The relation between product design and market efficiency

An application to capacity markets

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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 1

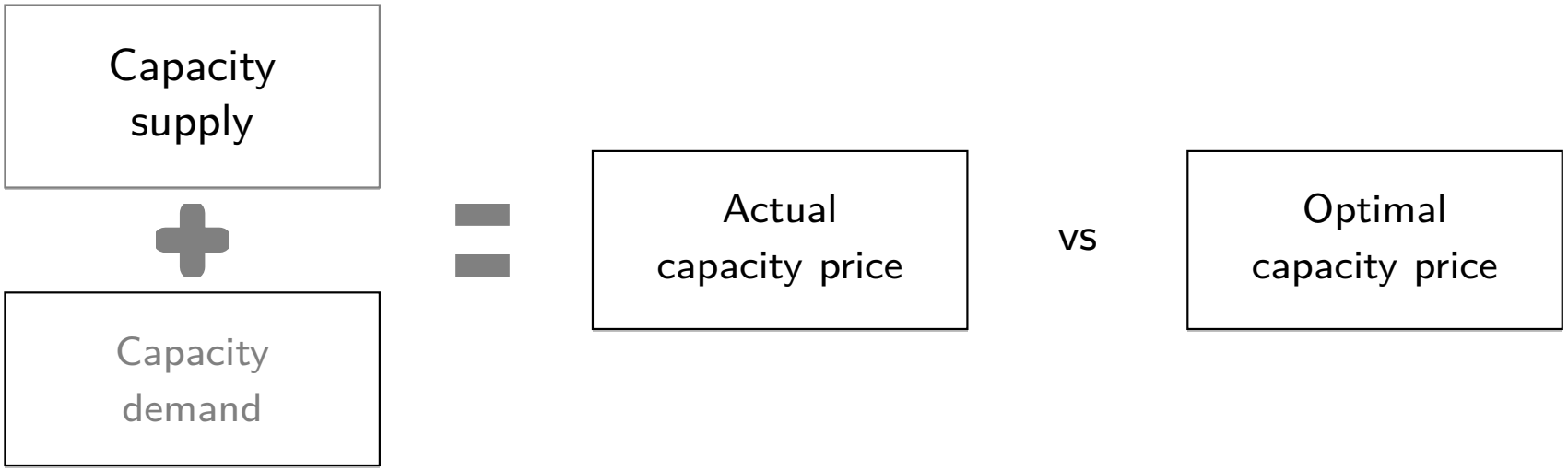
Relying on private incentives is sometimes not always efficient to provide sufficient investment: fixed costs, uncertainty, technical constraints, political intervention, unpriced externalities.

Capacity markets can be a solution: a producer sells the 'availability' of its investment in return for additional remuneration.

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.**
- **Market design theory must take into account the practical limits imposed by the actors' behavior in the face of specific rules.**



What optimal payment for capacity?

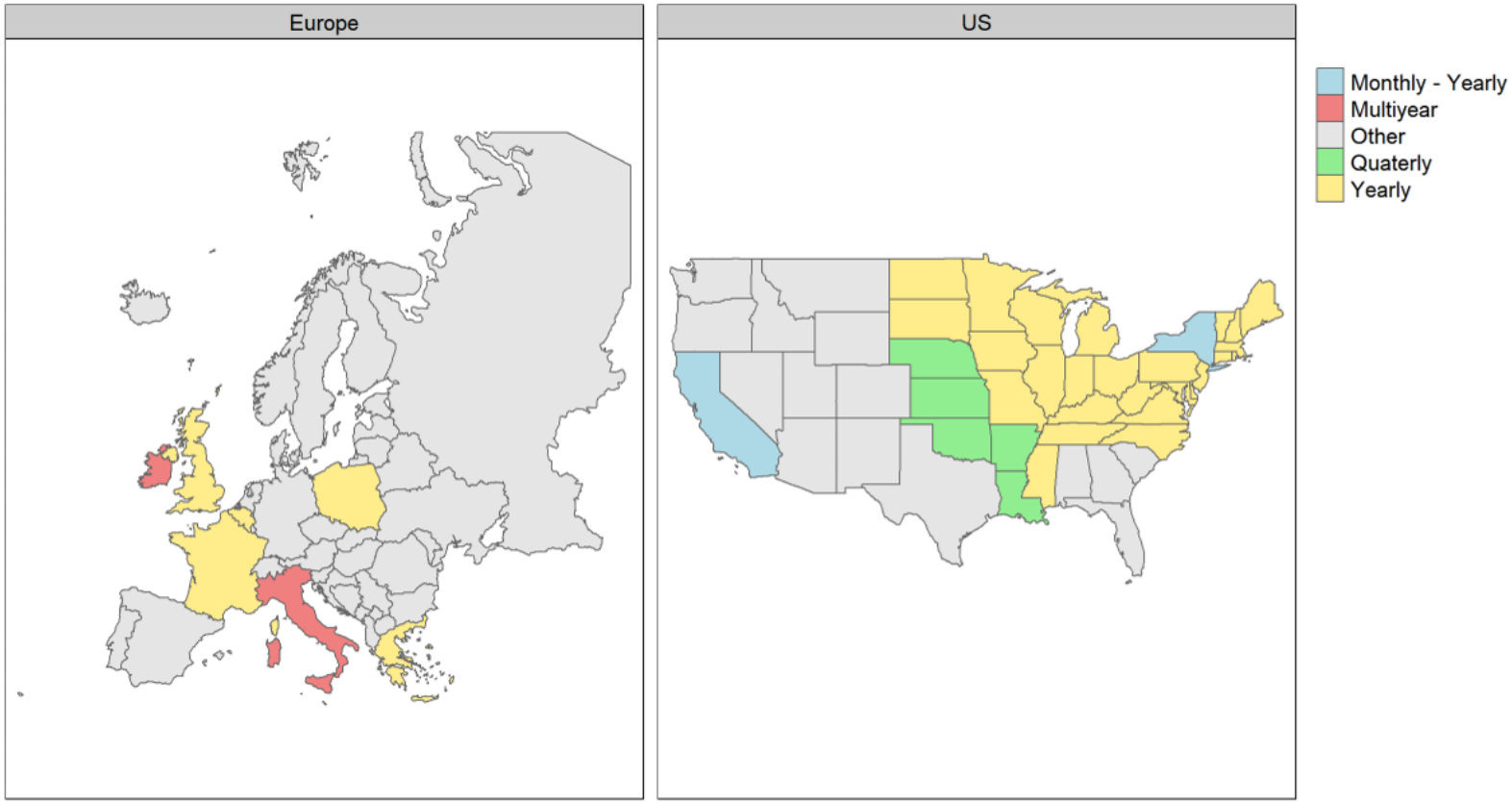
- **Missing markets**
  - **Price cap** - The expected difference between the optimal scarcity price (ex VOLL) and the price cap. [Leautier, 2016]
- **Missing money**
  - **Public good** - The marginal value of black outs. [Holmberg and Ritz, 2020]
  - **Risk** - The cost of uncertainty / risk aversion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

What about the demand side of capacity markets? *Paper presented last month in group E - centralization vs decentralization*

What we do?

- **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
- 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?**
- As the microeconomics theory states if we have the marginal costs you have prices.

A diversity of market design



What we find?

We provide a qualitative discussion on which determining factors should be used in assessing this marginal cost. We stress the potential **non-linearity between this marginal cost and the duration of the procurement.**

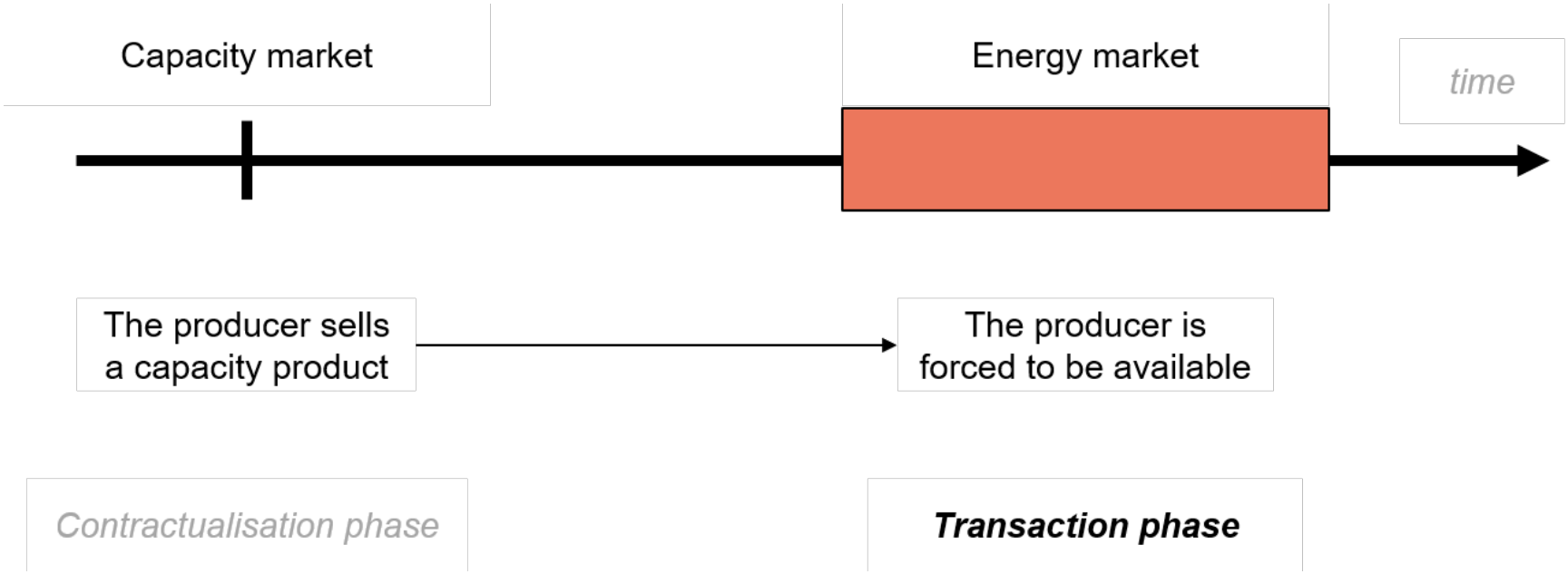
We underline the multidimensional aspect of this issue in relation with

- **The interdependence between markets**
- **Irreversible decisions outside the market**, which imply option values
- **Agent heterogeneity**

What we find?

- We also build a quantitative model that simulates future prices and costs on the power market.
- Based on those simulations we can find what will be the marginal (opportunity) cost associated with the participation in the capacity market
- We can quantify the effect of different product design on the investment value for a producer and the cost for consumers

How to keep the light on?



Capacity = electricity that is committed to being available in the future. But to be available you have to be open or to invest ...

Capacity product length = transaction phase length

Why focusing on capacity prices?

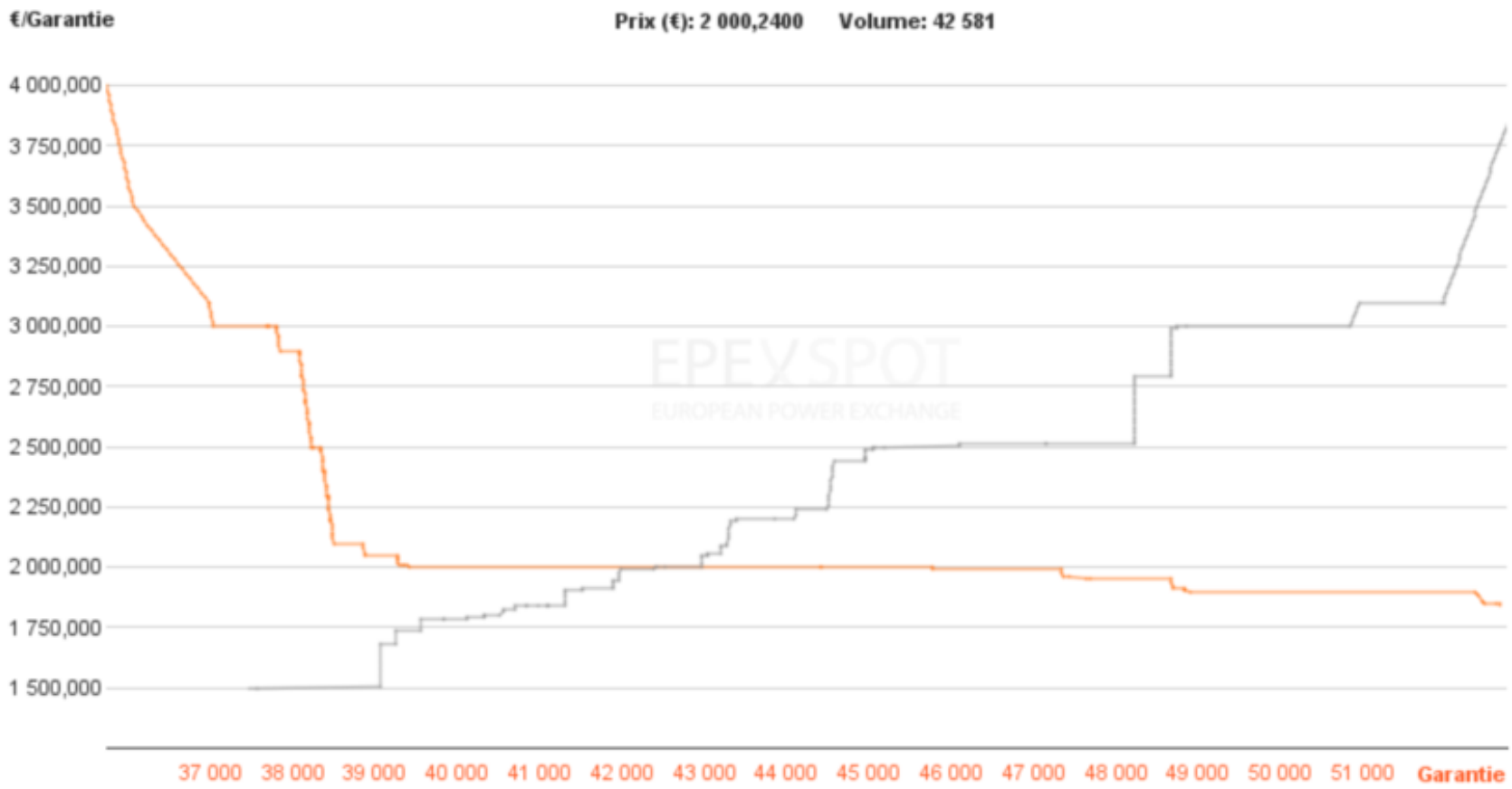
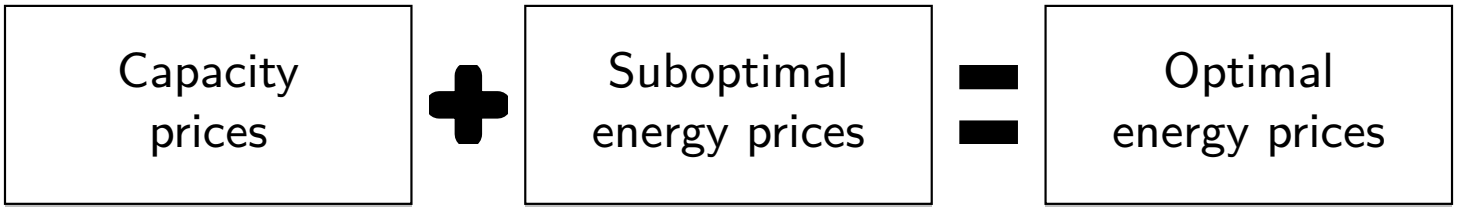


Figure: Auction results for the French capacity mechanism – 16-05-2019 for the delivery year 2020

Why focusing on capacity prices?



Too high capacity prices $\rightarrow$ to much incentives for producers $\rightarrow$ to much capacities in the system.

Too low capacity prices $\rightarrow$ to low incentives for producers $\rightarrow$ to low capacities in the system.

Approach

We provide a theoretical framework to discuss how the transaction phase can be related to the bidding behavior on the capacity market. It is based on **a marginalist approach** and allow to "*dissect*" the opportunity cost of selling a future commitment :

- What cost will I sustain when being forced to be available?
- What revenue will I lose when being forced to be available?

We use a single valuation model to assess the **channel between the transaction phase and the bids**. This is a "project finance" vision based on empirical data:

- The value of an investment is estimated without interference with other projects (eg. no portfolio effect) and without interaction with other players (eg. no competition).

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., 2017c], [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]

Single valuation project

[Fleten et al., 2007], [Fuss et al., 2012], [Kettunen et al., 2011], **[Hach and Spinler, 2016]**

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
- k : capacity level
- u_t : unavailability ratio

Which gives the energy market net revenue (no strategic behavior):

$$\pi_t = (p_t - c_t)\ k\ u_t$$

Two different fixed costs:

- IC : investment costs
- OM : operation costs (*periodic but not linked to the production decision*)

An optimal energy market

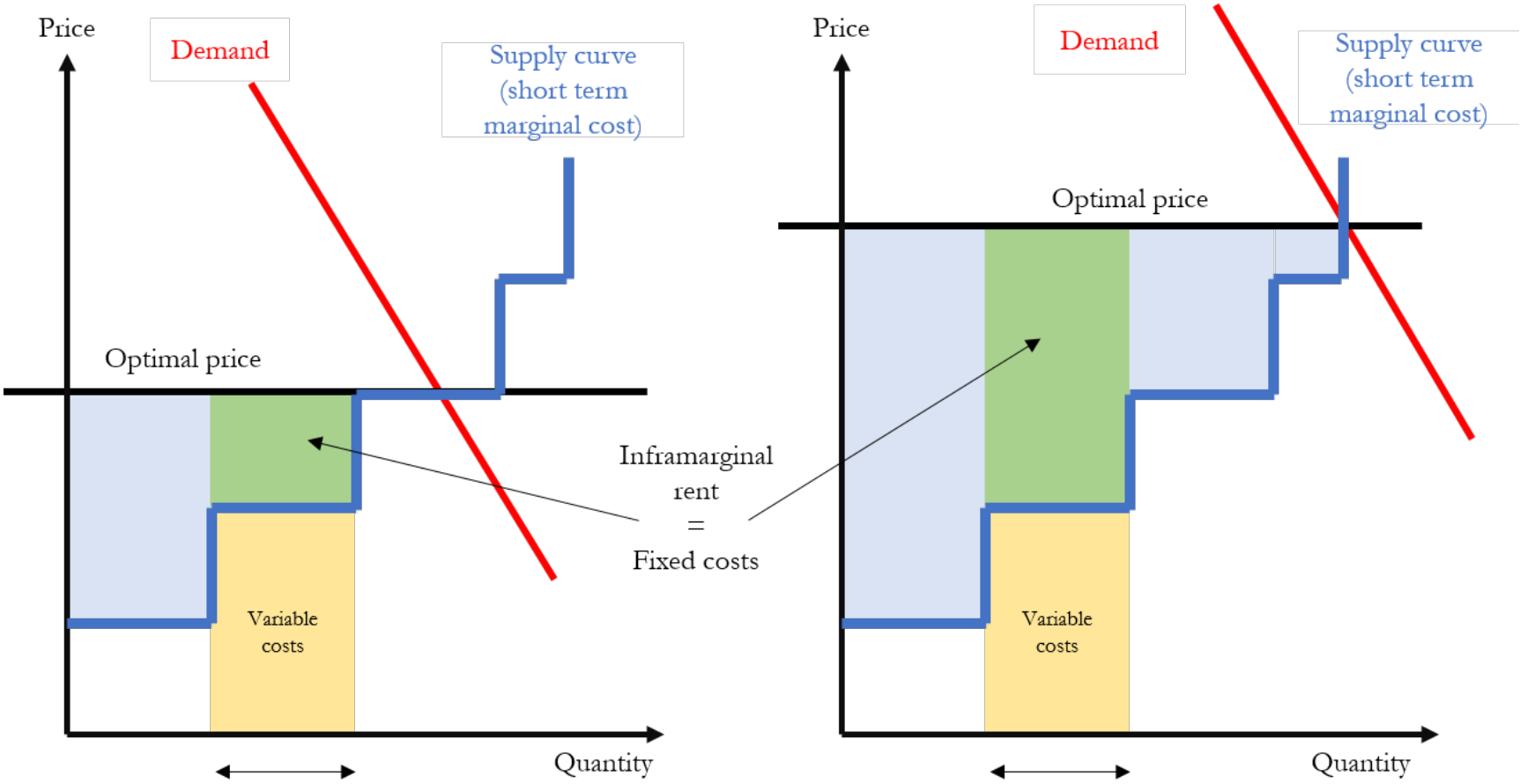


Figure: Revenue in an optimal energy market

But in reality ...

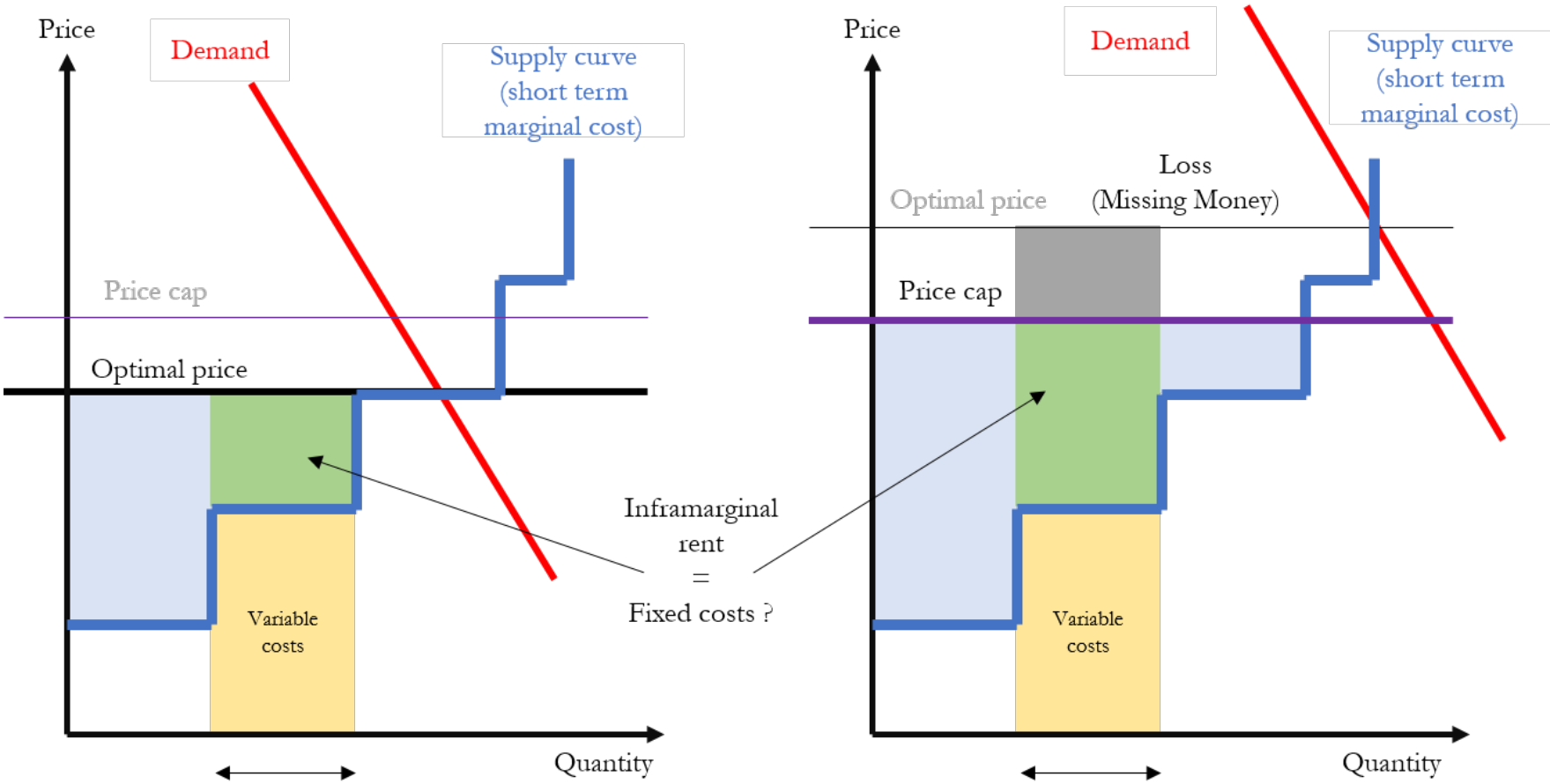


Figure: Revenue in an suboptimal energy market due to a price cap

Implementing the capacity market

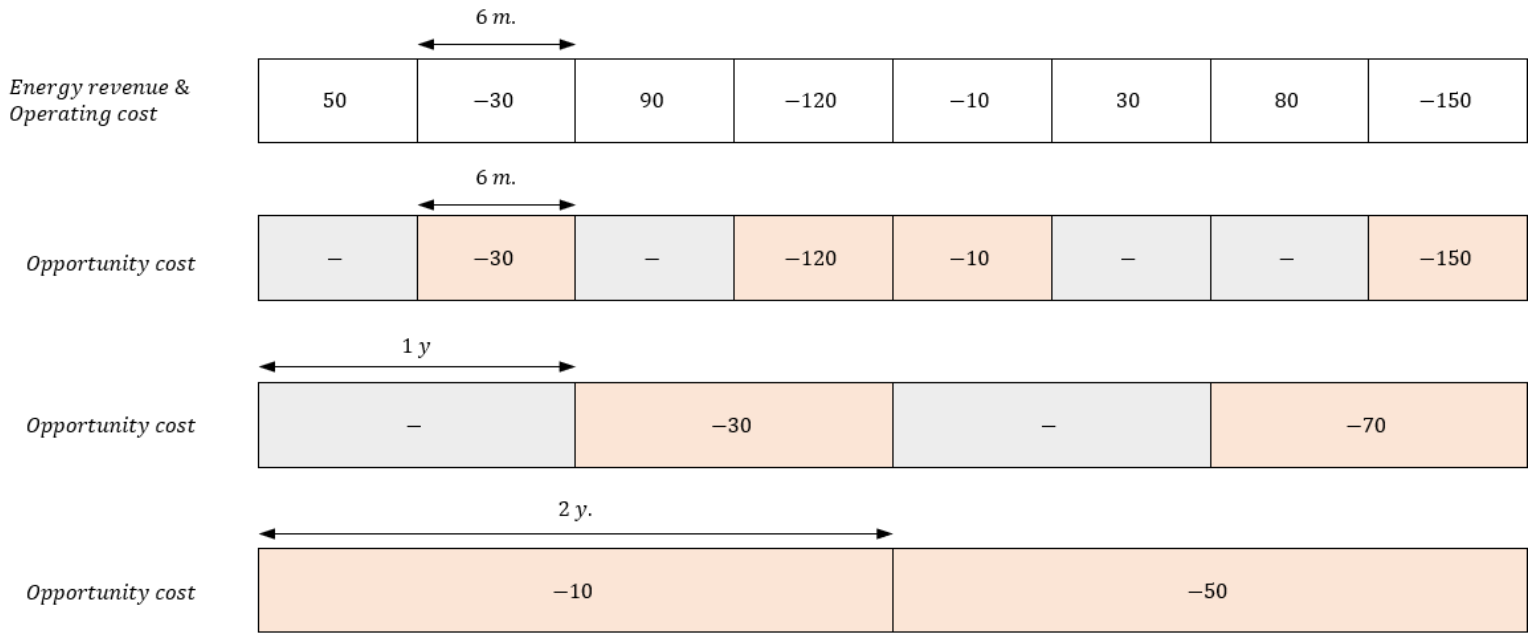
In the following discussion, we assume that the **level of capacity is optimal** and normalized to 1, but **energy prices are too low**.

We set up the capacity market with a transaction phase of n^{ts} days to restore market efficiency :

- **Whenever a producer sells a capacity product, he will be forced to be available during those n^{ts} days.**

What is an opportunity cost when you are forced to produce during n^{ts} days?

First dimension : the missing money rationale



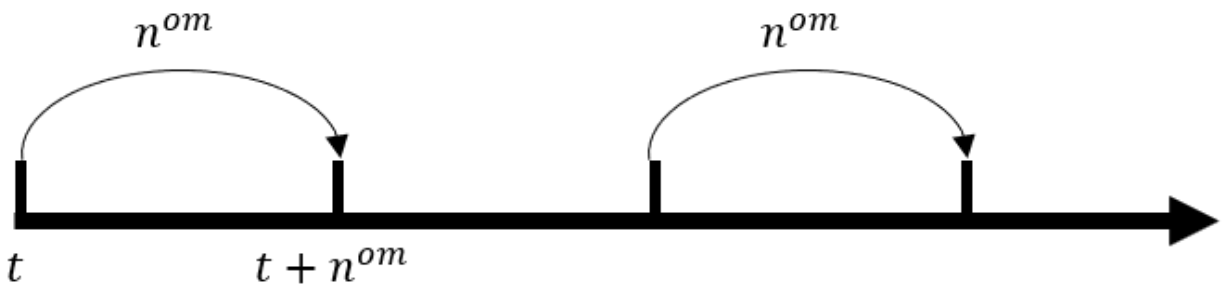
Proposition

With a longer transaction phase, the bids on capacity markets are either equal or lower than with a shorter transaction phase. On the other hand, it raises the first bids made when a product enters the market.

What if producers have industrial options?

OM costs are irrevocably incurred over a specific period of length of n^{om} as soon as the investment is opened.

The next decision to open/close **is made at the next OM period**.



Options and market inefficiencies

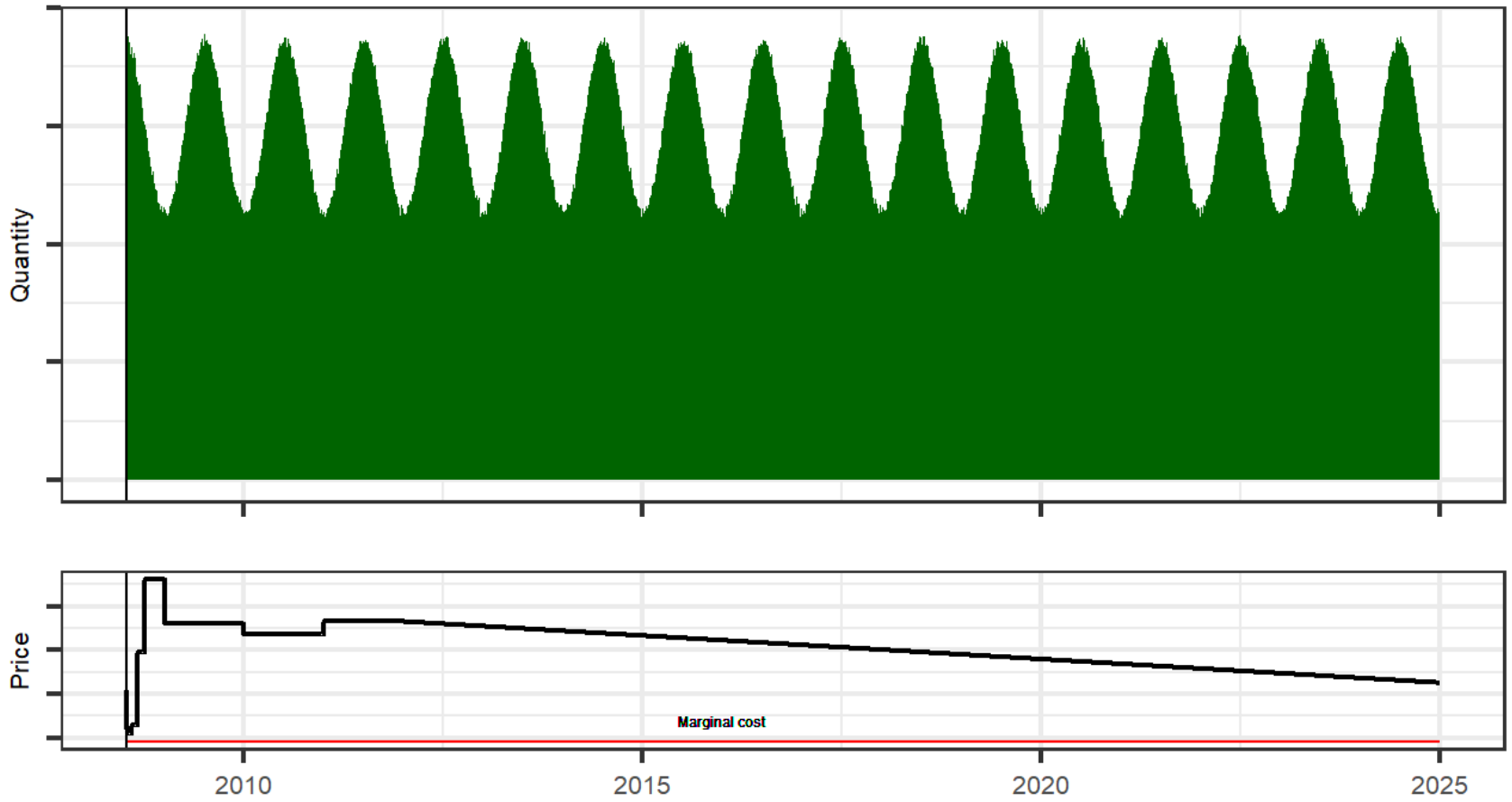


Figure: Production in an optimal setting

Options and market inefficiencies

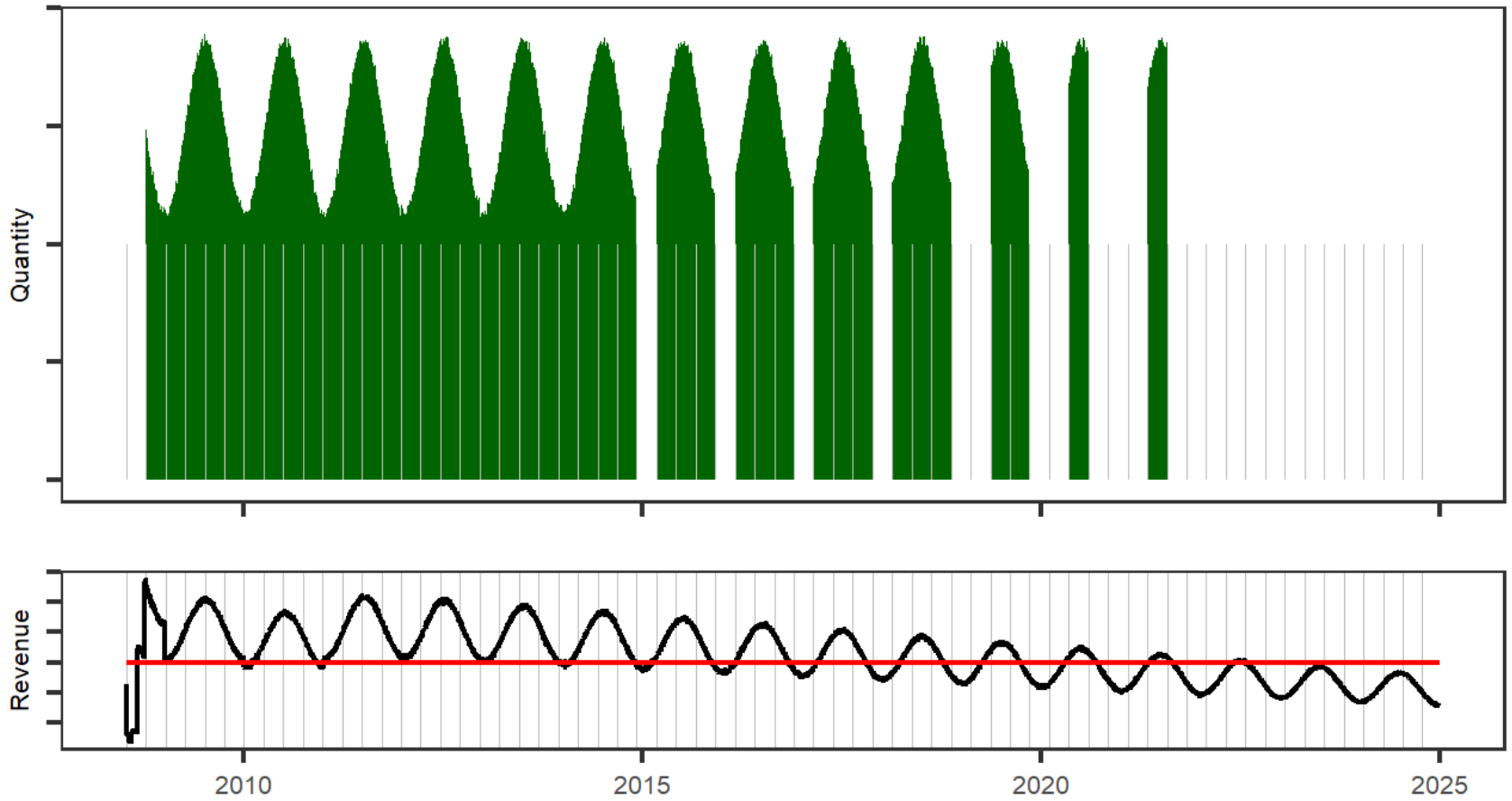


Figure: Production in an suboptimal setting due to closing option

The option value opportunity cost

We assume that the producer, besides, to cover its losses**, also covers the foregone profit made with industrial options**.

If the producer invests with the capacity market

- $V_t = -10$

The *Missing Money* opportunity cost is **10**.

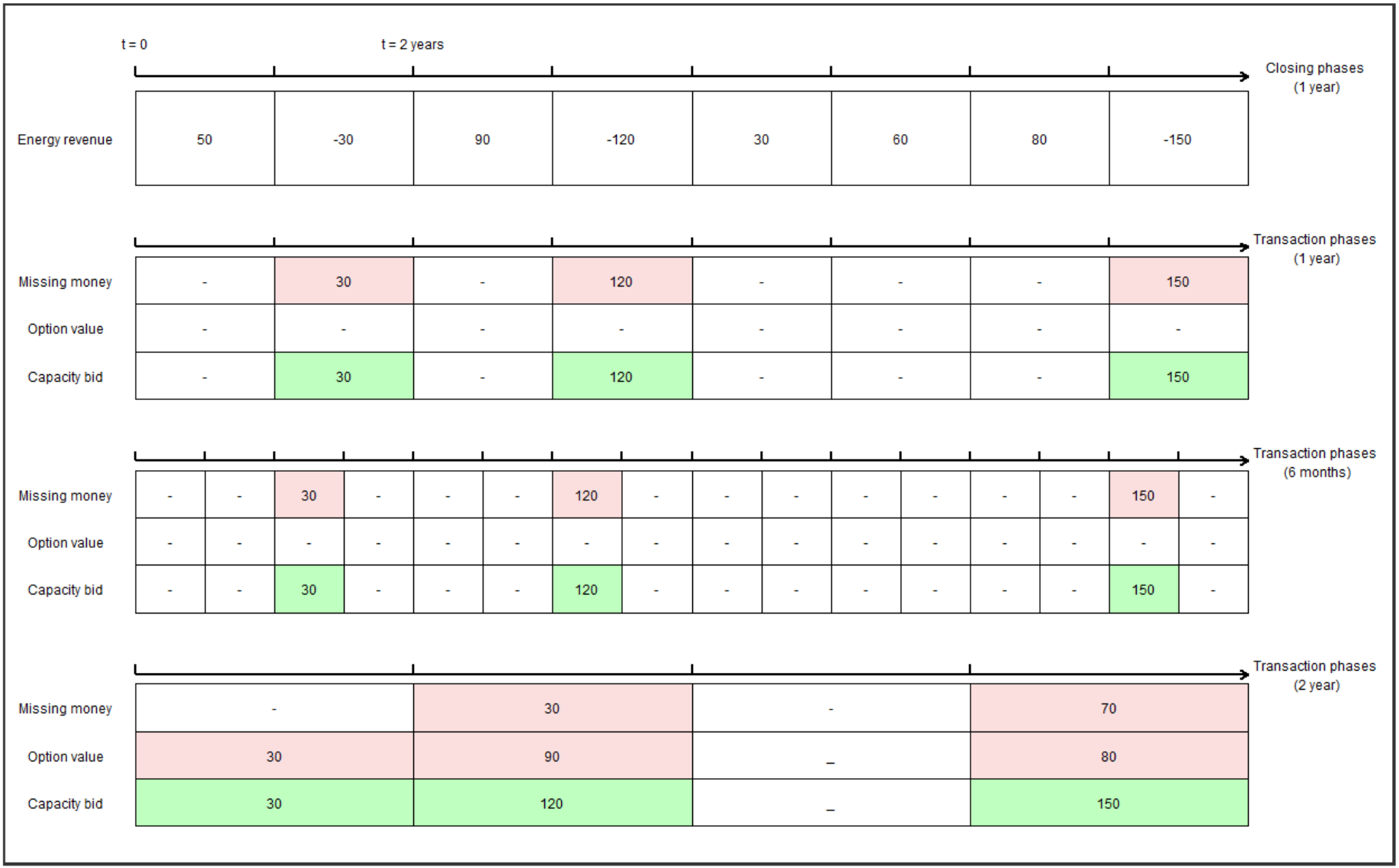
What if the producer invests with future closing :

- $V_t = 5$

The forgone value is **5**

The total opportunity cost is **15**.

Examples


t = 0
t = 2 years
Closing phases
(1 year)
Energy revenue
50
-30
90
-120
30
60
80
-150
Transaction phases
(1 year)
Missing money
Option value
Capacity bid
Transaction phases
(6 months)
Transaction phases
(2 year)
70
80
150

To sum up

Proposition

Including irreversible options leads to significant changes in the opportunity cost definition.

With shorter transaction phases :

- ***Lower volatility**: given similar opportunity costs, the number of null price is increasing*

With longer transaction phases :

- ***Option value rational** : A new rationale appears when the transaction phase is longer than the duration of the irreversible option.*
- ***Highest value** : The option value counter the effect of a longer transaction phase on the missing money.*

Other dimensions?

Cost structure and technical characteristics
Fixed costs vs Variable costs + Seasonal generation + Mothballing . Different technologies have different technical specificities (eg. renewables only produce when the wind is blowing and the sun is shining) and operational constraints. [Bialek and Unel, 2019].

Penalty rule and unavailability uncertainty
Practitioners recognize the importance of penalty to insure correct behavior from producers (*you only offer what you have*). But introducing a penalty also indirectly changes the opportunity cost. [Mastropietro et al., 2016].

Risk and uncertainty
Longer transaction phases imply higher hedging, which lowers the cost of risk. But at the same time it covers a longer future period, so a higher uncertainty regarding future rationales. What is the effect of risk aversion? [Bhagwat et al., 2017b] [de Maere d'Aertrycke et al., 2017]

Roadmap

A project finance approach

(1) We forecast future energy prices (p_t).

(2) Based on real data (c_t,u_t,IC,OM), we deduce the periodic profit and the investment value.

(3) We can deduce future opportunity costs, hence future bids on capacity markets (**bid profiles**), given those forecasts.

(4) Assuming that a producer receives what he offers, we have the impact of different product design on the **investment value** and its terms of **cost for the society**.

We run the model for **500 different valuations dates** with a different forecast. We also use different transaction and closing phases **4 transactions phases**: monthly, quarterly, annually, multiyear.

Example of a forecast

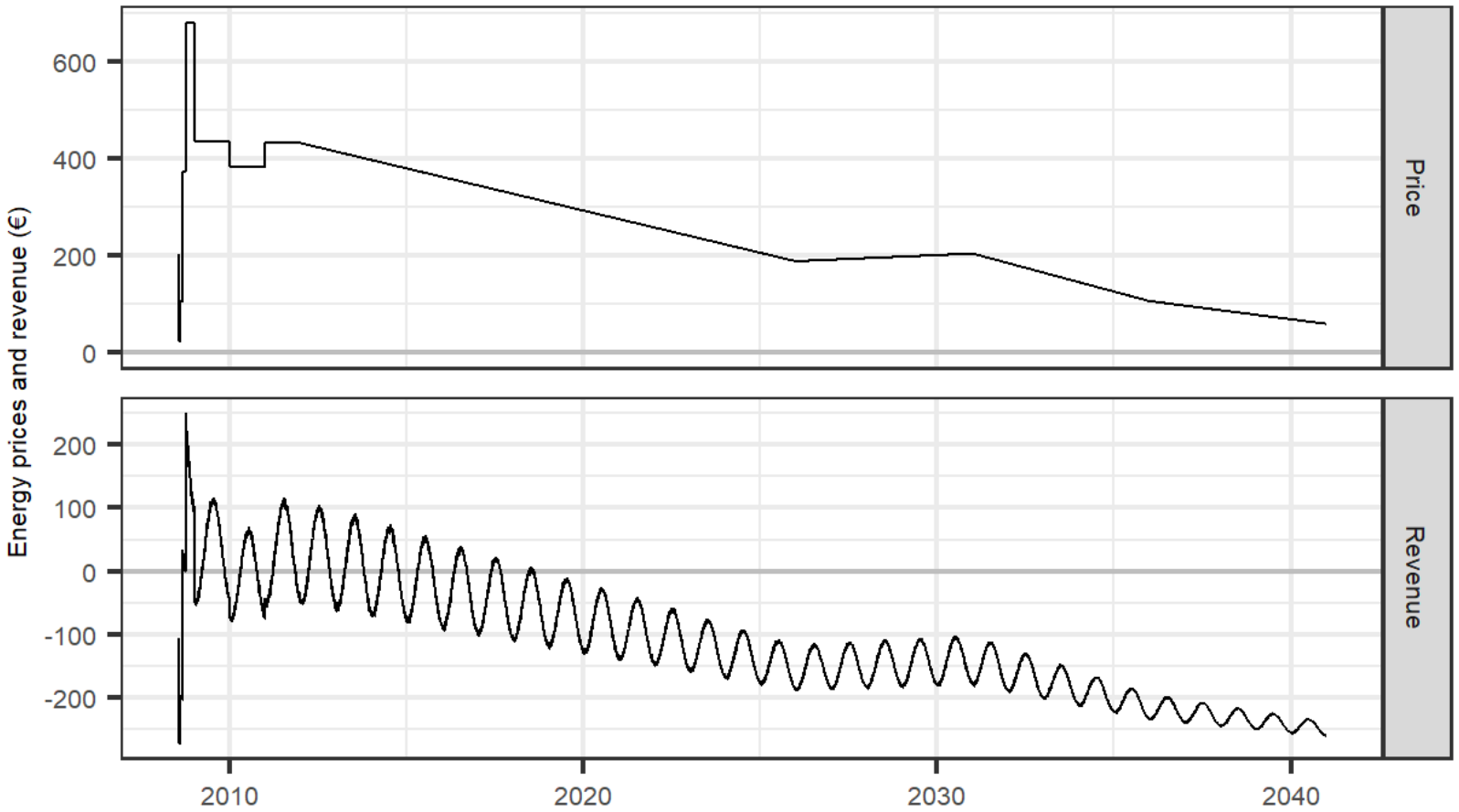


Figure: Evolution of future prices and revenue given an evaluation date (18-07-2008)

Investment value without capacity markets

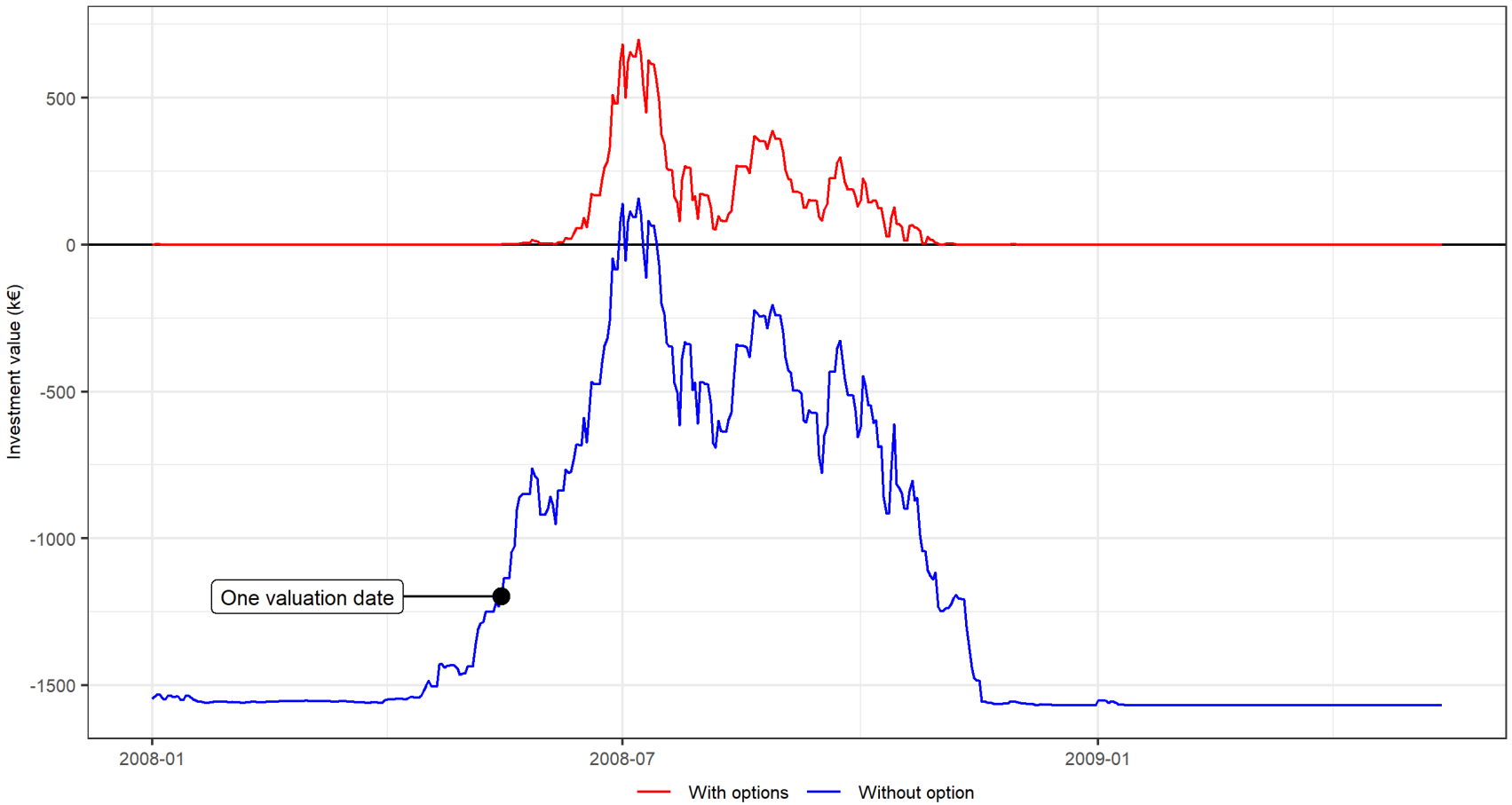


Figure: Average total existing bids for different closing and transaction periods (Proposition 1 & Proposition 2)

Options and inefficiencies

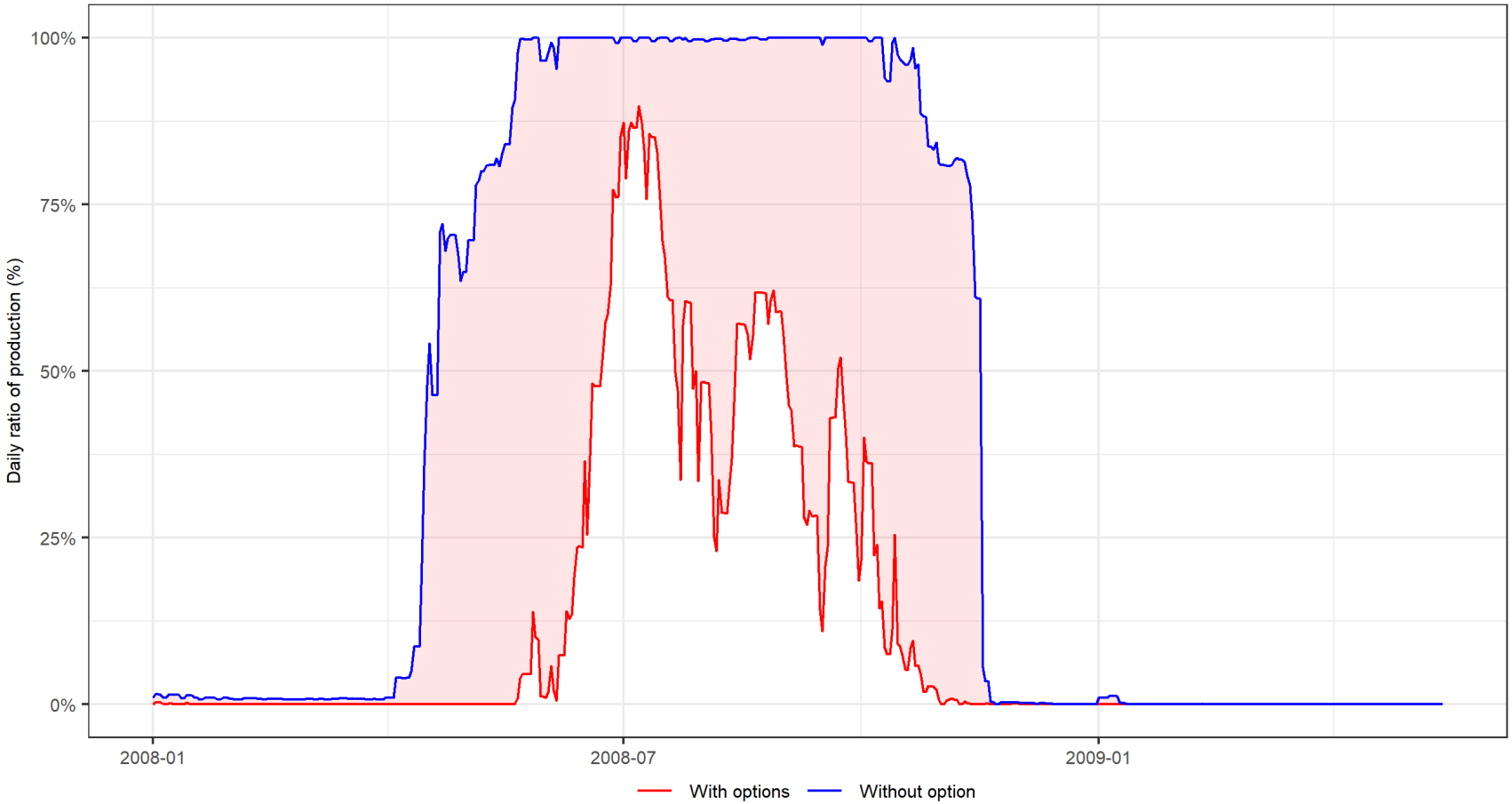


Figure: Average total existing bids for different closing and transaction periods (Proposition 1 & Proposition 2)

Some precision

Our project finance approach allows simulating both future cash flow and also the investment value.

We can express the consequences of several product designs on the system with

- Capacity bids value - full cost for consumers
- Investment value - added value of the mechanism for producer

We focus on the following slides on the bid's value. For now, the extension to the investment value is straightforward.

Example of a capacity bid profile

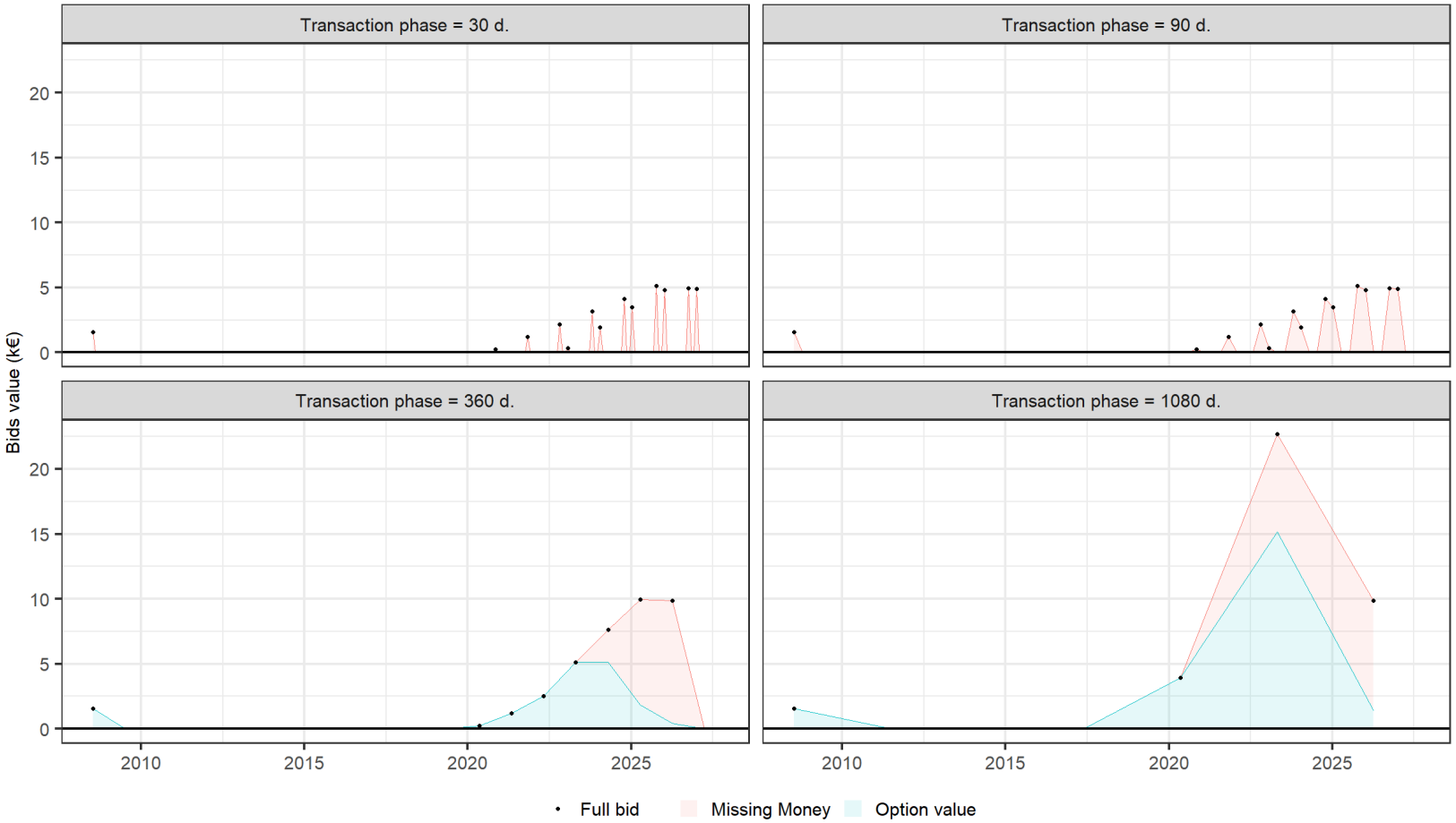


Figure: Average total existing bids for different closing and transaction periods (Proposition 1 & Proposition 2)

Existing bids and option value

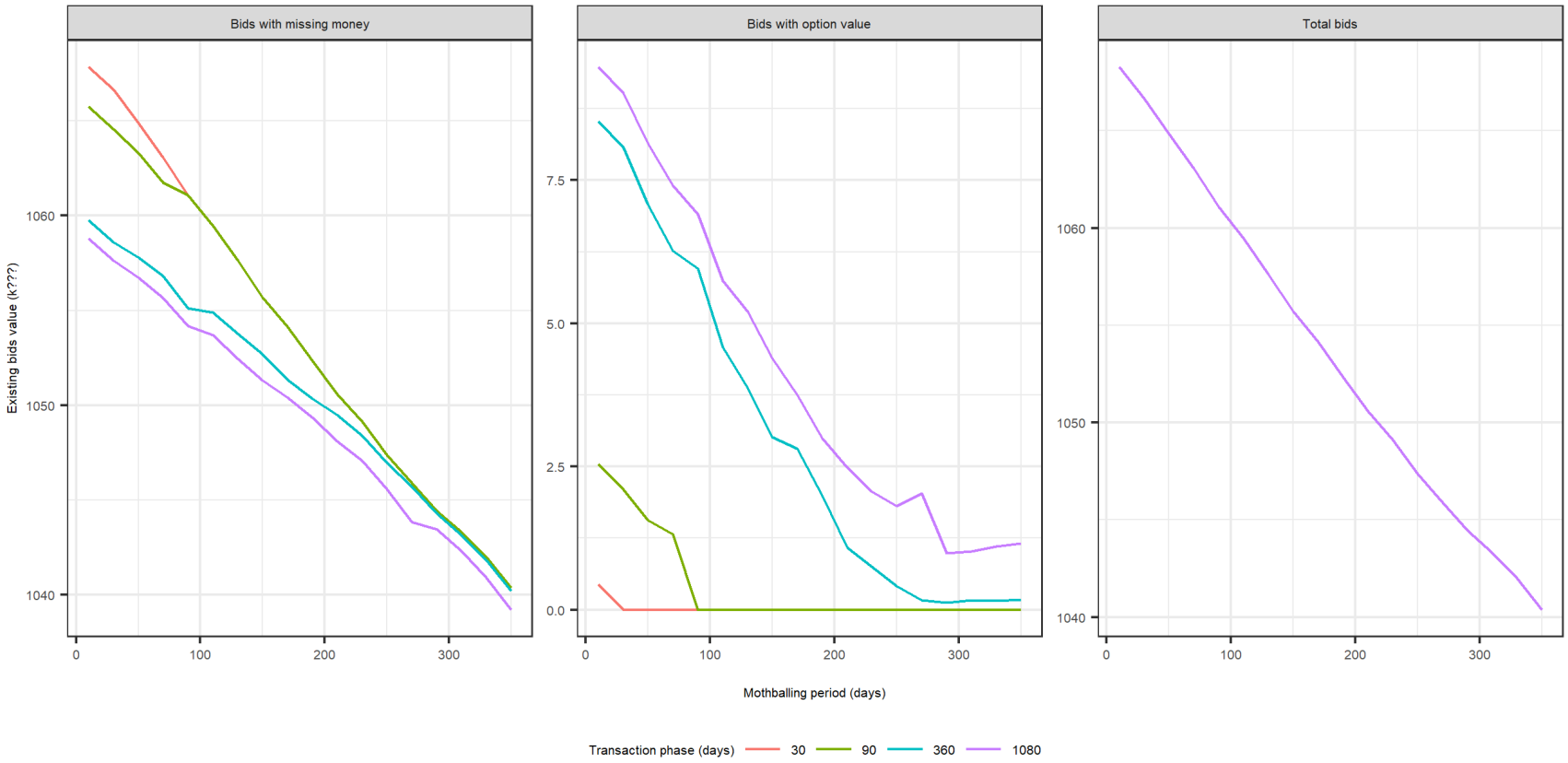


Figure: Average total existing bids for different closing and transaction periods (Proposition 1 & Proposition 2)

Bid composition and investment profitability

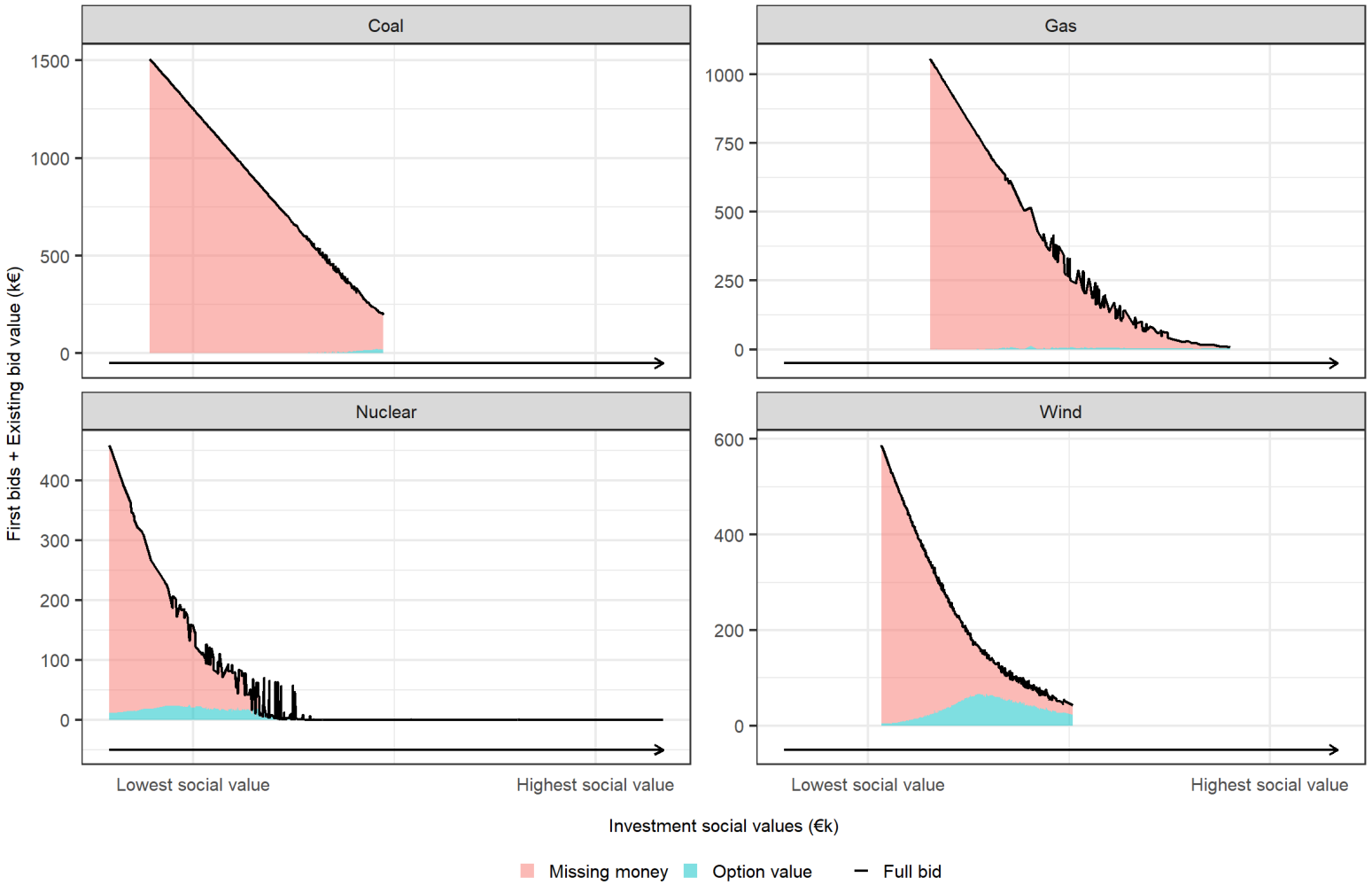


Figure: Average composition of bids for each valuation date (Proposition 6)

Bid composition and transaction phase

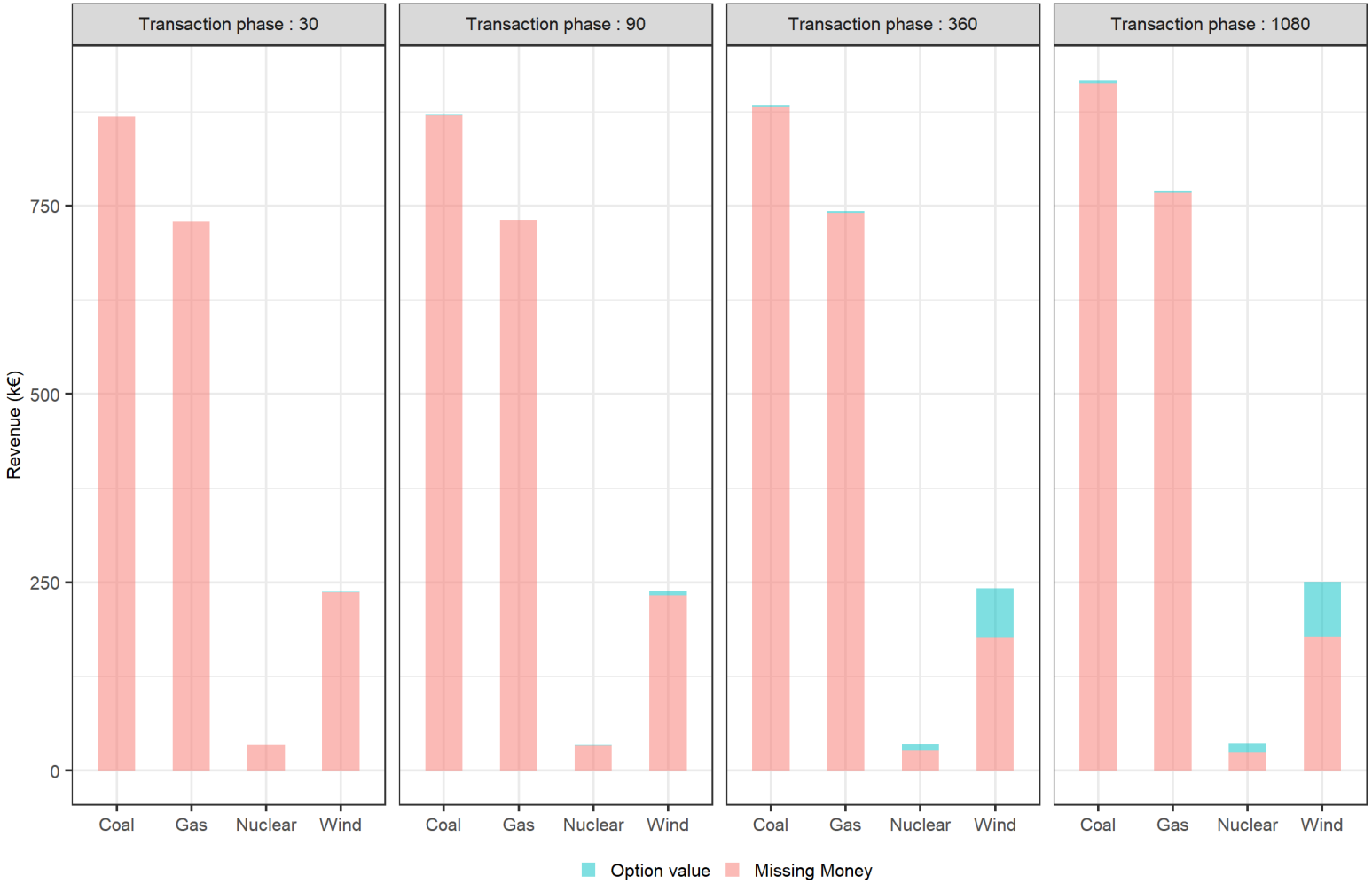


Figure: Average composition of bids for each transaction phase (Proposition 6)

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 :

- Include the penalty associated with non-compliance with the transaction phase.
- Model the uncertainty/risk/risk aversion.
- Integrate the model in a system with interactions between producers.

Roadmap

Fundamental drivers of an investment value

- **Energy Prices** : based on the French forwards priced at date t covering the next four years + means of 3 scenarios for beyond ;
- **Quantity and Capacity** : no strategic behavior, quantity = available capacity, capacity normalized to 1 MW ;
- **Technology unavailability** : based on a seasonal econometric estimation (Aid 2012) + short term random variations ;
- **Variable / OM / Investment costs** : constant based on historical data, no construction lead time.

Four technologies : Nuclear + Wind + Gas + Coal

Example - price forecast

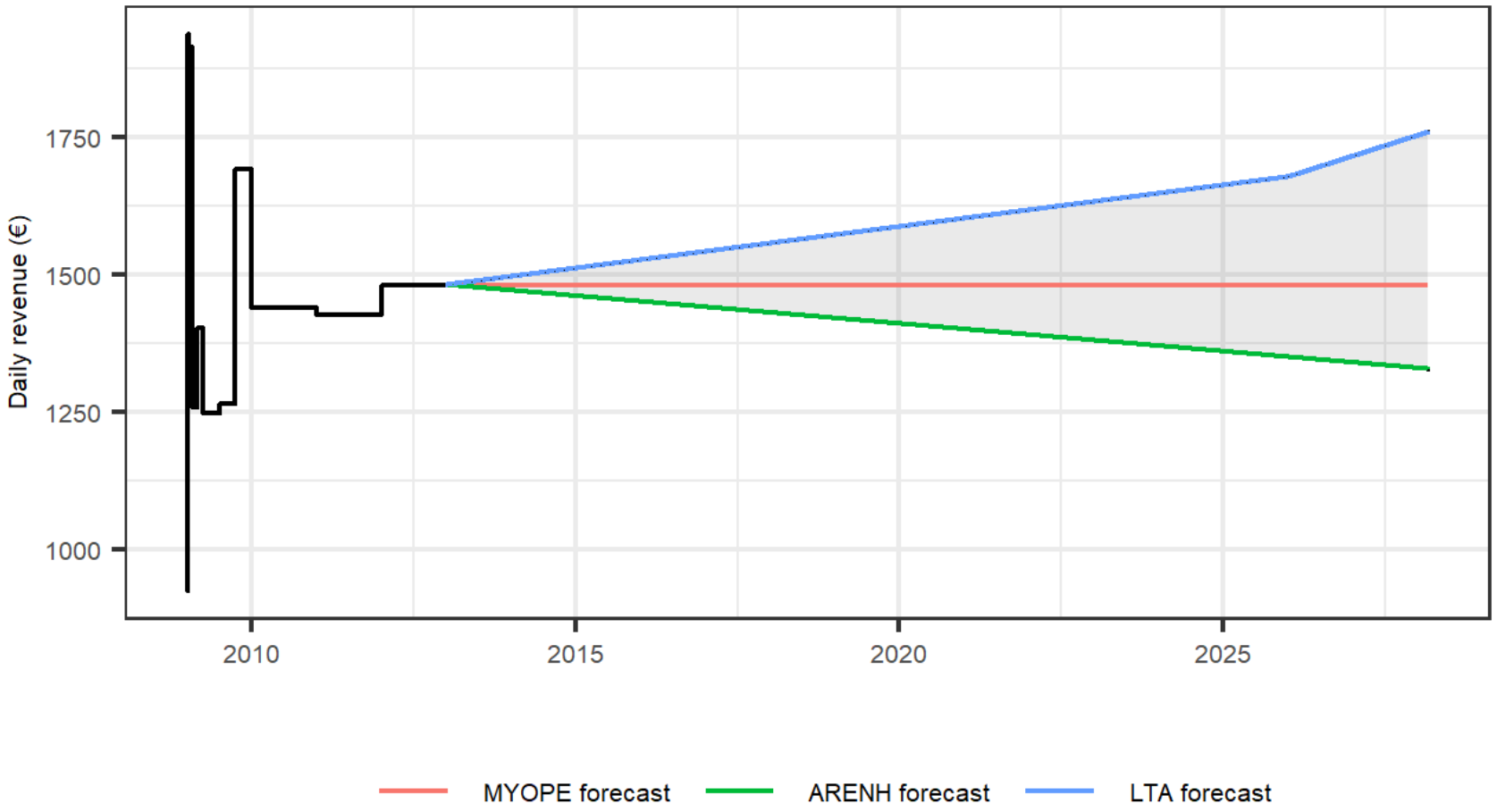


Figure: Price forecast at t = 01-01-2009

Example - technical unavailability

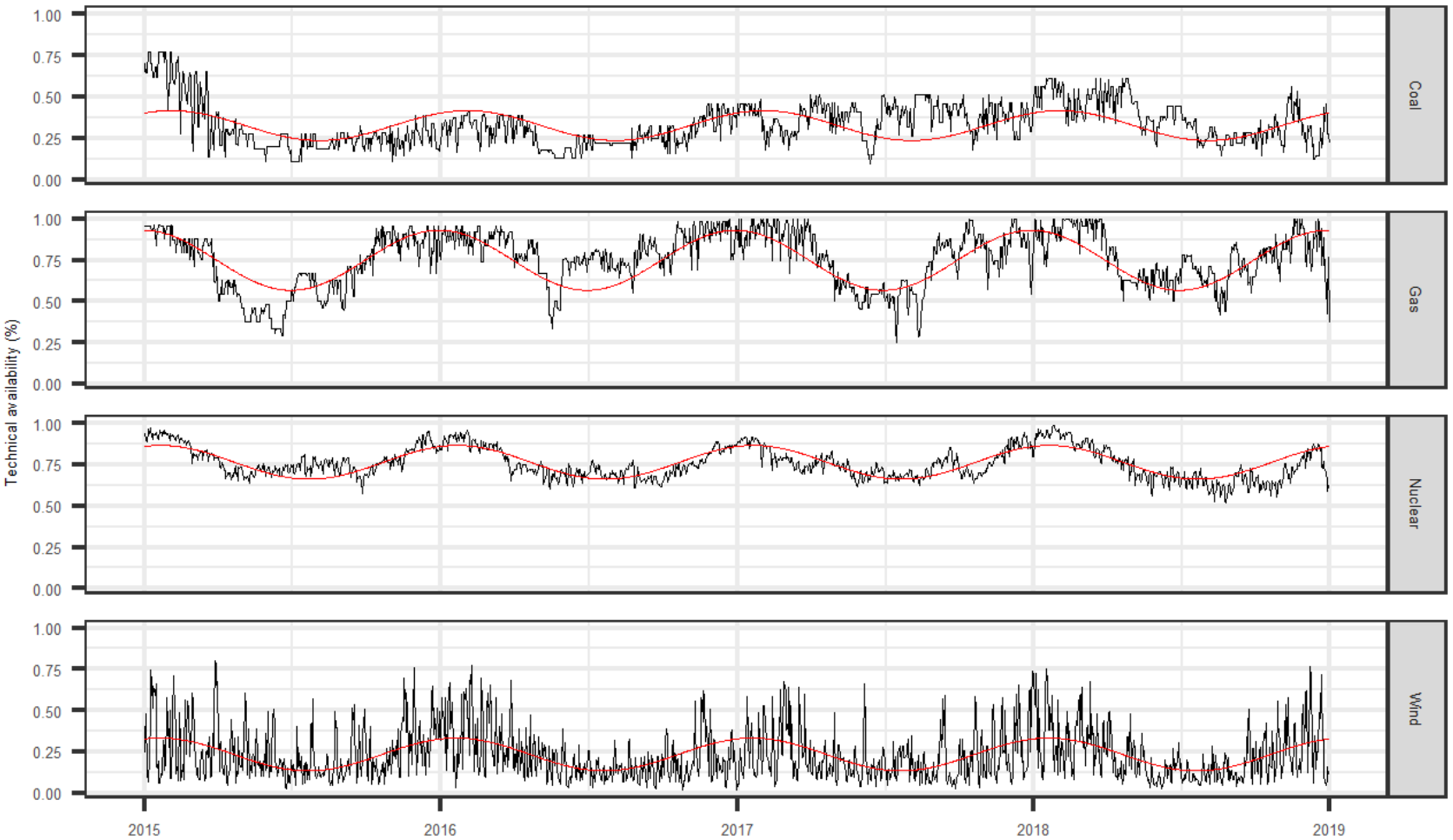


Figure: NLS estimation of technical unavailability

Other variables

Drivers	**Nuclear**	**Coal**	**Gas**	**Wind**
Investment costs (k€/KW)	4000	1400	800	1600
OM costs (k€/KW/y.)	500	217	107	190
Variable costs (€/MWh)	10	42	66	0
Lifetime (yr.)	20	20	20	20

Table: Cost values for different technologies ($r_f = 4\%$)

$$I^n > I^w > I^c > I^g$$

$$OM^n > OM^w > OM^c > OM^g$$

$$c^w < c^n < c^c < c^g$$

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

Will capacities always be there for us?

Électricité : cet hiver, il se pourrait que le courant ne passe plus par moments

Par crainte d'un black-out ce vendredi, RTE demande à limiter sa consommation d'électricité en France

Santé

Coronavirus: pourquoi les masques ont-ils disparu?

ABONNÉS **La campagne de vaccination est-elle menacée par une pénurie de seringues ?**

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