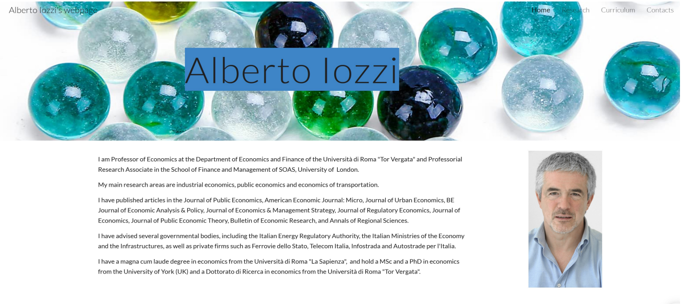
Law & Economics: Regulation of public services

Alberto Iozzi

Housekeeping: about your teacher



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Formerly

- Teaching this course for ∼5 years
- Teaching Microeconomics in this programme for ∼10 years
- Director of this programme for 18 months in 2020-2021

Housekeeping: syllabus

- Industries with limits to competition
- Regulation of a Monopoly with Full Information
- Regulation of a Monopoly under Informational Constraints
- Non-Linear Pricing in Regulation
- Regulation of Quality
- Regulation of Investment

Housekeeping: textbook

- Main textbook:
  - Auriol, E, C Crampes and A Estache, 2022. Regulating Public Services: Bridging the Gap between Theory and Practice. Cambridge University Press
- Useful (classical) references are:
  - Panzar, J C, 1989. Technological Determinants of Firms and Industry Structure. in Schmalensee, R and R Willig (eds), Handbook of Industrial Organization (vol. 1), Amsterdam: North-Holland.
  - Armstrong, M. and D.E.M. Sappington, 2007. Recent advances in the theory of regulation. in M. Armstrong and R. Porter (eds.), Handbook of Industrial Organization (vol. 3), Amsterdam: North-Holland.
  - Armstrong, M, S Cowan and J Vickers, 1994. Regulatory Reform: Economic Analysis and British Experience. Cambridge (MA): MIT Press.
  - Laffont, J-J and J Tirole, 1993. A Theory of Incentives in Procurement and Regulation. Cambridge (MA): MIT Press.

Housekeeping: exam

- Written exam
- Four open questions, two for each module
- All 4 questions carrying equal weight for the final grade

What is this course about

- Imagine you are the head of the government of a country and believe that your citizens/country may benefit from a good/service
- First issue: can this good/service be produced in a competitive market?
  - YES: do nothing
  - NO: need to design the market

What is this course about (ctd)

- Market design: you have these options
  - produce it through a government department (possibly buying inputs from the market) and distribute it "as a public good " to the population
  - produce it through a state-owned company and distribute/sell it to the population/consumers
  - award the duty/right to produce it to (a) private firm(s) that sells it to consumers and set the rule for its (their) behaviour
  - buy it from (a) private firm(s) and distribute/sell it to the population/consumers
- Formidable problems
  - choice between above options
  - price
  - investment
  - quality
  - mode of distribution
  - length of concession period
  - ...

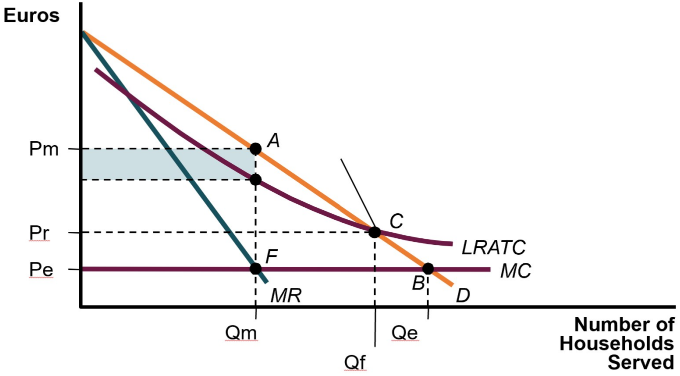
Cost concepts, demand and market structure

- Focus is on the existence of limits to competition:

  Relationship between cost and demand conditions
  dictates the efficient number of firms in an industry

- How is the existence of limits to competition related to features of the technology?

Received wisdom



Single product technology and scale economies

Single product technology

- Only 1 input
- Technology is such that $y = f(x)$
- When $f(kx) = k'f(x)$,

$$k' \begin{cases} > k & \text{INCREASING returns to scale (IRS);} \\ = k & \text{CONSTANT returns to scale (CRS);} \\ < k & \text{DECREASING returns to scale (DRS).} \end{cases}$$

  If (say) you double the input, returns to scale depend on whether you obtain exactly/more/less than twice as much output
- Local definition
- Easy to show that $IRS \Leftrightarrow \frac{dAC(y)}{dy} \leq 0$.
  If (say) doubling the input one obtains more than twice the original output, the average content of the input for a unit of output decreases and AC must decrease.

Single product technology and scale economies (ctd)

- Many inputs
- Technology is such that $y = f(\mathbf{x})$
- When $f(k\mathbf{x}) = k'f(\mathbf{x})$,

$$k' \begin{cases} > k & \text{INCREASING returns to scale (IRS);} \\ = k & \text{CONSTANT returns to scale (CRS);} \\ < k & \text{DECREASING returns to scale (DRS).} \end{cases}$$

  If (say) you double all input in the same proportion, returns to scale depend on whether you obtain exactly/more/less than twice as much output
- In this case however $IRS \Rightarrow \frac{dAC(y)}{dy} \leq 0$, but not viceversa !
  - Efficient production may require changing the optimal mix of inputs as output varies

Multiproduct technology and scale economies

Multiproduct firm

- Making use of the transformation function $\phi(\mathbf{x}, \mathbf{y})$
  - T is the transformation set: the set of $(\mathbf{x}, \mathbf{y})$ such that $\mathbf{y}$ can be produced with $\mathbf{x}$,
  - such that: $\phi(\mathbf{x}, \mathbf{y}) \geq 0$ iff $(\mathbf{x}, \mathbf{y}) \in T$
    $\phi(\mathbf{x}, \mathbf{y}) = 0$ iff $(\mathbf{x}, \mathbf{y}) \in T$ and production is efficient.
  - $\phi(.)$ not decreasing in x,
  - $\phi(.)$ not increasing in y,
- Intuition: with only 1 input and 1 output: $\phi(x, y) = f(x) - y$

Multiproduct technology and scale economies (ctd)

Returns to scale on the production side

- Define

$$S' = \frac{\sum x_i \frac{\partial \phi}{\partial x_i}}{\sum y_i \frac{\partial \phi}{\partial y_i}}$$

- Then

$$S' \begin{cases} > 1 & \text{INCREASING returns to scale (IRS);} \\ = 1 & \text{CONSTANT returns to scale (CRS);} \\ < 1 & \text{DECREASING returns to scale (DRS).} \end{cases}$$

- Intuition: with only 1 input and output: $S = \frac{x f'(x)}{f(x)} = \frac{f'(x)}{\frac{f(x)}{x}} = \frac{MP(y)}{AP(y)}$

  $\rightarrow$ if marg product $<$ average product, $f(x)$ is concave

Multiproduct technology and scale economies (ctd)

Returns to scale on the cost side

- Cost function equal to $C(\mathbf{y}, \mathbf{w})$
- With many outputs, there is not such a thing as the average cost function...
- Define

$$S = \frac{C(\mathbf{y}, \mathbf{w})}{\sum y_i \frac{\partial C(\mathbf{y}, \mathbf{w})}{\partial y_i}}$$

- Then

$$S \begin{cases} > 1 & \text{INCREASING returns to scale (IRS);} \\ = 1 & \text{CONSTANT returns to scale (CRS);} \\ < 1 & \text{DECREASING returns to scale (DRS).} \end{cases}$$

- Intuition: with only 1 input and 1 output: $S = \frac{C(y,w)}{y\frac{\partial C(y,w)}{\partial y}} = \frac{AC(y)}{MC(y)}$
- S' and S are equivalent measures of scale economies/diseconomies

Multiproduct technology and scale economies (ctd)

- Can also define <u>single-product scale economies</u>
- First define
  - product i <u>incremental cost</u>:

$$IC_i = C(\mathbf{y}) - C(\mathbf{y}^{-i})$$

    where $\mathbf{y}^{-i} = \{y_1, \dots, y_{i-1}, y_{i+1}, \dots, y_n\}$,
  - product i <u>average incremental cost</u>

$$AIC_i = \frac{IC_i}{y_i}$$

Multiproduct technology and scale economies (ctd)

- Define

$$S_i(\mathbf{y},\mathbf{w}) = \frac{IC_i(\mathbf{y},\mathbf{w})}{y_i \frac{\partial C(\mathbf{y},\mathbf{w})}{\partial y_i}} = \frac{AIC_i(\mathbf{y},\mathbf{w})}{\frac{\partial C(\mathbf{y},\mathbf{w})}{\partial y_i}}$$

- Then, product i scale economies are such that

$$S_i \begin{cases} > 1 & \text{INCREASING returns to scale (IRS);} \\ = 1 & \text{CONSTANT returns to scale (CRS);} \\ < 1 & \text{DECREASING returns to scale (DRS).} \end{cases}$$

- This measure can be easily extended to any subset of products

Scope economies

- Other useful concept is that of scope economies.
- Assume only 2 products (can easily generalise to n), then the output vector is $\mathbf{y} = \{y_1, y_2\}$.
  There are scope economies iff

$$C(\mathbf{y}) < C(y_1, 0) + C(0, y_2).$$

Natural monopoly

- What is then a natural monopoly ?

  An industry is a NM at $\mathbf{y}$ iff
  $C(\mathbf{y})$ is strictly subadditive at any $\mathbf{y}' \leq \mathbf{y}$.

- $C(\mathbf{y})$ is strictly subadditive at $\mathbf{y}$ iff, for any possible output combination $\{\mathbf{y}^1, \mathbf{y}^2, \ldots, \mathbf{y}^K\}$ such that
  - $\mathbf{y}^i \neq \mathbf{y}$ for each i,
  - $\sum_i \mathbf{y}^i = \mathbf{y}$,

  then,

  $$C(\mathbf{y}) < \sum_i C(\mathbf{y}^i)$$

- Then, with a NM, aggregate cost are minimised with only one firm.
- With a single product firm, $\frac{d\,AC(y)}{d\,y} < 0$ (for each relevant level of output) implies subadditivity of the cost function, but not viceversa

Natural monopoly

Conditions for a natural monopoly

- With a single product firm,
  - IRS sufficient for a NM
  - IRS not necessary for a NM
- With a multiproduct firm,
  - IRS neither sufficient nor necessary for a NM
  - Scope economies necessary but not sufficient for a NM
  - IRS + scope economies not sufficient for a NM

- Checking for a NM often complex (theoretically and econometrically....) but sometimes...
- Sufficient conditions for subadditivity (and then NM)
  - Single product scale economies + scope economies
  - Single product average incremental cost decreasing + scope economies

Natural oligopoly

- Can we imagine an industry in which it is socially efficient to have only a limited number of firms producing a set of goods??

NATURAL OLIGOPOLY

- Need to introduce the concepts
  - Industrial configuration
  - Feasible industrial configuration
  - Efficient industrial configuration

Natural oligopoly

Industrial configuration

- An industrial configuration is a vector $\mathbf{y} = \{\mathbf{y}_1, \ldots\ldots, \mathbf{y}_N\}$, where N is the number of firms, M is the number of goods and $\mathbf{y}_i = \{y_i^1, \ldots\ldots, y_i^M\}$ is the output vector of firm i, such that $\sum_i y_i^j = q^j(p)$ at some price p for each $j = 1, \ldots, M$
  $\rightarrow$ there exist demand for what is produced by the N firms

Feasible industrial configuration

- An industrial configuration is feasible if $\sum_j p_i(\mathbf{y}) y_i^j \geq C(\mathbf{y}_i)$ for each i
  $\rightarrow$ each firm makes non-negative profits

Natural oligopoly

Efficient industrial configuration

- A feasible industrial configuration $\{\mathbf{y}^1, \ldots, \mathbf{y}^N\}$ is efficient if

$$\sum C(\mathbf{y}^i) = \min_{N,\mathbf{y}^1,\ldots,\mathbf{y}^N} \sum C(\mathbf{y}^i)$$

$\rightarrow$ the number of firms and the output level of each firm is chosen to minimise the aggregate production cost

Natural oligopoly

How to determine an efficient industrial configuration?

- Hp: single-product firms
- Hp: single peaked cost function
- Let $[x]$ be the integer part of x
- Ignore the integer problem
- Let AC^{min} the minimum AC
- Let y^{min} the quantity such that $AC = AC^{min}$
- Then,

  no more than $[D(p = AC^{min})/y^{min}]$ firms belong to the efficient industrial configuration
- Easy to find this number?
  - Look for the demanded quantity when $p = AC^{min}$
  - Divide this quantity by the quantity that minimises average cost

Profit maximization for a monopoly

- Profit and marginal profit:

$$\pi(q) \equiv R(q) - C(q)$$

$$\frac{d\,\pi(q)}{d\,q} = \frac{d\,R(q)}{d\,q} - \frac{d\,C(q)}{d\,q}$$

- Profit maximization implies that $\frac{d\,\pi(q^*)}{d\,q^*} = 0$, which is equivalent to

$$MR(q^*) = MC(q^*)$$

Notes on marginal revenue

- What do you get from selling an extra unit?
  You get the price for which you sell it, but the additional (marginal) revenue is less than that.
- Price must be lowered in order for an extra unit to be sold; this lowers the margin on all units sold.
- Formally,

$$MR(q) \equiv \frac{d\,R(q)}{d\,q} = \frac{d\,(p(q) \times q)}{d\,q} = p(q) + \frac{d\,p(q)}{d\,q}\,q < p(q)$$

The elasticity rule

$$MR(q) = p(q) + \frac{d\,p(q)}{d\,q}\,q = p(q) + \frac{d\,p(q)}{d\,q}\,\frac{q}{p(q)}\,p(q)$$
$$= p(q) + \frac{1}{\frac{d\,q}{d\,p(q)}\frac{p(q)}{q}}\,p(q) = p(q)\left(1 + \frac{1}{\epsilon}\right)$$

Therefore, $MR = MC$ implies that $p\left(1 + \frac{1}{\epsilon}\right) = MC$, or

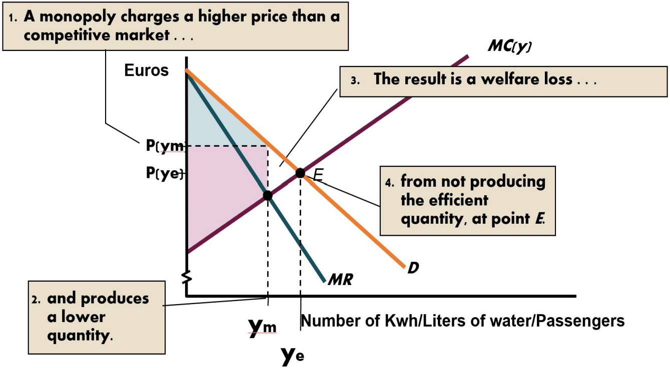
$$p = \frac{MC}{1 + \frac{1}{\epsilon}}$$

Alternatively, this may be written as

$$\frac{p - MC}{p} = -\frac{1}{\epsilon}$$

Monopoly and DWL

- Graphically, this gives rise to the well-known picture



- The lower is the elasticity, the greater is the welfare loss

The players in a regulation game

- the government (local, national)
- a firm (monopolist)
- the users (final or intermediate)
- a regulation and a competition agency
- the tax payers
- other firms (as users or competitors)
- other agencies

The players in a regulation game

- the government (local, national)
- a firm (monopolist) $\hookleftarrow$
- the users (final or intermediate) $\hookleftarrow$
- a regulation and a competition agency $\hookleftarrow$
- the tax payers $\hookleftarrow$
- other firms (as users or competitors)
- other agencies

The agenda

- Regulation in case of full information
- (Optimal) regulation in case of asymmetric information
- Regulation in case of asymmetric information

(Optimal) regulation in case of full/asy information

Ultra-classical references

- Ramsey (EJ, 1927)
  - full info
- Baron and Myerson [BM] (Econometrica, 1982)
  - full info
  - asy info: adverse selection
- Laffont and Tirole [LT] (JPE, 1986)
  - full info
  - asy info: adverse selection and moral hazard

- First, focus on full information case ...
  - results useful for any possible solutions to the regulator's problem
- ... then, focus on (optimal solution to the problem of) asymmetric information

The objective function of regulation

As discussed before, several interest groups

- consumers $\looparrowright$ utility
- firm(s) $\looparrowright$ profits
- taxpayers $\looparrowright$ use of tax revenues
- regulatory authority $\looparrowright$ benevolent, interested in productive and allocative efficiency

The objective function of regulation (ctd)

Firm

- Often, one firm only
- Standard measure of a firm's payoff

$$\pi = p(q)\, q + t - c(q)$$

where t possible transfer from the regulator

Consumers

- Often, representative consumer
- Consumer's utility given by the standard measure of the gross consumer's surplus

$$S(q) = \int_0^q p(x)\, dx$$

- Notice that this implies

$$S'(q) = p(x)$$

- Alternatively, could use net consumer's surplus

$$V(q) = \int_0^q p(x)\, dx - p(q)\, q$$

The objective function of regulation (ctd)

Taxpayers

- Transfer to firm financed by public funds
- Raising public funds is inefficient
- cost of 1€ of public funds given by $1 + \lambda$ where $\lambda \geq 0$

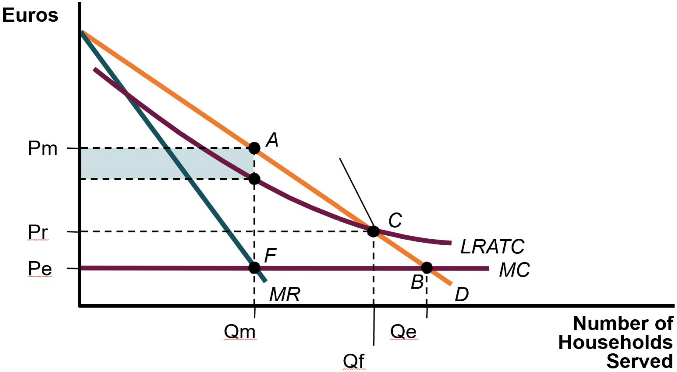
Overall, objective function of regulation is

$$\begin{aligned} W &= V(q) - (1+\lambda)t + \pi \\ &= S(q) - p(q)q - (1+\lambda)t + p(q)q + t - c(q) \\ &= S(q) - \lambda t - c(q) \end{aligned}$$

- the higher is λ, the more the regulator dislikes the transfer

Monopoly regulation

- Useful to start looking at the simplest case



Monopoly regulation

Assume the regulator is able to determine the behaviour of the regulated firm

Assume $c(q) = c\,q + F$

Equivalent expressions for social welfare

$$\begin{aligned} W &= V(q) - (1+\lambda)t + \pi \\ &= S(q) - \lambda t - c\,q - F \end{aligned}$$

Regulator's problem need to include also the firm's non-negativity constraint

$$p(q)\,q + t - c(q) \geq 0$$

Hence

$$\begin{aligned} &\max_{q,t} S(q) - \lambda t - c\,q - F \\ &\text{s.t. } p(q)\,q + t - c\,q - F \geq 0 \end{aligned}$$

Monopoly regulation with full info: marginal and average cost pricing

Recall

$$\max_{q,t} S(q) - \lambda t - c\,q - F$$
$$\text{s.t. } p(q)\,q + t - c\,q - F \geq 0$$

- If $\lambda = 0$ so that transfer has zero social cost
  - q^* is such that $S'(q^*) = p = c \rightarrow$ FIRST BEST
  - t^* solves the IR as an equality
- If $\lambda = \infty$ so that transfer cannot be used
  - p^* from the IR constraint such that $p(q^*) = \frac{c(q^*)}{q^*} \rightarrow$ AVERAGE COST PRICING
  - $t^* = 0$

Monopoly regulation with full info: Ramsey pricing

When $\lambda = \infty$, average cost pricing generalises to the case of more than 1 good

$$\max_{\mathbf{q}} S(\mathbf{q}) - c(\mathbf{q})$$
$$\text{s.t. } p(\mathbf{q}) \cdot \mathbf{q} - c(\mathbf{q}) \geq 0$$

- Optimal policy needs to trade-off the distortion in each market to ensure that IR constraint is satified
- q_i^*'s are such that

$$\frac{p_i(\mathbf{q}^*) - c_i'(\mathbf{q}^*)}{p_i(\mathbf{q}^*)} = -\frac{\mu}{1+\mu}\frac{1}{\tilde{\epsilon}_i}$$

  - μ is the Lagrange multiplier, which gives the social cost of the firm's non-negativity constraint; μ is the same for all goods
  - distortion for each good inversely related to demand elasticity, as in the unregulated monopoly case
  - $\tilde{\epsilon}_i$ is a measure of the demand elasticity
    - with independent goods, $\tilde{\epsilon}_i$ equal to own-price elasticity, ie $\tilde{\epsilon}_i = \epsilon_i$
    - with interdependent demand, $\tilde{\epsilon}_i$ equal to "superelasticity" $\tilde{\epsilon}_i = f(\epsilon_i, \epsilon_j, \epsilon_{ij}, \epsilon_{ji})$

Monopoly regulation with full info: Baron and Myerson model

Assume $\lambda \in (0, \infty)$ and recall

$$\max_{q,t} S(q) - \lambda t - c\,q - F$$

$$\text{s.t. } p(q)\,q + t - c\,q - F \geq 0$$

- Optimal policy need to trade-off the distortion in the output market against the distortion in public funds financing the transfer
- at optimal policy, since $\frac{dW}{dt} < 0$, t^* is set to make the non-negativity constraint to hold

$$t^* = \max\{c\,q^* + F - p(q^*)\,q^*, 0\}$$

- q^* is such that

$$\frac{p(q^*) - c}{p(q^*)} = -\frac{\lambda}{1+\lambda}\frac{1}{\epsilon}$$

  - λ is the shadow cost of public funds; if it is sufficiently low, optimal transfer t^* may be positive
  - distortion in the output market inversely related to demand elasticity, as in the unregulated monopoly case

Monopoly regulation with full info: Laffont and Tirole model

- Assume $\lambda \in (0, \infty)$
- Assume $c(q) = (c - e)q + F + \psi(e)$, where e is cost-reducing effort and $\psi(e)$ its monetary cost (with $\psi', \psi'' > 0$)
  - marginal cost is the result of an exogenous parameter c and an endogenous e choice variable
  - with asymmetric info, c will become an adverse selection parameter
  - with asymmetric info, e will become a moral hazard parameter
  - firms's profits may be written as

$$\pi = p(q)\,q + t - (c - e)\,q - F - \psi(e)$$

Monopoly regulation with full info: Laffont and Tirole model

The regulator' problem

$$\max_{q,t,e} S(q) - \lambda t - (c-e)\, q - F - \psi(e)$$
$$\text{s.t. } p(q)\, q + t - (c-e)\, q - F - \psi(e) \geq 0$$

- Since $\frac{dW}{dt} < 0$, t^* is set to make the non-negativity constraint to hold
- q^* and e^* are such that

$$\psi'(e^*) = q^* \qquad \frac{p(q^*) - (c - e^*)}{p(q^*)} = -\frac{\lambda}{1+\lambda}\frac{1}{\epsilon}$$

- Optimal effort equalises marginal cost and benefit of effort
- Quantity rule similar to the case of Baron and Myerson model

Regulation and asymmetric information

- We now look at the asymmetric information case, both for BM and LT model
- In BM
  - firm's cost is given by $C = cq + F$
  - marginal cost is stochastic: c is a draw from a discrete random variable whose possible realisations are c^l and c^h, with $c^l < c^h$ and $Prob(c = c^l) = \nu \in (0, 1)$
  - c and $C = cq + F$ not observed by the regulator
  - regulator is risk-neutral, firm is risk-averse
  - hypothesis allowing to focus on inefficiencies deriving from informational asymmetries on the firm's exogenous efficiency
- In LT
  - firm's cost is given by $C = (c - e)q + F$
  - marginal cost is stochastic: c is a draw from a discrete random variable whose possible realisations are c^l and c^h, with $c^l < c^h$ and $Prob(c = c^l) = \nu \in (0, 1)$
  - C is observed by the regulator, but c and e are not
  - regulator is risk-neutral, firm is risk-averse
  - hypotheses allowing to focus on inefficiencies deriving from informational asymmetries on the firm's exogenous efficiency <u>and</u> cost-reducing behaviour

Regulation and asymmetric information

- These models are cornerstones of contract theory: they are among the first being able to analyse meaningfully a principal-agent problem
- Solution is a menu of take-it-or-leave-it contracts among which the firm freely chooses, based on her true type/behaviour
- With BM, contracts are written in such a way the firm finds it optimal to
  - accept the contract aimed at her type, truthfully revealing it
- Solution is optimal thanks to the *revelation principle* which ensures that no other contract (ie not based on the truthful revelation of the hidden info) can do better than this.
- With LT, slightly more involved process, but same basic idea

Regulation and asymmetric information
Baron and Myerson

Regulator's problem

$$\max_{q^l,t^l,q^h,t^h} \nu\left(S(q^l) - c^l q^l - F - \lambda t^l\right) + (1-\nu)\left(S(q^h) - c^h q^h - F - \lambda t^h\right)$$

$$s.t. p(q^l)q^l - c^l q^l - F + t^l \geq 0 \tag{IR-l}$$

$$p(q^h)q^h - c^h q^h - F + t^h \geq 0 \tag{IR-h}$$

$$p(q^l)q^l - c^l q^l - F + t^l \geq p(q^h)q^h - c^l q^h - F + t^h \tag{IC-l}$$

$$p(q^h)q^h - c^h q^h - F + t^h \geq p(q^l)q^l - c^h q^l - F + t^l \tag{IC-h}$$

Regulation and asymmetric information
Baron and Myerson

- Easy to show that, when (IR-h) and (IC-l) hold as an equality, (IR-l) and (IC-h) are slack
  - the IR constraint holds "more easily" for a low-cost firm than for a high-cost firm
  - a low-cost firm gains by pretending to be a high-cost firm, but not viceversa
- Then, solve (IR-h) for t^h and (IC-l) for t^l and plug it into the objective function to obtain

$$t^h = c^h q^h + F - p(q^h) q^h$$
$$t^l = c^l q^l + F - p(q^l) q^l + q^h (c^h - c^l)$$

- High cost firm gets a transfer equal to its costs
- Low cost firm gets a transfer equal to its costs plus an informational rent to make sure it does not pretend to be high cost
  - this rent is equal to the benefit of pretending to be high cost !!!

Regulation and asymmetric information
Baron and Myerson

Using optimal t^l and t^h, the regulator's problem becomes

$$\max_{q^l,q^h} \nu \left(S(q^l) + \lambda p(q^l)q^l - \lambda q^h(c^h - c^l) - (1+\lambda)(c^l q^l + F) \right) +$$
$$+ (1-\nu) \left(S(q^h) + \lambda p(q^h)q^h - (1+\lambda)(c^h q^h + F) \right)$$

At the solution

- $\frac{dW}{dq^l}$ identical to the case of full info

$$\frac{p(q^l) - c^l}{p(q^l)} = -\frac{\lambda}{1+\lambda}\frac{1}{\epsilon^l}$$

same quantity as in full info: $\hookrightarrow$ NO DISTORTION AT THE TOP!

Regulation and asymmetric information
Baron and Myerson

Regulator's problem

$$\max_{q^l,q^h} \nu \left(S(q^l) + \lambda p(q^l)q^l - \lambda q^h(c^h - c^l) - (1+\lambda)(c^l q^l + F)\right) +$$
$$+ (1-\nu)\left(S(q^h) + \lambda p(q^h)q^h - (1+\lambda)(c^h q^h + F)\right)$$

At the solution

- firm l's expected gain when pretending to be firm h equal to $\nu\,(c^h - c^l)q^h$
- possible to reduce this informational rent by reducing q^h

$$\frac{p(q^h) - c^h}{p(q^h)} = -\frac{\lambda}{1+\lambda}\frac{1}{\epsilon^h} + \underbrace{\frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\frac{c^h - c^l}{p^h}}_{>0}$$

- $p(q^h)$ higher than under full information, then lower output for firm h. This quantity reduction is greater
  - the larger is the cost differential (hence the potential gain from cheating)
  - the more likely is the realisation of a low-cost firm
  - the more costly is the transfer

Regulation and asymmetric information
Laffont and Tirole model

Regulator's problem

$$
\begin{aligned}
\max_{q^l,t^l,e^l,q^h,t^h,e^h} \; & \nu\left(S(q^l)-(c^l-e^l)q^l-F-\psi(e^l)-\lambda t^l\right)+\\
& (1-\nu)\left(S(q^h)-(c^h-e^h)q^h-F-\psi(e^h)-\lambda t^h\right)\\
s.t. \;\; & p(q^l)q^l-(c^l-e^l)q^l-F-\psi(e^l)+t^l\geq 0 && \text{(IR-l)}\\
& p(q^h)q^h-(c^h-e^h)q^h-F-\psi(e^h)+t^h\geq 0 && \text{(IR-h)}\\
& p(q^l)q^l-(c^l-e^l)q^l-F-\psi(e^l)+t^l\geq\\
& \qquad p(q^h)q^h-(c^l-e^h)q^h-F-\psi(e^h)+t^h && \text{(IC-l)}\\
& p(q^h)q^h-(c^h-e^h)q^h-F-\psi(e^h)+t^h\geq\\
& \qquad p(q^l)q^l-(c^h-e^l)q^l-F-\psi(e^l)+t^l && \text{(IC-h)}
\end{aligned}
$$

Regulation and asymmetric information
Laffont and Tirole model

- Easy to show that, when (IR-h) and (IC-l) hold as an equality, (IR-l) and (IC-h) are slack
- Then, solve (IR-h) for t^h and (IC-l) for t^l and obtain

$$t^h = (c^h - e^h)q^h + F + \psi(e^h) - p(q^h)q^h$$
$$t^l = (c^l - e^l)q^l + F + \psi(e^l) - p(q^l)q^l + \psi(e^h) - \psi(e^h - (c^h - c^l))$$

- Last two terms in t^l are the informational rent to firm l, to be paid to make sure it does not pretend to be a high-cost firm

Regulation and asymmetric information
Laffont and Tirole model

Using optimal t^l and t^h, the regulator's problem becomes

$$\max_{q^l,e^l,q^h,e^h} (1-\nu)\Big(S(q^h)+\lambda p^h(q^h)q^h-(1+\lambda)((c^h-e^h)q^h+F+\psi(e^h))\Big)+$$
$$\nu\Big(S(q^l)+\lambda p^l(q^l)q^l-(1+\lambda)((c^l-e^l)q^l+F+\psi(e^l))+$$
$$-\lambda(\psi(e^h)-\psi(e^h-(c^h-c^l)))\Big)$$

At the solution

- $\frac{dW}{dq^l}$ and $\frac{dW}{dq^h}$ are identical to the case of full info

$$\frac{p(q^l)-(c^l-e^l)}{p(q^l)}=-\frac{\lambda}{1+\lambda}\frac{1}{\epsilon^l} \quad \text{and} \quad \frac{p(q^h)-(c^h-e^h)}{p(q^h)}=-\frac{\lambda}{1+\lambda}\frac{1}{\epsilon^h}$$

- $q^h<q^l$ and $p^h>p^l$
- same mark-up as in full info: $\hookrightarrow$ CLASSICAL DICHOTOMY!

Regulation and asymmetric information
Laffont and Tirole model

- Since $(c - e)$ is observable, effort e may be made part of the contract
- Contractual e^l and e^h are

$$\psi'(e^l) = q^l$$

$$\psi'(e^h) = q^h - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left[\psi'(e^h) - \psi'(e^h - (c^h - c^l))\right]$$

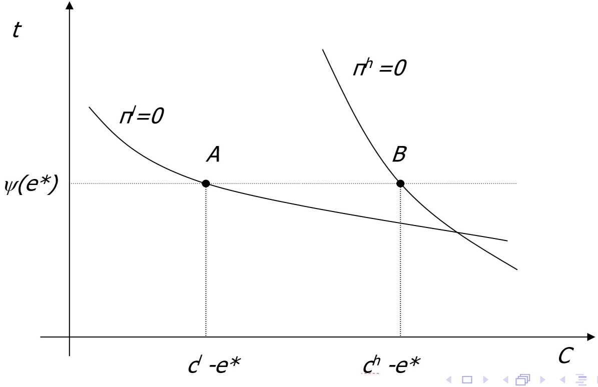
- optimal effort for a low-cost firm
- lower-than-optimal effort for a high-cost firm $\Rightarrow$ higher-than-optimal marginal cost $\Rightarrow$ lower-than-optimal quantity
- this distortion is greater
    - the higher is the probability that the firm is low-cost
    - the higher is the cost of public funds

Regulation and asymmetric information
Laffont and Tirole model

To illustrate, assume

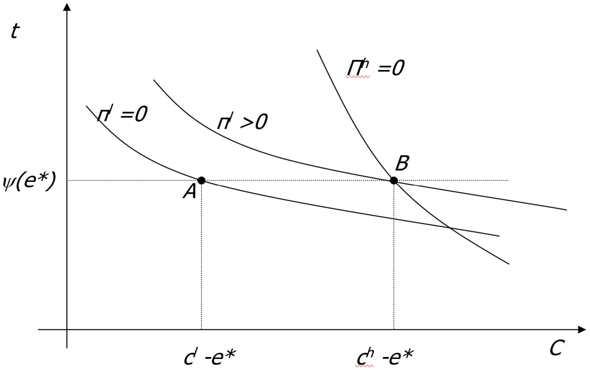
- Fixed-sized project S
- $F = 0$
- Fixed and variable cost fully reimbursed to the firm

With full info



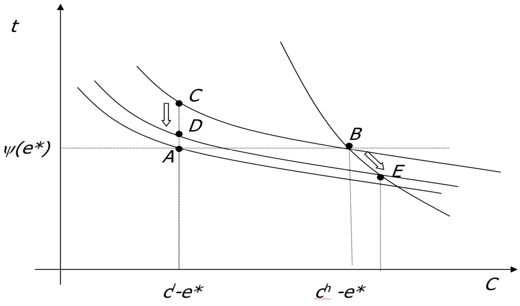
Regulation and asymmetric information
Laffont and Tirole model

Full info contracts are not incentive compatible



Regulation and asymmetric information
Laffont and Tirole model

under asymmetric info



- Contracts A e B NOT incentive compatible.
- Contracts A e C incentive compatible; however, they entail too large a rent to the low-cost firm
- Optimal contracts trade-off
  - the lower-than-optimal effort and higher-than-optimal cost by high-cost firm
  - the rent left to the low-cost firm

Regulation and asymmetric information
Linear contracts

- Optimal contracts may be expressed as contracts under which the transfer is a linear function of the realised cost

$$t^l = a^l - b^l C(c^l)$$
$$t^h = a^h - b^h C(c^h)$$

with $a^l < a^h$ and $|b^l| < |b^h|$

- Contracts are such that each firm self-select into the contract designed for its type
- For the low-cost firm
  - the fixed payment is small and the reimbursement of the cost is small
  - incentive to exert high effort since claimant of resulting profits
- For the high-cost firm
  - the fixed payment is large and most of the costs are reimbursed
  - little incentive to exert effort

Taxonomy of regulatory contracts

So far,

- Bayesian contracts
  - based on a priori information on the AI parameter and on the revelation of the private information

Useful?

- Literally speaking, not much...
- Real-life regulatory contract are typically non-Bayesian: NOT based on a priori information on the AI parameter and NOT on the revelation of the private information
- Why?
  - complexity
  - regulator's accountability: ν and λ are very soft information
- However, extremely useful to illustrate a few crucial points
  - information on adverse selection parameter is a valuable asset: regulated firm needs to be rewarded to give up this information
  - moral hazard is an issue: regulated firm must be given incentives to exert the socially optimal level of effort

Regulatory contracts

- Regulatory contracts can be seen as price setting rules
- Regulatory contracts have two main features:
  - Link between the price and the realised firm's cost
  - Possibility of a transfer to the firm, independent to the firm's cost
- Typical contract

$$p(C) = \bar{p} + (1 - b)\, C$$

  where C is realised total cost
  - $\bar{p}$ is an exogenously determined price, independent to the firm's cost
  - b is the link between the price and the firm's cost
- b is usually defined the power of the incentive contract
- $(1 - b)$ is the fraction of the firm's cost borne by the firm
  - When $b = 0$, COST-BASED CONTRACT
    - the firm's profits do not depend on costs, which are fully covered
  - When $b = 1$, CAP-BASED CONTRACT
    - realised cost reduction increase the firm's profits on a 1:1 proportion.

Taxonomy of regulatory contracts

Forms of regulatory contracts

Regulatory approach	
	Cost-based formulae
Cost-plus	$p_t = (1+m)C_{M(t-1)}$
Rate of return	$R_t = OPEX_{t-1} + AM_t + rK_{t-1}$
	Cap-based formulae
Price cap	$p_t = p_{t-1}(1 + RPI_t - X_t) + Z_t^p$
Revenue cap	$R_t = R_{t-1}\,(1 + RPI_t - X_t) + Z_t^R$
	Other formulae
Benchmarking/yardstick	$p_i = (1+m)\left(\sum_{j\neq i} \frac{C_{Mj}}{(n-1)}\right)$ or $p_i = (1+m)\left(\sum_{j\neq i} \frac{OPEX_j}{(n-1)}\right)$
Hybrid	$R_t = R_{t-1}\,(1 + RPI_t - X_t) + \alpha\left(\pi_{t-1} - \tilde{\pi}_{t-1}\right)$

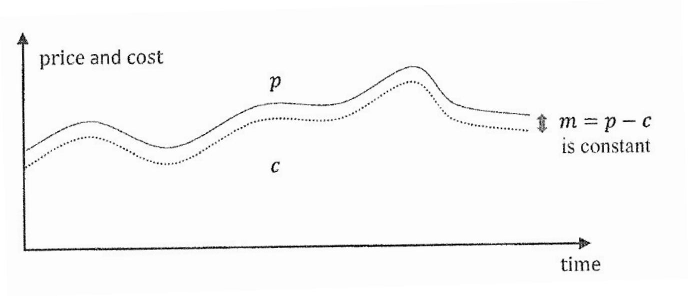
- *RPI* Retail Price Index
- X expected efficiency gain
- C_M average total cost
- *OPEX* average operating expenditure
- m allowed profit margin
- r allowed rate of return
- K value of assets
- Z extra cost

Cost-plus contract

$$p_t = (1 + m)C_{M,t-1}$$
$$R_t = OPEX_{t-1} + AM_t + rK_{t-1}$$

In terms of the previous classification

- $b = 0$, hence COST-BASED CONTRACT: the firm's profits do not depend on costs, which are fully covered



Cost-plus contract

Pros

- full insurance of firms and investors against all forms of uncertainty on cost and demand
  - some risk sharing may be optimal

Cons

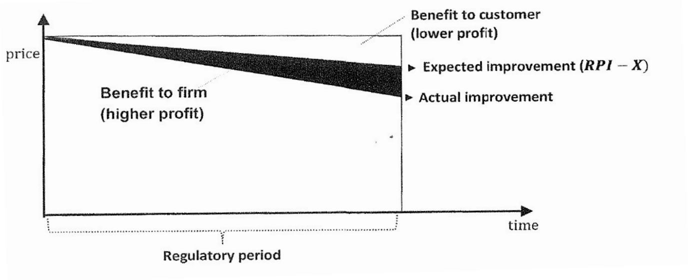
- no incentives to productive efficiency
- tricky definition of ‘fair’ rate of return
  - typically, Weighted Average Cost of Capital (WACC) and Capital Asset Pricing Model (CAPM)
- difficult definition of the value of the asset base
- incentive to overcapitalization (Averch-Johnson effect)

Cap-based contract

$$p_t = p_{t-1}(1 + RPI_t - X_t) + Z_t$$
$$R_t = R_{t-1}(1 + RPI_t - X_t) + Z_t$$

In terms of the previous classification

- $b = 1$, hence CAP-BASED (FIXED-PRICE) CONTRACT: realised cost reduction increase the firm's profits on a 1:1 proportion



Cap-based contract

$$p_t = p_{t-1}(1 + RPI_t - X_t) + Z_t$$
$$R_t = R_{t-1}(1 + RPI_t - X_t) + Z_t$$

Fixed price, but

- regulatory period
- adjustment for inflation
- adjustment for industry-wide and individual potential efficiency gains
- full coverage of some specific cost components
  - specific investment programmes
  - input cost
  - quality improvements

Cap-based contract

Pros

- full incentives to productive efficiency
- delegation of pricing decisions (see below)

Cons

- little control of informational rent
- zero insurance of firms and investors against uncertainty on demand and costs
  - some risk sharing may be optimal
- incentive to manipulate efficiency gains over regulatory periods
- allocative efficiency??
- investment risk (if investment cost are not included in the pass-through component)
- quality risk

Hybrid contracts

Yardstick regulation

$$p_t = (1+m)\frac{\sum_{j\neq i} AC^j_{t-1}}{n-1}$$

$$R_t = (1+m)\left[q^i_t \frac{\sum_{j\neq i} AC^j_{t-1}}{n-1}\right]$$

As in cost-plus contract, but based on average cost of similar firms
Pros

- full incentives to productive efficiency

Cons

- how similar are the similar firms?
- zero insurance of firms and investors against uncertainty
- allocative efficiency??

Price cap regulation for multiproduct firm

Ignore for the moment the other components of the price cap formula and focus on the constraint on prices

With a multiproduct firm, the price cap can only take the following form

$$I(\mathbf{p}) \leq I(\bar{\mathbf{p}})$$

where

- $I(.)$ a price index
- $\mathbf{p}$ the price vector chosen by the firm
- $\bar{\mathbf{p}}$ a reference price vector

The maximisation problem for the firm is now

$$\max_{\mathbf{p}} \pi(\mathbf{p})$$
$$s.t.\ I(\mathbf{p}) \leq I(\bar{\mathbf{p}})$$

What form for $I(\mathbf{p})$??

Price cap regulation for multiproduct firm
Tariff basket approach

Consider the price index $I(\mathbf{p}) = V(\mathbf{p})$, where $V(\mathbf{p})$ is the indirect utility function of the representative consumer

Under this constraint, the firm's problem is

$$\max_{\mathbf{p}} \pi(\mathbf{p})$$

$$s.t. \; V(\mathbf{p}) \geq V(\bar{\mathbf{p}})$$

This constraint induces Ramsey price for $\pi(\mathbf{p}) \geq \pi(\bar{\mathbf{p}})$

Indeed, the firm's problem is the dual problem of a social welfare maximisation problem

$$\max_{\mathbf{p}} V(\mathbf{p})$$

$$s.t. \; \pi(\mathbf{p}) \geq \pi(\bar{\mathbf{p}})$$

However,

- High informational requirements
- Socially costly profits not under control

Price cap regulation for multiproduct firm
Tariff basket approach

It is possible to keep the advantages of delegation but reduce the informational requirements?

$$\mathbf{p} \cdot \mathbf{q}(\bar{\mathbf{p}}) \leq \bar{\mathbf{p}} \cdot \mathbf{q}(\bar{\mathbf{p}})$$

where "$\cdot$" indicates the dot product between vectors
In a two-dimensional world, the constrains is a line going through the price vector $\bar{\mathbf{p}}$ and with slope equal to the ratio between the quantities exchanged at $\bar{\mathbf{p}}$.

- Linear approximation of the constraint $V(\mathbf{p}) \geq V(\bar{\mathbf{p}})$!!!
  - ... but even more stringent

Properties

- Low informational requirements: only need to know quantities demanded at $\bar{\mathbf{p}}$!!!
- BUT no Ramsey prices

Price cap regulation for multiproduct firm
Tariff basket approach

Try to exploit the dynamic nature of regulatory contracts in order to

- further reduce the informational requirements
- increase the allocative efficiency properties

Assume

- infinitely lived firm and regulator
- firm choosing prices in each period
- regulatory constraint in each period
- myopic firm

A dynamic version of the tariff basket constraint makes the firm's problem as follows

$$\max_{\mathbf{p}^t} \pi(\mathbf{p}^t)$$
$$s.t.\ \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^{t-1}) \leq \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1})$$

Price cap regulation for multiproduct firm
Tariff basket approach

$$\max_{\mathbf{p}^t} \pi(\mathbf{p}^t)$$
$$s.t.\ \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^{t-1}) \leq \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1})$$

- As before, the constraint is an approximation of a constraint on consumer's surplus
- As before, this constraint is more stringent than the one on consumer's surplus
- Consumer's surplus increases in each period (and the firm's profit cannot be reduced)

Using standard properties of series, can prove that the series of prices converges

Price cap regulation for multiproduct firm
Tariff basket approach

$$\max_{\mathbf{p}^t} \pi(\mathbf{p}^t)$$

$$s.t.\ \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^{t-1}) \leq \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1})$$

Since the series of prices converges, focus on lung-run equilibrium

- Isowelfare tangent to the constraint (because of convergency)
- Isoprofit tangent to the constraint (because of profit maximisation)

$\hookrightarrow$ isowelfare tangent to the isoprofit, ie Ramsey prices !!!
Intuitively, consumer's surplus increases over time, but cannot do so indefinitely.
Need to reach its maximum, ie Ramsey prices
However, no control on firms profits

Price cap regulation for multiproduct firm
Tariff basket approach

To reduce the firm's profits, need to tighten the constraint over time (Vogelsang and Finsinger, 1979)
By doing so, run the risk of forcing it to negative profits
Imagine now a constraint such that the firm's problem is

$$\max_{\mathbf{p}^t} \pi(\mathbf{p}^t)$$
$$s.t.\ \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^{t-1}) \leq C(\mathbf{q}(\mathbf{p}^{t-1})) = \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1}) - \pi(\mathbf{p}^{t-1})$$

In each period of time t, given the previous period prices $\mathbf{p}^{t-1}$,

- The constraint has a slope equal to the slope of $V(\mathbf{p}^{t-1})$;
- Shifts towards the origin of the axis in proportion to the rate of profits at time $t-1$

Price cap regulation for multiproduct firm
Tariff basket approach

$$\max_{\mathbf{p}^t} \pi(\mathbf{p}^t)$$
$$s.t.\ \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^{t-1}) \leq C(\mathbf{q}(\mathbf{p}^{t-1})) = \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1}) - \pi(\mathbf{p}^{t-1})$$

Using standard results on series, can prove that the series of prices converges
In the long run equilibrium

- $\mathbf{p}^{t-1} = \mathbf{p}^t \hookrightarrow$ the slope of the constraint at time t is equal to the one at time t–1
- $\pi(\mathbf{p}^{t-1}) = 0 \hookrightarrow$ the intercept of the constraint at t is equal to the one at time $t-1$
- ... and the firm does not change its prices
- Isowelfare tangent to the constraint (because of convergency)
- Isoprofit tangent to the constraint (because of profit maximisation)

Then, isowelfare tangent to the isoprofit at $\pi(.) = 0$ and convergency to RAMSEY PRICES !!!

Price cap regulation for multiproduct firm
Tariff basket approach

VF ensures a long run equilibrium with Ramsey prices without transfer and with no information other than on historical accounts!!!
Hp needed:

- Decreasing ray average cost (a form of IRS, technical)
- Myopic firm (can relax)
- Stable demand and exogenous cost (critical)

If demand can vary over time:

- firm can exploit at time t its knowledge of demand at time $t-1$ and make price not converge to Ramsey price any more

With endogenous cost and not myopic firm, paradoxical results

- firm prefers to be inefficient
- reduction in long run welfare

Price cap regulation for multiproduct firm
Revenue approach

Alternative form of the price index

$$R(\mathbf{p}^t) = \mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^t) \leq \mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1}) = R(\mathbf{p}^{t-1})$$

or

$$\frac{R(\mathbf{p}^t)}{q_i^t} = \frac{\mathbf{p}^t \cdot \mathbf{q}(\mathbf{p}^t)}{q_i^t} \leq \frac{\mathbf{p}^{t-1} \cdot \mathbf{q}(\mathbf{p}^{t-1})}{q_i^{t-1}} = \frac{R(\mathbf{p}^{t-1})}{q_i^{t-1}}$$

Some differences with respect to the tariff basket approach

- Some insurance to firm and investors against demand risk
  - possible to pass on prices an unanticipated reduction in demand
- Symmetrically, no incentive to increase demand
- Unclear theoretical properties

The X factor (no, not the one you see on TV)

How to assess the expected efficiency gains on which the X factor is based

Three main methodologies

- price or quantity indexes
  - typically, input/output ratios
  - eg Tornqvist index: weighted geometric average of the relative quantity in two different periods, with weights given by the simple average of the value shares in these two periods
- Data Envelopment Analysis (DEA)
  - linear programming method that constructs a non-parametric production frontier by fitting a piece-wise linear surface over the observed data on outputs and inputs
  - distance to the frontier illustrates the degree of inefficiency
  - useful to identify both productive and allocative inefficiency (in production)

The X factor (no, not the one you see on TV)

How to assess the expected efficiency gains on which the X factor is based

Three main methodologies

- Stochastic frontier analysis (SFA)
  - econometric methods to estimate production or cost function
  - inefficiency measure derived from the analysis of the error term
  - deterministic portion of the specification represents the efficient output/cost frontier
  - error term with two components
    - inefficiency term measuring the systematic departure from the estimated frontier

Regulation and social concerns

Typically,

- regulators are given the objective of providing for the needs of low-income consumers
- at the very least, regulators are concerned with the distributional effects of the actions
- also, regulators are given the objective of taking care of some specific social value of the regulated goods
  - with externalities, both firms and consumers cannot perceive the correct social value of a regulated good
    - electricity, postal services, broadband access

When the focus is on distributional effects, two main issues

- access
- affordability

Main problems

- choosing the target
- choosing the appropriate instrument

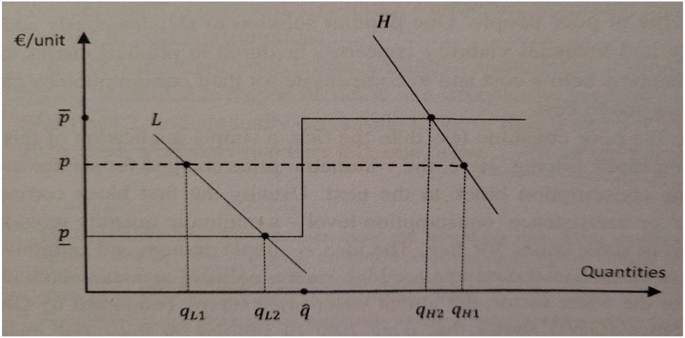
An example: block pricing

- Efficient prices at levels allowing full cost recovery may be unaffordable to poor people
- Assume
  - Two types of consumers, L and N, with demand $q_L(p)$ and $q_H(p)$
  - At any p, $q_L(p) < q_H(p)$
  - Numerosity n_L and n_H
  - Income of consumers L lower than income of consumers H
- Possible solutions: increasing block pricing

$$T(q) = \begin{cases} \underline{p}q & \text{if } q \leq \hat{q}; \\ \underline{p}\hat{q} + \overline{p}q & \text{if } q > \hat{q} \end{cases}$$

An example: block pricing

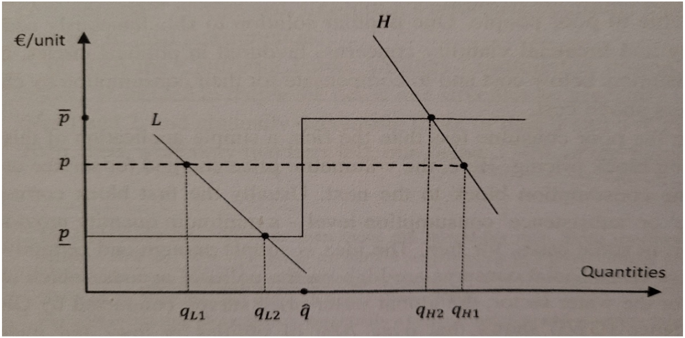
- Assume firm breaks-even at p



Effects on

- Expenditure and demand for each group
- Aggregate demand
- Total revenues: cross-subsidy

An example: block pricing



Possible adverse effects

- What if higher demand is by low income groups?
- Possible increase of total quantities
- Effect of the distortion in each market?

General social objectives

Several instruments

Most relevant: price subsidies

- Final prices not covering the investment costs, but part or all of the operating cost

Applied in many industries, for different reasons

- Water and sanitation: health objectives
- Railways: environmental objectives
- Transport: congestion management and environmental objectives

General social objectives

Tab. III.1 – Corrispettivi e contributi in c/esercizio al gruppo FS 1992-2013 (milioni di euro)

	Contributi c/corrente esercizio della rete ferroviaria	Corrispettivi per obblighi di servizio e tariffari			Utilizzo fondo ristrutt. per esodi anticipati	Altri contributi in c/esercizio	**Totale in c/esercizio**
		Dallo Stato	Dalle Regioni	Totali			
1992	1.808	2.221		2.221		31	4.059
1993	2.515	1.218		1.218	1.054	3	4.790
1994	2.523	1.323		1.323	89	436	4.371
1995	2.437	1.432		1.432	472	97	4.438
1996	2.524	1.452		1.452	89	4	4.068
1997	391	1.436		1.436	98	7	1.931
1998	1.692	1.510		1.510	16	7	3.225
1999	1.431	1.512		1.512	100	17	3.060
2000	1.450	1.613		1.613	92	124	3.278
2001	1.478	527	1.273	1.800		66	3.344
2002	1.453	481	1.274	1.755		29	3.237
2003	382	481	1.298	1.778		20	2.181
2004	1.304	481	1.311	1.792	39	21	3.157
2005	1.289	481	1.331	1.812	96	57	3.253
2006	902	367	1.348	1.715	66	71	2.753
2007	1.154	568	1.636	2.204		44	3.402
2008	1.041	599	1.712	2.311		123	3.475
2009	849	533	1.853	2.386			3.235
2010	975	542	1.551	2.093			3.069
2011	975	539	1.513	2.052			3.027
2012	1.110	514	1.508	2.022			3.133
2013	1.050	490	1.532	2.022			3.072
Totale 1992-2013							**73.558**
Media annua							3.344

Fonte: elaboraz. su dati Relaz. di bilancio FS (1992-95) e Relaz. Corte dei Conti su bilanci FS (1996-2013).

Specialised social objectives

Two main issues

- affordability: expenditure not larger than a given share of the consumer' budget
- access: access to consumption of the good/service

Affordability

- targeting consumers whose expenditure is larger than a given share of their budget

Targeting mechanisms

- categorical/group
  - demographical
  - geographical
- individual
  - means-tested
  - community-based
- self-selection

Specialised social objectives

Problem with access

- definition of prices and subsidies
  - Example: two part tariff and subsidies for targeted consumers (source of finance?)
- service obligations
  - Auctioned to an existing operator (source of finance?)
  - what quality?
- quality

Quality regulation

Quality is a slippery concept

- multidimensional
- observed vs perceived
- vertical vs horizontal
- exogenous vs endogenous
- input vs output measurement
- verifiable vs unverifiable
- timing of observability
    - search attributes
    - experience attributes
    - credence attributes

Socially and privately optimal quality

- z is actual quality
- $\bar{z}$ is perceived quality
- demand is $p(q, \bar{z})$
- quality is costly: $c(q, z)$, with $c_z > 0$
- Profits are

$$\pi(q, z, \bar{z}) = p(q, \bar{z})\, q - c(q, z)$$

- Social welfare is

$$W = V(q, \bar{z}) + \pi(q, z, \bar{z}) = S(q, \bar{z}) - c(q, z)$$

Socially and privately optimal quality

$$\pi(q, z, \bar{z}) = p(q, \bar{z})\, q - c(q, z)$$

$$W = V(q, \bar{z}) + \pi(q, z, \bar{z}) = S(q, \bar{z}) - c(q, z)$$

- Assume $z \neq \bar{z}$
- Since $\pi_z(.) = -c_z(.)$, privately optimal quality is zero

Socially and privately optimal quality

$$\pi(q, z, \bar{z}) = p(q, \bar{z})\, q - c(q, z)$$
$$W = V(q, \bar{z}) + \pi(q, z, \bar{z}) = S(q, \bar{z}) - c(q, z)$$

- Assume $z = \bar{z}$
- Privately optimal quality satisfies

$$p_z(q, z)q = c_z(q, z)$$

- Socially optimal quality satisfies

$$S_z(q, z) = c_z(q, z)$$

  - Monopolist interested to the marginal consumer only
  - Planner interested to inframarginal consumers too
- Monopolist may under or over provide quality

Baron and Myerson with verifiable quality
Full information

Assume

$$c(q, z) = cq + z$$

Firm's profits

$$\pi(q, z) = p(q, z)\, q - c\, q - z + t$$

Consumers' surplus

$$V(q, z) = S(q, z) - p(q, z)\, q$$

Social welfare

$$W = V(q, z) + \pi(q, z) - (1 + \lambda)t = S(q, z) - c\, q - z - \lambda t$$

Transfer is socially costly, so that t is at the lowest value

$$t = c\, q + z - p(q, z)\, q$$

and Social welfare

$$W = S(q, z) - (1 + \lambda)(c\, q + z) + \lambda p(q, z)\, q$$

Baron and Myerson with verifiable quality
Full information

At the solution, since transfer is socially costly, then t is set at the lowest value

$$t = c\,q + z - p(q,z)\,q$$

so that social welfare becomes

$$W = S(q,z) - (1+\lambda)(c\,q + z) + \lambda p(q,z)\,q$$

Solving for q and z

$$\frac{p-c}{p} = \frac{\lambda}{1+\lambda}\frac{1}{\epsilon(q,z)}$$

and

$$S_z(q,z) + \lambda p_z(q,z)\,q = 1 + \lambda$$

Baron and Myerson with verifiable quality
Asymmetric information

Assume, as usual, $c \in \{c^l, c^h\}$ and not observed by the regulator

Quality is contractible, hence can be made part of the contract

Usual constraints IC-l and IR-h reduce to

$$t^h = c^h q^h + z^h - p(q^h, z^h) q^h$$
$$t^l = c^l q^l + z^l - p(q^l, z^l) q^l + q^h (c^h - c^l)$$

As before

- High cost firm gets a transfer equal to its costs
- Low cost firm gets a transfer equal to its costs plus an informational rent to make sure it does not pretend to be high cost

Baron and Myerson with verifiable quality
Asymmetric information

New regulator's problem

$$\max_{q^l,q^h,z^l,z^h} \nu \left(S(q^l,z^l) + \lambda p(q^l,z^l)q^l - \lambda q^h(c^h - c^l) - (1+\lambda)(c^l q^l + z^l) \right) +$$
$$+ (1-\nu) \left(S(q^h,z^h) + \lambda p(q^h,z^h)q^h - (1+\lambda)(c^h q^h + z^h) \right)$$

Optimal quality is as in full information

$$S_z(q^i,z^i) + \lambda p_z(q^i,z^i)\, q^i = 1 + \lambda \text{ for } i = l, h$$

- crucially depends on simple functional form for quality
- at equilibrium: $z_q > 0$: quality increases with quantity

Baron and Myerson with verifiable quality
Asymmetric information

New regulator's problem

$$\max_{q^l,q^h,z^l,z^h} \nu \left(S(q^l,z^l) + \lambda p(q^l,z^l)q^l - \lambda q^h(c^h - c^l) - (1+\lambda)(c^l q^l + z^l) \right) +$$
$$+ (1-\nu) \left(S(q^h,z^h) + \lambda p(q^h,z^h)q^h - (1+\lambda)(c^h q^h + z^h) \right)$$

Optimal quantity rule for the low-cost firm is as in full information

$$\frac{p(q^l,z^l) - c^l}{p(q^l,z^l)} = -\frac{\lambda}{1+\lambda}\frac{1}{\epsilon(q^l,z^l)}$$

- Since quality is also at the first best level, SAME quantity as in full info
- $\hookrightarrow$ NO DISTORTION AT THE TOP!

Baron and Myerson with verifiable quality
Asymmetric information

New regulator's problem

$$\max_{q^l,q^h,z^l,z^h} \nu\left(S(q^l,z^l)+\lambda p(q^l,z^l)q^l-\lambda q^h(c^h-c^l)-(1+\lambda)(c^lq^l+z^l)\right)+$$
$$+(1-\nu)\left(S(q^h,z^h)+\lambda p(q^h,z^h)q^h-(1+\lambda)(c^hq^h+z^h)\right)$$

Optimal quantity rule for the high-cost firm

$$\frac{p(q^h,z^h)-c^h}{p(q^h,z^h)}=-\frac{\lambda}{1+\lambda}\frac{1}{\epsilon(q^h,z^h)}+\underbrace{\frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\frac{c^h-c^l}{p^h}}_{>0}$$

- as with fixed quality, $q^h < q^l$ and $p^l < p^h$
- as a result, $z^h < z^l$

Baron and Myerson with unverifiable quality

- Things are much more complex with unverifiable quality
- Quality cannot contracted upon, then the regulator need to resort to quantity and price instruments
- regulator's task made difficult by the fact she does not know the direction of the distortion due to the firm's choices
    - monopolist may under or over provide quality

Quality regulation in practice

With a cost-plus contract

- firm has an incentive to overprovide quality if
  - quality is fully perceived by consumers
  - quality is reflected in the firm's cost
- this may results in
  - higher costs
  - higher prices
  - affordability problems

Quality regulation in practice

With a price-cap contract

- firm has an incentive to underprovide quality
  - unless low quality reduces demand too much
- Possible policy to regulate quality

$$p_t = p_{t-1}(1 + RPI_t - X_t) + Z_t$$

  where Z_t is quality index
  - the higher is Z_t, the higher is the price allowed to the firm

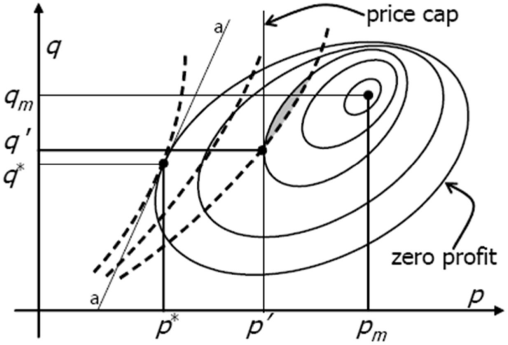
Additional instruments are quality standards

- individual: compensation to the damaged consumer in case of failure to meet the standard
- general: fines in case of failure to meet the standard

Problems with quality standards

- what is the right level? difficult to set in case of asymmetric information
- difficult to cover all the relevant dimensions of quality
- how to set the level of the compensation?
- unwanted rigidity and strategic play of standards
  - firm's cost
  - damage to consumer(s)

Issues with quality-augmented price cap



In the picture

- q_j is quality along dimension j
- privately optimal oversupply of quality
- possible Pareto improvements starting from quality standard

Issues with quality-augmented price cap

Possible to mirror the VF mechanism and deal with quality as if one was dealing with prices

The quality-adjusted VF constraint. *In each period, the firm must choose a price-quality vector satisfying:*

$$\frac{\mathbf{x}^{t-1} \cdot \mathbf{p}^{t}}{\mathbf{x}^{t-1} \cdot \mathbf{p}^{t-1}} \leqslant 1 - \left(\frac{\pi^{t-1}}{R^{t-1}} - \frac{\mathbf{u}^{t-1} \cdot \left(\mathbf{q}^{t} - \mathbf{q}^{t-1}\right)}{R^{t-1}} \right), \tag{11}$$

where $\mathbf{u}^{t-1} = \left(u_1^{t-1}, \ldots, u_m^{t-1}\right)$ *and*

$$u_j^{t-1} = \frac{\partial v\left(\mathbf{p}^{t-1}, \mathbf{q}^{t-1}\right)}{\partial q_j} \qquad j = 1, \ldots, m, \qquad t = 1, \ldots. \tag{12}$$

- quantity of good i denoted by x_i
- the firm's quality choices are treated in the same way as prices in VF

Issues with quality-augmented price cap

The quality-adjusted VF constraint. *In each period, the firm must choose a price-quality vector satisfying:*

$$\frac{\mathbf{x}^{t-1} \cdot \mathbf{p}^{t}}{\mathbf{x}^{t-1} \cdot \mathbf{p}^{t-1}} \leqslant 1 - \left(\frac{\pi^{t-1}}{R^{t-1}} - \frac{\mathbf{u}^{t-1} \cdot (\mathbf{q}^{t} - \mathbf{q}^{t-1})}{R^{t-1}} \right), \qquad (11)$$

where $\mathbf{u}^{t-1} = \left(u_1^{t-1}, \ldots, u_m^{t-1}\right)$ *and*

$$u_j^{t-1} = \frac{\partial v\left(\mathbf{p}^{t-1}, \mathbf{q}^{t-1}\right)}{\partial q_j} \qquad j = 1, \ldots, m, \qquad t = 1, \ldots. \qquad (12)$$

- Slope of the hyperplane constraint given by the vector of first derivatives of the welfare function w.r. to the firm's choices
  - w.r. to prices, these are quantities, due to Roy's identity
  - w.r. to quality, these are the marginal benefit of that quality dimension, not easy to compute though
- if the welfare function is quasi-convex, the above constraint lead to a sequence of price-quality choices which converges to a Ramsey price-quality vector with zero profits
- crucial result:
  quality adjustments need to based on consumers' perceptions on the effect of quality variations and not on the firm's cost of quality