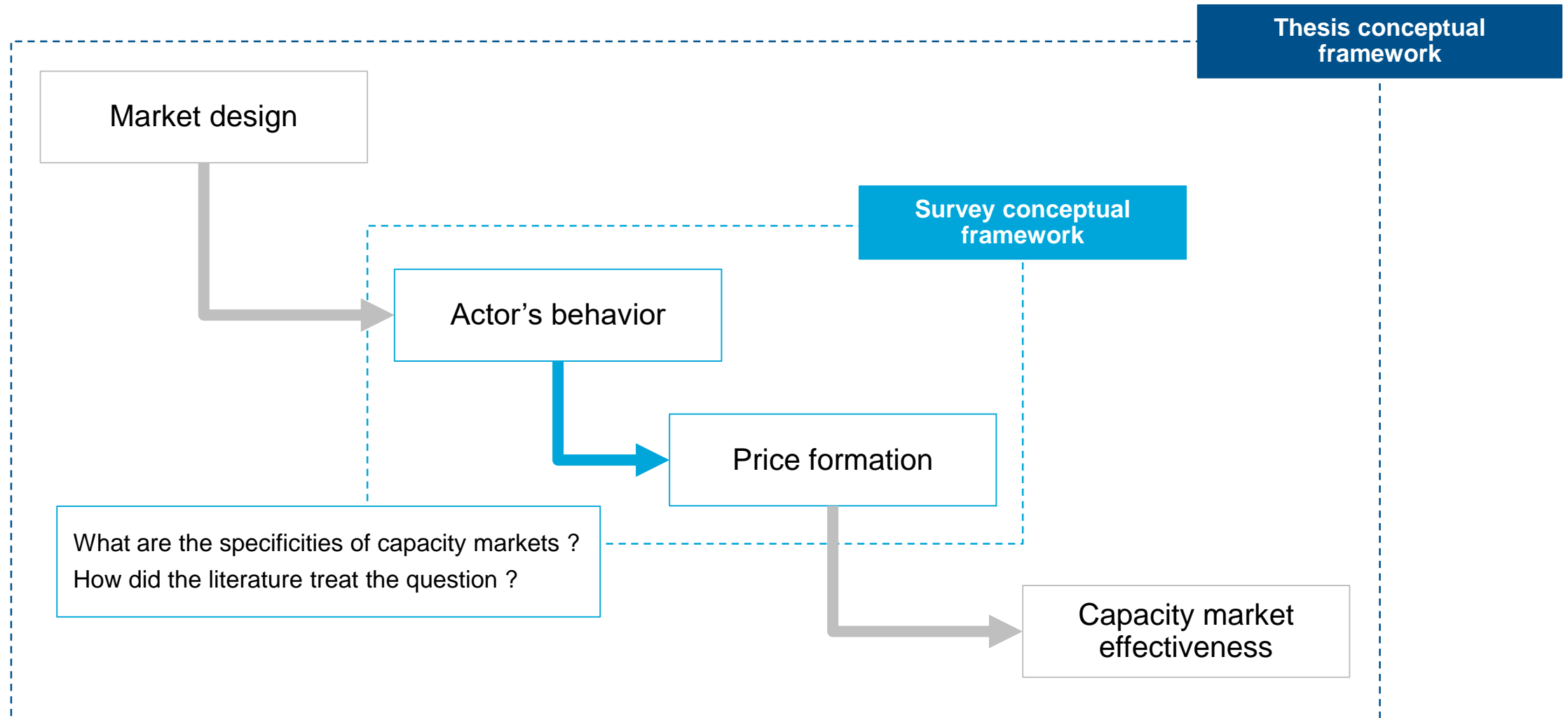
(b) Capacity market clearing



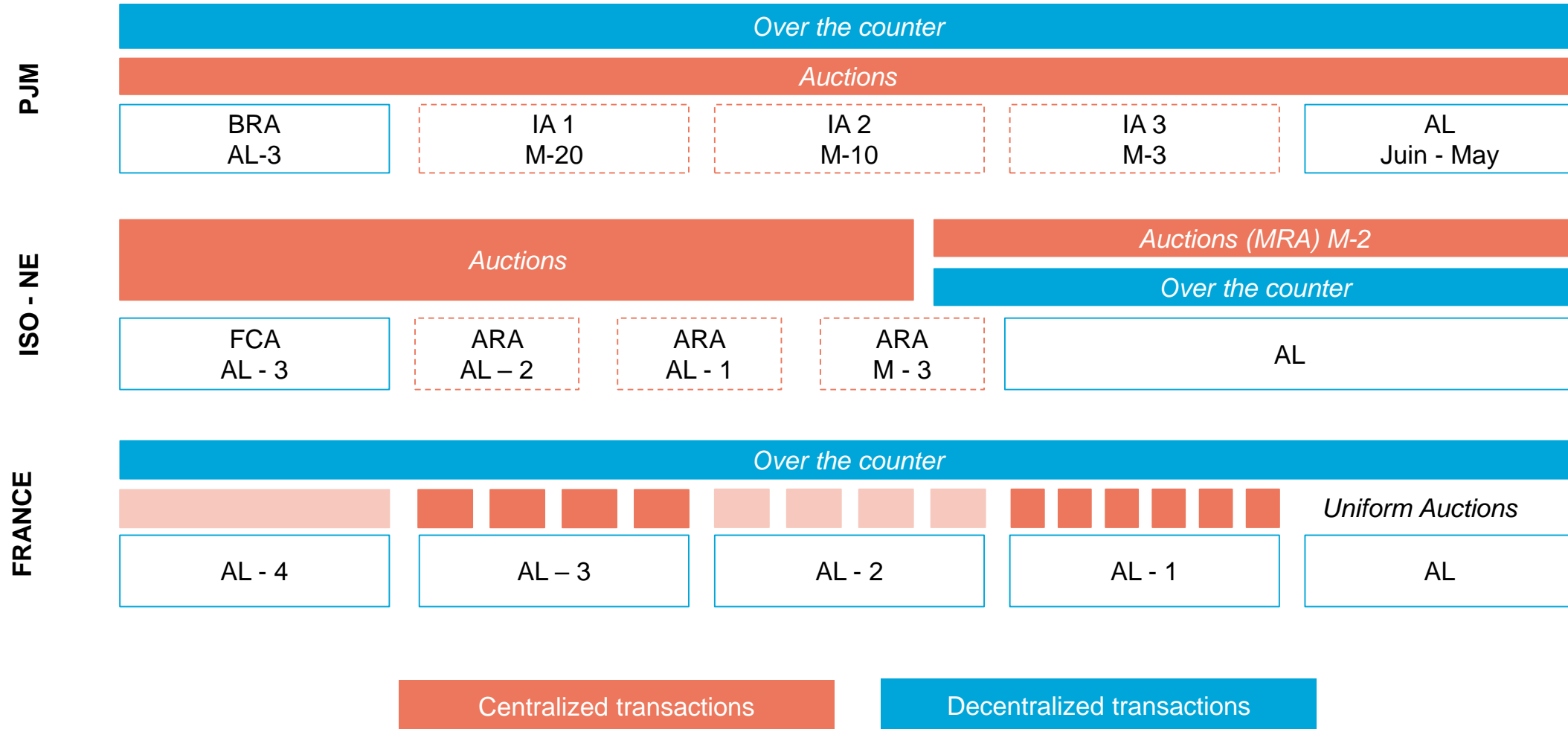
(c) Energy market clearing effect

Impact of capacity markets in the system

Conceptual framework for this survey

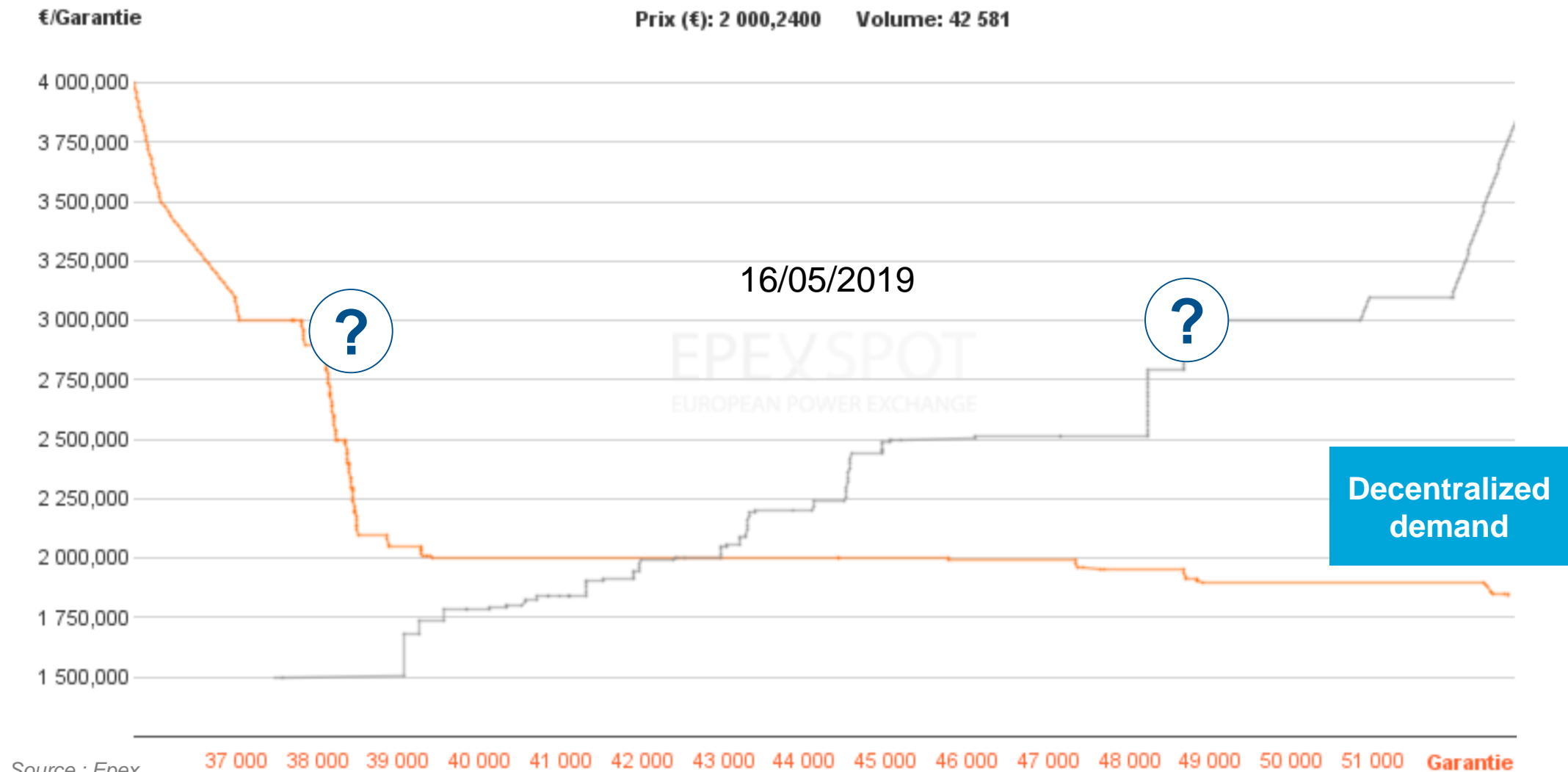


A great diversity in the design of capacity markets



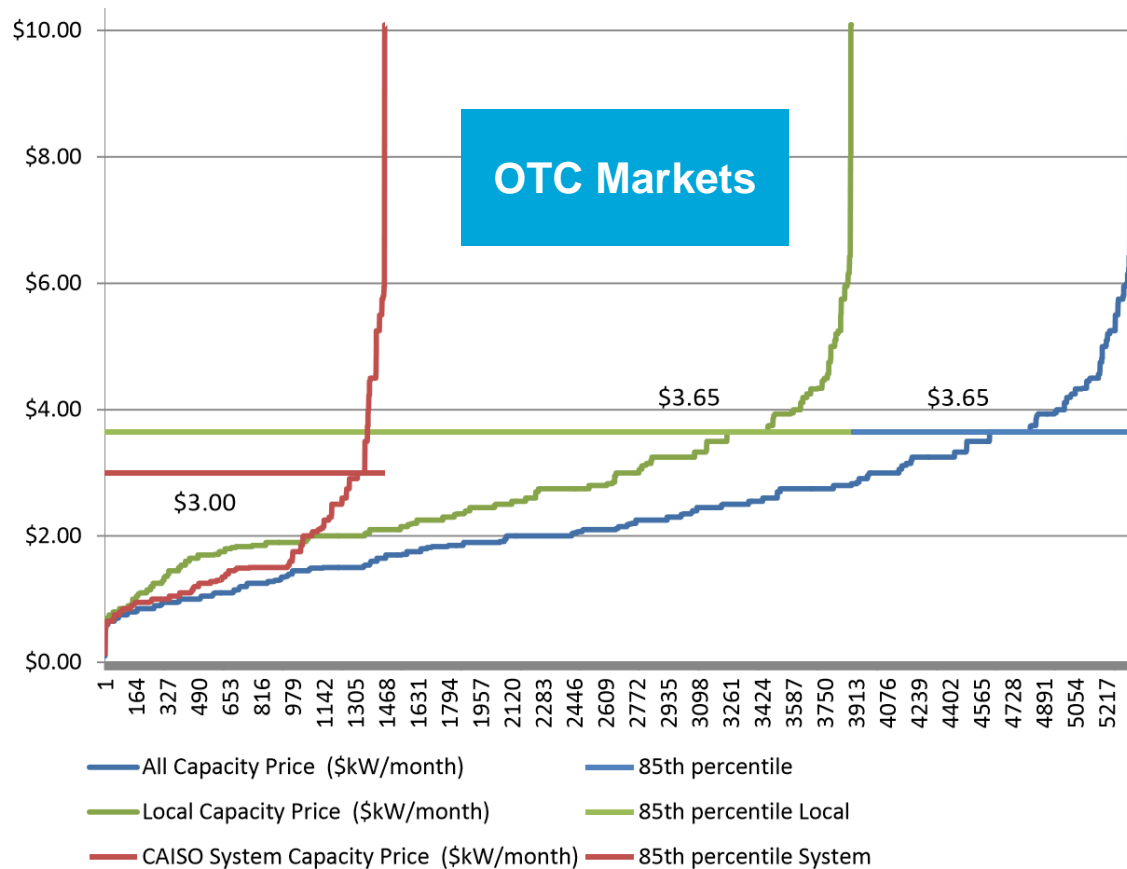
Example of price formation - France

Auction results for the French capacity mechanism – 16-05-2019 for the delivery year 2020



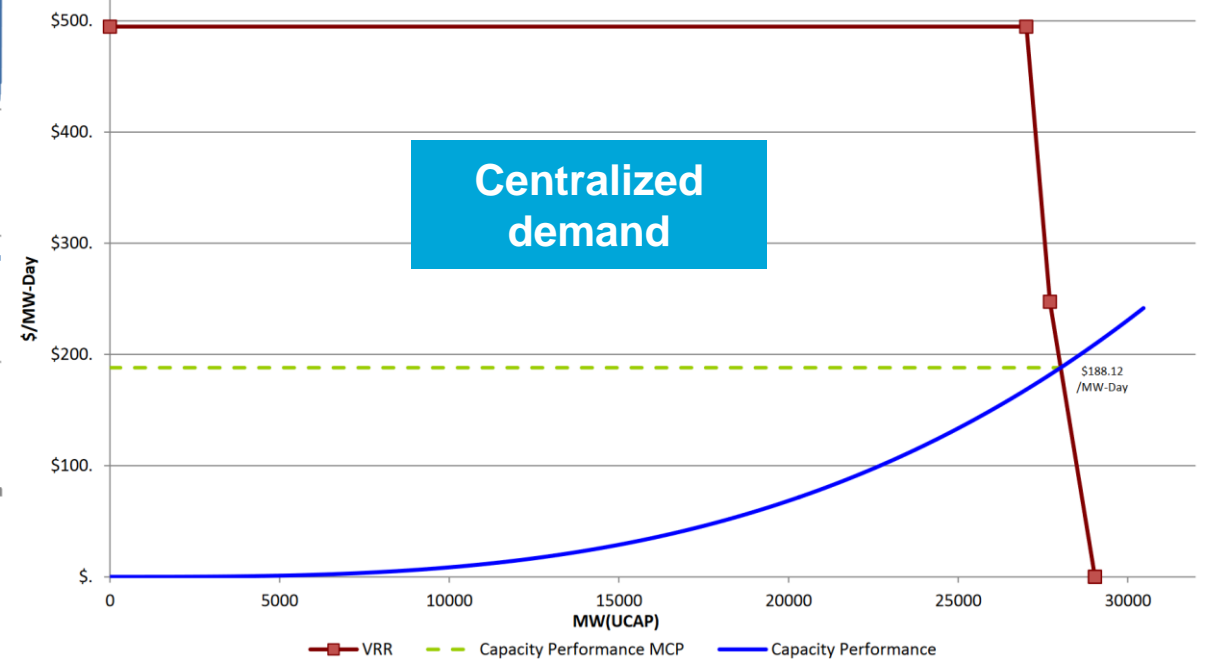
Example of price formation – Caiso and PJM

Price Curves for RA Capacity Contracts, 2017-2021



Source : CAISO

2020/2021 Base Residual Auction COMED Supply Curve



Source : PJM

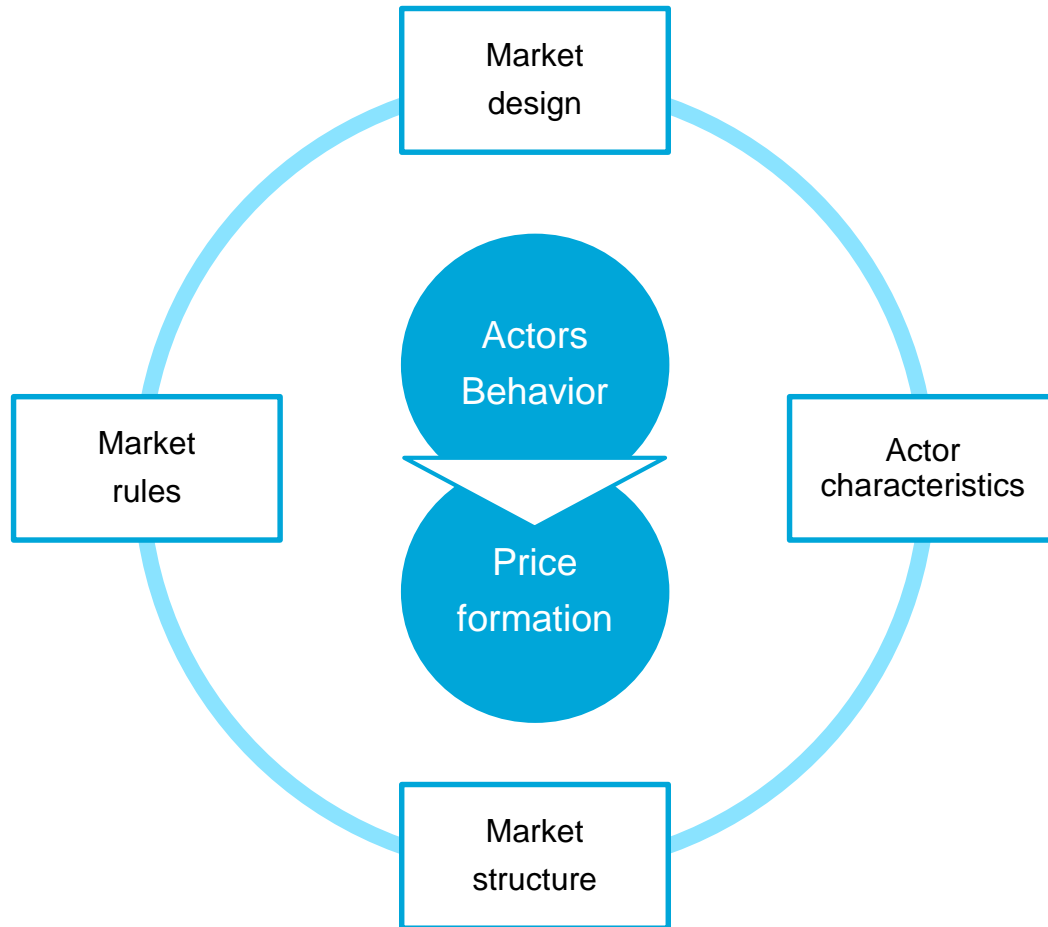


2

General approach

How can we analyze price formation?

Behavior is the main driver of price formation



Market and actor characteristics

- Level of risk and risk aversion
- Type and quantity of information
- Conjectural variation
- Technological specificities
- Corporate structure

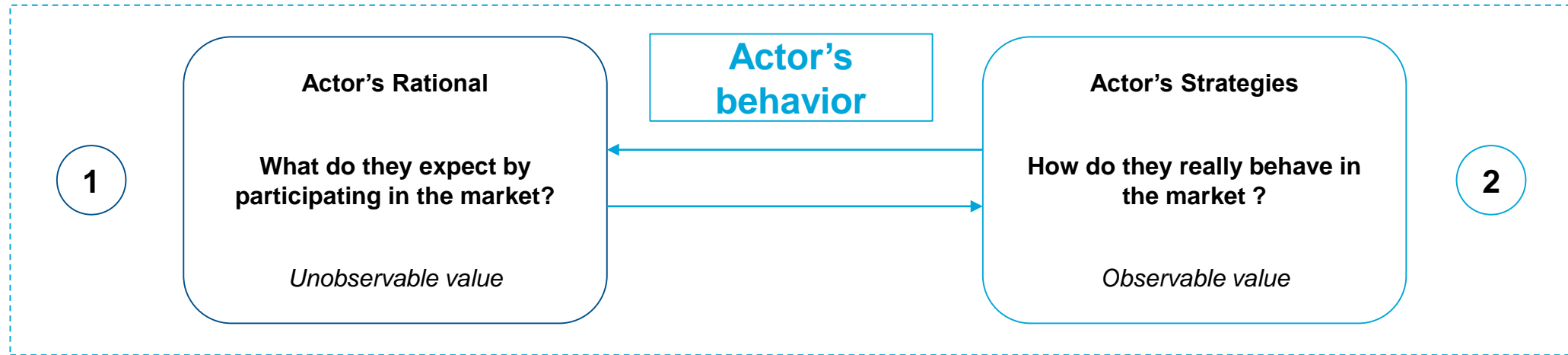
Market rule

- Type of product
- Associated penalties
- Period covered by the product
- Obligations on other markets

Market design

- Determination of the supply and demand curve
- Short term vs Long term contracts
- Sequentiality of transactions
- Centralization / Decentralization of transactions

Two-parts definition of an actor's behavior



A terminology found in most of economics theories

Auction Theory : *True value vs Offered value.*

Industrial Organization: Profit Function vs Conjectural Variation.
However, notions of market power

Contract Theory : Endogenous variable vs Signal.
However, notions of opportunistic behaviors

Examples of potential application to capacity markets

1 *Missing money over the delivery year*

2 *The supply curve is determined by the value of the Missing money for each producers*

Overview of the survey

44

papers modeling capacity remuneration mechanisms

Analytical models

- Nash Equilibrium
- Stochastic Equilibrium

Quantitative models

- Agent Based
- System Dynamics

Other models

- *Experimental*
- *Single firm optimization*

Why this work ?

- To give a benchmark and a baseline on how to properly represent behaviors in capacity markets.
- **We lack a bridge between the specificities of capacity markets and academic studies which focus on behaviors and price formation.**

From the framework to the survey

1

What do they expect through their participation in capacity markets ?

Determination of the offered value
To underline specificities of capacity markets

2

What factors can modify their expectations in capacity markets ?

How can you estimate the offered value ?

3

What are the strategies in the capacity markets ?

How can you represent the difference between the offered value and the true value ?



What good is traded on capacity markets?

What is so special about capacity markets ?

What are you offering in a capacity market ?

One capacity sold in the capacity market

CM



Obligation to produce during certain hours over the product period

RO



Obligation to give back the difference between energy price and the strike price

An opportunity cost of being available ?

The opportunity cost of being available

CONEfusion (Wilson 2010) :

Producers are not offering their annualized CONE at each auction in capacity markets.

They are offering the value of the opportunity of being remunerated on the capacity market and on the energy market.

Example - New entrant with the following annual characteristics for its **5 years** long capacity :

- Fixed cost - **200 €**
- Expected capacity price **110 €**
- Expected energy profit **60 €**
- Net total profit : - **30 €**

360

First bid in the capacity market ?

Opportunity cost in literature

Capacity markets

Creti et Fabra (2007)

Price spread between two markets



Recall obligation

Khalfallah (2009)

- *Reliability options :*

Loss of potential profit

or

Missing Money

- *Forward Capacity Mechanism (with ex ante control) :*

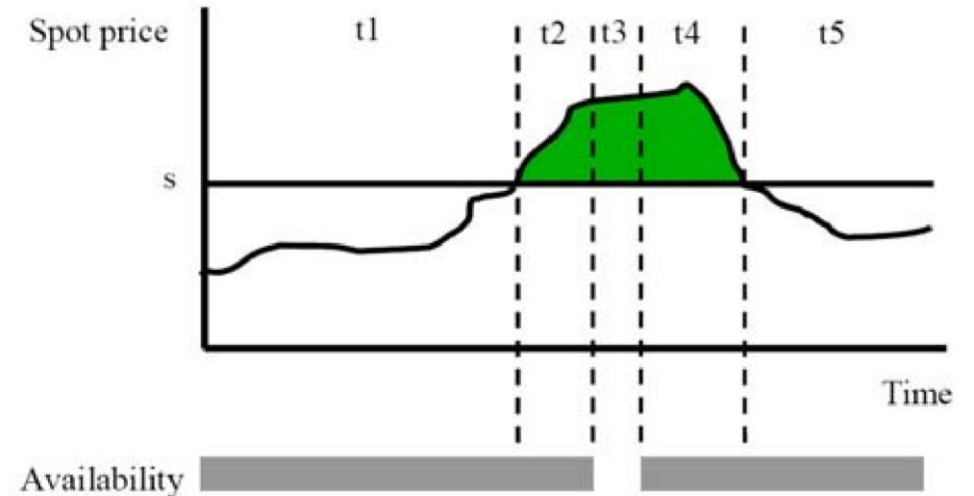
Inframarginal rent

or

Missing Money

The opportunity cost is more and more used in models (both quantitative and analytical). But we lack a precise idea on how much the fineness of opportunity cost can deeply modify analysis made in academic literature

Reliability options (Mastropietro et al. 2016)



Incumbents

$$\text{BID} = \text{Loss of potential profit} + \text{Penalty for unavailability}$$

New entrant

$$\text{BID} = \text{Loss of potential profit} + \text{Penalty for unavailability} + \text{Missing Money}$$



4

Formation and estimation of the offered value in capacity markets

The offered value is the opportunity cost

Opportunity cost of being available



Offered value



How can you forecast this opportunity cost ?

What drive the forecast of the offered value?

Type of cost and technology

Industrial decision

Origin of uncertainty

Risk aversion

Type of agents

Quantitative models (ABM – SD) tend to represent in more detail manner the forecast of the cost of being available.

What are the main market rules in capacity markets ?

Types of markets modeled

Obligation rule

Obligation period

Penalty rule

Very few works have studied the effect of market rules on behaviors, although practitioners know that they significantly alter the behavior

Effects of risk in capacity markets

Effect on the overall system

Main source of uncertainty : Demand / fuel / regulation

How capacity markets impact risk : add a new stream of fuel which is sometimes considered as fixed or dynamic

EOM vs Capacity Markets (*Petit et al. 2017*)

Capacity Market vs Strategic Reserve (*Hary et al. 2016*)

Model based on stochastic optimization model

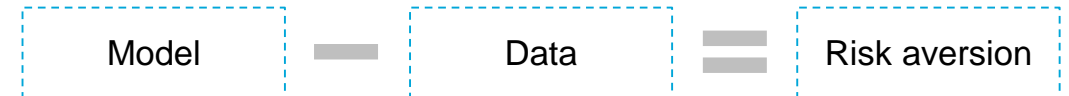
Ehrenmann and Smeers (2010, 2011, 20113); Abada et al. (2019); Peluchon (2019); Maere d'Aertrycke et al. (2017).

CVAR – CAPM – Utility Function

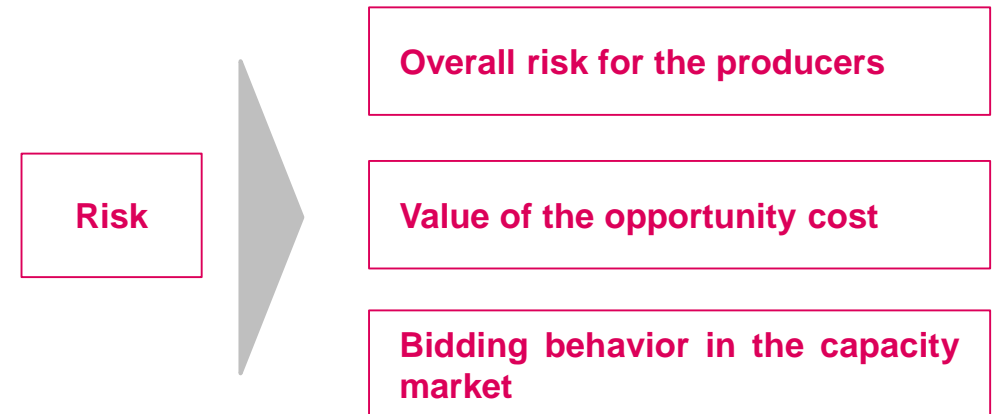
Risk + Risk Aversion + Risk Measure + Risk Trading
(*incomplete market*)

Effect on the bid of risk in capacity markets

Schwenen (2015)



Economic literature widely recognizes the effect on behavior and price formation of risk and risk aversion. See Meunier (2013) for a concrete application to investment in electricity.



Effects of industrial decisions in capacity markets

Having the choice in capacity markets

Dynamic and complex model including industrial decisions
Hary et al. (2016), Petit et al. (2017) and Abani et al. (2019)

Industrial decisions and the opportunity cost
Abani et al. (2019)

New technology vs Refurbish with risk averse producers
Abani et al. (2018); Lynch et Devine (2016).

Option value in capacity markets

Real option valuation with entry and mothballing in capacity markets with capacity payments
Hach and Spinler (2016)

Additional remuneration



Increasing option value

Would be interesting to formally represent option value for capacity owners to wait / participate in capacity mechanisms.

A model based on real option value with endogenous capacity price, multiple technology and strategic behavior ?

Importance of market rules

Obligation to produce and behavior

Capacity market and capacity withholding in energy market
Schwenen (2014), Brown (2018)

Flexible products can lower capacity market cost
Bialek et Unel (2019)

Obligation to be available and renewables development
Cepeda et Finon (2013)

What is the theoretical link between type and period of obligation and an actor's behavior ?

Penalty schemes

Penalty schemes to incentives producers to declare their true level of capacity and to avoid over procurement
Joung and al. (2007)

(π_1, π_2)	C_T	C_E
C_T	(π_{TT}, π_{TT})	$(\pi_{ET}^T, \pi_{ET}^E - Prob_{ET}F)$
C_E	$(\pi_{ET}^E - Prob_{ET}F, \pi_{ET}^T)$	$(\pi_{EE} - Prob_{EE}F, \pi_{EE} - Prob_{EE}F)$

Penalty schemes and opportunity cost for producers
Mastropietro et al. (2016)

Would be relevant to have an auction model with such penalties (similar to the work of Kreiss et al. 2017)



5

Modeling the true value in capacity markets

Modeling strategies in capacity markets

Measure of strategies



True value



Offered value

How can you represent the true value ?

Pure and Perfect Competition

Symmetric oligopoly

Asymmetric oligopoly

Auctions

Information asymmetries

Analytical models (Nash – Auctions) tend to represent in more detail manner the potential distance between true value and offered value

What are the main market design in capacity markets ?

Determination of the supply and demand curve

Short term vs Long term contracts

Sequentiality of transactions

Centralization / Decentralization of transactions

Very few works have studied the effect of market design on behaviors

Asymmetries in capacity markets

Incumbent vs New entry

Price dumping and capacity withholding with new entry
Teirilä (2018)

Barrier to entry strategies in capacity markets
Brown (2012)

Impact of inefficient technologies entry through subsidies
Brown (2018)

Strategic asymmetries

No model *a la Stackelberg* of capacity markets, but some model with investment decision and mothballing decision
Bajo-Buenestado (2017), Brown (2018)

Partial oligopoly with competitive fringe *Teirilä (2018) Elberg et Kranz (2014) Fabra (2018)*

Information asymmetries

The truthful signal on the actual capacity, during participation in capacity markets. *Creti & Fabra (2007) and Fabra (2018)*

Effect of level of reserve margin on the incentive to over-report capacity. *Joung et al. (2007)*

Capacity market based on contract theory with information asymmetries *Le Cadre et Soubra (2013)*

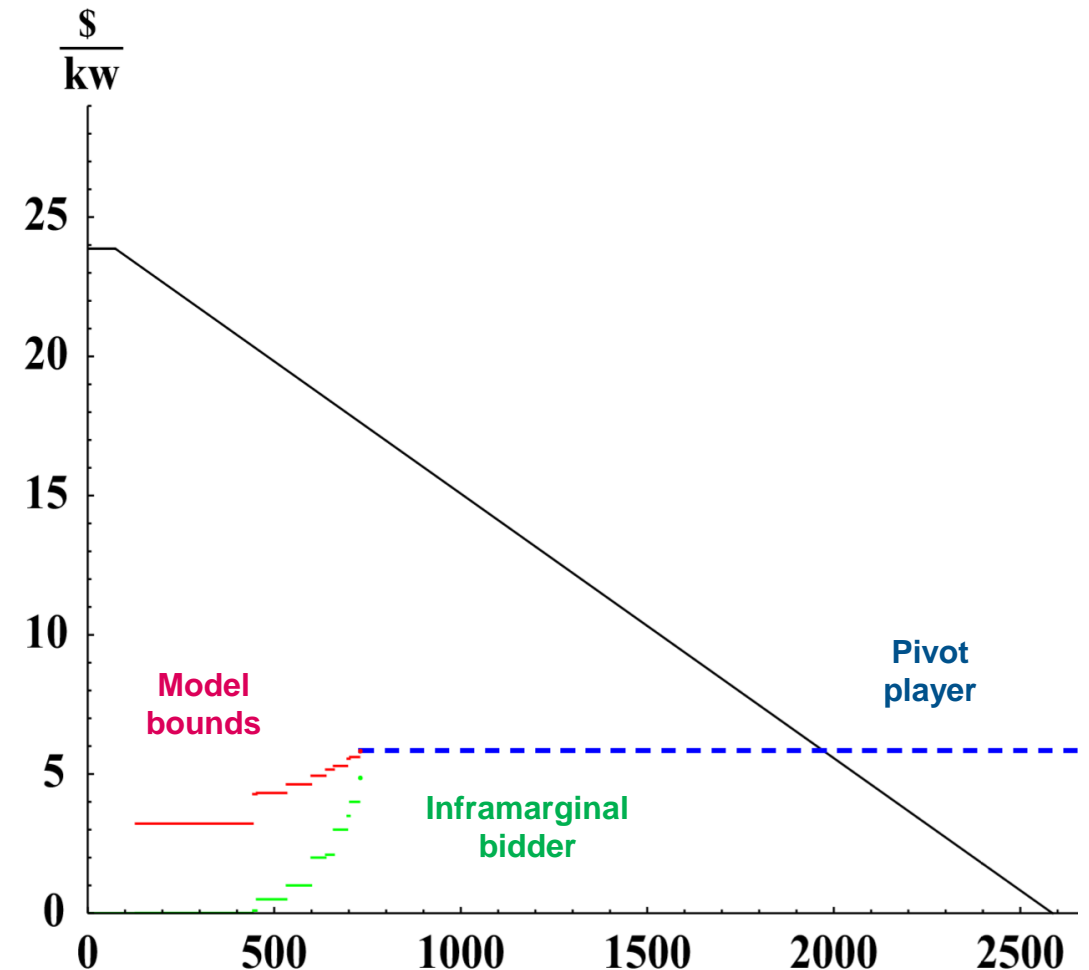
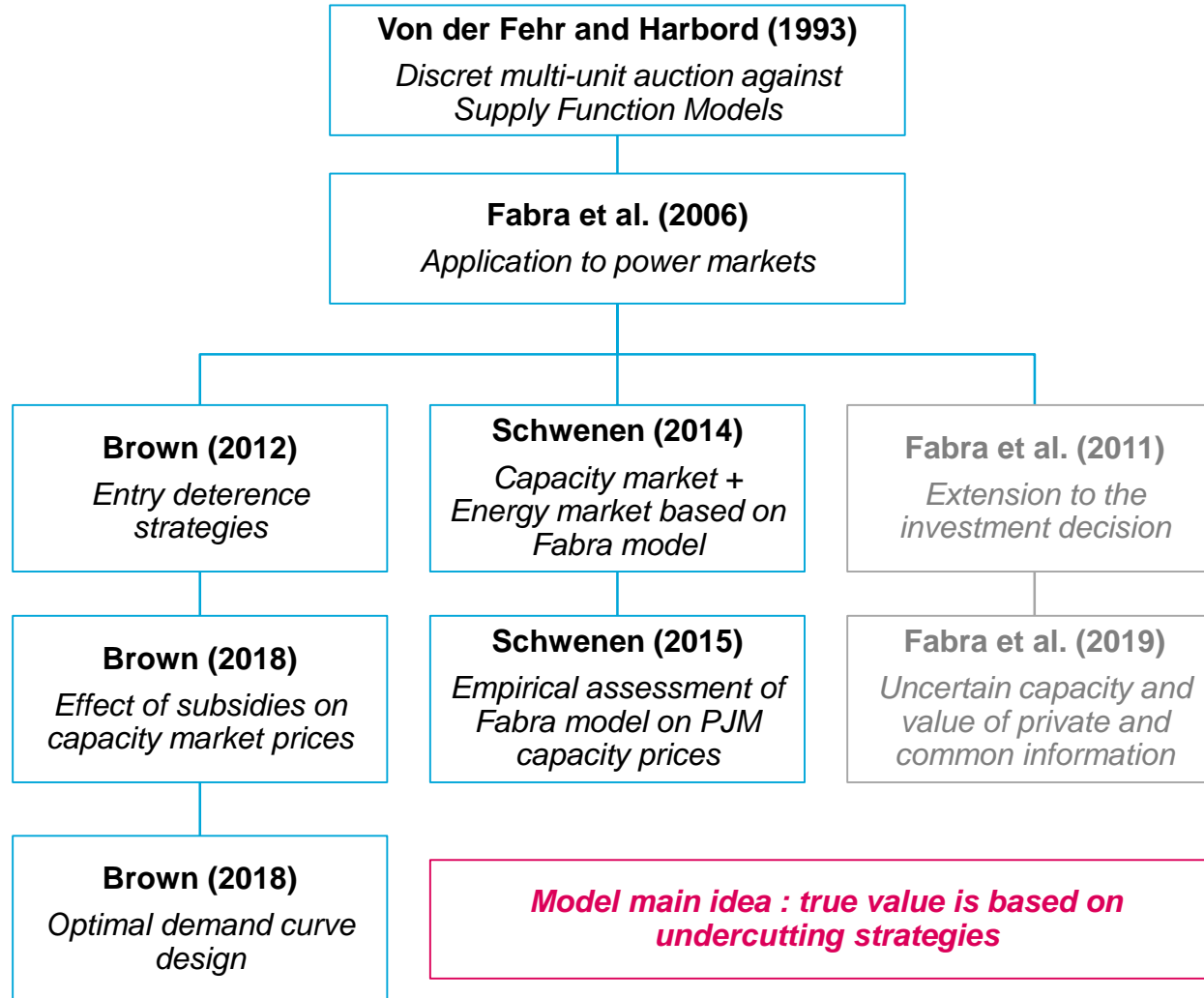
?



- The value of information between actors
- The strategies of information transmission between actors

Works, based on the theory of auctions, could highlight the importance and the value of information in capacity markets

Auction theory in capacity markets



The importance of demand curve in capacity markets

Demand curve and capacity markets

Qualitative effect of demand curve in capacity markets and potential market power

Some qualitative works assume a direct effect of capacity markets into energy markets as a mitigation tool to reduce market power.

Staggering of market power between energy market and capacity market *Teirilä (2018)*

The reasoning is simple : energy market has a very inelastic demand which leads to highly volatile prices and creates a favorable environment for the exercise of market power. On the other hand, demand curve on capacity markets can be much more elastic. **Terilla (2018)** demonstrated that the existence of capacity markets allows a sharing of market power between those two markets. Consequently, allowing a more elastic curve could lead to a decrease of overall market power in power system.

Optimal demand curve parameter with a regulator surplus maximizer *Brown (2018)*

The author provided a model with both a regulator and producers. The regulator in a first step maximizes the weighted total surplus (consumer + producer) in order to find the optimal demand parameters (slope, price cap ...). Capacity market is represented with an uncertain demand for capacity.



5

Conclusions

The questions are known but not treated

What we already know

We know that capacity markets are very specific (see *opportunity cost*)

We know that they may have significant and direct impacts in the level and composition of the production mix, but also indirectly on other markets.

The way additional compensations are integrated by investors

What's need to be done

Analytical models : to go deeper with opportunity costs in order to provide full conceptual models (industrial decisions + risk + market rules).

Quantitative models : to develop models with strategies and asymmetric actors. Huge opportunities to merge analytical models and ABM / SD models.

What about market design ?

What about market design ?

Sequentiality of transactions

Most of capacity markets are characterized by sequential auctions based on uniform price (*Salant 2019*)

Decentralization of prices

Auctions are mostly based on uniform multi unit ascending auctions
What about discriminatory auctions ? (*Fabra et al . 2006*)
New market design : descend clock auctions for reliability options in Ireland (*Teirilä 2018*)

Decentralization of transactions

Many markets include over the counter transactions which allow actors to negotiate, or renegotiate, capacity products. (*Milgrom 2000*)

Capacity demand

Some capacity markets are characterized by the participation of load serving entities (LSE). Each LSE has to cover their peak demand by acquiring (through the capacity market, or vertical integration) a certain amount of capacity.

Such participation can be direct (France, California) where the demand curve is thus set endogenously and is decentralized. Or indirect, where the regulator buys capacities on behalf of the LSE. However, any deviations from the initial allocation should be directly manage by the LSE.

At our best knowledge, no academic work has been conducted in order to represent endogenous capacity demand with different actors. In models, capacity markets with a centralized or a decentralized demand curve is strictly identical, which therefore lead to the same price formation.

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