Public Policy Towards Network Industries

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Focus of Analysis

- Regulation of *network infrastructure industries* such as railroads, electric power, telecommunications
  - Nature & extent of legal, regulatory constraints
- Decision criteria are economic efficiency
  - How to generate most total surplus
- This analysis requires understanding of:
  - Production costs
  - Demand characteristics
  - Informational constraints
  - Pricing Theory
  - Market Definition & market power…

Basic Distinction

- Government interventions in markets are of two basic types:

  ex-ante (regulation) ***OR*** ***ex-post*** (competition policy/anti-trust)
- Choice between these depends on:
  - Probability of need for restraint
  - Cost of punishment vs Cost of regulation
- Part I focuses on regulation, with more limited attention to anti-trust issues.
  - Unavoidable mixing because of “liberalization” of (portions of) most infrastructure networks.

Summary and Overview: Network Characteristics and Policy Issues

- Characteristics of Network Infrastructure Industries
  - Economies of scale and scope
  - Long-lived, sunk assets
  - Vertical integration of "monopoly" and "competitive" components
  - Multiple services and/or customer classes
  - Network externalities
- Resulting Policy Problems
  - Mark-ups over cost required to break-even
  - Recovering capital investments
  - "Unbundling" (vertical disintegration) and Access pricing
  - Price discrimination and Cross-subsidization
  - Universal Service funding

Lecture 1: Costs

Reading:

J. Panzar, “Technological Determinants of Firm and Industry Structure,” Chapter 1 in the *Handbook of Industrial Organization*

Cost analysis forms the basis for public policy toward network industries

- *Marginal costs* are the benchmark for efficient pricing
- *Incremental costs* and *stand-alone* costs form the price floors and ceilings relevant for subsidy analysis.
- Intertemporal analysis of costs essential for understanding *total service long run icremental costs* (TSLRIC) and other regulatory “terms of art.”

Natural monopoly and economies of scale

Natural Monopoly or Subaddivity of Cost: (at output level y^0)

$$C(y^0) \leq \sum_{i=1}^{m} C(y^i)$$

Economies of scale: (single output)

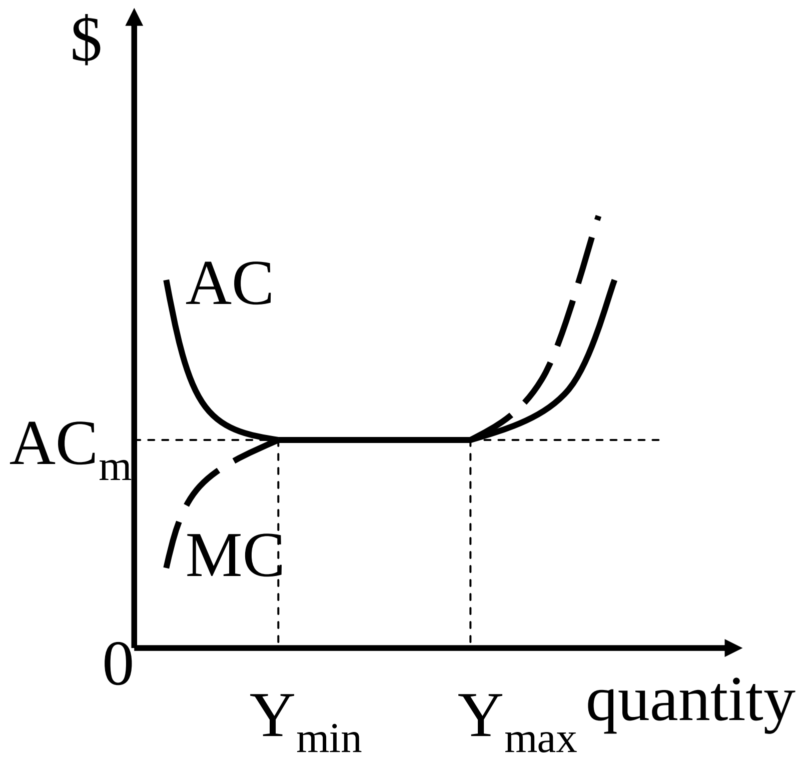
$$\sum_{i=1}^{m} y^i = y^0 \qquad m \geq 2$$

Economies of scale through y^0 imply NM at y^0, but not conversely

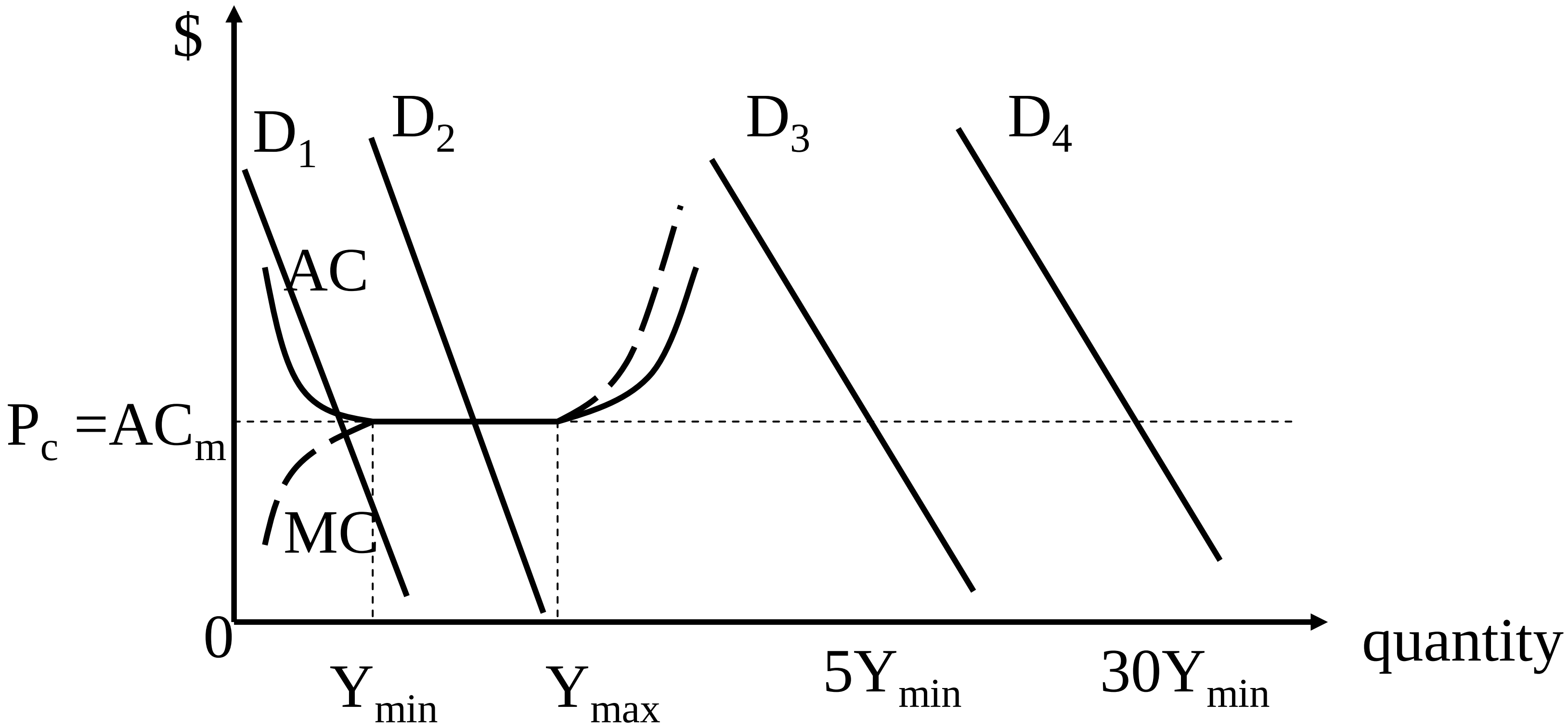
$$S(y) = \frac{AC(y)}{MC(y)} = \frac{C(y)}{yMC(y)}$$

Increasing, constant and decreasing returns to scale

- For $Y < Y_{min}$, AC>MC, unit costs are falling, and the firm enjoys *increasing returns to scale.*
- For $Y_{min} < Y < Y_{max}$,AC=MC, unit costs are constant, and the firm experiences *constant returns to scale.*
- For $Y > Y_{max}$, AC < MC, unit costs are rising, and the firm experiences *decreasing returns to scale.*

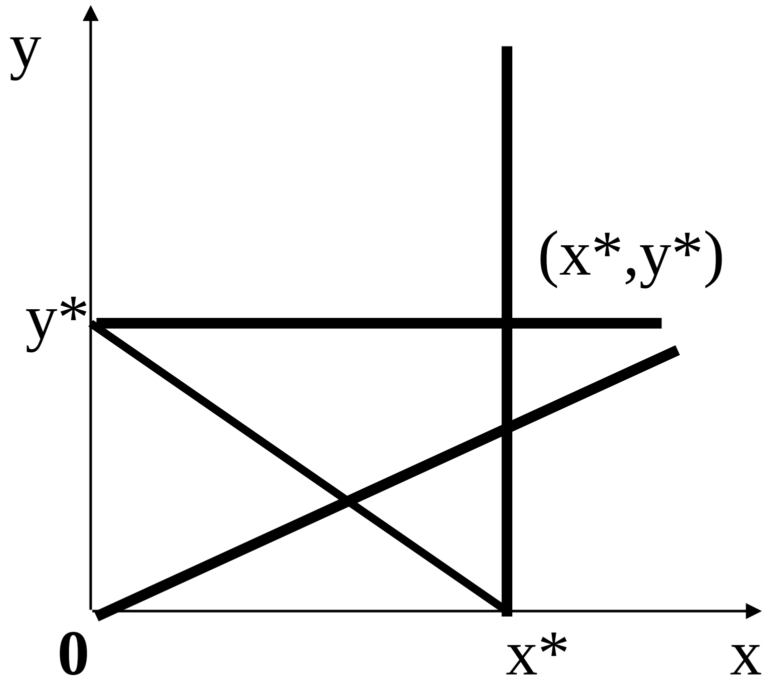


“Natural” industry structure determined by demand *relative* to min efficient scale



Multi-product cost concepts for network industries

- Ray-average cost
- Incremental and stand-alone costs
- Product specific fixed costs
- Economies of scope
- Trans-ray convexity



Ray-average costs and multi-product economies of scale

- RAC measure the behavior of costs along a ray through the origin.
- RAC reaches a minimum at the point of constant (multi-product) returns to scale.

$$RAC(\mathbf{y}) \equiv C(\mathbf{y}) / \mathbf{a} \cdot \mathbf{y}$$

$$\frac{dRAC(t\mathbf{y})}{dt} =$$

$$RAC(t\mathbf{y})\left[\frac{\sum_i y_i C_i(t\mathbf{y})}{C(t\mathbf{y})} - \frac{1}{t}\right]$$

Let t^* minimize $RAC(t\mathbf{y})$

and normalize $t^* = 1$:

Then $S(\mathbf{y}) \equiv \dfrac{C(\mathbf{y})}{\mathbf{y} \cdot \nabla C(\mathbf{y})} = 1$

at minimum RAC

Multi-product economies of scale

- Marginal costs for individual products are well-defined
- Average costs for individual products are *not* well-defined
- S measures the behavior of costs as all outputs vary in proportion.

$$MC_x = \frac{\partial C(x, y)}{\partial x}$$

$$MC_y = \frac{\partial C(x, y)}{\partial y}$$

$$\text{e.g.} \quad AC_x \neq \frac{C(x, y)}{x}$$

$$S(x, y) \equiv \frac{C(x, y)}{x \cdot MC_x + y \cdot MC_y}$$

Incremental and stand-alone costs

- Two product example: total costs = $C(x,y)$.
- Stand-alone costs measure the cost of producing *only* that product: e.g., $C(x,0)$.
- Incremental costs are the *added* costs caused by a product: e.g., $IC_x=C(x,y)-C(0,y)$.
- Average Incremental Costs *are* well-defined on a per unit basis: $AIC_x=IC_x/x$

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- $AIC_x = IC_x / x$

Let $S \subseteq N = \{1,\ldots,n\}$

and $\mathbf{y} \in \Re^n_+$.

Define $\mathbf{y}_S$ s.t.

$(\mathbf{y}_S)_i = y_i$ for $i \in S$,

$(\mathbf{y}_S)_i = 0$ for $i \notin S$.

$$SAC_S(\mathbf{y}_S) = C(\mathbf{y}_S)$$

$$IC_S(\mathbf{y}) = C(\mathbf{y}) - C(\mathbf{y}_{N-S})$$

Product specific fixed costs

- Fixed costs result from a discontinuity of the cost function at the origin.
- Product-specific fixed costs result from discontinuities along axes.

$$\text{Let}\, C(y) = F\{S\} + c(y)$$

$$s.t.$$

$$S = \{i \in N : y_i > 0\}$$

$$c \in C^2, c(\mathbf{0}) = 0$$

$$T \subseteq S \Leftrightarrow F\{T\} \leq F\{S\}$$

$$psfc_S = F\{N\} - F\{N - S\}$$

Product specific fixed costs

- Fixed costs result from a discontinuity of the cost function at the origin.
- Product-specific fixed costs result from discontinuities along axes.
- PSFC's are part of IC

$$\mathrm{C}(0,0) = 0$$

$$C(x, y) = F + c_x x + c_y y$$

$$C(x,0) = F_x + c_x x$$

$$C(0, y) = F_y + c_y y$$

$$F_x, F_y \le F \le F_x + F_y$$

$$psfc_x = F - F_y$$

$$psfc_y = F - F_x$$

Examples of fixed and product specific fixed costs

- Fixed costs do not vary with volume and are common to all of the firm's products:
  - General Headquarters
  - CEO's salary
- Product specific fixed costs also do not vary with volume, but can be avoid if product line shuts down
  - Divisional HQ
  - Salary of Divisional VP

Economies of scope

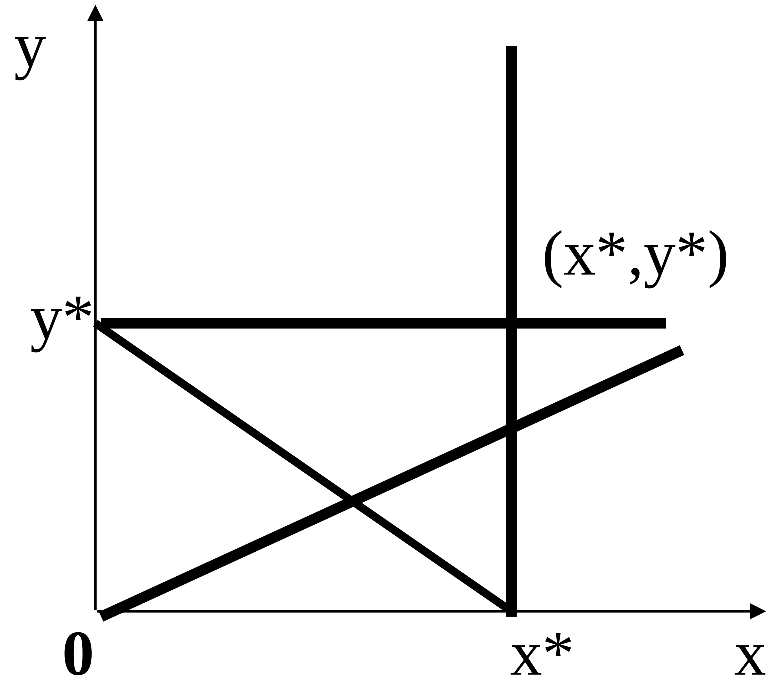
- Scope economies are present when it is cheaper to produce multiple products together:

$$C(x,0) + C(0,y) > C(x,y)$$

- Arise from shared inputs:
  - peak load structure (day/night service)
  - shared facilities
  - joint production (wool/mutton)
- Network pricing problem: apportion benefits of economies of scope among user groups

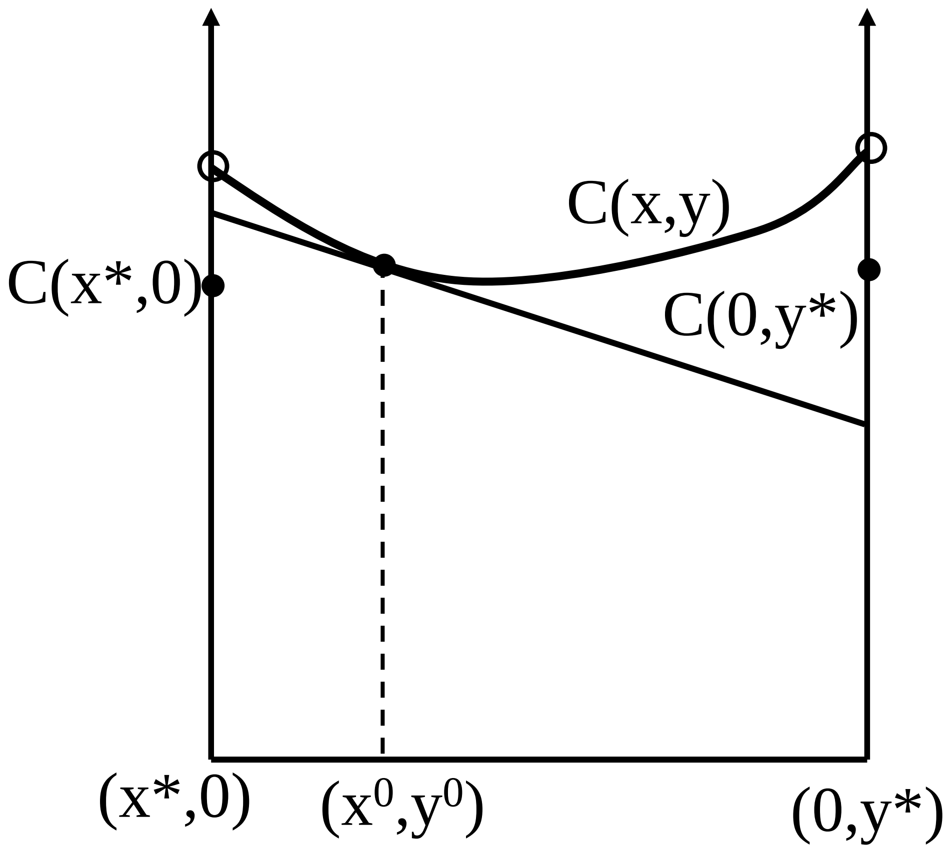
Multi-product cost concepts for network industries

- Ray-average cost
- Incremental and stand-alone costs
- Product specific fixed costs
- Economies of scope
- Trans-ray convexity



Trans-ray behavior

- The behavior of costs across rays reflects the extent of *complementarities*.
- Basic notion is *trans-ray supportability*
  - Does cost surface have a support at a point?
- Product specific fixed costs pose difficulties for this property
  - E.g., *without* psfc the tangent line supports the cost surface at (x^0,y^0) along the transray connecting points (x*,0) and (0,y*).

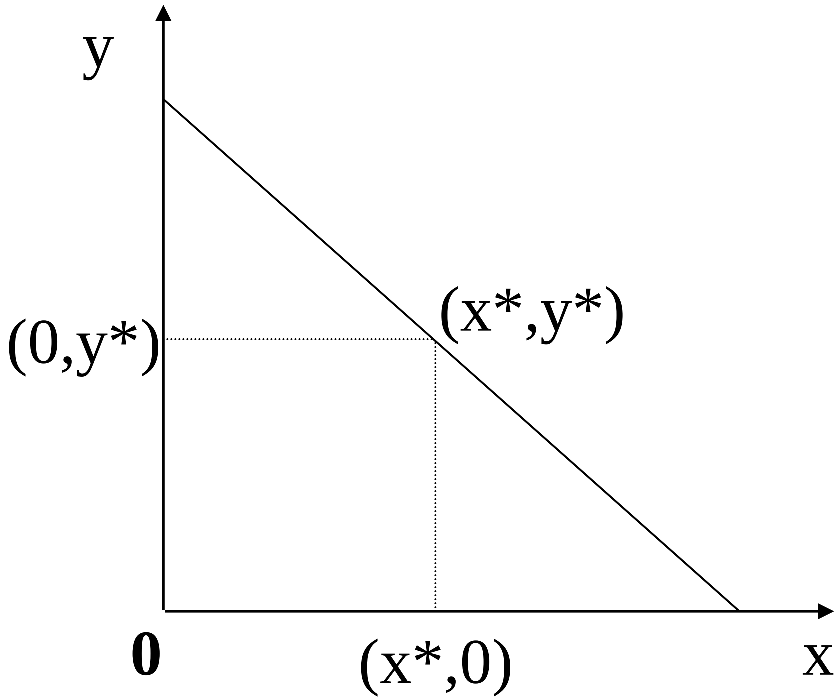


Complementarities and submodularity

- *Weak cost complementarities* are captured by the assumption $C_{ij}(\mathbf{y}) \leq 0$ for $i \neq j$.
  - Intuitively, the marginal cost of product i falls when the level of product j increases.
- A twice continuously differentiable cost function is *submodular* if it exhibits weak cost complementarities everywhere.
- More generally, a multiproduct cost function is submodular if $C(\mathbf{y}_S+\mathbf{y}_V)-C(\mathbf{y}_S) \geq C(\mathbf{y}_T+\mathbf{y}_V)-C(\mathbf{y}_T)$ for $S \subseteq T$
- Submodularity is *sufficient*, but *not necessary* for economies of scope to exist. (E.g., let $S = \emptyset$, above)

Economies of scale, economies of scope, and natural monopoly

- Surprisingly, Ec of Scale *and* Ec of Scope do not imply Natural Monopoly.
- Two types of sufficient conditions:
  - Strengthen Ec of Scale: e.g., Declining Average Incremental Costs (DAIC)
  - Strengthen Ec of Scope: e.g., trans-ray supportability
- Exercises: 2 product proofs
  - DAIC and Ec Scope $\Rightarrow$ NM
  - Q-Convexity of Costs and Ec of Scale $\Rightarrow$ NM



Implications of economies of scope and scale

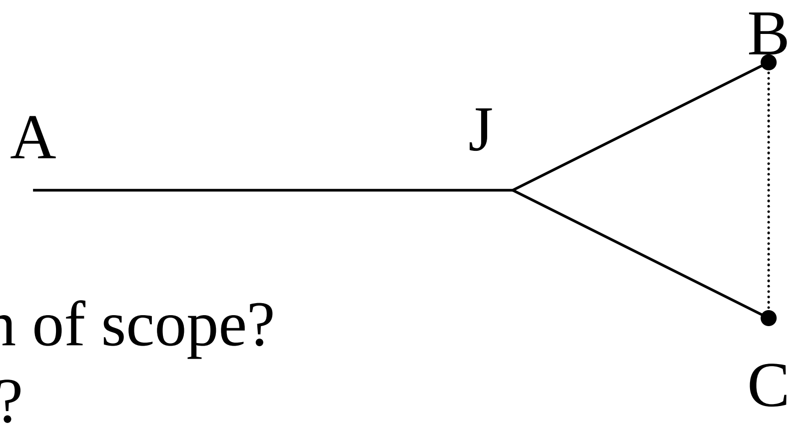
- Economies of scale mean there will be a deficit from marginal cost pricing:

$$S(x,y)>1 \Rightarrow x \cdot MC_x + y \cdot MC_y < C(x,y)$$

- Economies of scope mean there will be a deficit from pricing at average incremental cost:

$$IC_x + IC_y = [C(x,y) - C(0,y)] + [C(x,y) - C(x,0)]$$
$$= C(x,y) - [C(x,0) + C(0,y) - C(x,y)] < C(x,y)$$

Network cost example
(assume JB,JC<BC<JB+JC)



"Products:"

(1) (2) (3)

Y_{AB}, Y_{AC}, Y_{BC}

Costs (all fixed)

AJ, JB, JC, BC

Econ of scope?

IC's?

SAC's?

Examples of cost concepts in a network

- Stand alone costs:
  - $SAC_1 = AJ + JB$
  - $SAC_2 = AJ + JC$
  - $SAC_3 = BC$
- Incremental costs:
  - Individual services: $IC_1 = IC_2 = IC_3 = 0$!
  - Subsets of services:
    - $IC_{1,2} = AJ + JB + JC - BC$ (Why not just AJ?)
    - $IC_{1,3} = JB$
    - $IC_{2,3} = JC$

Network Economies of Scope: Several partitions to consider

- Totally separate versus joint:

  C{1}+C{2}+C{3} = (AJ+JB) + (AJ+JC) + BC > AJ+JB+JC = C{1,2,3}

- All combinations of one and two:

  C{1,2}+C{3} = (AJ+JB+JC) + BC > AJ+JB+JC = C{1,2,3}

  C{1,3}+C{2} = (AJ+JB+JC) + (AJ+JC) > AJ+JB+JC = C{1,2,3}

  C{2,3}+C{1} = (AJ+JB+JC) + (AJ+JB) > AJ+JB+JC = C{1,2,3}

- All partitions enjoy economies of scope in this example

Covering costs "fairly" using *subsidy free* prices

- Basic principle: No service or group of services should pay more than their stand-alone costs.
- Example: Let AJ=20; JB=JC=5 and BC=6.
- What does the *stand-alone cost test* require?
  - $P_1 \leq 25$; $P_2 \leq 25$; and $P_3 \leq 6$
  - $P_1+P_2 \leq 30$; $P_1+P_3 \leq 30$; and $P_2+P_3 \leq 30$
  - $P_1+P_2+P_3=30$ (break-even)
- Note that "equal division" ($P_1=P_2=P_3=10$) won't work
- Notice the role played by the cost of link BC, even though it is not part of the efficient network.

Economically meaningful multiproduct cost concepts

- *Total costs* of the enterprise (C) depend on all output levels
- *Marginal cost* of any service *i* (MC_i) is the cost of producing *one more unit* of that service
- *Stand-alone costs* of a service *i* (SAC_i) are the costs of providing *only* that service
- *Incremental costs* of any service *i* (IC_i) are the *added* costs incurred because a service is provided
  - $IC_i = C - SAC_{others}$
- AVERAGE COSTS do not exist!

- Example:
  - Total and marginal costs are
    - $C = F + c_1Q_1 + c_2Q_2 = 900 + 500 + 1000 = 2400$
    - $MC_1 = c_1 = 5$
    - $MC_2 = c_2 = 10$
  - Stand-alone costs are
    - $SAC_1=F_1+c_1Q_1=700+500=1200$
    - $SAC_2=F_2+c_2Q_2=500+1000=1500$
  - Incremental costs are
    - $IC_1 = C - SAC_2 = F - F_2 + c_1Q_1 = 400 + 500 = 900$
    - $IC_2 = C - SAC_1 = F -F_1 + c_2Q_2 = 200 + 1000 =1200$

Fully distributed cost pricing

- FDC attempts to determine *the* costs of individual services
- Each service recovers the costs unambiguously assigned to it plus an allocated “fair share” of overhead costs
- Allocation rules base upon “objective criteria”
  - Volume
  - Attributable costs

- Example:
  - Output: $Q_1=Q_2=100$
  - Attributable costs per unit: $c_1=5$, $c_2=10$.
  - Overhead costs:
    - $F_1 = 700$ if *only* service 1
    - $F_2 = 500$ if *only* service 2
    - $F = 900$ if *both* provided
  - Allocation using relative volume:

    $C_1 = c_1Q_1 + Q_1F/(Q_1+Q_2) = 950$

    $C_2 = c_2Q_2 + Q_2F/(Q_1+Q_2)= 1450$
  - Allocation using relative attributable costs:

    $C_1 = c_1Q_1 + c_1Q_1F/(c_1Q_1+c_2Q_2) = 800$

    $C_1 = c_2Q_2 + c_2Q_2F/(c_1Q_1+c_2Q_2)=1600$

Cross-subsidization: When is a rate structure "subsidy free?"

- Total revenues equal total costs
  - If not, the *firm* is either providing or receiving a subsidy
- Revenues from a service must not exceed the *stand-alone costs* of the service
  - If they do, the service is *providing* a subsidy
- Revenues from a service must not be less than *incremental costs* of providing that service
  - If they are, the service is *receiving* a subsidy

- Total revenues equal total costs

  $p_1Q_1+p_2Q_2=F+c_1Q_1+c_2Q_2=2400$

  $p_1 + p_2 = 24$
- Stand-alone cost tests

  $p_1Q_1 \leq SAC_1 = 1200$

  $p_1 \leq 12$

  $p_2Q_2 \leq SAC_2 = 1500$

  $p_2 \leq 15$
- Incremental cost tests

  $p_1Q_1 \geq IC_1 = 900$

  $p_1 \geq 9$

  $p_2Q_2 \geq IC_2 = 1200$

  $p_2 \geq 12$

Can subsidy-free charges always be found?

- Example: 3 towns A, B, and C seeking water service
- Cost structure:
  - Any individual town can be provided at cost of 14 = C(1)
  - Any pair of towns can be served at a cost of 18 = C(2)
  - All 3 towns can be served at a cost of 30 = C(3)
- Economies of scope are present:
  - 18 = C(2) > 2C(1) = 28
  - 18+14 =C(2)+C(1) > C(3) = 30
- Joint service is efficient

- But, no subsidy-free charges exist that recover costs!
- Try symmetric charges of 10:
  - 10 < C(1) = 14
  - But, 2(10) > C(2) = 18
- To be free of subsidy requires charges r_A, r_B, and r_C such that
  - $r_A \leq 14$; $r_B \leq 14$; and $r_C \leq 14$
  - $r_A + r_B \leq 18$
  - $r_A + r_C \leq 18$
  - $r_B + r_C \leq 18$
- But, this requires $r_A + r_B + r_C \leq 27 < 30 = C(3)$

Policy problems posed by cross-subsidization

- What happens is subsidy-free prices are not established?
  - Incentives for inefficient entry are created
    - Entrants anticipate a profit by providing service to users *providing* a subsidy
  - Competitors of services *receiving* a subsidy complain
    - E.g., UPS and Deutsche Post
    - Claims often made, rarely proven
- Contrary to the example, subsidy-free prices can usually be found
  - But, doing so places restrictions on efficient cost recovery
- Most cross-subsidies are established politically, for non economic reasons
  - E.g., rail passenger service
  - Rural postal service