608: Economics of Regulation

Lecture 4: Natural Monopoly Regulation
Part – I: Pricing Strategies

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Outline

- Natural Monopoly pricing problem
- Single Product case
  - Linear Pricing
  - Non-linear Pricing
- Multi-product monopolists
  - Ramsey Pricing
- Basic understanding of Imperfect Information
  - Unknown Costs - Loeb-Magat
  - Baron-Myerson model

Readings

- Armstrong et al 2003, Sections 2.1.1, 2.1.2, 2.1.3; 2.2.1, 2.2.2. (Sections 2.3, 3.1 and 3.3 we will do later)
- Baldwin et al (2012), Chapter 22
- VVH 2005, Chapter 11
- You can also read Baron-Myerson (82) original paper

Natural Monopoly Pricing Strategies

- Is it really a natural monopoly?
  - **Do nothing**, if potential monopoly power is not great, eg. cable tv
- **Linear pricing**
- **Two part tariffs**
- **Loeb-Magat proposal**
- **Franchise Bidding** e.g. Cable TV
- **Ramsey Pricing** e.g. telephone service?
- **Public Enterprise** e.g. MBTA

Aim of the regulation game (reminder)

- **Regulator** wants level of output, price, quality, innovation, cost-reducing effort to **maximise welfare**.
  - – Aim for allocative, technical and dynamic efficiency
- Regulator can't deliver the outcome himself. Needs firm to do it.
- But **firm** wants level of output, price, quality, innovation, cost-reducing effort that **maximises profit**.

What contract can the regulator (the principal) offer the monopoly firm (the agent) to ensure the firm delivers the regulator's objective?

- What the regulator can do depends on the information that he has and on the industry characteristics.

Let's assume….. three cases

Market environmental set-up –

- There's a benevolent regulator
- Firm is a natural monopoly
  - – AC(Q) declining as output increases
- Both Regulator and firm have perfect information about –
  - demand and production technology (hence costs)

- Let's think of three cases:
  - **(A)** Firm produces one product and
    regulator can pay a transfer to the firm.
  - **(B)** Firm produces one product and
    regulator can't pay a transfer to the firm.
  - **(C)** Firm produces multiple products and
    regulators can't pay a transfer to the firm.

Single Product Case:

Pricing Strategy 1: Linear Pricing

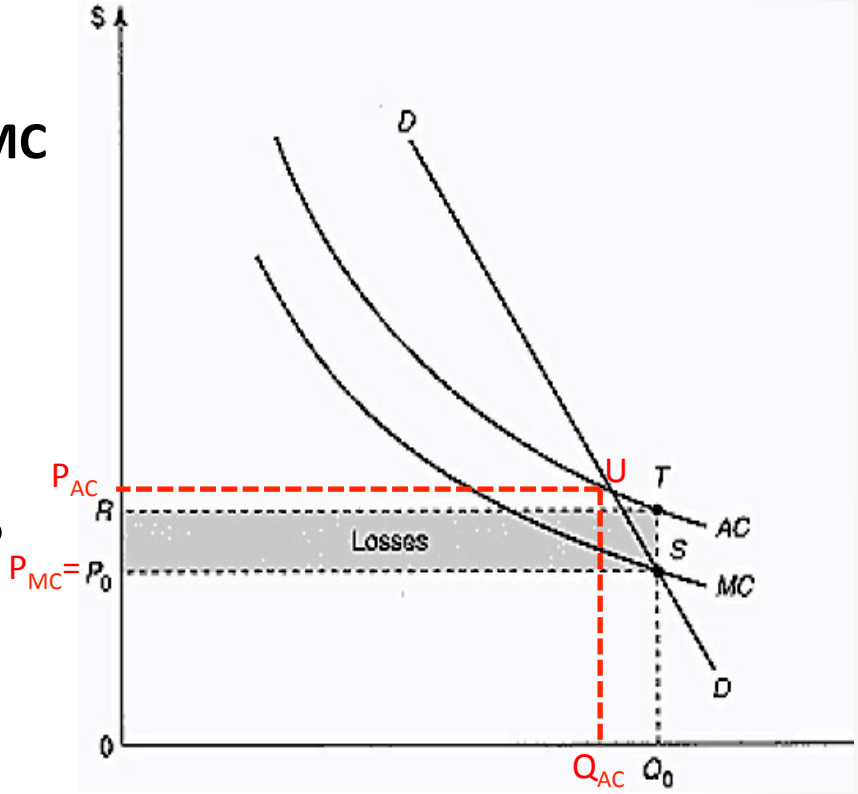
- **Max π(P,Q)**
  - **Operate where MR=MC, p>MC**
  - **What's the problem?**
- **Dillemma 1 -**

  P=AC or P=MC?
- **Max W(P,Q)=CS(P,Q)+π(P,Q)**

  => Allocative efficiency at **P=MC**

  But how are losses to be funded?

Raise some lump-sum tax (non -distortionary) to pay the subsidy.



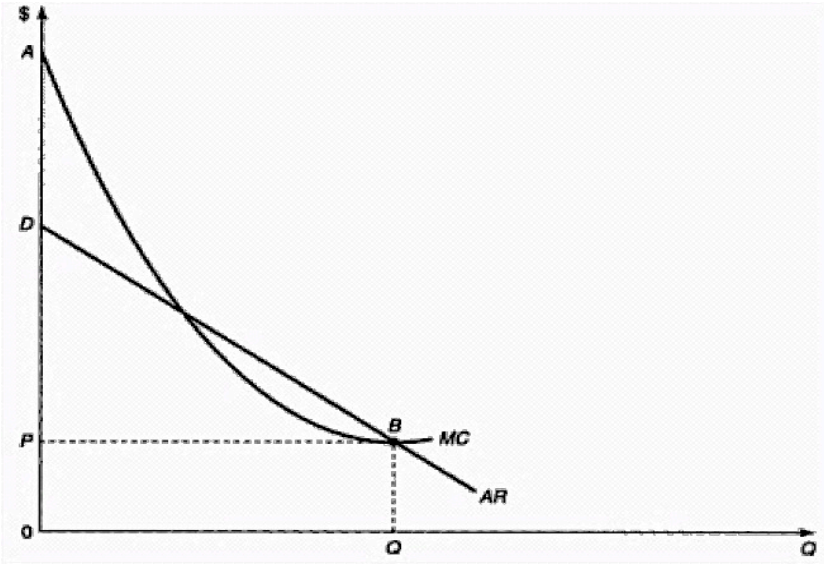
- **Dillemma 2 –**

If we have a private firm how does regulator know costs?

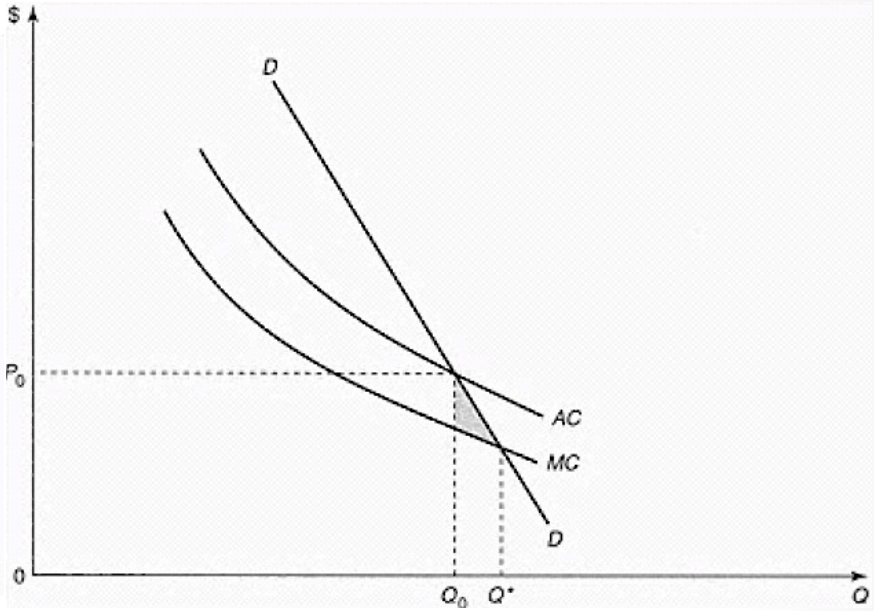
- Loeb-Magat case?

- **A linear price is such that buyer pays a single price/unit and thus buyer's total expenditure is proportional to total consumption.**

Issues with linear Pricing



Natural Monopoly with Costs exceeding Benefits



Welfare Loss with Average Cost Pricing

Linear Price when – Case 1
The regulator can (costlessly) pay a transfer…

Max W(P,Q,T)

$$C(Q) = cQ + F$$

$$P(Q) = a - Q$$

$$CS(Q) = \int_{p}^{p^{\max}} P(Q)\,dQ = \frac{Q^2}{2}$$

$$\pi(P,Q) = P(Q) \times Q - cQ - F + T = (a-c)Q - Q^2 - F + T$$

Maximise welfare subject to constraint that firm must break-even at least

$$\max_{Q,T} \; W(P,Q,T) = CS(Q) + \pi(Q,T) s.t. \pi(Q,T) \geq 0$$

$$\frac{\delta W}{\delta Q} = \frac{\delta CS}{\delta Q} + \frac{\delta \pi}{\delta Q} = a - c - Q = 0$$

$$\Rightarrow P(Q) = c$$

$$\Rightarrow \pi(Q,T) = cQ - cQ - F + T = 0 \text{ if T=F}$$

Result: P=MC and pay transfer (subsidy) to cover fixed costs

Issues with Linear (or uniform) marginal cost pricing

- It is Socially efficient but the enterprise exhibits losses
- Subsidy is needed, but

  where the subsidy is to come from and what effect this will have on economic efficiency?

1. If total costs are not covered by consumer expenditures , it is possible that total consumer benefits are less than total costs which means that the good should not be produced at all
2. As the firm's management knows losses will be subsidized, the incentive and capacity to control costs is weakened (e.g. Postal Service vis-à-vis Steel Industry)
3. Non-byers of the natural monopoly good should not be required to subsidize the marginal cost buyers
4. Since many public utilities are privately owned firms, it is politically unrealistic to imagine government to subsidizing the losses of private firms

Linear Price when – Case 2. the regulator can't pay a transfer…..

Max W(P,Q,T) subject to $\pi(P,Q) \geq 0$

Proof (by contradiction):

- P<AC: firm making loss and won't operate
- P>AC: can reduce price a little, closer to MC (P>AC>MC), and increase welfare (increase CS greater than reduction in profit)

With increasing returns, P=AC is the lowest price at which firm won't make a loss.

- Trading off some allocative efficiency to ensure good is produced.
- This result holds, even if put weight ($\alpha<1$) on profit in the welfare function.

Result: P = AC (> MC)

Pricing Strategy 2: Nonlinear pricing when - (the regulator can't pay a transfer…..)

Max W(P, Q) subject to π(P, Q) ≥ 0

- What is a two-part tariff?
  - – Pay fixed fee (e.g. monthly contract fee for mobile)
  - – Pay per unit charges (e.g. additional call charges)
  - – Unit charge **could** equal marginal cost.
- With homogenous consumers, consumer surplus becomes:
  - **CS(Q, A) = CS(Q) – A** , A is fixed fee
- Firm Profit becomes: **π(Q, A) = P(Q).Q – c.Q – F + A**
- Regulator maximises: **W(Q, A) = CS(Q, A) + α.π(Q, A)**
- Optimum solution is: **A = F and P(Q) = MC** **[:**Deduce the soln]
- With heterogenous consumers, for example some low demand and some high demand, need to design range of non-linear tariffs to balance allocative efficiency with desire to encourage consumer participation in market (i.e. CS(Q) – A ≥ 0)

Result: Two-part tariff: T(Q) = A + p.Q

Issues with Nonlinear Pricing

- Problems:
  - **Uniform/Nondiscriminatory** Fixed charge may discourage some people from taking service at all.
  - Some consumers are driven out from the market if the fee exceeds their individual CS at the point P=MC
  - Hence efficiency loss, as these customers might have been willing to pay price/unit at MC (without the fixed fee)
    - Can guess, Low end or high end customers?
- Solutions:

  1) **Discriminatory** two-part tariffs: different fixed fees to different consumers; cross-subsidise low users. Illegal?

  2**) Optimal two-part tariff** : a price/unit that exceeds marginal cost and a fixed fee that excludes some consumers from the market

Nonlinear pricing: Other cases…
1. Multipart tariffs or declining-block tariffs

Example: Local telephone service

Uniform Fixed fee per month: Rs 5

+10p per call for up to 100calls

+5p per call for all calls between 100 to 200

+0p per call for all calls above 200

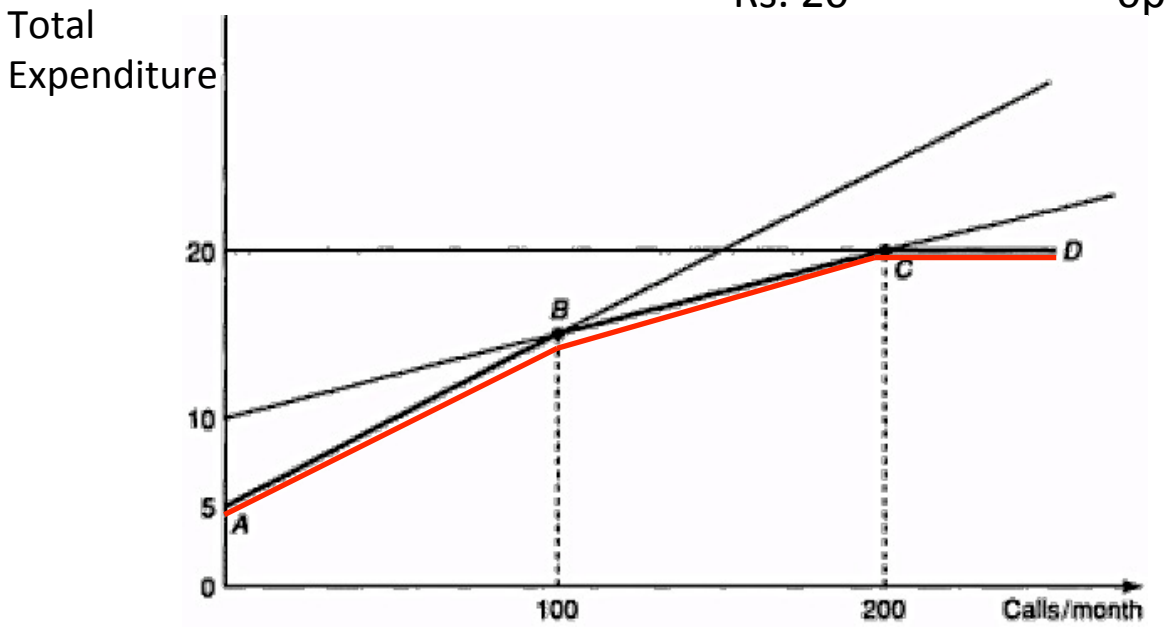
- Marginal price falls as one moves to successively larger calling "blocks"
- Economies of scale, falling marginal prices stimulate consumption
- Self-selecting set of the two-part tariffs; no consumers are excluded

2. Multi-part tariff for local telephone

- Consumers with high willingness to pay will pay high fixed fees in return for low prices/unit
- Discriminatory fixed fee

Three "self-selecting" two-part tariffs

Fixed Fee	Price/unit
Rs. 5	10p
Rs. 10	5p
Rs. 20	0p



Multi-product case: Heterogeneous demand Value-based (or Ramsey) pricing

- It is applicable to **multiple-product** natural monopolist that would generate losses if linear marginal cost pricing were used.
- Linear prices that satisfy the total revenues equal total cost constraint and minimize the deadweight welfare losses
- It involves margins being different on different products, but fixed on each individual product
- Margins on good in relatively elastic demand should be lower than those on relatively inelastic demand (high intensity to use)
- The Ramsey pricing "rule" that gives the prices that minimize the deadweight losses is to raise price in inverse proportion to demand elasticities.

Multi-products firm – Ramsey pricing

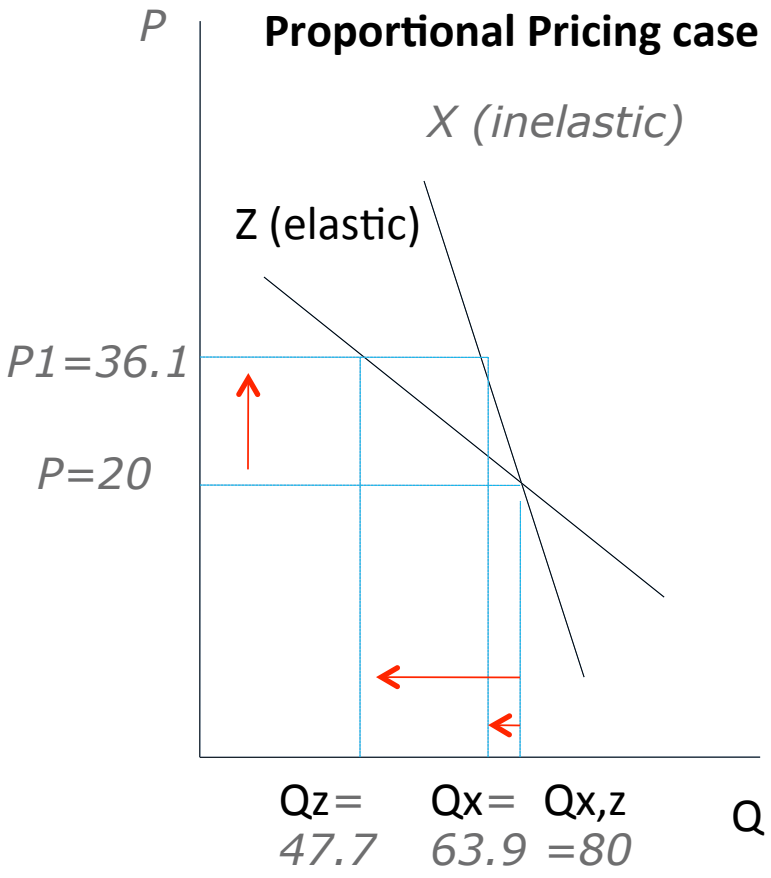
$$Max\ W(P_1,Q_1,P_2,Q_2,.....P_n,Q_n)\ \text{s.t.}\ \pi(P_1,Q_1,P_2,Q_2,.....P_n,Q_n) \geq 0$$

- **Objective**: maximise welfare s.t. constraint that firm must break-even
  - Welfare is a function of the vector of prices for all goods produced.
- When the goods produced are **independent** in demand, the optimal price vector involves setting prices above marginal cost for those products that have less elastic demand.
  - Optimal price cost mark-up of a product is inversely related to the level of elasticity (See Armstrong et al, 1994)
  - $(P_i - MC_i)/P_i = \lambda/\eta_i$, where η_i : is the absolute value of the elasticity of demand of good i , λ: is a non-negative constant.
  - Mark-up above marginal cost on some products covers fixed costs
- If one product has inelastic demand (e.g. essential access product) then other products should be priced at marginal cost and the mark-up on this product set high enough to cover all fixed costs.
- Have this form of price discrimination, even if same marginal cost of production for each product.
- Attempts at Ramsey Pricing in telecoms, postal services and railroads.

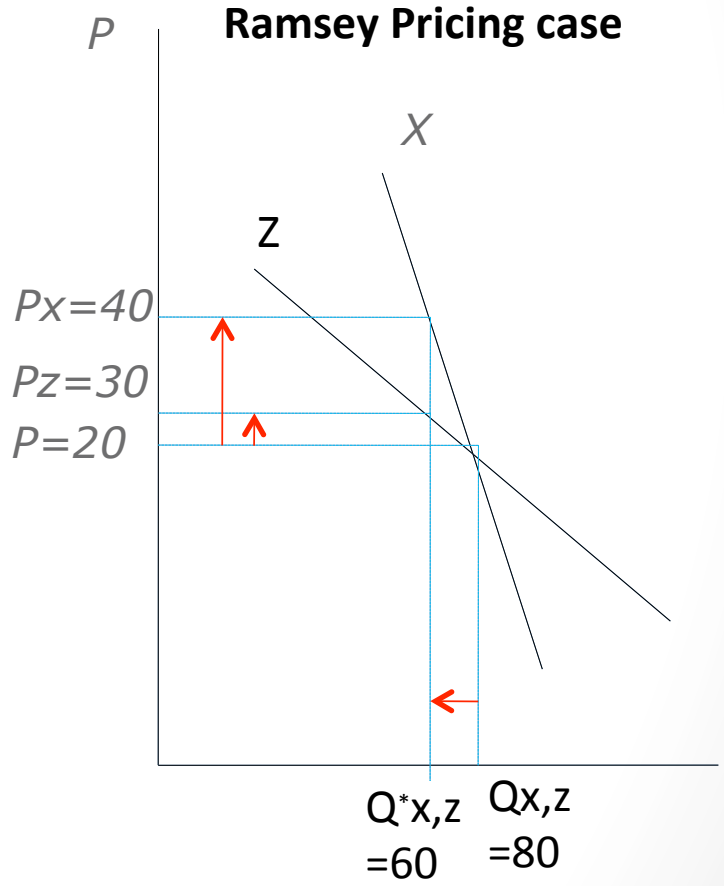
Result: **Ramsey pricing:** $P_i = f(\eta_i)$ => *A Linear Price for each commodity*

Value-based (or Ramsey) pricing

Suppose, Cost, C=1800 +20X + 20Y; Demands: X= 100 – P_x and Y =120 - 2P_y
i.e. P=MC_x=Mc_y=20 this covers variable cost, but F=1800 remains loss. Two options
– 1. Proportional price : when $\pi = \mathbf{P_1}(100- \mathbf{P_1}) + \mathbf{P_1}(120- 2\mathbf{P_1}) -1800 -20x -20y$
– 2. Ramsey pricing: when $\pi = TR - TC = P_x(100- P_x) + P_y(120 - 2P_y) -1800-20.\mathbf{q_1}-20.\mathbf{q_1}$



Welfare losses: 390



Welfare losses: 300

What about technical efficiency?

- Firm's cost level depends on level of *effort* put into cost-reduction (e.g. monetary investment and/or human effort)
  - ***C(Q, e) = c(e).q + F(e)***
- Managers in firm will invest in effort to reduce costs up to the point where the private marginal benefit from cost reduction is equal to the private marginal cost of effort.
- Regulator wants firm to operate at cost level consistent with the optimal level of effort, e*
  - Level of effort that maximises welfare, subject to firm break-even constraint
- Case-1: When have transfers, optimal contract is:
  - ***P(Q) = c(e*)*** and ***T = F(e*)***
- Case-2: When don't have transfers, optimal contract is:
  - ***P(Q) = AC(e*)*** for linear tariff or
  - ***T = A + P(Q)***, with ***A = F(e*)*** and ***P(Q) = c(e*)***
- ***Try to deduce these results on your own***

With perfect information the regulator can get (close) to allocative and technical efficiency but…

- Will a regulator know as much as the firm?
  - ① – Can the regulator know demand?
  - ② – Can the regulator know costs?
  - ③ – Can the regulator know the optimal level of cost reducing effort?
- Does it matter if the company is publicly owned or privately owned? (this our next topic of lecture)
- Does it matter if we have ex-ante or ex-post regulatory contract?

Skim: AS03 sections 2,
IOCB introdns of Ch 17, 18, 19

Consider: Three different information issues

1. Hidden information – adverse selection
   - – Firm has information about operating environment (costs, demand) that regulator does not have. Firm can not affect the operating environment.
2. Hidden action – moral hazard
   - – Firms choices about how level of cost-reducing effort (or more realistically those of managers within firm) can change cost function. Regulator can not observe cost-reducing effort choices made.
3. Uncertainty
   - – Firm and regulator can't predict the future. Have known unknowns and unknown unknowns.
   - – Firm and regulator may have different degrees of uncertainty.

Regulators have to contend with all three

1. Hidden information - The problem

- Monopoly firm will generally be better informed about their production technology than regulator
  - – Hands-off regulator doesn't see day-to-day operations
  - – Input price contracts, such as wage agreements or procurement agreements, not in public domain
  - – Regulator doesn't have technical expertise to assess whether best available technologies are being used
- Monopoly firm will generally be better informed about market demand
  - – Direct experience with customers
  - – Can experiment with price changes to see impact on demand
  - – More expert at assessing customer responsiveness to price
- Public ownership may help with this
  - – But within 'big' government, may be difficult for one part of government to fully understand what other part is doing

Hidden information: Some examples

- To set average cost prices a telecoms regulator needs to know what the cost of each elements of the network is (e.g. wires, manpower) and demand at different prices.
  - – If the regulator doesn't run the business how would he get this information?
- To set Ramsey prices for different postal services the regulator needs to know the elasticity of demand for different products.
  - – If the regulator doesn't work directly with consumers and product specification how would he know this information?

Hidden information: Implications

- Regulated firm may try to pretend it is something, when actually it is not and make above normal profit
  - – e.g. pretend to be high cost to get price equal to high marginal cost
- Regulator may underestimate firm's cost, resulting in loss being made.
- Regulator may wrongly get elasticity estimate for products, and prices distort consumption and production choices.

Regulatory contract needs to ensure firm breaks even and get firm to reveal actual cost 'honestly'.

End up providing firm with 'information rent'.

2. Hidden action - The problem

- Managers choose level of cost-reducing effort to maximise their utility.
- Level of effort and impact of effort on costs not observed by regulator.
  - – Often not even observed by firm owners!
- Regulator can't identify welfare-maximising level of cost-reducing effort.

Hidden action: Examples

- Workers in water treatment plant could reduce costs by 10% if they worked an 8 hour day instead of a 7 hour day. Regulator observes annual hours worked per employee but does not know implication for cost level.

- Workers fixing the train track decide to use an expensive 'quick fix' method rather than investing time/effort into using a cheaper solution that requires more time from them. The regulator does not observe how they actually fix the track.

Hidden action: Implications

- Utility-maximising managers won't invest in levels of effort that maximise welfare.

- Regulator wants to encourage the firm to encourage the manager to invest in cost-reducing effort.
  - – Allow the firm to make profit if reduce costs.

End up providing firm with 'information rent'.

Trading off allocative efficiency and technical efficiency.

3. Uncertainty

- Hidden information and hidden action are problems for ex-ante and ex-post regulation.
- With ex-ante regulation have added complication that making forecasts for future and there will be inherent uncertainty.
  - – Even the firm won't be able to predict with certainty what the demand and costs will be.
- Firm may be better at predicting potential states of the world than regulator.
  - – Particularly if in steady-state so what happened in past good indicator of what will happen in future.
- Uncertainty is greater problem, even for firm, when have changes in demand characteristics (what firm has to deliver) and/or technology.

Uncertainty issue in electricity transmission: UK

- 1950s to 1990s:
  - – Transmission company had long lead time before power plant would become operational.
  - – Needs of traditional power plants, with predictable demand for network services, were stable and well understood.
  - – Built/design transmission network so that have sufficient capacity to meet committed (known) future demand.
- Since mid-1990s:
  - – Increase in energy from wind which has much shorter lead times, less predictable because of planning objectives and intermittent energy once up and running.
  - – Old tools for planning capacity requirements no longer work.
  - – Uncertainty affecting investment decisions and regulation of investment requirements.

Build to meet highest expected capacity requirement, risking high prices and under-utilisation of assets, or build to meet lowest expected capacity requirement, risking having insufficient capacity (lights going out)?

Implications of uncertainty

- What actually happens unlikely to be the same as what was forecast when ex-ante contract set.
  - – Firm may make gains or losses depending on direction in which forecasts were inaccurate.
- Regulator needs to determine how best to share cost of 'insurance' against uncertain events between customers and firm.
- Big question of whether firm can manage business in a way that protects is from uncertain events.
- Regulatory contracts may include terms under which contract revised if environment in which firm operates changes (uncertainty mechanisms).

End up providing firm with 'insurance' for unforeseen events.

Why have we spent all this time looking at regulation with perfect information?

- First best solution provides benchmark for regulation with asymmetric information
  - – In practice most regulators are looking for 'cost reflective pricing' and minimising allocative inefficiency.
- Allowed us to become more familiar with concepts and language/terminology relating to natural monopoly and the regulatory contract.
- Provides starting point for literature on regulation with asymmetric information.
  - – Note: literature says very little about uncertainty!

What would you do if you were a regulator of a monopoly water company and you did not have the same information as the company about costs?

Consequence of information asymmetry

- First best regulation solutions no longer feasible.
- Theoretical models look at second best options.
  - – How incentivise firm to deliver regulator's objective without changing firm profit-maximising objective?
  - – Provide firm with profit (information rent) to get closer to welfare maximising outcomes.
- Regulation in practice focuses on 'best available' contracts which may be 'third best' or 'nth best' as theoretical second best options are often not feasible.
- We will look at:
  - – Models of regulation with hidden information
  - – Models of regulation with hidden action
  - – Practical regulatory solutions to information asymmetry

Unknown Cost structure: Loeb-Magat Proposal (1979)

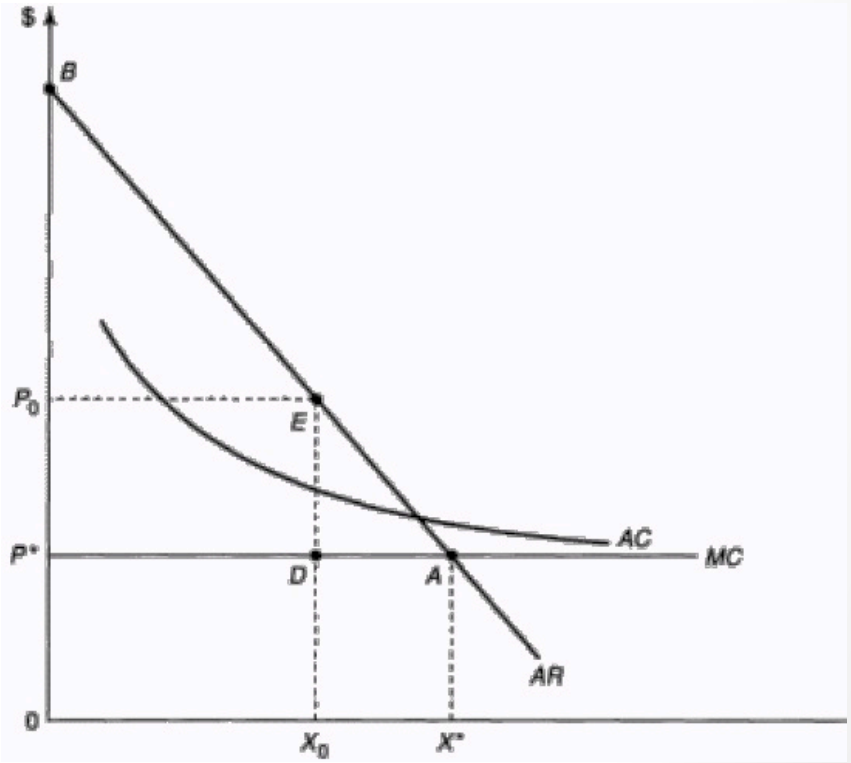
- If regulators had perfect information regarding the monopolist's costs and demands, then the ideal pricing schemes can be used.
- In reality, the monopolist has relatively better knowledge of its costs than the regulators do.
  - The firm's profits will increase with higher prices, so it has an incentive to overstate its costs (which is the usual basis that a regulator uses to set prices).
- **Loeb and Magat (L-M) assumed** that the monopolist knows costs and demand information perfectly, but that the *regulator knows demand only*. (Issue is even more critical if regulator has a sketchy idea of dd)
- Given this asymmetry of information and the assumption that the monopolist's objective is to maximize profit, **what might the agency do to induce efficient pricing?**
- **L-M proposes** to allow the monopolist to choose its own price , but the agency should subsidize the firm by an amount equal to consumer surplus at the selected price.

L-M subsidy model

- Firm's cost, C(Q,e), is unknown to regulator
- Demand, Q(P), and consumer surplus, V(P), are known to regulator
- Regulator puts equal weight on consumer surplus and profit
  - **Max W(P,e)=V(P)+π(P,e)**
- Loeb and Magat mechanism:
  - – Pay firm lump-sum transfer equal to entire (observed) consumer surplus
  - – Changes firm's profit function to be equal to welfare function
    - **Max V(P)+π(P,e)**
  - – Firm has internalised impact of choices on consumer surplus and will choose optimal prices and optimal level of effort.
  - – Get allocative and technical efficiency
  - – Distributional concerns because consumers get no gains from trade).

Understanding L-M proposal

- Monopolist has declining demand (*AR*), and assume the TC fn is *K + c.X;* hence, *MC* is constant and equal to *c.*
- Firm can charge some price P_0 . Then profit=P*DEB – K, one part from customers (OX_0EP_0) and other from regulator (P_0EB)
- However, in L-M scheme, it can do better by charging P*.
  Profit= P*AB – K
- Since with subsidy, AR now is actually MR, and MR=MC, thus it is a profit maximising solution for the monopolist.
- Solution is efficient i.e. encou-



rage private firm to charge P=MC; but challenged under distributional ground. This solves the informtn problem but worsens the losses problem.

Limitations of L-M model

- Model criticised because regulator unlikely to:
  - – put equal weight on consumers and producers,
  - – know demand function and hence consumer surplus and
  - – be able to pay transfers that result in consumers getting no gains from trade.
- Could pay transfer less than consumer surplus if ensures firm can break-even.
  - – In absence of information on firm's cost level, difficult to be certain on how much less than total consumer surplus the transfer needs to be.
  - – Loeb and Magat suggest requiring firms to bid for franchise to be monopoly, with auction revealing how much subsidy needs to be.
- Model useful in demonstrating idea that regulator needs to incentivise firm by internalising impact on consumer surplus into profit function.

Baron and Myerson (1982) : Regulation with hidden information – **set up**

- Firm and regulator know demand: $Q(P)$
- Firm has cost function which is determined exogenously (i.e. not affected by firm's effort choice): $C(Q) = F + c.Q$,
- Regulator and firm know F. Firm knows unit cost, c, but regulator does not.
- Regulator knows that firm could be high cost, with unit cost c_H, or low cost with unit cost c_L. $\Delta c = c_H - c_L > 0$
- Regulator expects firm is low cost with probability ρ and high cost with probability $(1-\rho)$.
- Regulator offers the firm a choice of welfare maximising contracts:
  - $\{(P_L, T_L), (P_H, T_H)\}$
  - where T_i is the transfer that the firm earns given price P_i (with i=L,H).
- Firm chooses regulatory contract (transfer T_i and price P_i) to maximise profit (and reveals marginal cost ?!):
  - $max\ \pi(T(P), P) = (P - c).Q(P) + T(P) - F$

Baron and Myerson (1982) model of regulation with hidden information – **Optimisation**

- Regulator's objective is to maximise weighted sum of consumer surplus and producer surplus:

$$W(P) = V(T(P)) + \alpha.\pi(T(P)), \qquad 0 \leq \alpha \leq 1$$

- Regulator chooses T(P) to maximise expected welfare

$$E(W) = \rho.[V(P(c_L) + \alpha.\ \pi(P(c_L))] + (1-\rho).[V(P(c_L)) + \alpha.\ \pi(P(c_L))]$$

- Subject to two constraints:
  - – Firm makes non-negative profits (individual rationality)

$$\pi(T(P_i), P_i) \geq 0 \text{ for } i = L,H$$

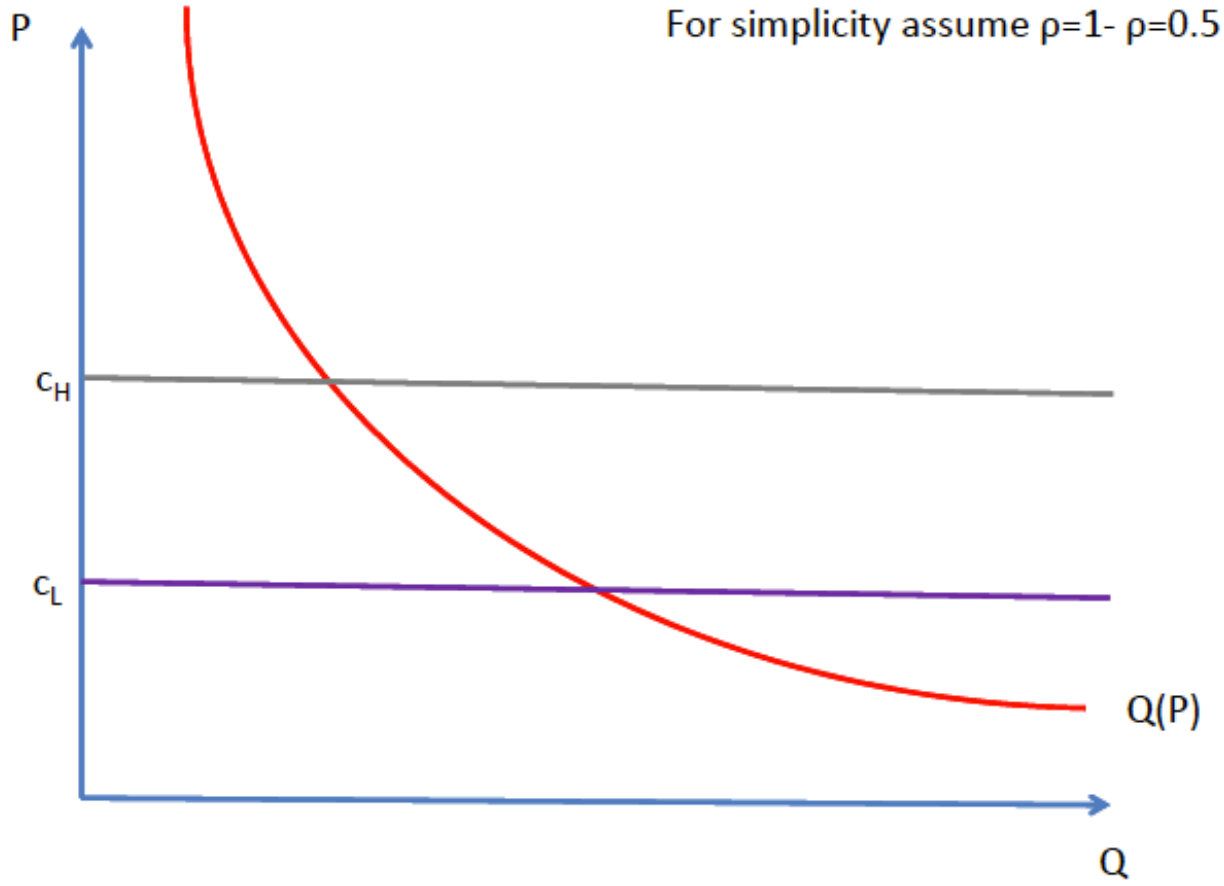
    make sure firm participates. (Often called participatory constraint)
  - – Firm chooses contract consistent with its actual cost type (incentive compatability):

$$\pi(T_L \mid c = c_L) \geq \pi(T_H \mid c = c_L)$$

$$\pi(T_H \mid c = c_H) \geq \pi(T_L \mid\ c = c_H)$$

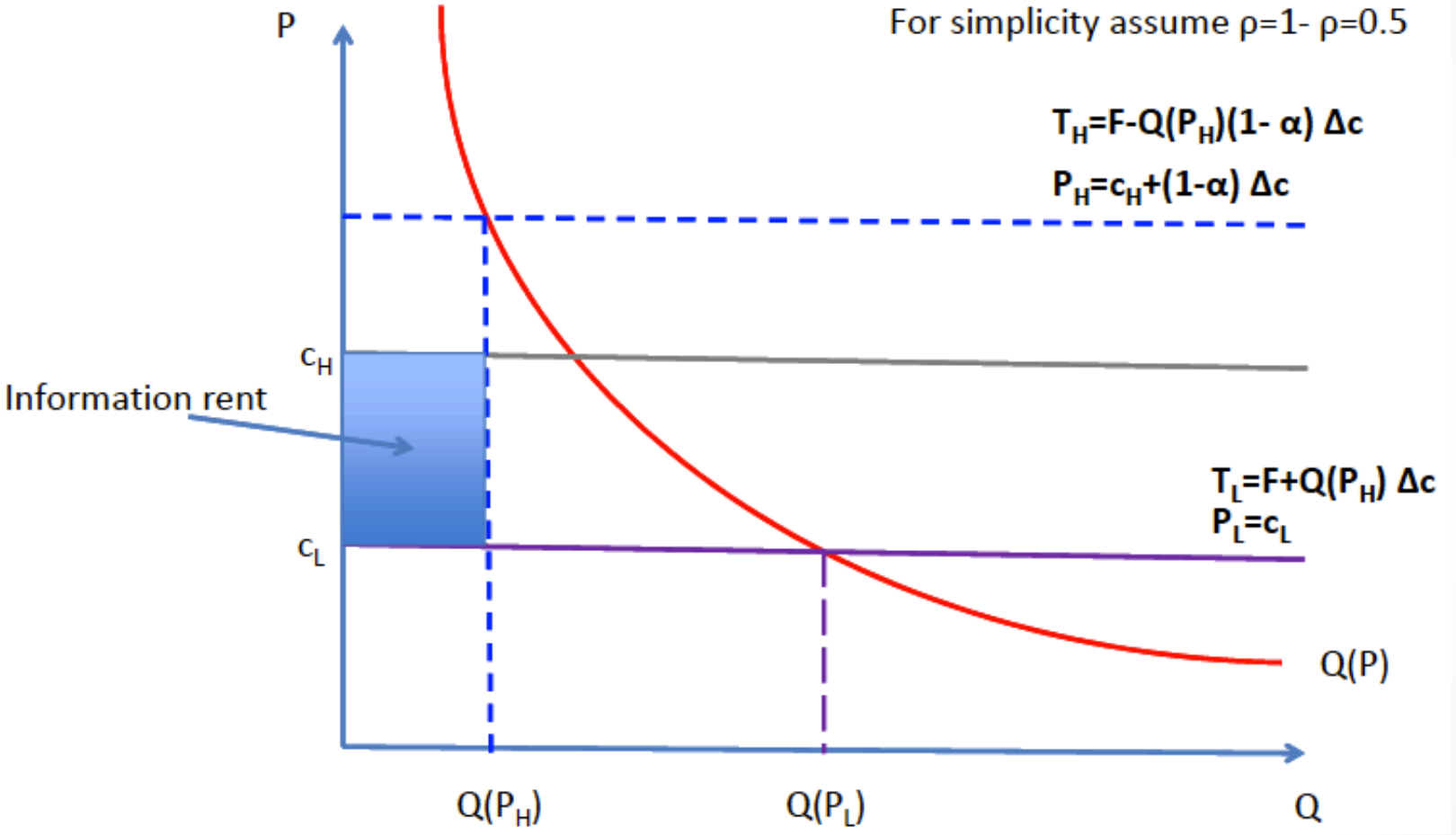
  reward firm for revealing its type but minimise size of reward to limit cost to consumers.

Baron and Myerson (82) – **optimal contract I**



What happens with perfect information:?

Baron and Myerson (82) – **optimal contracts II**



Paying firm an information rent to reveal it is low cost (if it is)

Baron and Myerson (82) – **Results**

When there is hidden information the optimal contract allows for information rent to be paid to low cost firm. Amount of rent paid depends on difference between high and low cost types.

- Say $\{(P_L, T_L), (P_H, T_H)\} = \{(c_L, F), (c_H, F)\}$
  - – If firm is low cost type, it will want to take high cost contract and make a profit.
  - – Need to pay low cost type a rent to reveal that it is low cost.
- Rent is paid through transfer to low cost type which is set to cover fixed costs and potential profit of pretending to be high type

$$(P_L, T_L) = (P_L = c_L ; T_L = F + Q(P_H)\,\Delta c)$$

- High cost type will always choose high cost contract as would make a loss if chose low cost type contract. Regulator able to fix high type contract so high cost firm earns zero information rent.

$$(P_H, T_L) = (P_H = c_H + (\rho/1-\rho).(1-\alpha).\,\Delta c,\ \ T_H = F - Q(P_H)(1-\alpha)\,\Delta c$$

Not at allocative efficiency because high cost type's price is above marginal cost. How much above depends on weights placed on profit in welfare function, on probability attached to different cost types and scale of difference between costs.

Limitations of Baron and Myerson (1982)

- Regulator may not be able to pay transfers to firm.
- Costs may not be exogenous. They could depend on managerial effort.
- Regulator may not know demand function and/or fixed costs, which would complicate analysis of optimal contract further.

- We shall come back to these issues later with more detail.

Conclusions

- Economic regulation continues for transmission and distribution of electricity (and residential billing and metering).
- Generation markets have been deregulated in many US states but this has not resulted in cheaper electricity for many residential customers so far.
- Price cap regulation is theoretically and empirically superior to traditional rate of return regulation.
- Economically efficient recovery of fixed costs often involves 'unfair' distribution of payments between different customers. Efficient pricing structures are therefore difficult to implement for that reason.