Capacity mechanisms and the technology mix in competitive electricity markets

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INTRODUCTION

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Electricity markets are special

1) Electricity is expensive to store

2) Many consumers do **not** have full control of their demand

3) Capacity payments

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Electricity is expensive to store

Demand is fluctuating and not much storage => some production capacity is only used as back-up.

Optimal technology choice depends on how often a plant will produce.

For example:

Baseload: Low marginal cost, high investment cost. E.g. nuclear power

Peaker: Low investment cost, but high marginal cost. E.g. gas turbine.

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Some consumers do not have full control of their demand => price cap

Some consumers could not switch off their electricity consumption. This does not mean that these consumers' marginal valuation of electricity is infinitely high.

$\Rightarrow$ To protect consumers, system operator switches off consumers if price becomes too high => price cap.

In Nordic countries, price cap is 5000 Euro/MWh, which is 100 times normal price.

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Capacity mechanisms

To reduce risk of black outs, most countries have a capacity mechanism.

Strategic reserve: System operator procures back-up capacity (Sweden, Germany)

Capacity auction: System operator sets and procures total capacity. Uniform payment in US. Different auction for each technology in UK.

Why capacity payments?

Why isn't it enough with one policy instrument, the price cap? Why are capacity payments needed?

1) Capacity payment => Lower price cap => Less financial risk
2) Mitigate market power
3) Internalize system externalities (Fabra, 2018)
4) Regulatory time inconsistency => Investors prefer money up front
5) Uncoordinated government bodies
6) Trade policy (Tangerås, 2018)

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Research question

There are two policy instruments:

1) Price cap
2) Capacity payments.

How should they be used to get optimal investments for each technology?

We consider uniform capacity payment as in US and focus on how this instrument can be used to manage system externalities and mitigate market power. We focus on perfectly competitive markets.

Contribution relative to previous literature

Fabra (2018), Léautier (2016), Llobet & Padilla (2018) and Joskow & Tirole (2007) consider 1-2 types of technologies. We consider a broad range (continuum) of technologies.

Zöttl (2010) also consider broad range of technologies, but he does not consider price caps and capacity payments.

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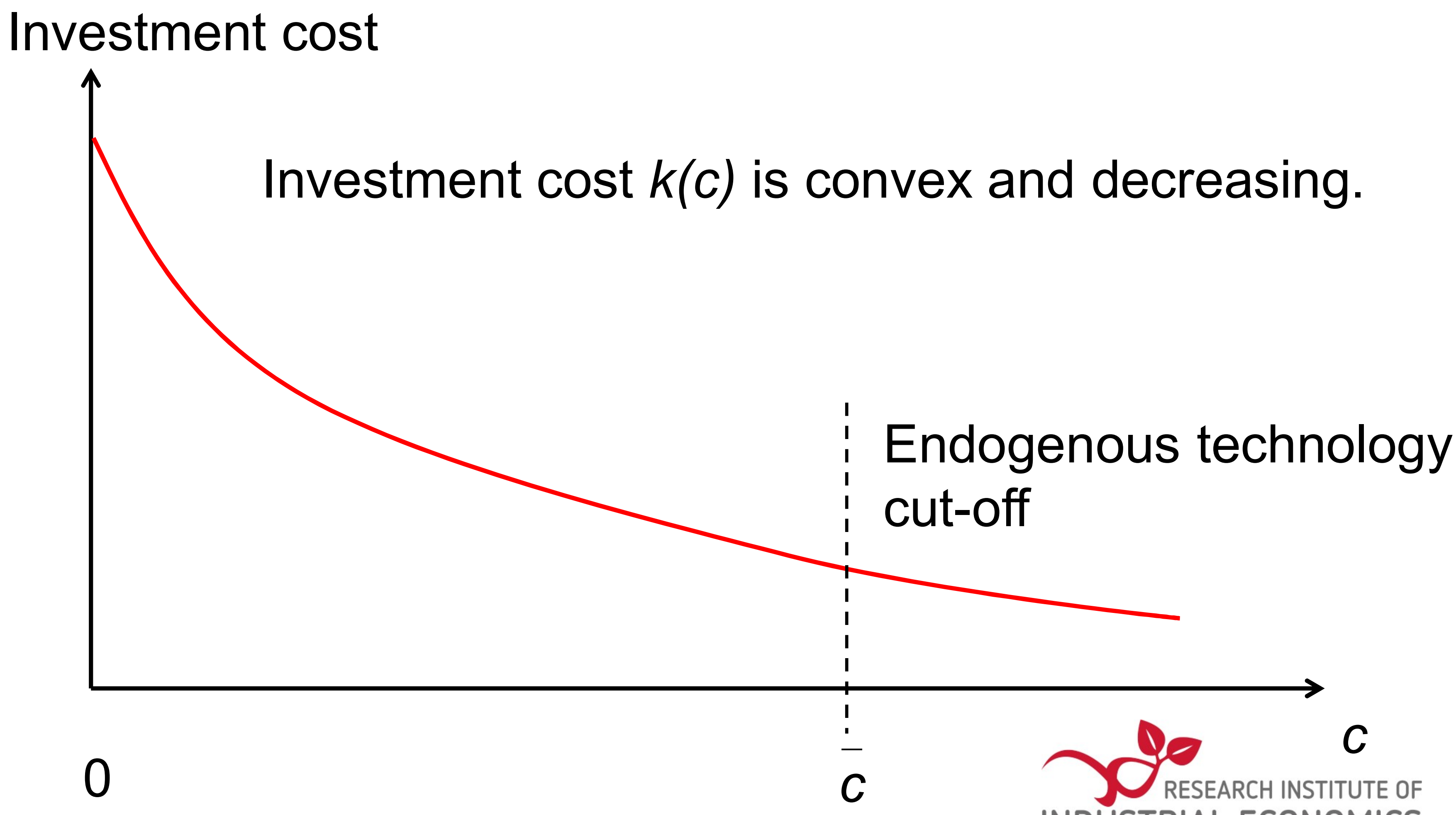
MODEL

Continuum of technologies

Each technology is indexed by its marginal cost *c.*



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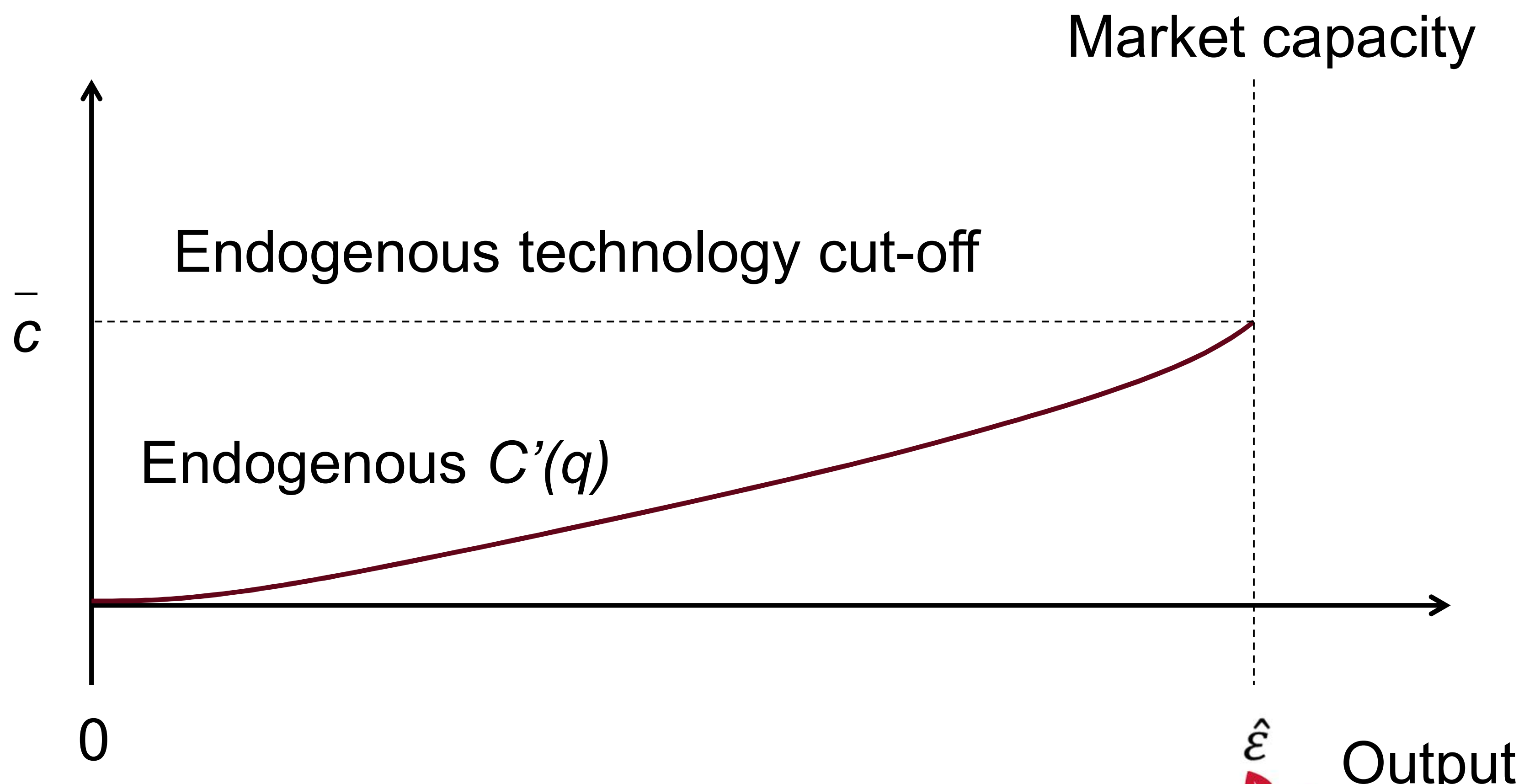
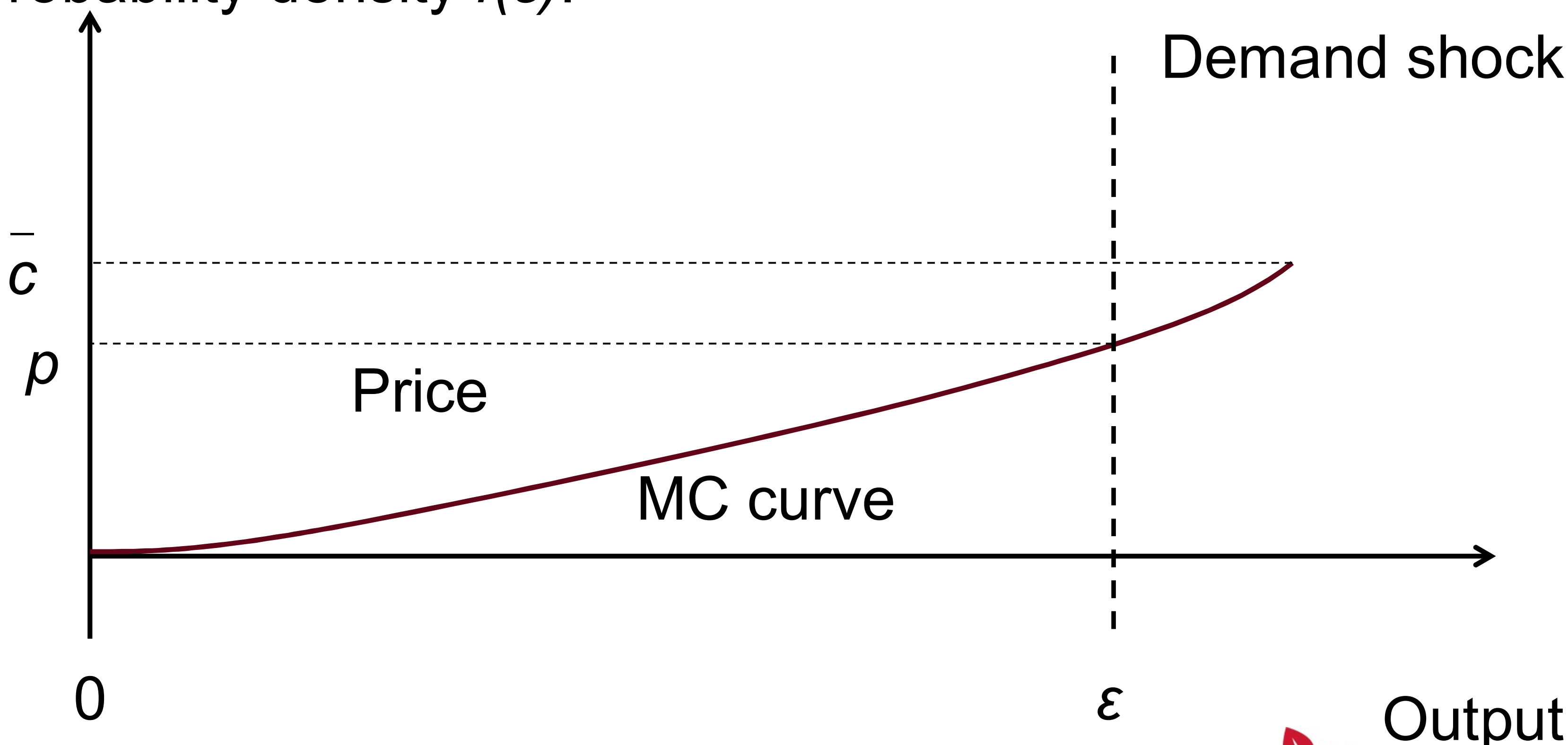
Investment: stage 1

Producers choose how much to invest into each technology.
=> Marginal cost curve



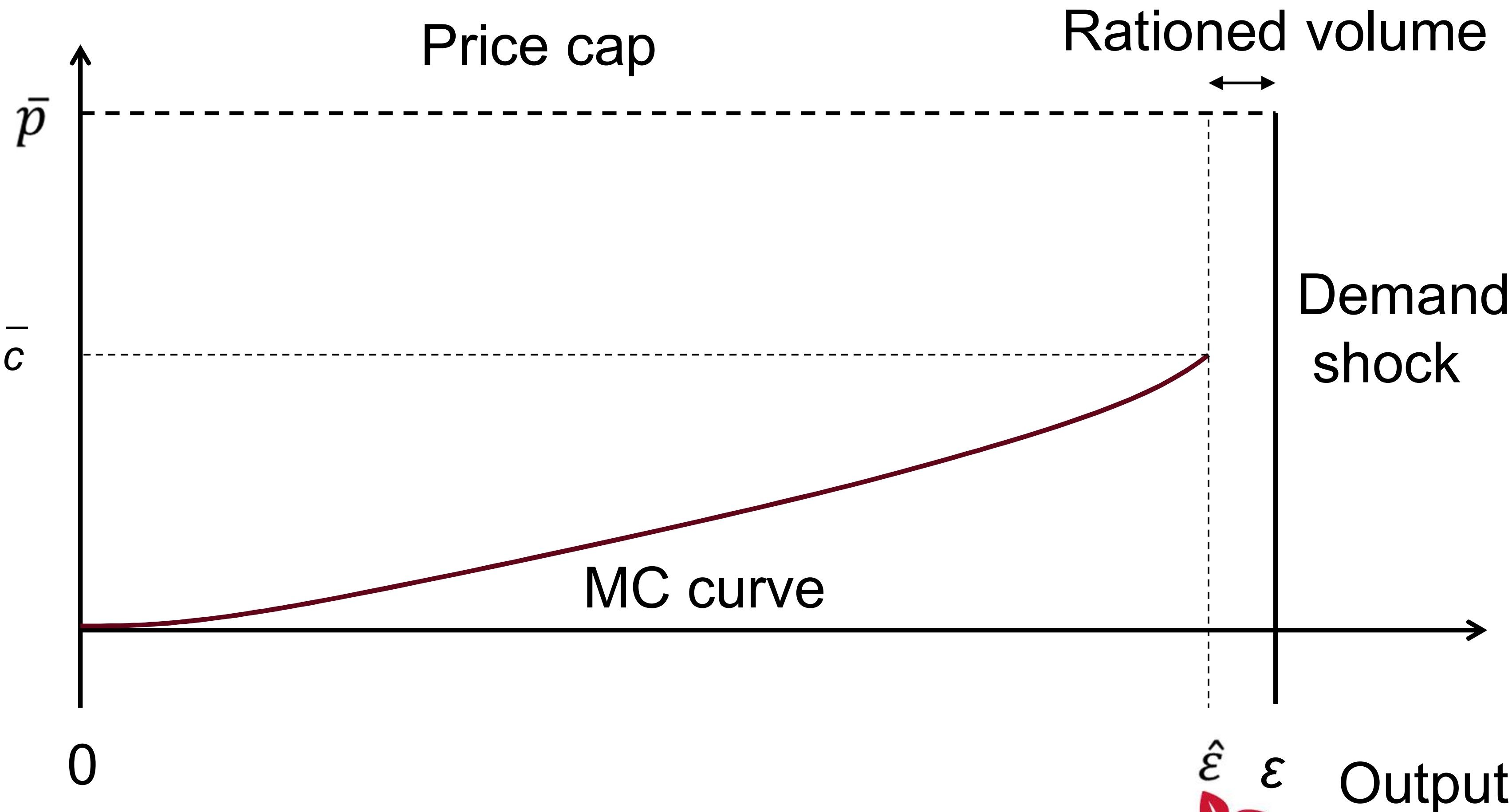
Spot market: stage 2

* Producers price-takers => supply at marginal cost.
* Consumers' marginal valuation is p^*, but there is no demand response => Demand is inelastic.
* Demand shock *ε* follows probability distribution *F(ε)* and probability density *f(ε)*.



Rationing

Demand exceeds the market capacity with probability $1 - F(\hat{\varepsilon})$ => Rationing and price equals price cap.



Black outs

Total black outs occur with some probability.

Assume probability decreases with installed capacity.

Let $M(\hat{\varepsilon})$ be expected cost associated with black outs, where $M'(\hat{\varepsilon}) \leq 0$ and $M''(\hat{\varepsilon}) \geq 0$.

Reliability is a public good. Investments of one firm improves reliability of the grid, which increases the benefit of other market participants (externality).

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ANALYSIS

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Social planner (benchmark)

Social planner chooses *C'(q)* to maximize expected benefit

$$p^* \int_0^{\hat{\varepsilon}} f(\varepsilon)\varepsilon d\varepsilon + p^*\big(1 - F(\hat{\varepsilon})\big)\hat{\varepsilon}$$

net of investment cost

$$\int_0^{\bar{c}} k(c)q'(c)dc,$$

net of expected production cost

$$\int_0^{\hat{\varepsilon}} C(\varepsilon)f(\varepsilon)d\varepsilon + \big(1 - F(\hat{\varepsilon})\big)C(\hat{\varepsilon}),$$

and net of expected black out cost

$$M(\hat{\varepsilon})$$

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Proposition 1 – part I (technology mix)

For a given market capacity, total production and investment costs will be globally minimized under condition:

$$1 - F\big(q(c)\big) = -k'(c)$$

Intuition: Consider two technologies. Their marginal costs differ by *Δc*. Investing more in low-mc and less in high-mc technology=>

1) *Saves (1-F(q(c)))Δc* on production costs
2) Investment costs will be *–k'(c)Δc* higher.

Proposition 1 – part I => At extremum, producer cannot gain by investing more in one technology and less in another.

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Prop. 1 – part II (market capacity)

The optimal technology cutoff is determined from:

$$-(p^* - \bar{c})k'(\bar{c}) - k(\bar{c}) - M'\big(q(\bar{c})\big)=0$$

Technology cutoff does not depend on market uncertainty!

Intuition: Part I of Proposition 1=>

$$\underbrace{(p^* - \bar{c})\big(1 - F(\hat{\varepsilon})\big) - M'\big(q(\bar{c})\big)}_{Expected\ gain\ in\ stage\ 2\ from\ extra\ unit} - \underbrace{k(\bar{c})}_{Investment\ in\ extra\ unit} = 0$$

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Perfectly competitive market

Analyze how investments depend on price cap $\bar{p}$ and uniform capacity payment *z*.

Perfectly competitive market => In equilibrium there is zero payoff for each investment.

Proposition 2:

Part 1 of Proposition 1 still holds:

$$1 - F\big(q(c)\big) = -k'(c) \text{ for } c \in [0, \bar{c}].$$

The technology cutoff is determined by:

$$z - k(\bar{c}) - (\bar{p} - \bar{c})\, k'(\bar{c}) = 0$$

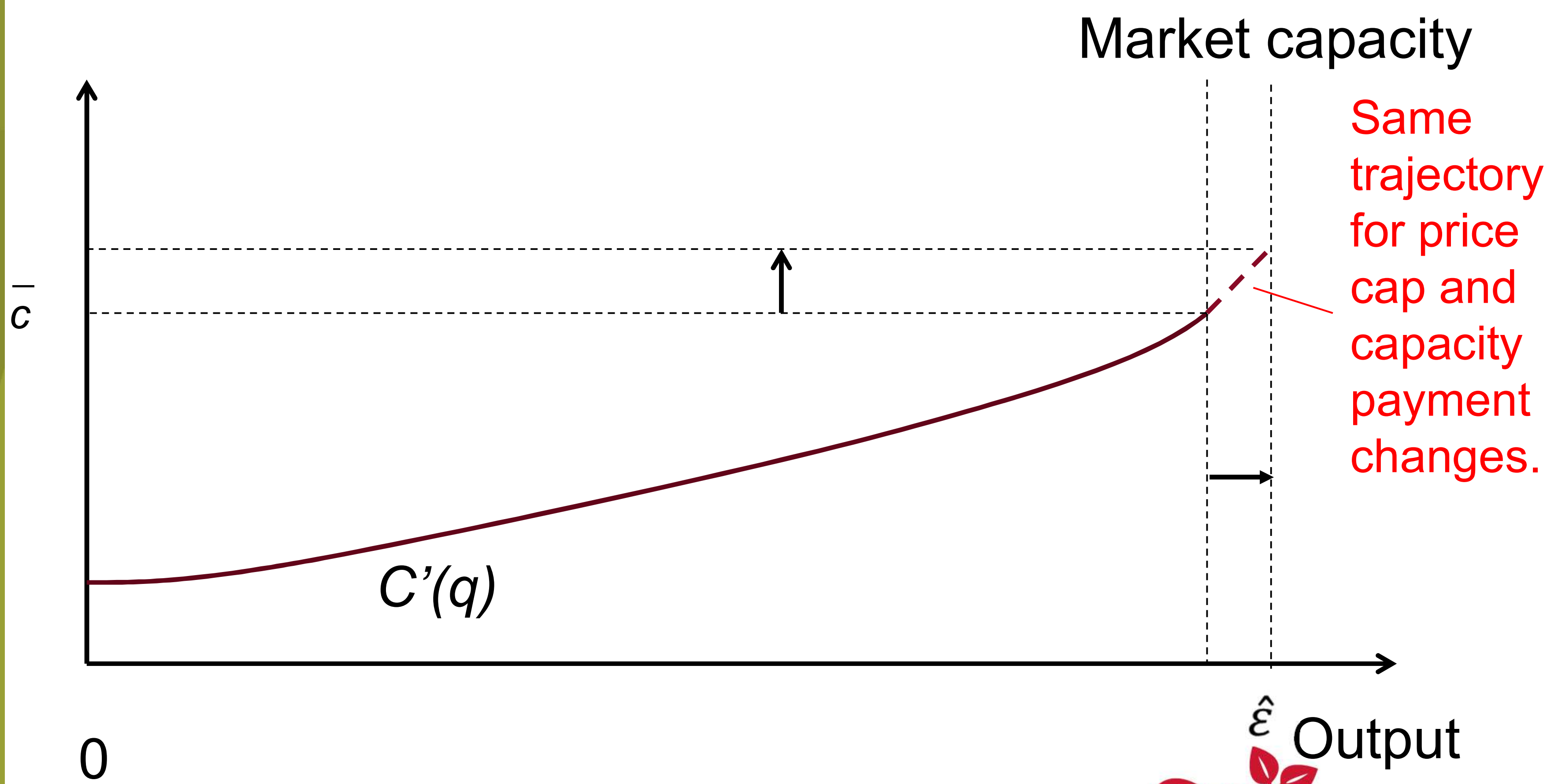
⇒Price cap and capacity payments influence investments into peak power, but not baseload investments.

Investments are socially optimal when

$$z + M'\big(q(\bar{c})\big) + (p^* - \bar{p})k'(\bar{c}) = 0$$

There are many combinations that satisfy this condition, e.g. $\bar{p} = p^*$ and $z = -M'\big(q(\bar{c})\big)$.

Higher price cap and/or capacity payment increases technology cutoff and market capacity, but investments below old cutoff are unchanged.



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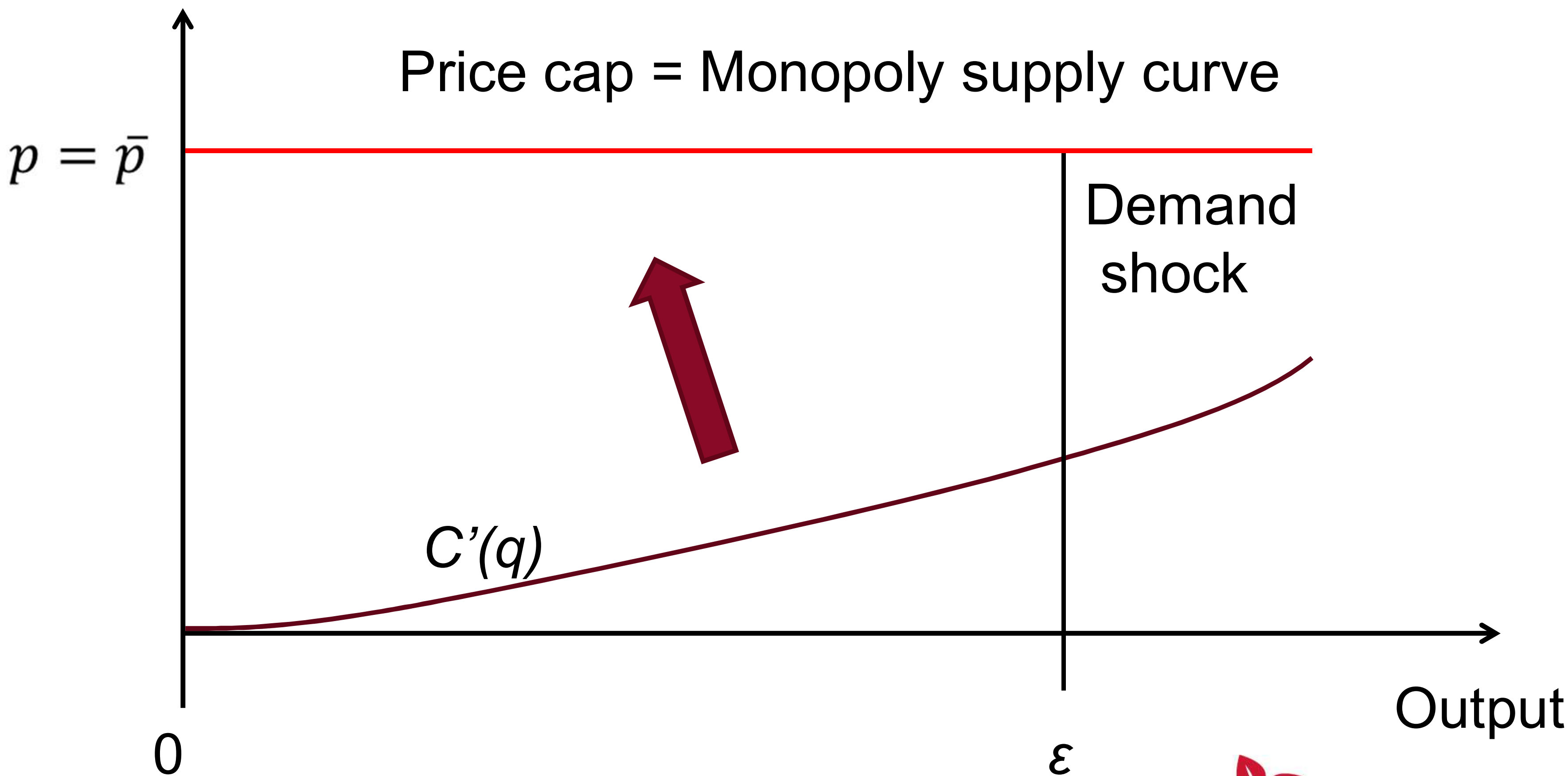
Extension: Monopoly producer

Demand is inelastic => In spot market, monopolist sets price at highest possible price, i.e. at the price cap.



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Monopoly investments

Investments and output of monopolists do not influence price, it is always at price cap. =>

* Production and investments of producer are non-strategic.

* Investments and social welfare are same as perfectly competitive market.

Positive payoff from each investment, but zero payoff from investment at cutoff technology.

⇒Lower consumer surplus.

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Proposition 6

Maintaining optimal social welfare, profit of monopolist can be reduced by reducing price cap and increasing capacity payment *z*.

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Conclusion

- We contribute by analysing investments in a continuum of technologies for price cap and capacity payments.
- There is wide range of combinations of price caps and uniform capacity payments that maximize social welfare, both for perfect competition and monopolist.
- Lower price cap and higher capacity payment would increase consumer surplus for monopoly markets.
- Changes in price cap and capacity payment only influence investments in peakers. Baseload investments are unchanged.

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