The Insurance Value of Renewable Energies

Ph.D. candidate: Thibault Deletombe (CEA-ITESE, Université Paris Dauphine-PSL)

Thesis supervisors:

Hyun Jin Julie Yu (CEA-ITESE), Patrice Geoffron (Université Paris Dauphine-PSL)

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Overview

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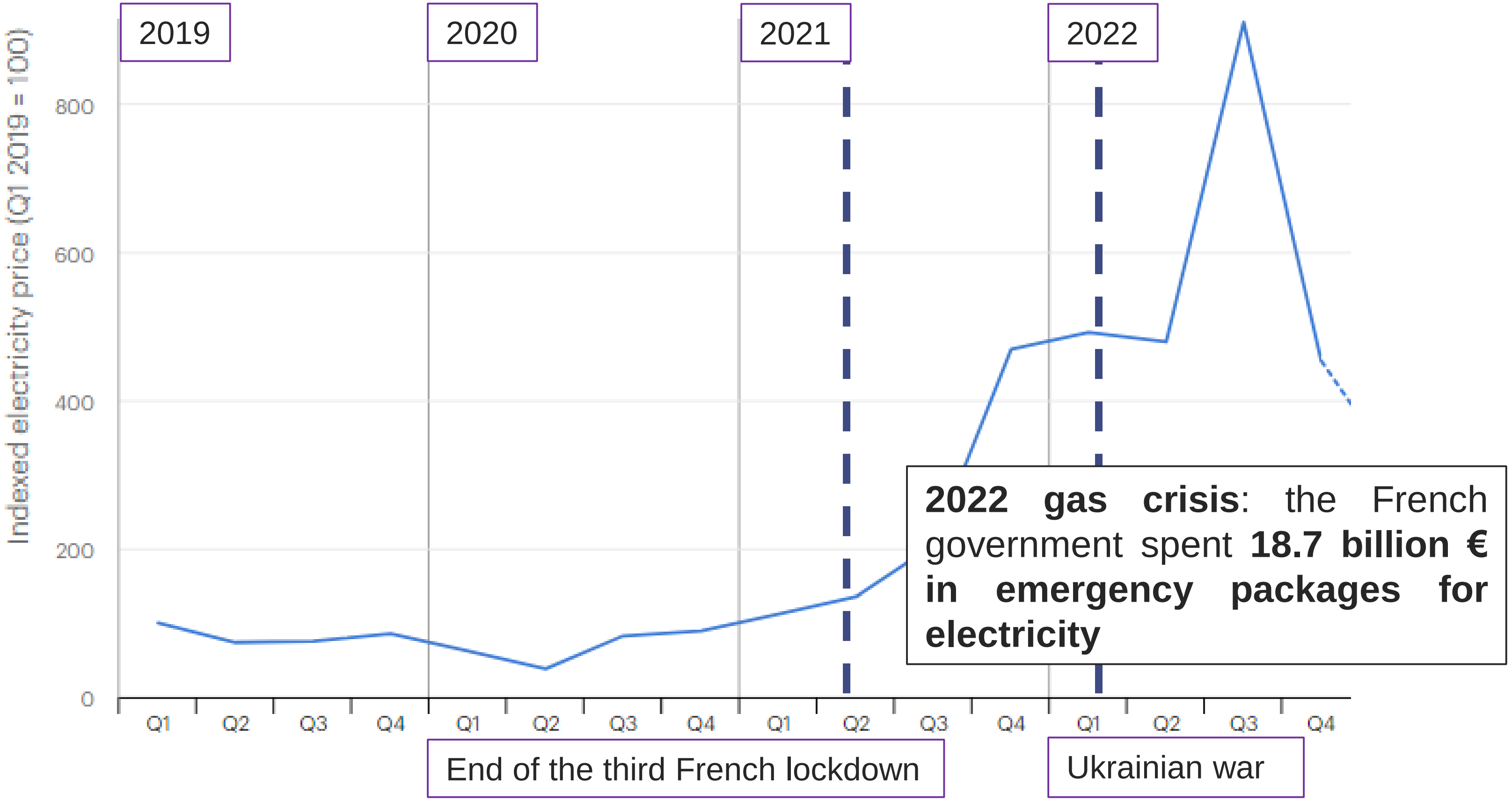
Introduction

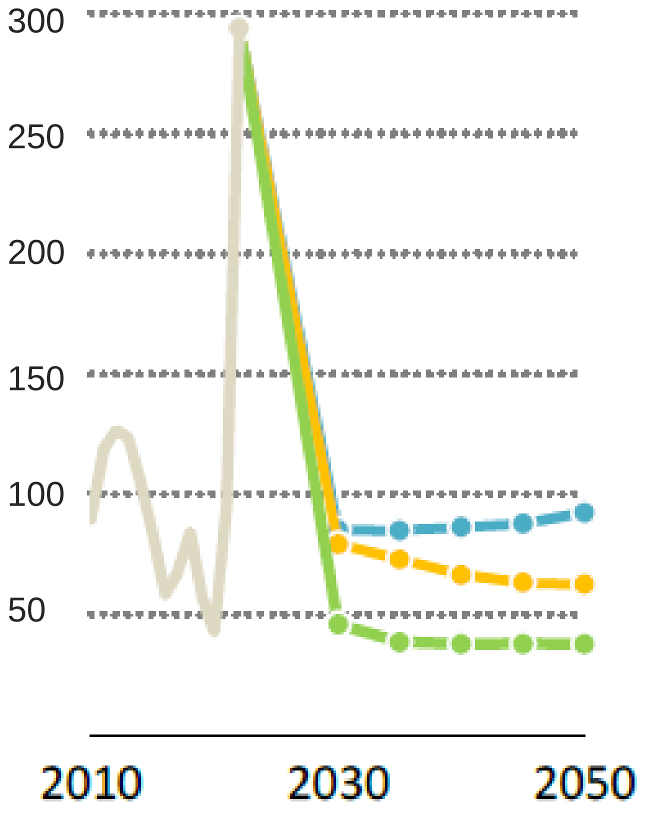
Context

Indexed French electricity prices



Indexed quarterly average wholesale electricity prices for France (source: IEA website – 01/04/2023)

Indexed EU gas prices

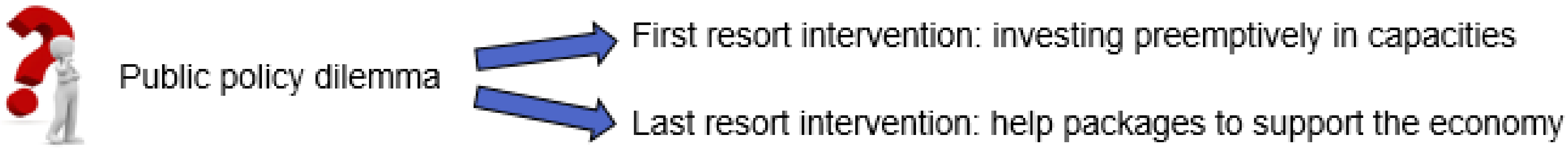


Indexed gas prices - EU (2010=100) (source: IEA, 2022)

Introduction

Motivation

- 18.7 billion euros can fund approximately 15 GW of wind or 20 GW of photovoltaic (PV) capacities



Questions

- **What is the insurance value of a power capacity that consumers are willing to pay to hedge against energy shocks?**
- **Can solar and wind be effective hedging tools against a risk on gas price?**

Introduction

Literature review

- The generation expansion planning problem under uncertainty is a largely studied topic.
  - Many studies investigate risks and their impacts on investment decisions from the producer's side through various approaches: portfolio theory (Tietjen *et al*., 2016), stochastic optimization (Möbius *et al*., 2021), agent-based models (Petitet, 2016), market equilibrium (Abada *et al*., 2017)
  - A significant part of this literature is also dedicated to investigating the need for a capacity market and long-term contract to secure investment (de Maere d'Aertrycke *et al*., 2017; Kaminski et al., 2023; Hu *et al*., 2023; Bichuch *et al*., 2023)

Less attention has been paid to the consumer side

Introduction

Literature review

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- In optimization problems, the economic value of a power capacity is given by the dual variable of the energy constraint, interpreted as a wholesale price (Brown and Reichenberg, 2021; Prol and Schill, 2021; Mahler *et al.*, 2022; Tao *et al*., 2023)

What does the shadow price overshadow?

Introduction

What is this paper about?

Aim

1. Investigate consumer’s willingness to pay for extra protection against price risk in electricity markets
2. Study how solar and wind contribute to shielding the power system against gas price shocks

Method

- A stochastic model of a risk-averse cost-optimizing social planner
- A stochastic model representing the surplus of a risk-averse consumer in a power market under marginal pricing
- Break down the economic value of a power capacity in each case to clearly identify the effect of risk

Contribution

- **A method** to evaluate the economic value of power capacities in a context of uncertainty
- **A result** on renewable economics and how solar and wind act as insurance against gas price shocks

Theoretical framework

A framework for electricity markets under uncertainty

Step 1 – Define the lottery on the states of the world faced by electricity market participants for a fixed capacity mix

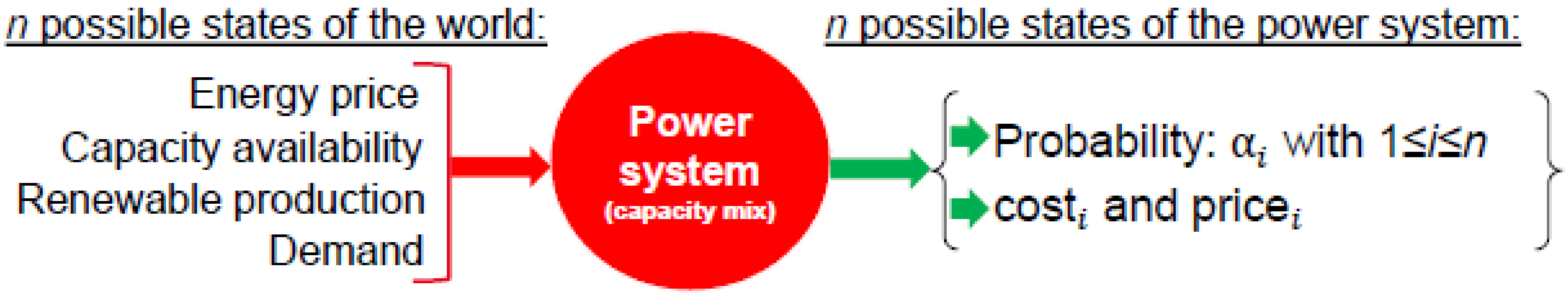


Illustration of the lottery faced by electricity market participants (source: author's proposition)

Theoretical framework

Optimization 1 – A risk-averse planner concerned costs

Step 2.a – Build the objective function

- A risk-averse planner concerned about **the social surplus in electricity markets**

  ➡ **Inelastic demand ⪢ cost perspective**

- The *objective function* of the planner is:

Social surplus (costs)

$$\underbrace{\sum_i -\alpha_i \mathrm{Exp}[-\rho\,\overbrace{(SC_i + SP_i)}^{\text{Social surplus (costs)}}]}_{\text{Expected utility of the planner (constant absolute risk-aversion)}}$$

Expected utility of the planner
(constant absolute risk-aversion)

Theoretical framework

Optimization 2 – A planner concerned about the expected utility of market participants

Step 2.b – Build the objective function

- A planner concerned about the **expected utility of market participants under marginal pricing**

  ➡ **Integration of consumers' risk preference and price effects ⪢ consumer perspective**

- The *objective function* of the planner is:

$$\underbrace{K_c \sum_i -\alpha_i \mathrm{Exp}[-\rho_c \overbrace{SC_i}^{\text{Consumer surplus (price)}}]}_{\text{Expected utility of consumers (constant absolute risk-aversion)}} + \underbrace{K_p \sum_i \alpha_i \overbrace{SP_i}^{\text{Producer surplus}}}_{\text{Expected utility of producers (risk neutral)}}$$

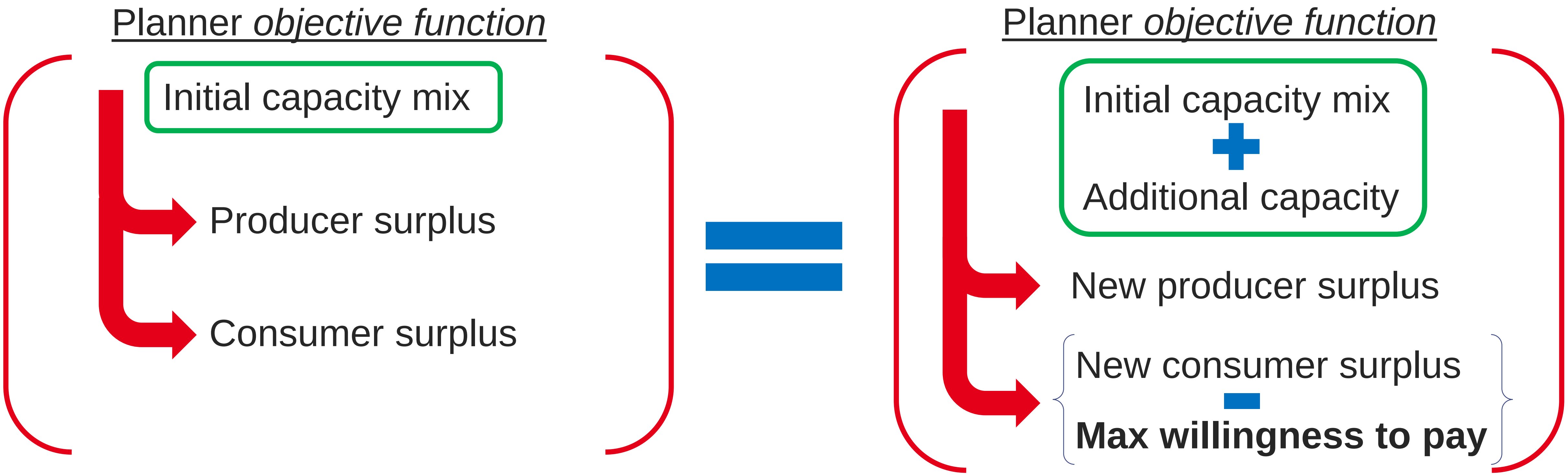
Theoretical framework

Economic value under uncertainty of a power capacity

Step 3 – Evaluate the social economic value of a capacity in a context of uncertainty

Willingness to pay under uncertainty for an additional capacity

- The **maximum willingness to pay** for an additional capacity satisfies the following equation:



Theoretical framework

Economic value under uncertainty of a power capacity

Step 3 – Evaluate the social economic value of a capacity in a context of uncertainty

Insurance value and economic value

- We define:
  - **The insurance value** I (€/MW) of a capacity C (MW) as its ability to reduce the risk premium Π (in €):

$$I = -\frac{d\Pi(C)}{dC}$$

  - **The economic value** V (€/MW) of a capacity as follows:

$$V = \lim_{\Delta C \to 0} \frac{mWTP(\Delta C)}{\Delta C}$$

* $mWTP$ = maximum willingness to pay

Theoretical framework

Economic value under uncertainty of a power capacity

Step 3 – Evaluate the social economic value of a capacity in a context of uncertainty

We demonstrate that, in each case, the economic value of a capacity can be expressed as follows:

$$V = \frac{dE[SS]}{dC} + I$$

- ➡ V = Economic value (€/MW)
- ➡ $\frac{dE[SS]}{dC}$ = Variation in expected surplus (€/MW)
- ➡ I = Insurance value (€/MW)

Case study

Goal, modeling tool, data, and assumption

The case study aims to investigate the insurance value of solar capacities regarding gas price risk using a prospective model of the French power system in 2030

Tool

- Cost optimization model of the power system – GenX (MIT, 2023)

Data source

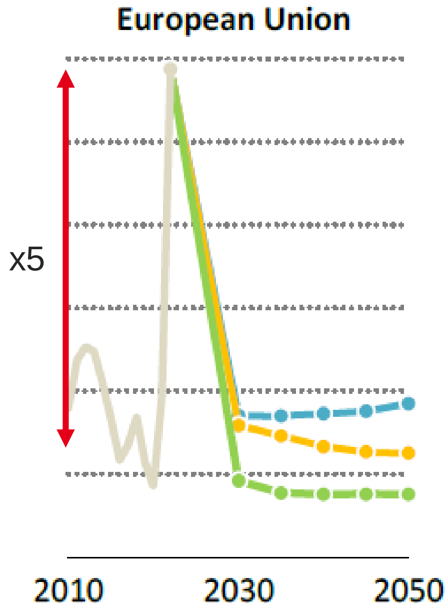
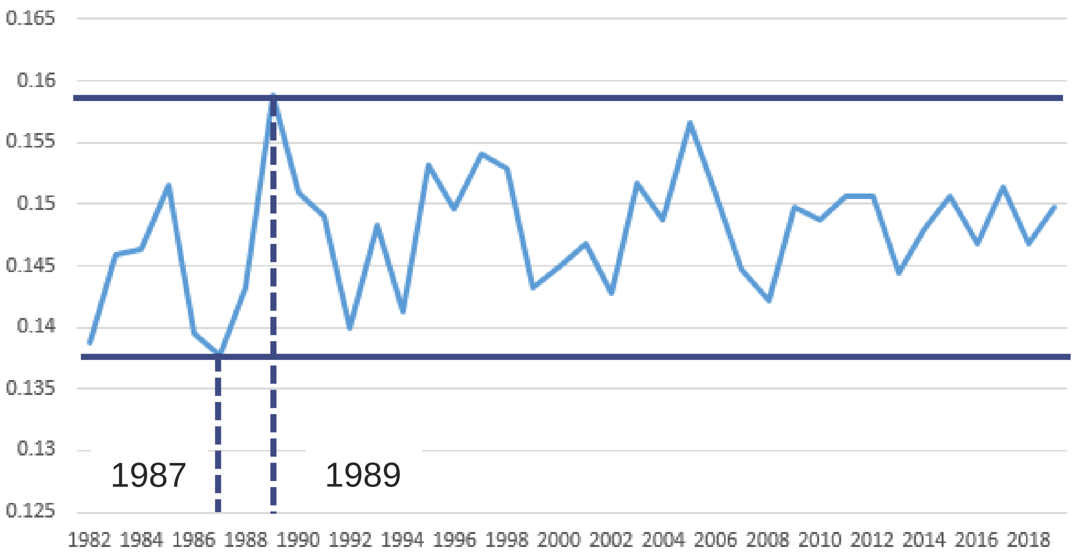
- Réseau de Transport d’Electricité – Les Futurs Energétiques (2021)
- International Energy Agency – World Energy Outlook (2022)
- European Resource Adequacy Assessment (2022)

Assumption

- Based on the climate year 2016

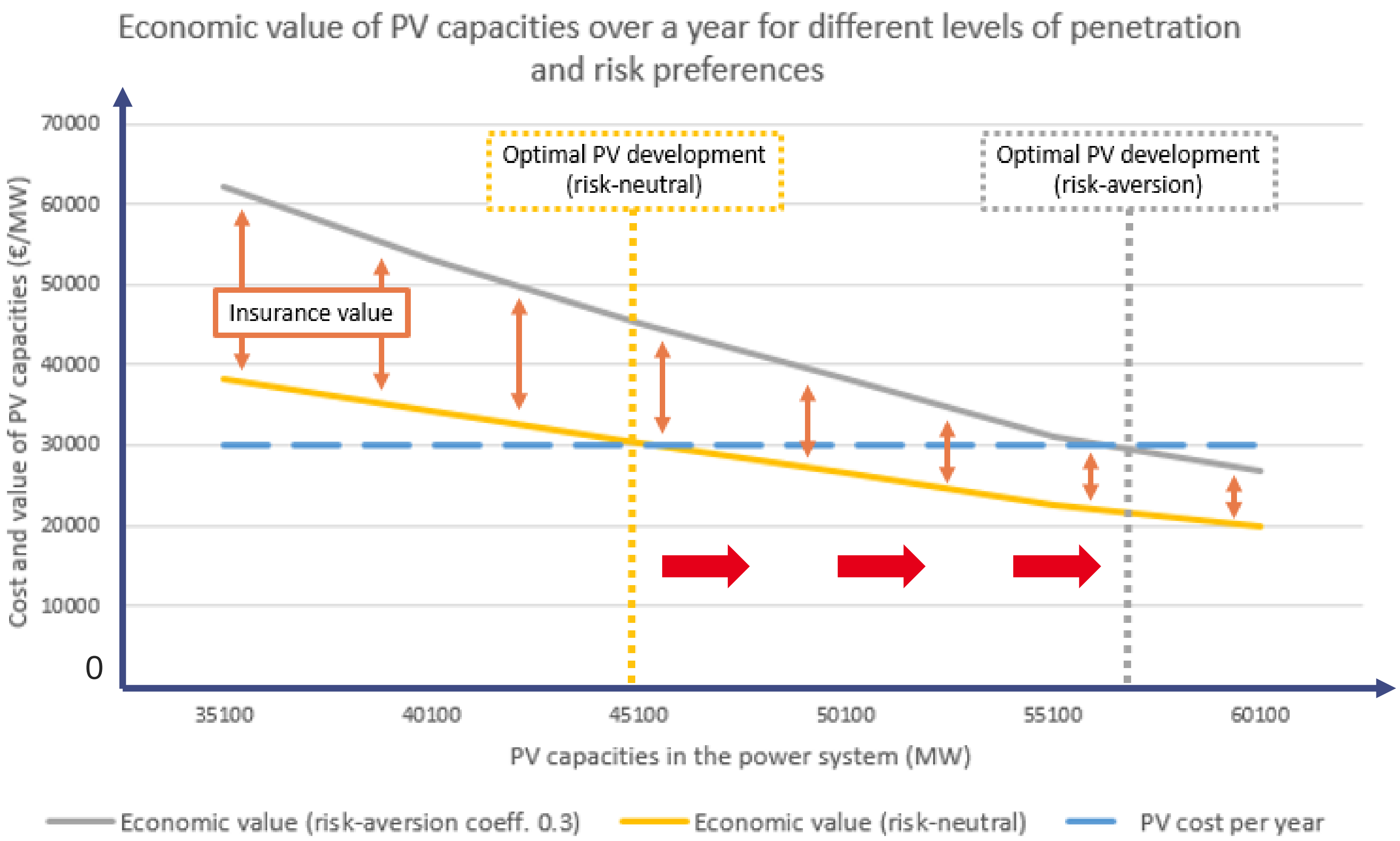
Case study

Modelling uncertainties

<table>
<tr><th>Gas price uncertainty</th><th>Solar intermittency</th></tr>
<tr><td>
Indexed gas prices - EU (2010=100) (source: IEA, 2022)</td><td>
Average PV load factor in 2030 for the corresponding climate year (source: ERAA 2022)</td></tr>
<tr><td>A shock on gas occurring once every 50 years</td><td>Equiprobabilties between high and low load factors</td></tr>
</table>

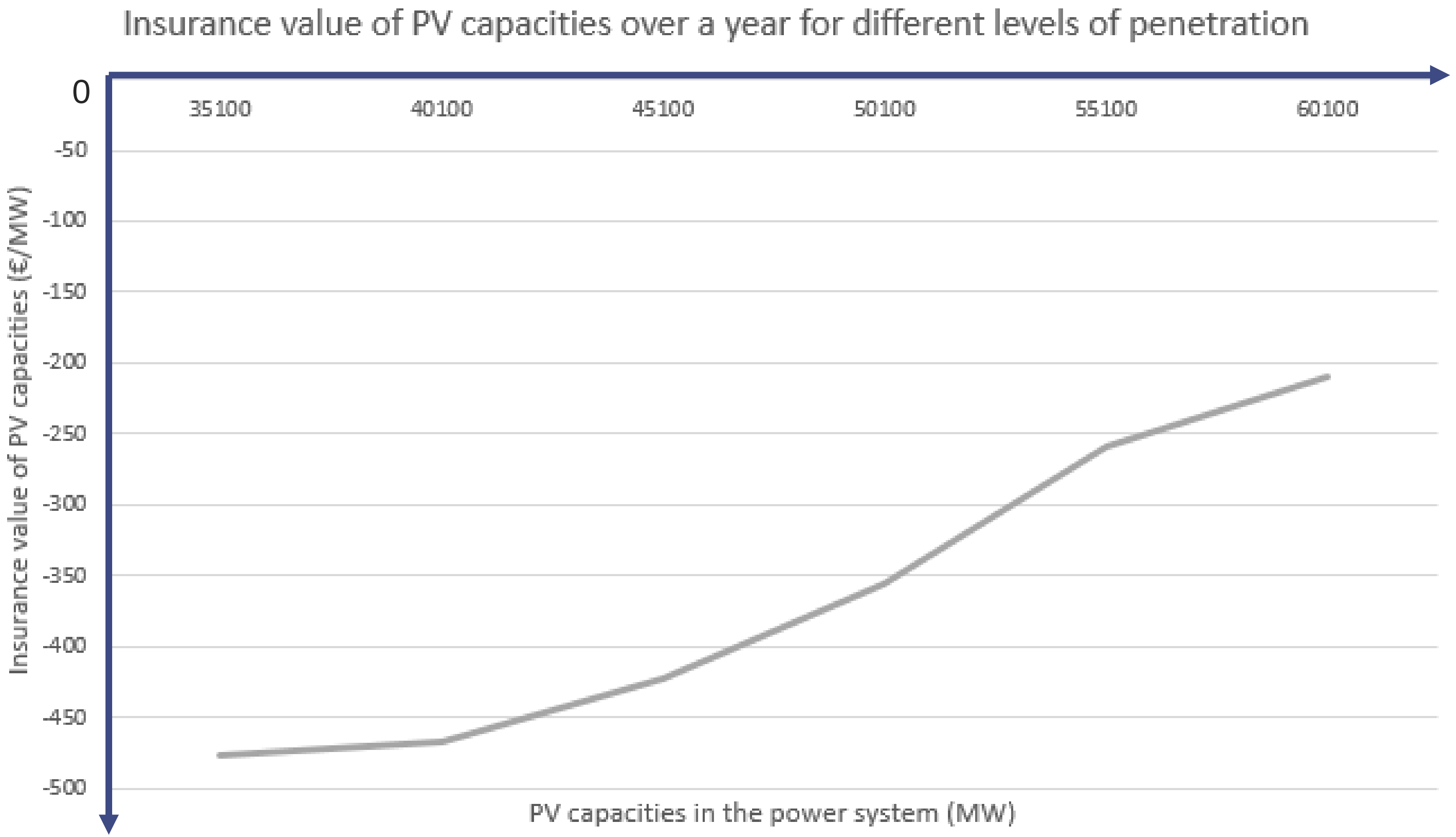
Case study

Results Optimization 1 – Economic value of PV capacities (cost)



Case study

Results Optimization 2 – Economic value of PV capacities (consumer / marginal pricing)



Conclusion

Main findings

- In a context of uncertainty, the economic value of a power-generating capacity is an addition of two components:
  - One is the variation in expected surplus in the electricity market
  - One is the variation of the risk premium

- Considering a shock on gas prices…
  - …from a welfare perspective:
    - Solar and wind can have a positive insurance value despite their intermittency
    - This positive insurance value leads to increased development of renewable capacities
  - …from a consumer perspective in a power market under marginal pricing:
    - Solar and wind can have a negative insurance value because of their intermittency

Conclusion

Limits and perspectives

- Sensitivity analysis on the risk aversion coefficient
- Extend the method to other low-carbon technologies (nuclear, storage, …)

Policy recommendation

- The current design of European electricity markets better captures the uncertainty related to renewable intermittency than the uncertainty of low-probability and high-impact events such as gas supply shocks.
- Therefore, there is a gap between market outcomes and the socially optimal situation.

In addition to the environmental benefit, this work suggests that there can be a new incentive for public intervention to support renewable development.

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