Competition among Renewables

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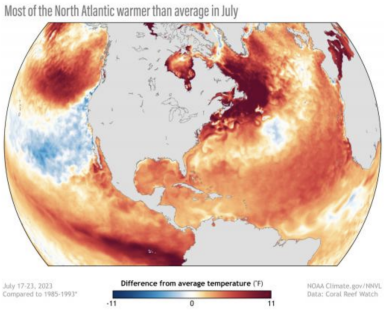
Oxford, Compass Lexecon Conference
September 2023

Climate Change: A Worrisome Reminder



Exceptional heat and rain, wildfires and floods mark summer of extremes

Tags: Public health Climate Climate change

3 Published 3 August 2023

There is an urgent need to decarbonize our economies

The Power Sector's Key Role

Decarbonazing power is critical to addressing climate change

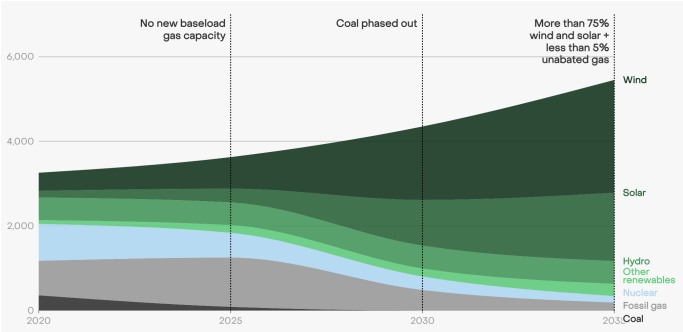


Figure: 1.5C pathways to clean power by 2035 in Europe

Decarbonazing power requires massively investing in renewables

Source: Ember

Heterogeneous Progress Across Countries

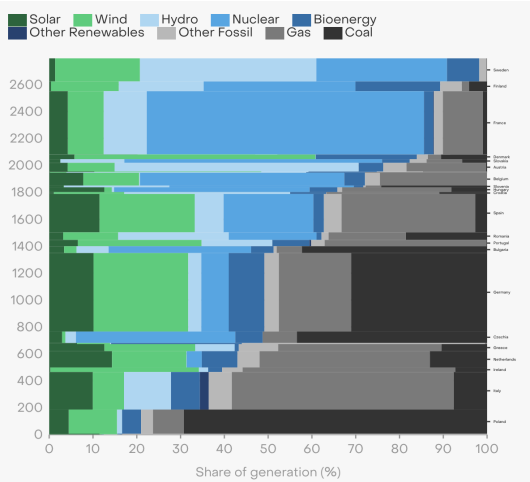


Figure: Power sector energy mix in EU countries

Research and Policy Questions

Research and Policy Questions

Electricity prices in the spotlight as they affect...

- Incentives to electrify
- Social and political support for the Energy Transition

"The current electricity market design is not doing justice to consumers anymore. They should reap the benefits of low-cost renewables. So, we have to decouple the dominant influence of gas on the price of electricity." (von der Leyen's State of the Union speech, 2022)

Research and Policy Questions

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Research and policy questions:

1. How do electricity firms compete in renewables-dominated markets?
2. How will competition in electricity markets evolve along the Energy Transition?
3. How does the ownership structure of electricity generation affect competition?

A New Competitive Landscape

"The traditional utilities are thinking again. For many, the answer is to specialise and build scale in one or two parts of the chain, such as renewables."

FINANCIAL TIMES

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Utilities + Add to myFT

Europe's utilities battle for survival in changing market place

Traditional companies face threat to business models as deals shake up sector

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Chimney stacks at the Cockenzie power station in Scotland were demolished in 2015 in a dramatic sign of the changes afoot in Europe's utility sector © Alamy

Nathalie Thomas, Energy Correspondent FEBRUARY 28 2019

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A New Competitive Landscape

Utilities split and divest their businesses

E.ON completes split of fossil fuel and renewable operations

Newly formed Uniper will assume control of the German energy giant's fossil fuel assets, with E.ON focusing on renewables and energy networks, reports BusinessGreen

The E.ON coal-fired power station in Gelsenkirchen. The German energy giant has separated its fossil fuel assets into a new company. Photograph: Martin Meissner/AP

Germany energy giant E.ON has officially separated its fossil fuel assets into a new company, dubbed Uniper.

(a) EON

RWE approves plans to split and create green powerhouse

Madeleine Cuff

11 December 2015 •

SHARE

German energy giant's supervisory board approves restructure plan which will see its renewable energy, grid and retail business areas pooled in a new subsidiary

(b) RWE

A New Competitive Landscape

Utilities split and divest their businesses

FastFT Drax Group PLC + Add to myFT

Drax to buy £700m of assets from Iberdrola

Move continues UK power supplier's shift away from generating electricity from coal

Myles McCormick OCTOBER 16 2018

UK power supplier Drax will buy £702m worth of rival ScottishPower's assets from the latter's parent company Iberdrola as it continues its shift away from coal-powered electricity.

The acquisition is made up of pumped storage, hydro and gas-fired power generation assets that in total generate 2,566MW of electricity, enough to power about 2m homes.

It also marks a move by Drax to position itself as a provider of flexible power generation, which it believes will become more important as the UK shifts towards intermittent wind and solar power.

(a) Iberdrola

Ørsted was once one of the most coal-intensive energy companies in Europe. Today, we're one of the world's most sustainable energy companies, and a global leader in the transition to green energy.

Our business transformation is a story of technological innovation, steep learning curves and difficult strategic choices that have led to long-term gains. We want to share what we've learnt, from our decision to move away from an unsustainable business model based on fossil fuels, to the action we took to build a truly green business – and the benefits and opportunities it's created for us.

(b) Orsted

A New Competitive Paradigm

These policy questions motivate our recent research:

- "Auctions with Privately Known Capacities: Understanding Competition among Renewables," *The Economic Journal*, April 2023.
- "Fossil Fuels and Renewable Energy: Mix or Match?," CEPR Discussion Paper 18458.

A New Competitive Paradigm

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A new competitive paradigm:

- Key differences: fossil fuels vs. renewable energies
  - **Fossil-fuel plants**: known capacities, marginal costs are private information,
  - **Renewables**: known (zero) marginal costs, avalaible capacities are private information

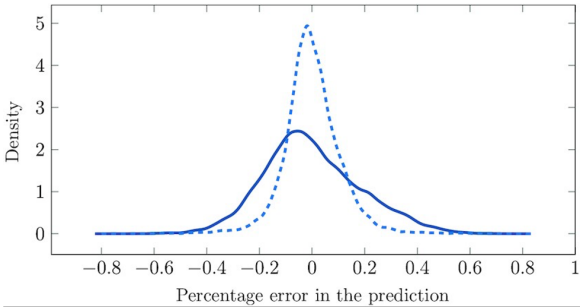
Differences in the information available about fossil-fuels and renewable sources fundamentally **change the nature of strategic interaction** among electricity producers

Firms have Private Information about their Available Capacity

(a) Meteo station (wind)

(b) Meteo station (solar)

Private Information Allows for Better Forecasts



Variables	(1)	(2)
Public forecast	0.582***	0.070***
	(0.035)	(0.021)
Private forecast		0.657***
		(0.008)
Observations	36,671	36,671
R-squared	0.520	0.826
Mean of the error	0	0
Standard deviation of the error	.18	.11

Table: Forecast errors with public versus private information.

The Model

Firms and Technology

- Two firms, $i = 1, 2$.
- **Two renewable plants (R):**
  - Marginal cost 0.
  - Uncertain capacity, $k_i \sim F(k_i)$ with density $f(k_i) > 0$ in $k_i \in \left[\underline{k}, \overline{k}\right]$.
  - Capacity is private information.

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- **Two thermal (gas) plants (G):**
  - Marginal cost $c > 0$.
  - Known gas capacity, $g > 0$, equal for both plants.

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  - Capacity is private information.
- **Two thermal (gas) plants (G):**
  - Marginal cost $c > 0$.
  - Known gas capacity, $g > 0$, equal for both plants.
- In the baseline case, plants are ex-ante identical: $E(k) = g$.
- No blackouts, i.e., $2\underline{k} + 2g > \theta$.

The Model

Bids, Market Clearing, and Timing

- Demand is inelastic and known, θ, with a price cap $P > c$.
- Each firm submits one bid per plant to supply the plant's capacity.
- We denote as b_i^s the bid of firm $i = 1, 2$ for plant of technology $s = R, G$.

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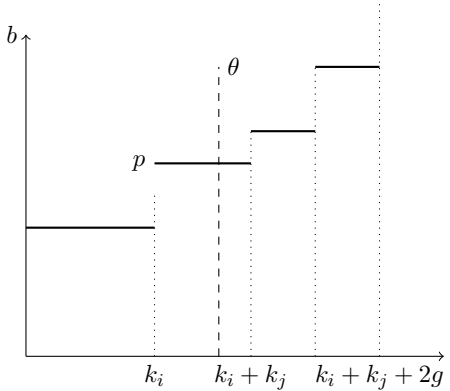
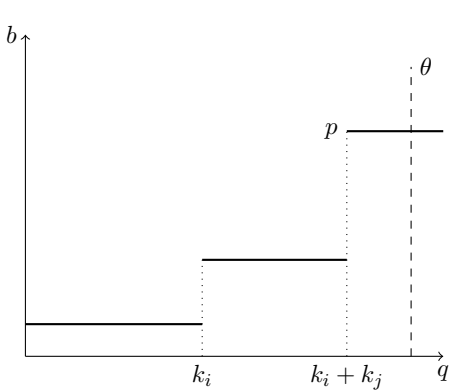
Market Clearing:

- Plants are called to produce in increasing price order.
- Production is paid at the highest accepted bid, p (**uniform-price auction**).
- All plants with $b_i^s \leq p$ are called to produce.
- Symmetric tie-breaking (precise rule is inconsequential).

Example: Bids and Market Clearing

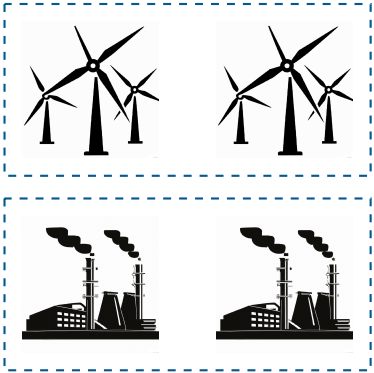


(a) Renewables are enough

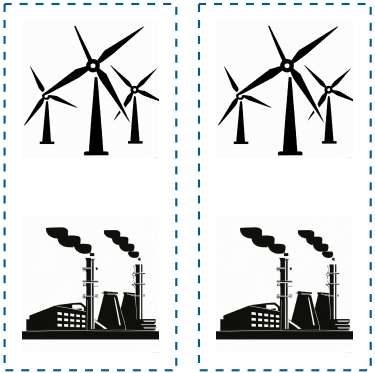


(b) Thermals plants are needed

Ownership Structures

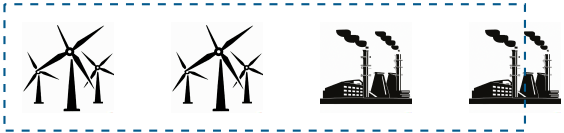


(a) Specialized firms

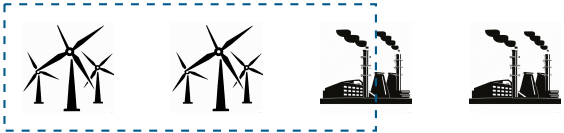


(b) Diversified firms

Three Demand Scenarios (or Stages along the Energy Transition)



(a) High Demand



(b) Intermediate Demand

(c) Low Demand

Low Demand

Equilibrium prices are weakly lower under a diversified ownership structure and the production is efficient under both ownerships

Proposition ($\theta \leq 2\underline{k}$)

Specialization:

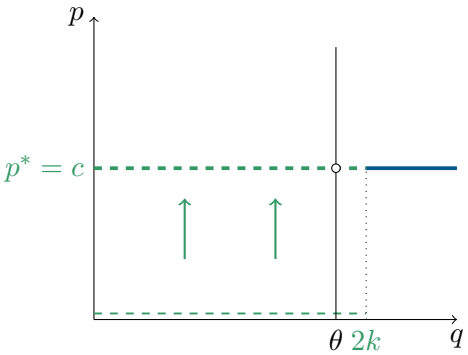
- *The equilibrium market price equals c and production is efficient.*

Diversification:

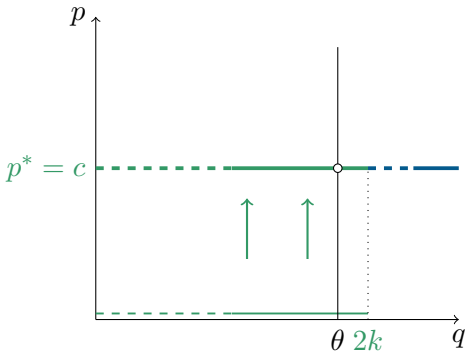
- *There exist asymmetric Bayesian Nash Equilibria, in all of which the market price equals c and production is efficient.*
- *There exists a unique symmetric Bayesian Nash equilibrium. The expected market price is weakly below c and production is efficient.*

Low Demand

Equilibrium bidding



(a) Specialized



(b) Diversified

Low Demand

Symmetric Equilibrium under Diversification

Proposition (Fabra and Llobet (2023))

- *Under diversification, there exists a unique symmetric equilibrium where firms offer their gas plant at c, and its renewable plant at*

$$b^R(k_i) = c\exp(-\omega^R(k_i)),$$

where

$$\omega^R(k_i) = \int_{\underline{k}}^{k_i} \frac{k-(\theta-k)}{\int_k^{\overline{k}}(\theta-k_j)f(k_j)dk_j} f(k)dk.$$

This bid is decreasing in k_i, with $b_i^R(\underline{k}) = c$ and $b_i^R(\overline{k}) = 0$.

Low Demand

Symmetric Equilibrium under Diversification

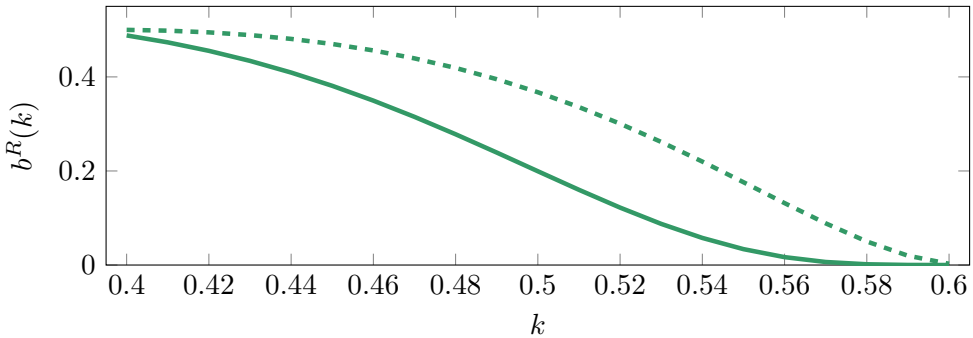
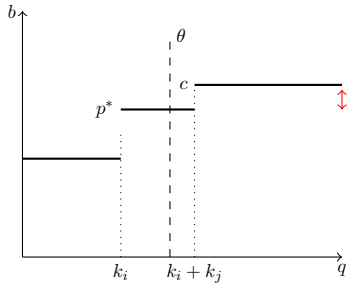


Figure: Equilibrium bid for the renewable plant with diversified firms (low demand, low price cap)

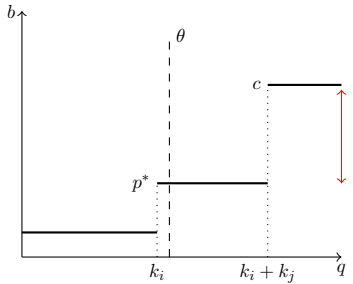
Notes: The figure shows the equilibrium bids for the renewable plant when $k_i \sim U[0.4, 0.6]$, $c = 0.5$, and $g = 0.5$ for demand values $\theta = 0.7$ (solid) and $\theta = 0.8$ (dashed).

Implications: Renewables' Price Depressing Effect

- When realized capacities increase (relative to demand)...
  - Supply functions shift downwards and outwards
  - Market prices fall but remain above (zero) marginal costs
- Renewables depress prices but less than expected by conventional wisdom (market power effect)



(a) Small price reduction



(b) Large price reduction

High Demand

Equilibrium prices are weakly lower under a diversified ownership structure and the production is efficient under both ownerships

Proposition ($\theta > 2\overline{k} + g$)

Specialization:

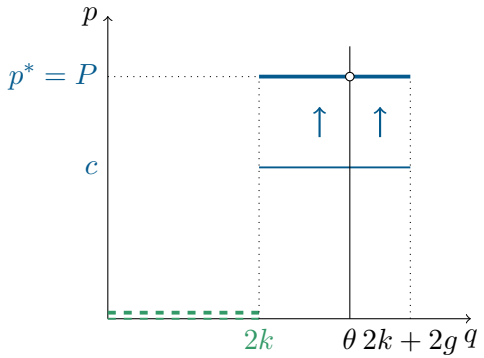
- *In any Nash equilibrium of the game, the market price equals P. There always exists an equilibrium with efficient production.*

Diversification:

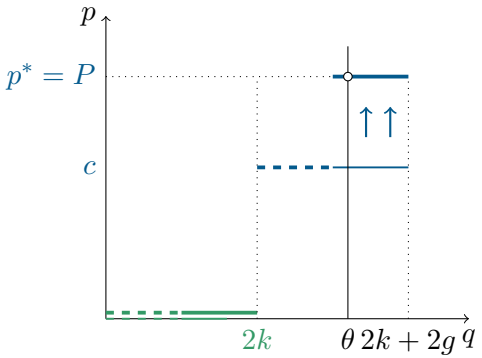
- *There exist asymmetric Bayesian Nash Equilibria, in all of which the market price equals P and production is efficient.*
- *There exists a unique symmetric Bayesian Nash equilibrium. The expected market price is between c and P and production is efficient.*

High Demand

Equilibrium bidding



(a) Specialized



(b) Diversified

- Same prices and efficient production across ownership structures.

High Demand

Symmetric equilibrium under Diversification

Proposition ($\theta > 2\overline{k} + g$)

When firms are diversified and $\theta > 2\overline{k} + g$, in any symmetric Bayesian Nash equilibria of the game, each firm $i = 1, 2$ offers a sufficiently low price for its renewable plant. The equilibrium price for its thermal plant is

$$b^G(k_i) = c + (P - c)\exp(-\omega^G(k_i)),$$

where

$$\omega^G(k_i) = \int_{\underline{k}}^{k_i} \frac{k + g - (\theta - k - g)}{\int_{k_i}^{\overline{k}} (\theta - k - g) f(k) dk} f(k) dk,$$

is decreasing in k_i, with $b_i^G(\underline{k}) = P$ and $b_i^G(\overline{k}) = c$.

High Demand

Symmetric equilibrium under Diversification

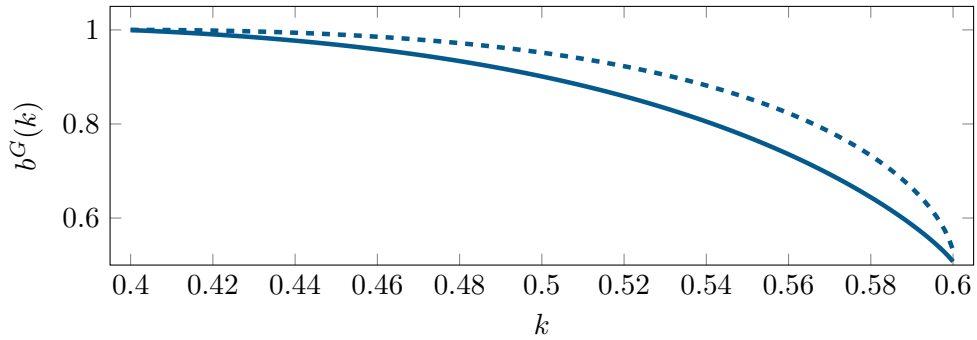


Figure: Equilibrium bid for thermal plants at the symmetric equilibrium with diversified firms (high demand)

Notes: The figure shows the equilibrium bids for the thermal plant when $k_i \sim U[0.4, 0.6]$, $c = 0.5$, $P = 1$, and $g = 0.5$ for demand values $\theta = 1.7$ (solid) and $\theta = 1.8$ (dashed).

Inefficiencies in Production

- In the two cases studied before, there is efficient production.
- However, the paper identifies two possible **sources of inefficiency**:
  1. When demand takes an intermediate value, **diversification** may yield inefficiencies:
     - One bidder might prefer to raise the price market to P even at the cost of not dispatching all its renewable power.
  2. When renewables are dominant, $E(k) > g$, **specialization** may also yield inefficiencies:
     - The renewable firm may want to raise the market price to P, even if that means serving the residual demand net of both thermal plants' capacities instead of total demand.

Main Take-Aways

1. **Will renewables put downward pressure on electricity prices?**
   - The answer depends on competitive conditions.
   - In particular, on the **ownership structure** and the **stage of the Energy Transition**.

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2. **How and why does the ownership structure matter?**
   - Specialized ownership leads to higher prices.
     - This also applies to intermediate demand cases and beyond the duopoly case.
   - Specialized ownership typically leads to greater productive efficiency.
     - However, large inefficiencies can arise under specialization if renewables are very abundant.

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The success of the Energy Transition also hinges on **the strength of competition**
Competition policy enforcers need to remain vigilant!

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Thank You!

Questions? Comments?

More info at nfabra.uc3m.es and energyecolab.uc3m.es

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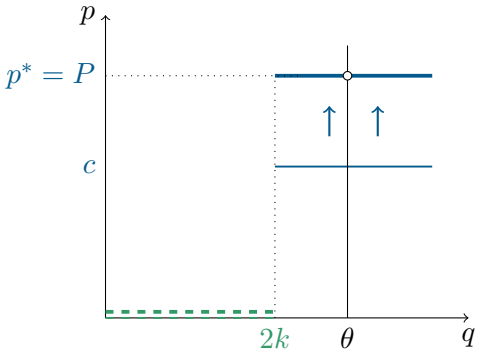
Back-up

Intermediate Demand

Specialization: Equilibrium bidding as when demand is high.



- The price is P and the equilibrium is efficient.

Intermediate Demand

Diversification: In an asymmetric equilibrium the high bidder, firm i with renewable capacity k_i can

- Bid at P with profits $PE(\theta - k - g)$.
- Bid at c with profits ck_i.

The price P is optimal if

$$P \geq \rho_I^s(k_i) \equiv \frac{ck_i}{E(\theta - k - g)}.$$

Intermediate Demand

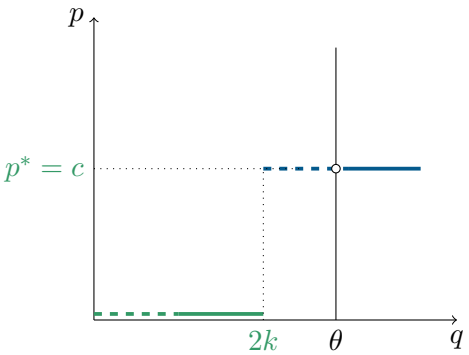
Diversified Ownership

Proposition ($2\overline{k} < \theta < 2\underline{k} + g$)

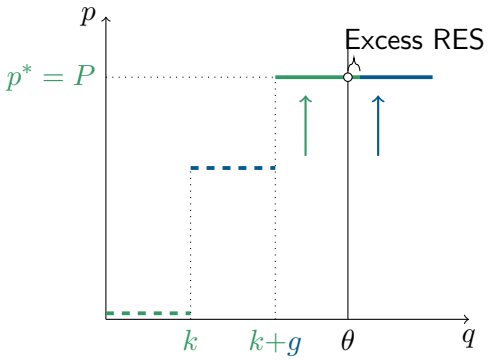
- *If* $P \geq \rho_I^s(\overline{k})$*, there exist asymmetric Bayesian Nash equilibria, in all of which the market price equals* P *and production is inefficient. There also exists a unique symmetric Bayesian Nash equilibrium with expected prices below* P *and inefficient production.*
- *If* $\rho_I^s(\underline{k}) < P < \rho_I^s(\overline{k})$*, there exists a unique symmetric Bayesian Nash equilibrium with expected prices below* P *and inefficient production.*
- *If* $P \leq \rho_I^s(\underline{k})$*, the equilibrium price is* c *and production is efficient.*

Intermediate Demand

Diversified Ownership



(a) Low P



(b) High P

- When P is high the equilibrium exhibits inefficiency in production. One of the thermal plants is dispatched before the second renewable plant.

Intermediate Demand

Symmetric Equilibrium Under Diversification

Proposition

Assume $P > \rho_I^d(\underline{k}|\underline{k})$. *When firms are diversified and* $2\overline{k} < \theta < 2\underline{k} + g$, *there exists a unique* $\hat{k}$ *such that, in the unique symmetric Bayesian Nash Equilibrium of the game, when* $k_i > \hat{k}$ *firm* i *bids* $b^R(k_i) \leq b^G(k_i) = c$. *Instead, when* $k_i \leq \hat{k}$, *firm* i *chooses the same bid for its renewable and thermal plants,* $b(k_i) = b^R(k_i) = b^G(k_i)$, *according to*

$$b(k_i) = c + (P - c)exp(-\omega^G(k_i)) - c\left[\gamma(k_i) - \gamma(\underline{k})\right] exp(-\omega^G(k_i)), \tag{1}$$

where $\omega^G(k_i)$ *is defined in* (4) *and* $\gamma(k_i)$ *is an increasing function of* k_i.
The equilibrium bid function $b(k_i)$ *is decreasing in* k_i, *with* $b(\underline{k}) = P$ *and* $b(\hat{k}) = \rho_I^d(\hat{k}|\hat{k}) \equiv \hat{\rho} > c$.

Intermediate Demand

Symmetric Equilibrium Under Diversification

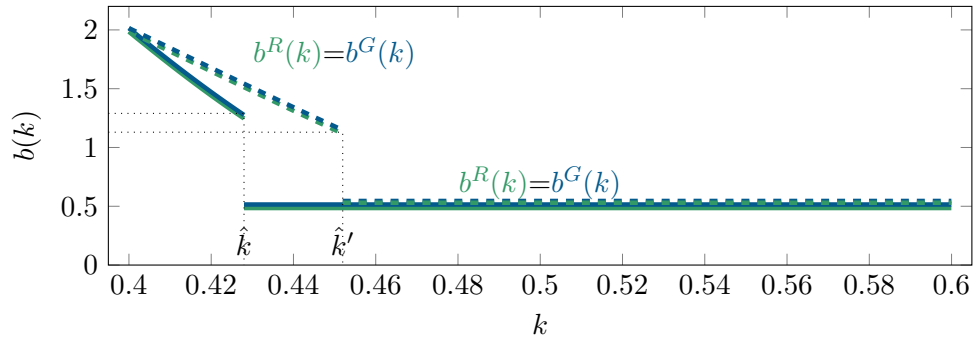


Figure: Equilibrium bids for the renewable and thermal plants with diversified firms (intermediate demand, high price cap)

Notes: The figure shows the equilibrium bids for the renewable (green) and thermal plants (blue) when $k_i \sim U[0.4, 0.6]$, $c = 0.5$, $P = 2$, $g = 0.5$, and $\theta = 1.2$ (solid) and $\theta = 1.3$ (dashed).

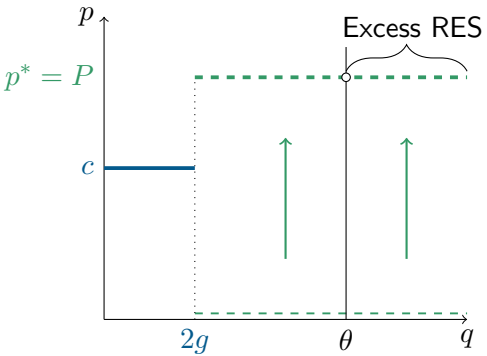
Asymmetric Firms

When Renewable Energy is Abundant

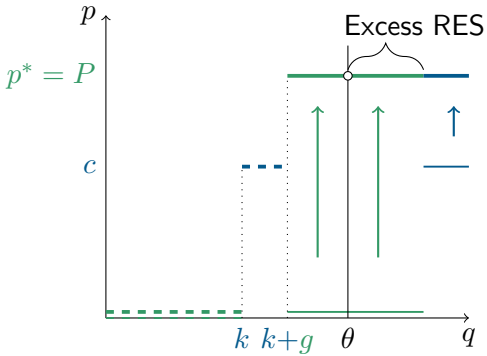
- When plants are asymmetric, the diversified ownership structure still leads to symmetric firms. This is not the case under specialized ownership.
- Results only change when renewable plants are larger than thermal plants and P is high, so that raising the bid to P and serving the residual demand is profitable. However,
  - **Specialized:** The renewable firm might now find it profitable to raise the price to P even at the expense of losing its output. Both thermal plants might be dispatched first.
  - **Diversified:** In an asymmetric equilibrium at most one thermal plant might be dispatched before the second renewable plant.

Asymmetric Firms

When Renewable Energy is Abundant



(a) Specialized



(b) Diversified

- Equal prices but lower productive efficiency under specialization.