Designing efficient capacity mechanisms

Bidding behavior and product definition

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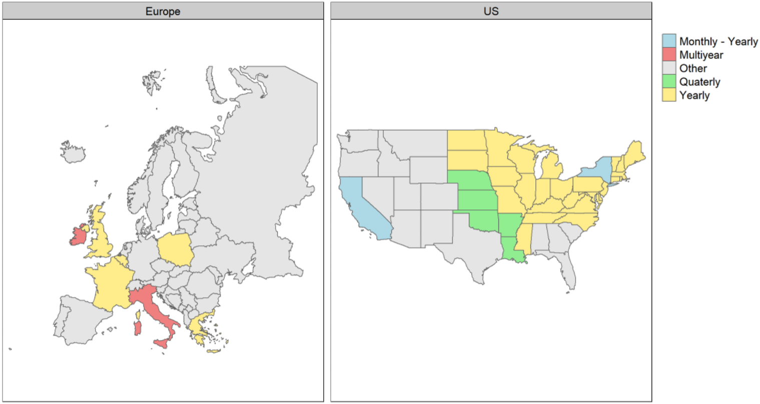
Why do we need capacity markets?

- For some "*essential*" goods, we need to have sufficient investment to produce them when needed. Example
- Relying on private incentives is sometimes not always efficient to provide sufficient investment: fixed costs, uncertainty, technical constraints, political intervention, unpriced externalities. Details
- Capacity markets can be a solution: a producer sells the 'availability' of its investment in return for additional remuneration. Illustration
- **In this paper, we focus on capacity markets where electricity producers offer their power plant availability.** But we can apply it to facemask/gel production facilities, laboratories.

But how to design markets?

- **This paper questions how to effectively set up a mechanism based on competition which was implemented to improve economic efficiency.**
- **Our objective is to show how the capacity product design affects the bidding behavior in capacity markets.**
  - **Product design** = duration of the procurement once a producer sells its capacity product in capacity market (**transaction phase**)
- The main idea: when a capacity product is sold, it implies **a (marginal) opportunity cost for the producer**.
- **What is the marginal cost of a producer selling a good on a specific market, and how can it depend on the product design?**

A diversity of market design



What we do? A marginalist approach

- **Market design theory must take into account the practical limits imposed by the actors' behavior in the face of specific rules.** We underline the multidimensional aspect of this issue in relation with
    - **The interdependence between markets**
    - **Irreversible decisions outside the market**, which imply option values
    - **Agent heterogeneity and other product rules**
- We begin with the canonical approach using **Net Present Value** to describe the marginal opportunity cost.
- We extend our analysis of the the bidding behavior using a **Real Option framework**
- We provide simulations using real world data.

What we find?

For the Net Present Value

- **A longer transaction** phase always implies **a lower expected bid** compared to the sum of expected bids for shorter periods.
- Does not capture the value of the possibility to close.

For the Real Option

- Producers place a higher value to close to avoid fixed costs
- Compared to NPV : **Higher bids** (even without missing money)
- Longer transaction : **Higher bids** (reverse effect)
- Counter intuitive effects of some variables on the bid

Provide new insight on policy-relevant issue

Literature

Opporunity cost and capacity markets [Wilson, 2010] [Abani et al., 2016], [Abani et al., 2018], [Bhagwat et al., 2016], [Bhagwat et al., 2017a], [Bhagwat et al., 2017b], [Teirilä and Ritz, 2018], **[Creti and Fabra, 2007]**, [Mastropietro et al., 2016] [Meyer and Gore, 2014], **[Brown, 2012]**.

Procurement design [Bushnell et al., 2017], [Bialek and Unel, 2019], **[Bialek and Unel, 2020]**, [Abani et al., 2018]

Real Option framework [Hach and Spinler, 2016] [Andreis et al., 2020] [Fontini et al., 2021] [Matthäus et al., 2021]

Roadmap

From a producer point of view

- You want to invest in a power plant and sell electricity on the energy market on a period (t): p_t energy price. c_t : marginal cost of production. Capacity and quantity normalized to 1

Which gives the energy market net revenue: $\pi_t = (p_t - c_t)$

Uncertain prior to t (Geometric Brownian Motion - Example):

$$d\pi_t = r\pi_t dt + \sigma\pi_t dW_t$$

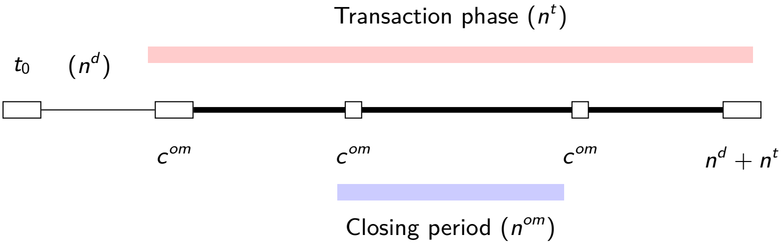
Two different fixed costs:

- c^I : Investment costs
- c^{om} : Operation costs **(avoidable if power plant is temporarily closed)**

Implementing the capacity market

Market inefficiency is assumed (investment is needed and prices are too low to cover fixed costs)

We set up the capacity market with a transaction phase of n^t days. An auction is set up at date t_0, n^d periods before the beginning of the obligation.:



What is your opportunity(marginal) cost ?

First dimension : the missing money rationale

Opportunity cost = maximum of the expected loss during the transaction phase

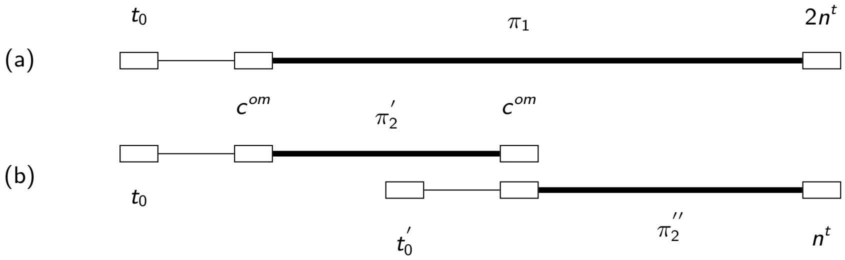
Existing plant (with $n^t = n^{om}$)

$$b_{t_0} = \left[c^{om} - \sum_{i=n^d}^{n^t+n^d} e^{-ri} E_0^*(\pi_i) \right]^+$$

New plant

$$B_0 = \left[c^I + \sum_{i=0}^{\bar{n}^{om}} e^{-r(i\times n^{om})} c^{om} - \sum_{i=0}^{T} e^{-ri} E_0^*(\pi_i) - \sum_{i=0}^{\bar{n}^t} e^{-r(i\times n^t)} b_{i\times n^t} \right]^+ \quad (1)$$

First dimension : the missing money rationale



Proposition

Expected bid of case(a) $\leq$ *Sum of expected bids of case(b)*

Intuition : $max(x, 0) + max(y, 0) \geq max(x + y, 0)$

Second dimension : the closing period for existing investment

Opportunity cost = option value to close to avoid c^{om}

Simplest form ($n^t = 1$): Capacity product is an European Put Option with payoff $max(c^{om} - \pi_t, 0)$, asset price π_t and strike price c^{om}.

$$b_{t_0}^{opt} = \quad -\pi_0 \quad \times \quad \boxed{\phi(z)} \quad + \quad c^{om} e^{-rn^d} \quad \times \quad \boxed{\phi(z + \sigma\sqrt{n^d})}$$

Compared to the NPV case :

$$b_{t_0}^{npv} = max(-\pi_0 + e^{-rn^d} c^{om}, 0) \tag{2}$$

Second dimension : closing the gap with reality

Technical issue : We cannot directly expend to the case $n^t > 1$

Solution : We consider the capacity product as a modified basket option ex.

Assumption

The sum of a log-normal r.v. is also going to be log-normal (Analytic approximation) illustration

$$b_{t_0}^{opt} = -\pi_0 \times \boxed{n^t} \times \boxed{\phi(z)} + c^{om} e^{-rn^d} \times \boxed{\phi(z+v)}$$

Second dimension : summing the bids

Not particularly challenging if the following assumption holds

Assumption

A closing decision for a specific period does not affect the profit or the producers' cost for other periods.

Intuition: exercising the closing option for a period does not change the value of another closing option.

$$\sum_{i=1}^{k} E^*_{t_0}[b^{opt}_k] = \sum_{i=1}^{k} b^{opt}_{t_0} \tag{3}$$

With k the number of successive auctions for short products.

Some comparative statistics

Product design	Transaction phase	n^t	+
Bid fundamentals *(in line with theory)*	Initial profit	π_0	-
	Periodic fixed cost	c^{om}	+
Policy instrument	Waiting time	n^d	$\sim$
Volatility of the revenue *(ex: introduction of RES)*		σ	+

Intuition : different values change the probability that $c^{om} > \pi_t$ and also the mean and the volatility of the total revenue.

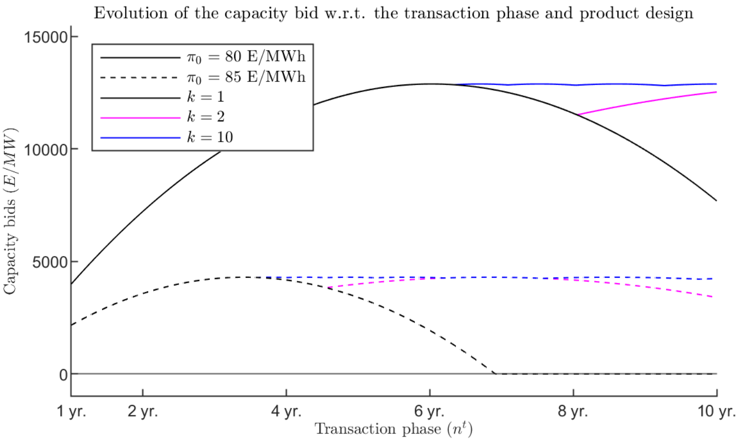
Roadmap

Initial value

We assume a French investment in a CCGT power plant.

Variable	Value	Source
Variable production cost (fuel + C02)	23 €/MWh	RTE (2017)
Fixed investment cost	830 €/kW	RTE (2017)
Fixed periodic cost	36 €/kW.yr	RTE (2017)
Risk-free rate	2.32%	French Y30 bonds
Production rate	30%	CRE
Brownian sigma	0.0051	Fontini et al. (2021)
n^d	4 years	French C.M.

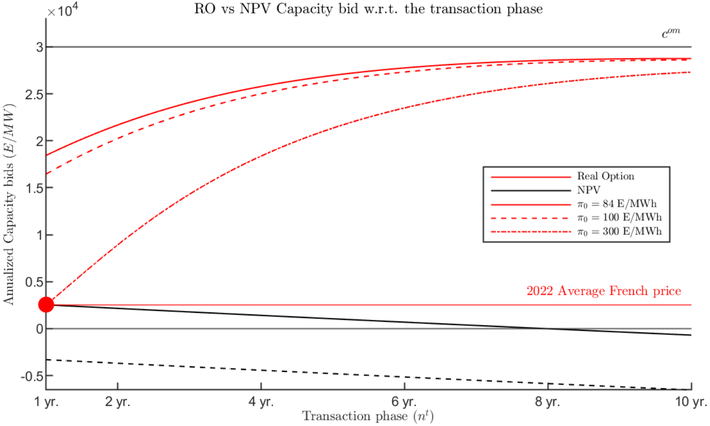
Longer transaction phase = lower bids (NPV)



π_0 = *initial value for the inframarginal rent*

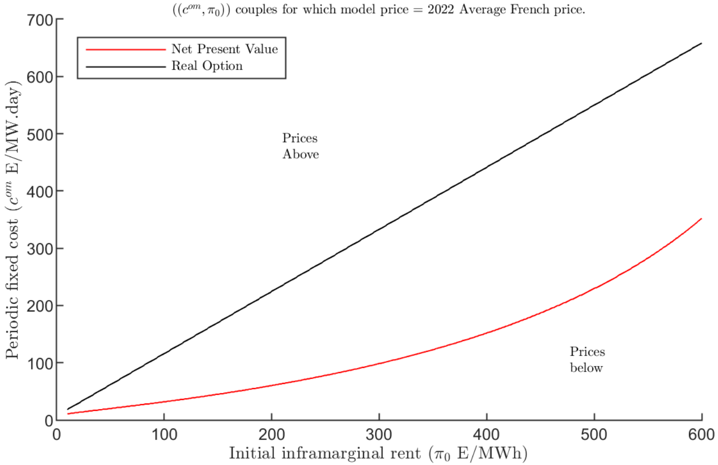
k = *number of products covering a single period* n^t Intuition

Real option bids > NPV bids

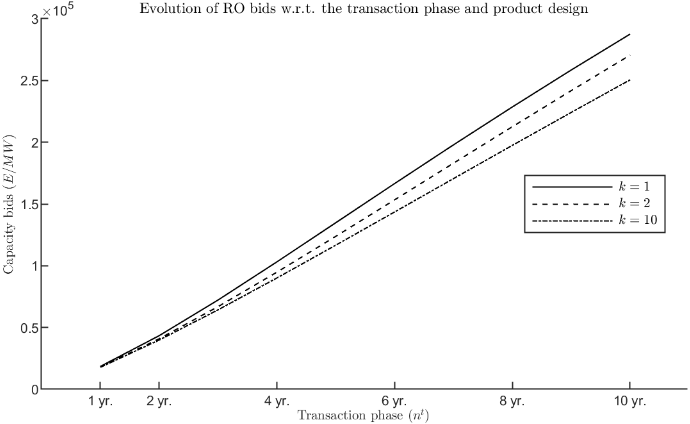


π_0 = *initial value for the inframarginal rent*
c^{om} = *annualized total operation fixed cost*

Importance of real option framework

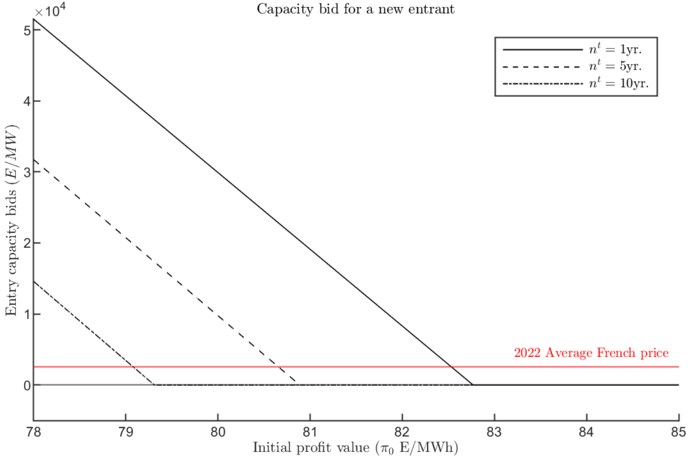


Longer transaction phase = higher bids (RO)

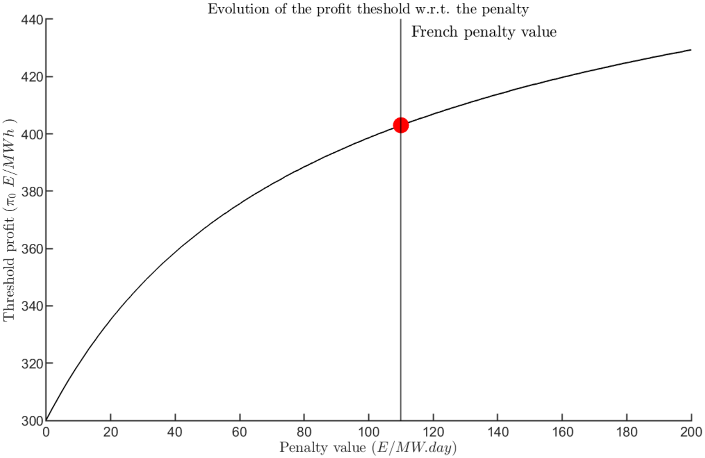


Intuition

Bids for new entry - T = 30 yr.



Bids and penalty



Policy discussion - Extensions

The paper aims at a better understanding of how producers bid in capacity markets. It helps to deepen many subjects :

- The cost of a capacity market for consumers / society.
- The study of anti-competitive behavior - ie market power.
- The non-technological neutrality of a technological-neutral capacity market.

It can incorporate many extensions :

- Option to invest.
- Different technology.
- Integrate the model in a system with interactions between producers.

Roadmap

Will capacities always be there for us?

California May Knock Out Power to 5 Million People Tonight

National Grid issues second warning on stretched electricity supplies

E.ON runs down power stations despite blackout warning

Millions of Texans without power as ERCOT declares highest level of energy emergency, 'rotating outages' to last longer

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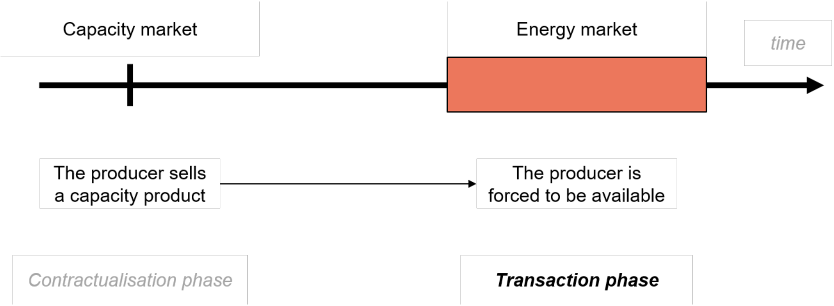
Framework for capacity markets



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What optimal payment for capacity?

- **Missing markets**
  - **Price cap** - The expected difference between the optimal scarcity price (ex VOLL) and the price cap. [Leautier, 2016]
- **Missing money**
  - **Public good** - The marginal value of black outs. [Holmberg and Ritz, 2020]
  - **Risk** - The cost of uncertainty / risk aversion / incompleteness [Meunier, 2013, de Maere d'Aertrycke et al., 2017]

What about the demand side of capacity markets?

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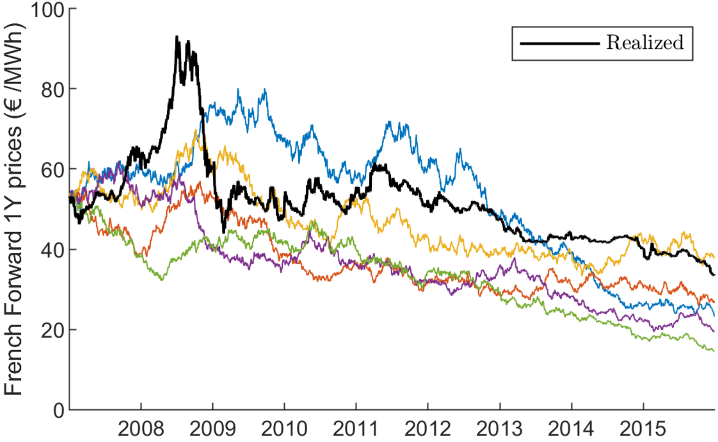
Example of GMB with respect to forward prices



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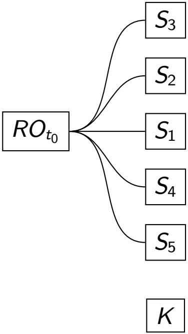
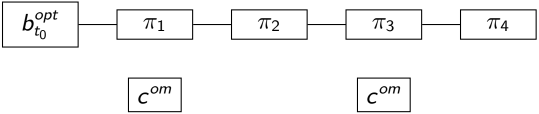
Basket option vs Capacity market

Basket Option



Capacity market



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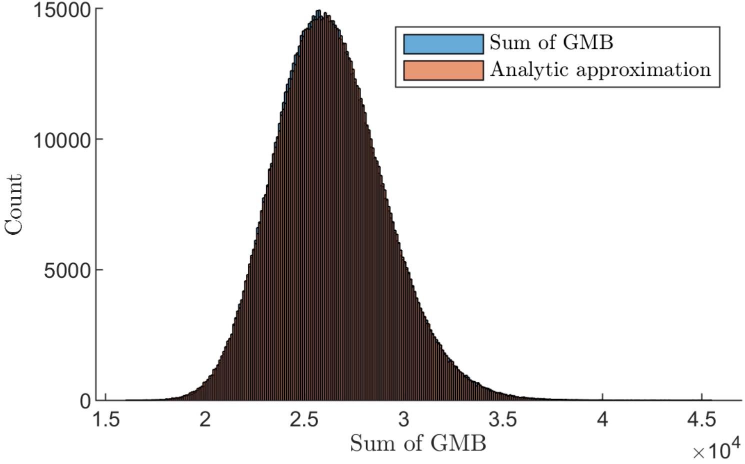
Comparison for Assumption 1



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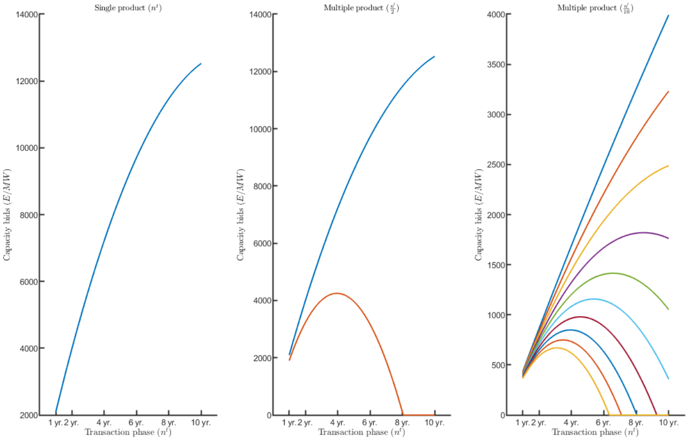
Evolution of each bid



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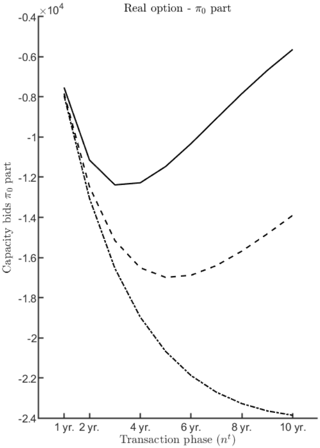
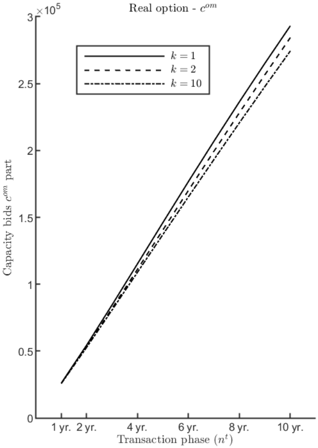
Intuition for the effect of k on the option value





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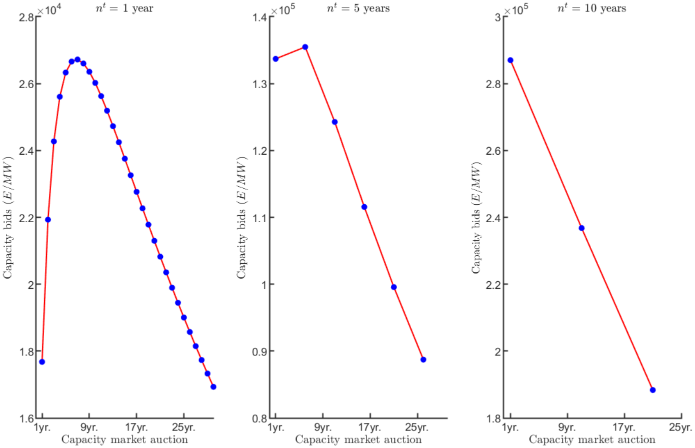
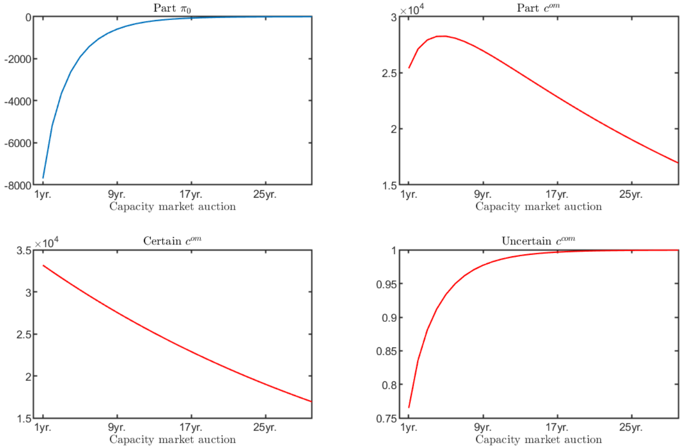
Lifetime bids



Intuition

Intuition for the effect of n^d on the option value



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