Centraal Planbureau

Tilburg University
Understanding Society

Tilec
Tilburg Law and Economics Center

Optimal Regulation of Network Expansion

work in progress

Bert Willems (TILEC - Tilburg University)

Gijsbert Zwart (CPB & TILEC, Tilburg University)

Paris, March 12, 2012

Introduction

- Large amount of investments is foreseen in distribution and transmission sector
  - Driven by demand growth, RES integration, Cross-border trade, replacement of existing assets, smart networks.
- Liberalization of energy market was often accompanied by
  - Unbundling of distribution operators
  - Incentive regulation (for instance price cap)
- There are concerns that current regulation does not give right incentives for firms to invest in capital intensive goods
  - Cost plus regulation gave more certainty (and overinvestments?)
  - Short regulatory periods
  - Vertical integrated firms → More coordination / risk offsets / no double marginalization
  - With a price cap the upside benefits of investments are capped. Downside risk is not.

Introduction

- Empirical evidence is mixed/positive on effect of incentive regulation
  - Empirical evidence on investments (Cambini & Rondi, 2010; Leautier)
  - Experimental study showing that price cap does quite well (Henze, Noussair, Willems, 2012)
- Many proposals to change / soften regulation
  - Regulatory holidays
    - With right duration (Gans & King, 2004)
    - For truly innovative products (Vogelsang, 2010)
- Limited theoretical research
  - Dobbs (2004) → Price cap: insufficient low level of investments
  - Nagel & Rammerstorfer (2008) → Price cap with revenue sharing

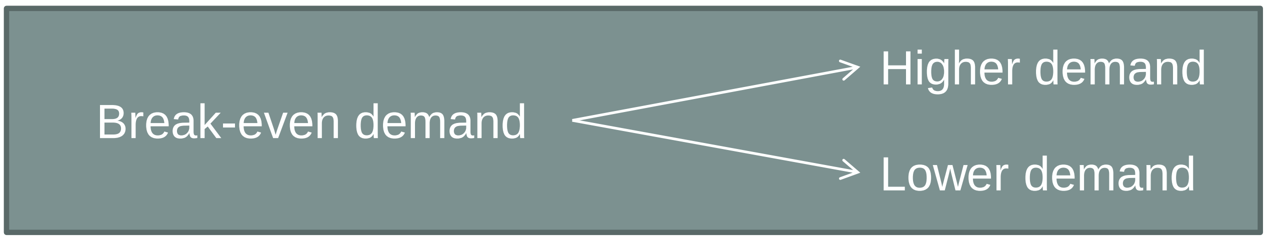
Introduction

1. Dobbs shows that with a price cap, investments are too little and too late. We check which regulatory scheme is efficient?
    - Assuming as in Dobbs that the regulator has perfect information
2. Dobbs assumes that the regulator has all information. Hence, it can effectively command the firm's actions. So how is the optimal regulation if has imperfect information about the costs?

- What is the optimal timing of investments?
- How much profit does the firm make?
- What is the price for consumers?
- How can this be implemented?

Our work combines:

- Real option theory (Dixit & Pindyck, 1991)
  - Investment under uncertainty
  - Delaying irreversibly investments in order to learn more about nature (i.e. avoid investment if demand is low)

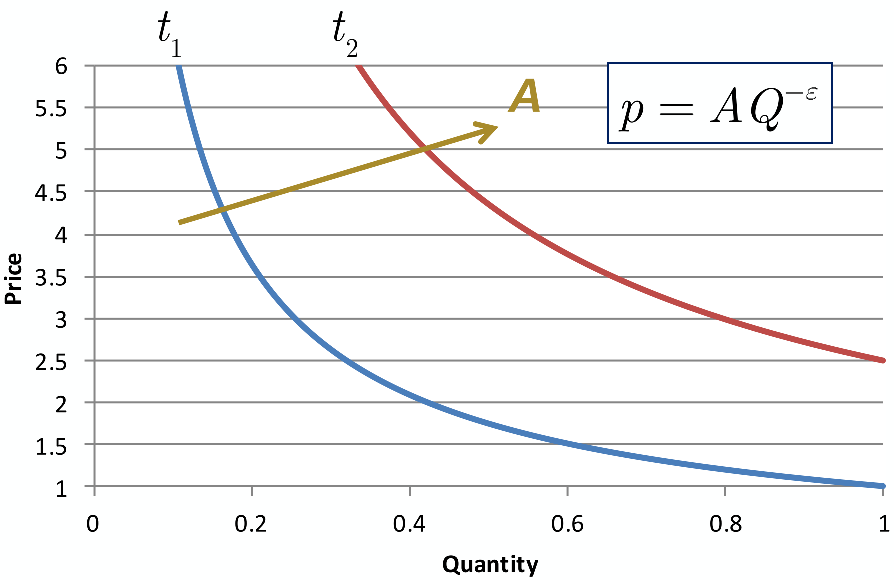


  - The value of waiting → Preserves a valuable options
- Optimal regulation (Laffont & Tirole, 1993, Baron & Meyerson)
  - Trade-off between rent extraction and efficiency
  - A low cost firm should receive a rent
  - To limit those rents, an high cost firm produces suboptimal quantities

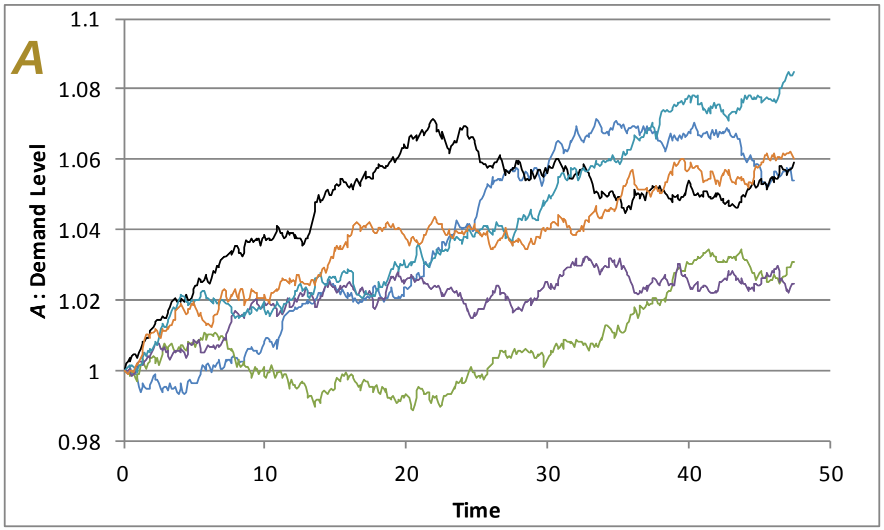
- Introduction
- **Model**
- Perfect information
- Asymmetric information
- Conclusions

Model: Demand for network capacity

- Constant elasticity (ε)



- Growth rate (μ > 0)
- Stochastic (Multiple possible paths) (σ: measure of volatility)



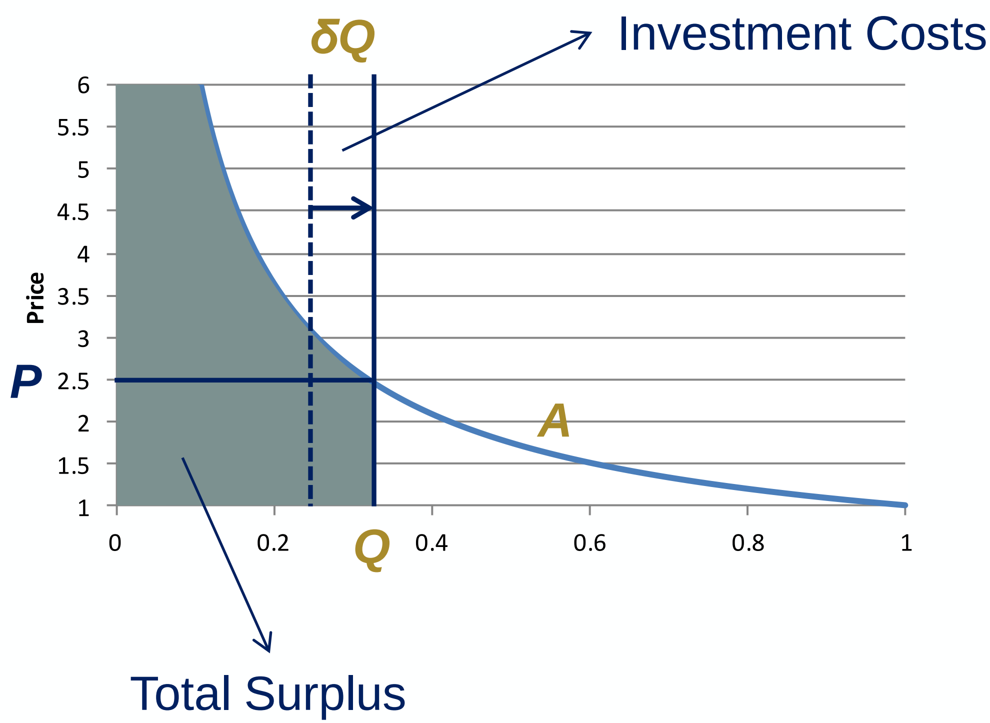
♦ Demand is observed by the regulator

Model: Supply of network capacity

- Network investments
  - Investments are irreversible → real option considerations
  - Constant marginal investment cost *c*
  - Continuous investments possible (no lumpiness)
- Network usage = costless

Model: Market Equilibrium at period t

- Given demand realization ***A***, Existing capacity ***Q***, new investment ***δQ***



- Introduction
- Model
- **Perfect information**
- Asymmetric information
- Conclusions

Perfect Information

- Maximize expected discounted welfare
  - → Expectation over demand realization paths *A*
  - → Discounted at discount rate *r*

$$\mathrm{NPV}\left[W(p,Q)\right] \qquad \text{with } \mathrm{NPV}\left[X\right] \sim \mathrm{E}_A \int e^{-rt} X dt$$

- By choosing an investment strategy / decision on network usage
  - → Given installed capacity Q & demand shock A → invest ***δQ***

$$\delta Q(p,Q)$$

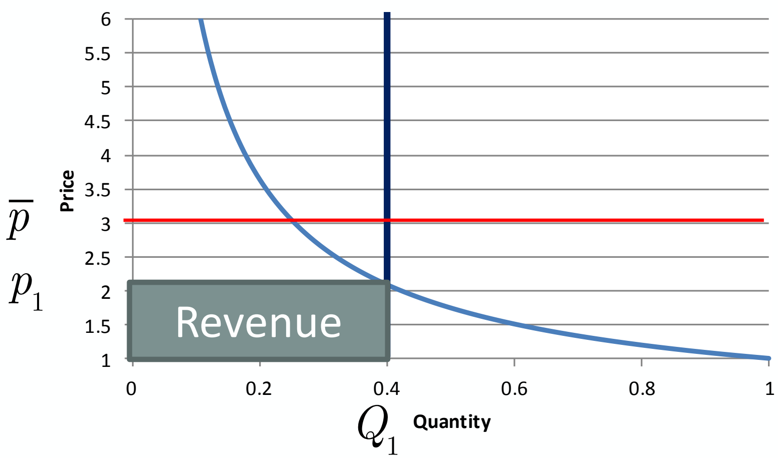
→ Stochastic optimization problem

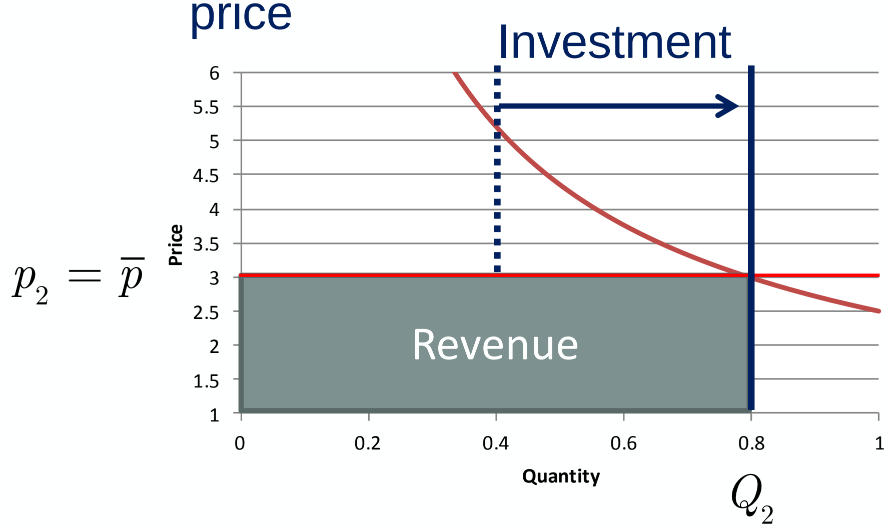
- First best optimum
  - ♦ Use network at full capacity → Peak load pricing
  - ♦ Expand capacity to prevent prices above a limit price

Perfect Information

(1) Usage: Use network at full capacity → peak load pricing

(2) Investment: Expand capacity to prevent prices raising above a limit price





(3) Reward: Firm is allowed to keep all revenue from selling capacity

→Firm will make zero profit

(4) Limit price: Limit price takes into account option value of waiting

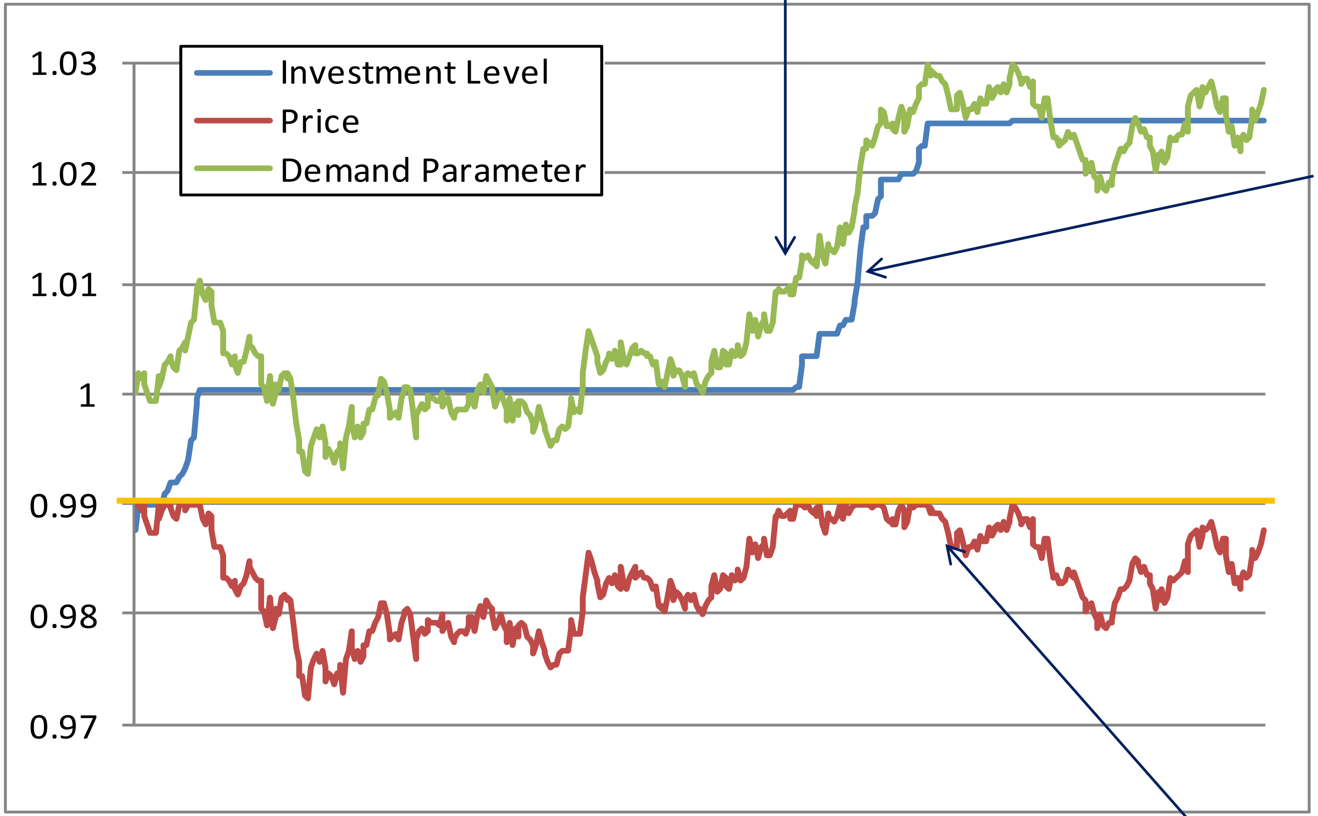
$$\overline{p} = \frac{\lambda}{\lambda - 1}(r - \mu)c$$

Real option correction increases with volatility σ

Annualization

Investment cost

Perfect Information



1 Realization of demand shocks

4 Invest whenever price hits limit price = demand shock reaches historical maximum

3 Limit price

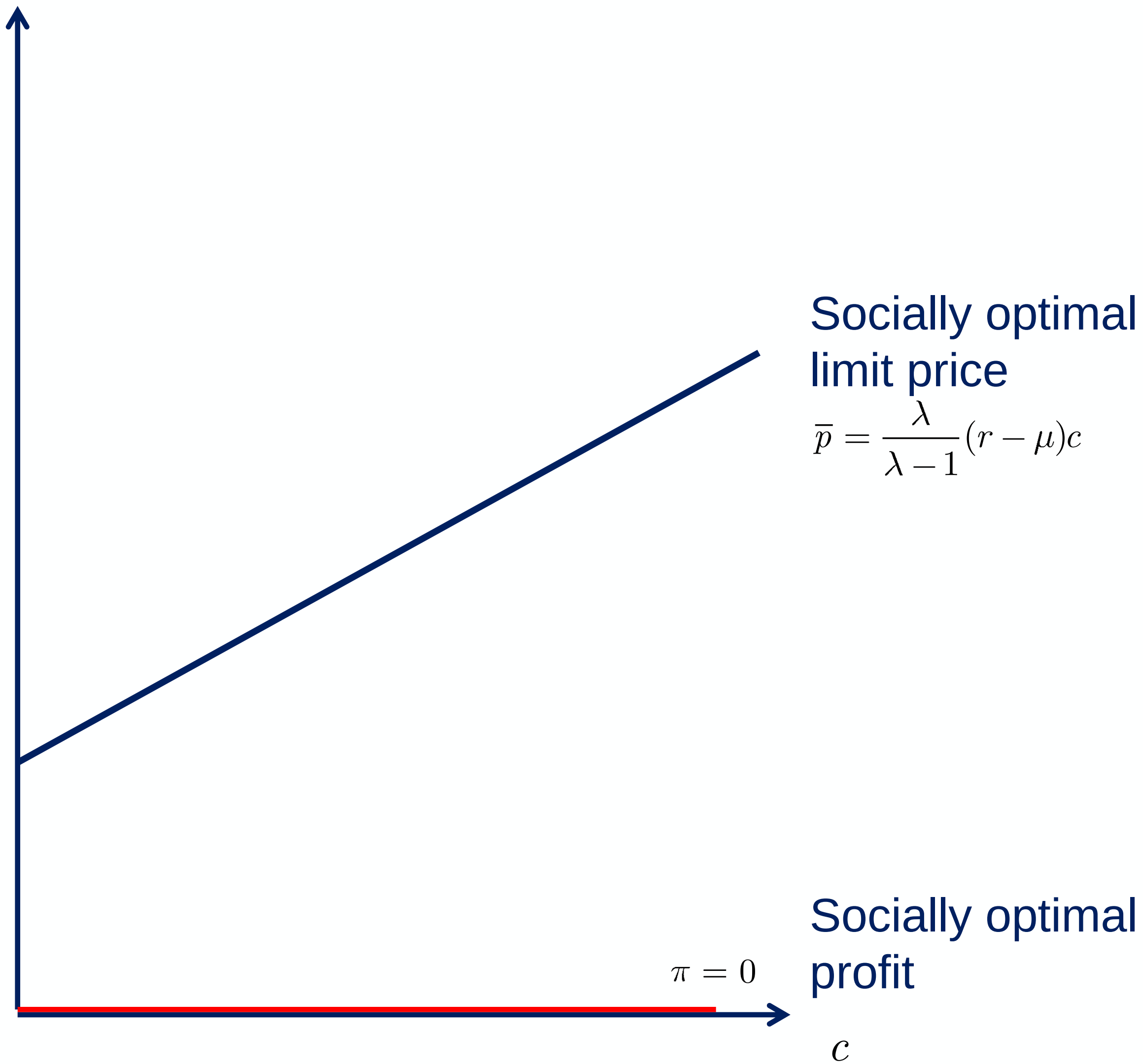
2 Market price depends on
(1) investment level *Q*
(2) demand shock *A*

Perfect Information

- Note 1: This is different from price cap regulation
  - Firm is **not allowed to withhold capacity**, even though price is below price cap
  - Firm is **obliged to invest** if price reaches limit price
    - It reduces likelihood of high prices in future → so not in the firm's best interest to do so.

    →Dobbs (2004): Firms invest too late with a price cap
- Note 2: This outcome mimics a competitive market
  - Firms price at short term marginal costs & invest if they break-even
    - "Strategically" delaying investments only works for firms with market power
  - Individual firms invest based on the stochastic prices they observe
    - In equilibrium, upside potential is limited by limit price
    - For individual firm, the stochastic price process is constant

Perfect information: Prices and Profits



Asymmetric information

- If regulator knows investments cost ***c*** and observes demand ***A***

  → It can impose optimal investment strategy
- Now assume that
  - Regulator knows cumulative distribution of investment cost ***F(c)***
  - Firm can only collect revenues from selling network access
- Question: What is the optimal regulation?
  - Regulator offers a menu of contracts

    $\pi(c)$ Expected profit of firm with investment cost c

    $\overline{p}(c)$ Investment price limit for firm with investment cost c
  - Truthful revelation principle: We can restrict ourselves to menus for which each firm reports its cost honestly

Asymmetric information

- Optimize expected discounted welfare
  - → Expectation over demand realization paths *A*,
  - → Discounted at discount rate *r*
  - → Expectations over all possible cost realizations c

$$\max_{p(c),\pi(c)} \mathrm{E}_c \ \mathrm{NPV}\left[w(P,Q) \mid \overline{p}(c)\right]$$

- Incentive constraint

$$\frac{d\pi(c)}{dc} \leq -NPV\left[\delta Q \mid \overline{p}(c)\right]$$

By pretending to be a high cost firm, a low cost firm saves investment costs for production volume. To avoid this, the low cost firm is promised an information rent dπ

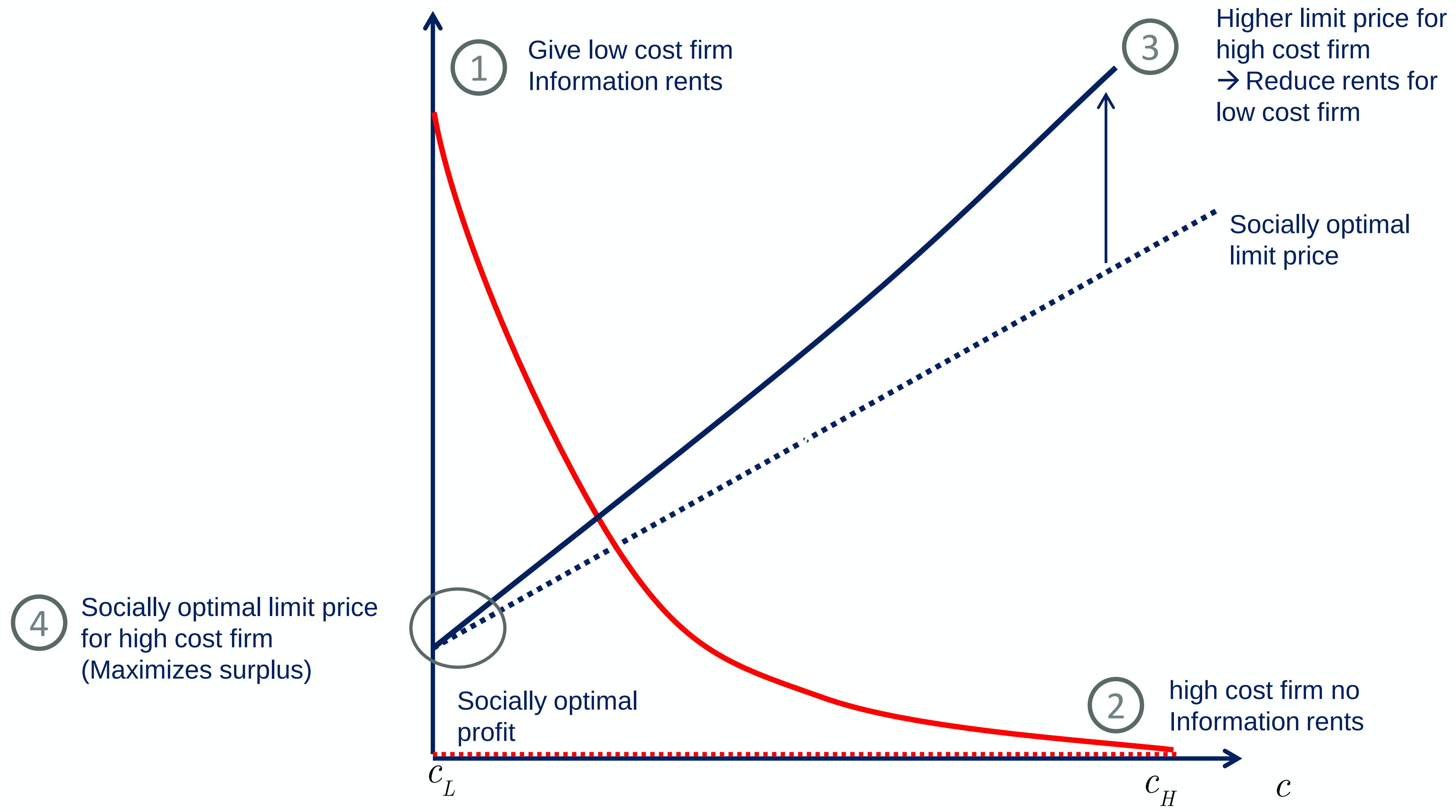
- Payment constraint

$$\pi(c) \leq NPV\left[PQ - c\,\delta Q \mid \overline{p}(c)\right]$$

The regulator needs to finance profits for the firms from the market

→ Simplifies to an optimal control problem, now some "intuition"

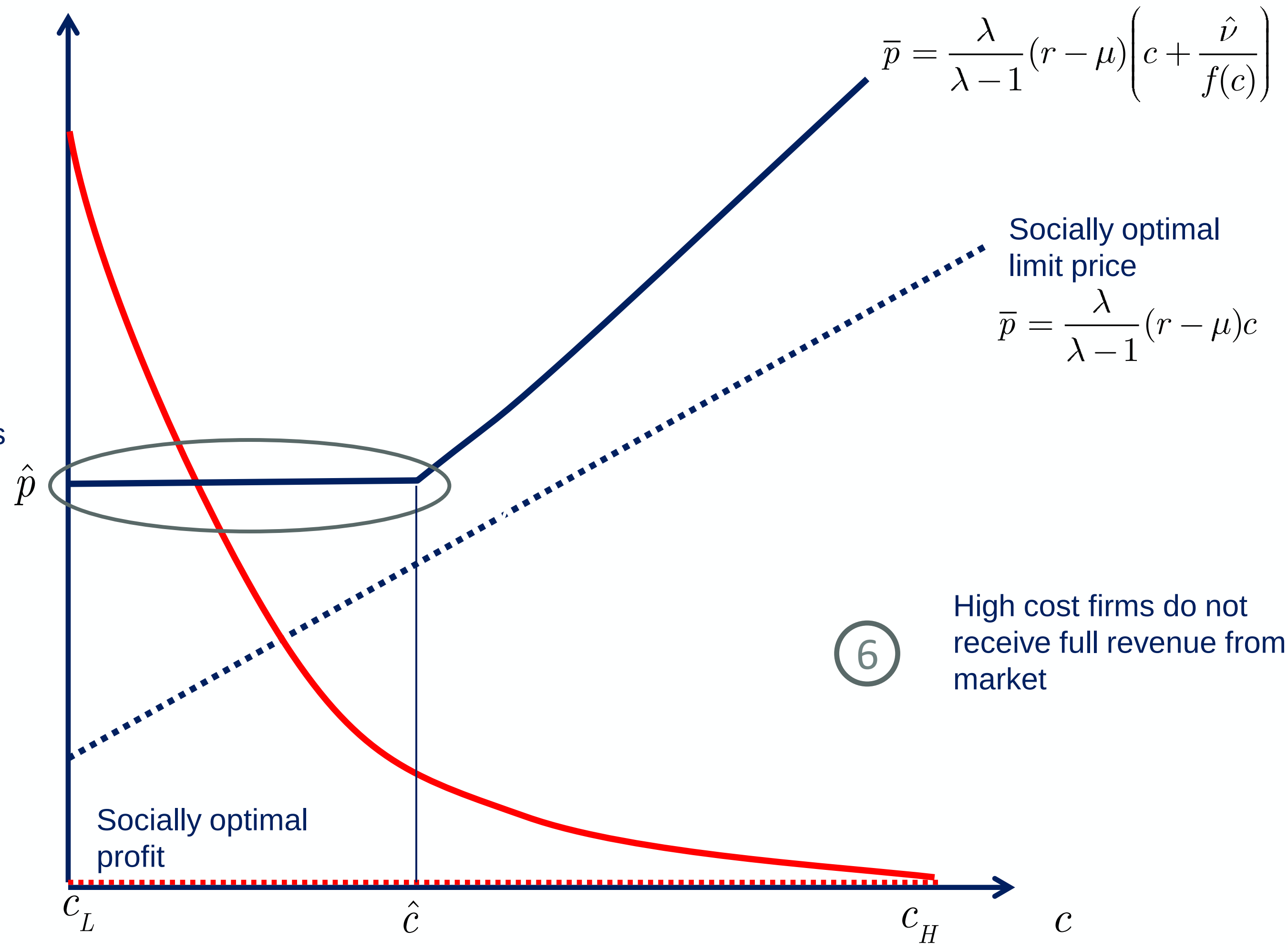
Asymmetric information
Lump-Sum subsidies (Baron-Myerson)



Asymmetric information
No subsidies

5

With socially optimal prices profits would be zero
→ Budget constraint binds
→ Lowest cost firms have identical limit price



6

High cost firms do not receive full revenue from market

Asymmetric information
No subsidies

Illustration

The optimum is given by the pair $\bar{c}, \bar{\nu}$ that form the joint solution of

$$\bar{\nu} = -\frac{\int_{c_L}^{\bar{c}} dc' f(c')(\bar{c} + \frac{\bar{\nu}}{f(\bar{c})} - c')}{\left(\bar{c} + \frac{\bar{\nu}}{f(\bar{c})}\right)(1-\gamma) - \bar{c}} \quad (21)$$

and

$$\frac{\bar{\nu}}{f(\bar{c})}\left(\bar{c} + \frac{\bar{\nu}}{f(\bar{c})}\right)^{-\frac{1}{\gamma}} = \int_{\bar{c}}^{c_H} dc' \left(c' + \frac{\bar{\nu}}{f(c')}\right)^{-\frac{1}{\gamma}}. \quad (22)$$

Two regions

In the optimal contract, all firms with cost below $\bar{c}$ get offered a price cap

$$\bar{p} = \bar{c} + \frac{\bar{\nu}}{f(\bar{c})} \quad (23)$$

while for higher cost firms, the price cap is

$$\bar{p}(c) = c + \frac{\bar{\nu}}{f(c)} \quad (24)$$

Constant price for low cost,

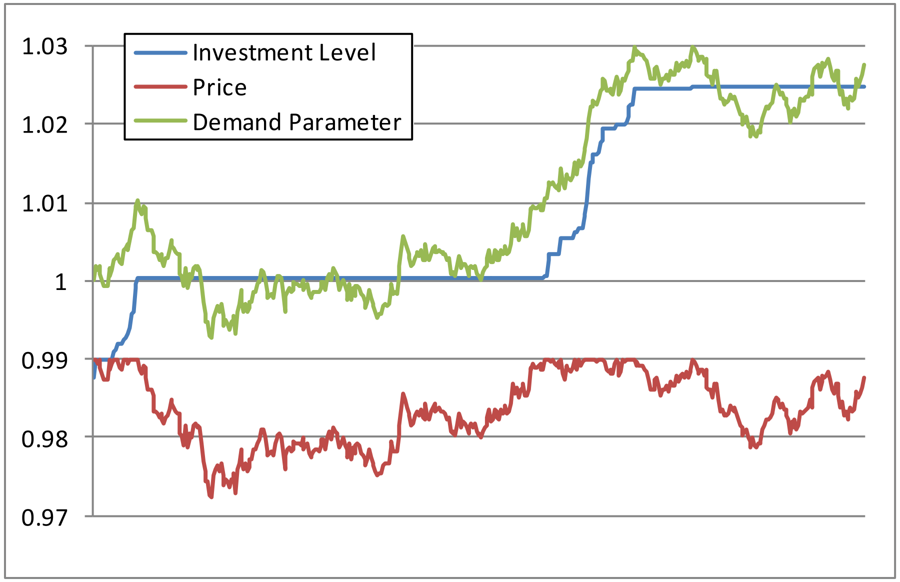
Increasing price for high cost

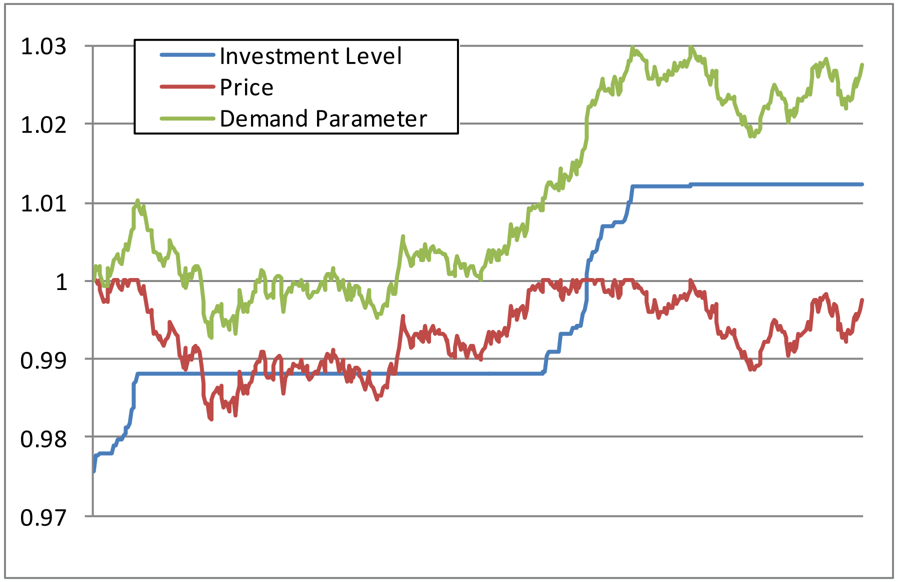
Conclusion

- Perfect information
  - Peak load pricing - Limit price - Obligation to invest
  - Firms receives full prices from consumers
- Asymmetric information
  - Menu of contracts
  - Peak-load pricing - Limit price - Obligation to invest
  - Low cost firm receives full prices from consumers/ high cost firm only fraction
  - Limit price is higher than socially optimal
    - For high cost firms: to reduce rents for low cost firm
    - For low cost firms: to collect sufficient profits from consumers.
    - → Regulatory imperfection delays investmens

Example

- Effect of different limit price on investments and prices





Perfect regulation, Monopoly and Imperfect regulation