ECN 145 Lecture 13

Transportation Economics: Production and Costs II

Methods of estimating costs:

- 1) Accounting approach
  - **uses accounting data, without factor prices**
- 2) Engineering approach
  - **estimate costs from technical standards**
- 3) Statistical approach
  - **estimate Cobb-Douglas or translog costs**
- We will focus on accounting and statistical approaches

Question: what are the outputs?

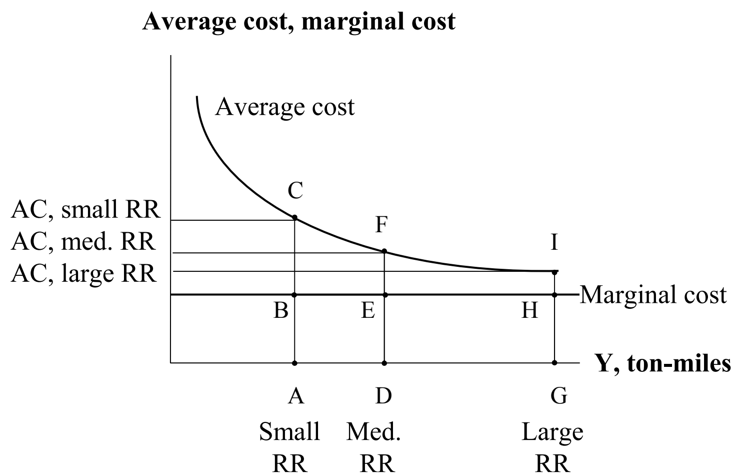
- 1) "Final" outputs (for consumer)
  - **trips between various destinations**
- 2) "Intermediate" outputs (from firms)
- A) Size of network:
  - **miles of road or track; number of flights**
- B) Density of network:
  - **vehicles per mile, or flights per hour**
- going from "intermediate" to "final" output involves decisions by the consumer

Accounting Approach, E.g. 1:

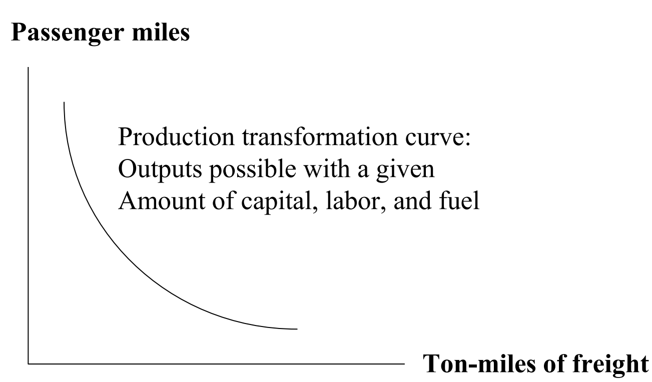
- Given fixed costs F and variable costs V, measure marginal costs m=V/y. Then write total costs as, $C = F + my$
- Properties:
  - **Increasing returns to scale:**

$$\frac{\text{average cost}}{\text{marginal cost}} = \frac{F/y + m}{m} > 1$$

Average and Marginal Cost for Railroads



Differing output for railroads



Accounting Approach, E.g. 2:

- Given:
  - **road miles (RM) - measure of size**
  - **peak vehicles (PV) - measure of density**
  - **vehicle-hours (VH) - measure of density**
  - **vehicle-miles (VM) - measure of density**
- measure costs as,

$$C = c_1 RM + c_2 PV + c_3 VH + c_4 VM$$

Returns to Scale:

$$C = c_1 RM + c_2 PV + c_3 VH + c_4 VM$$

$$\frac{AC}{MC} = \frac{\text{Total Costs}}{y \cdot (\partial C / \partial y)}$$

- =1 if all outputs are varied
- so constant returns to scale “overall”
- >1 if only density measures are varied,
- so increasing returns to scale in density

Accounting cost functions for public transport

	Rapid rail	*Light rail*	*Bus*
Capital Cost:			
Per Route-Mile ($M/year)	2.52	0.51	NA
Per Peak Vehicle ($K/yr)	41.5	55.0	11.3
Operating Cost:			
Per Route-Mile ($M/year)	0.604	0.15	0.
Per Peak Vehicle ($K/yr)	41.9	29.7	9.4
Per Train-Hour[h] ($)	27.3	35.8	20.1
Per Vehicle-Mile ($)	1.93	2.05	0.64

Peak versus off-peak service:

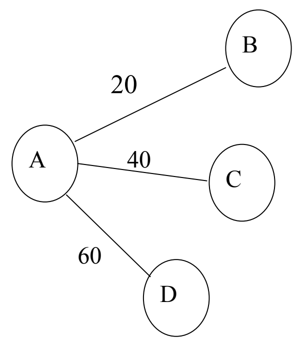
$$C = c_1 RM + c_2 PV + c_b VH_b$$
$$+ c_p VH_p + c_4 VM$$

- Distinguish vehicles-hours in peak (VH_p) versus off-peak hours (VH_b)
- Estimates are that c_p is 1.5 - 2 times larger than c_b, dues to extra costs for drivers in peak hours

Statistical Approach: what outputs?

- E.g. Airlines

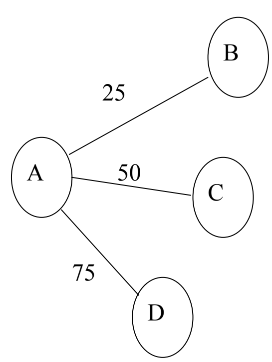
a. Initial operation



y = 120 ton-miles
N = 4 points served

Economies of Density

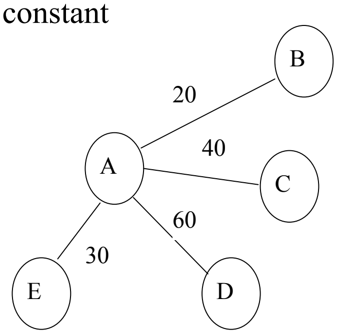
- b. Size of network held constant, density increased 25 percent



y = 150 ton-miles
N = 4 points served

Economies of Size:

- c. Size of network increased 25 percent, density held constant



y = 150 ton-miles
N =5 points served

Airlines:

- Variables to measure *outputs:*
- Y=passenger miles
- N=number of points on network
- D=stage length (distance of flight)
- G=load factor (fraction of seats occupied)
- Variables to measure *inputs:*
- wage, fuel price, price of capital and materials

Long-Run Cost Function for Airlines

- Cobb-Douglas form:

$$\ln C = c + \underset{\substack{(0.066)\\ \text{output}}}{0.836 \ln Y} + \underset{\substack{(0.064)\\ \#\text{points}}}{0.131 \ln N} - \underset{\substack{(0.054)\\ \text{stage length}}}{0.135 \ln D}$$

$$- \underset{\substack{(0.143)\\ \text{load factor}}}{0.277 \ln G} + \underset{\substack{(0.005)\\ \text{wage rate}}}{0.356 \ln w} + \underset{\substack{(0.002)\\ \text{fuel price}}}{0.166 \ln f} +$$

$$\underset{\substack{(0.002)\\ \text{cost of capital, material}}}{0.478 \ln r} + \text{time and firm dummies} :$$

Time and Firm Dummies

Time (base,77)		*Firm (base, Delta)*		*Firm (base, Delta)*	
1970	0.141 (0.038)	American	0.140 (0.049)	Western	-0.114 (0.085)
1971	0.140 (0.036)	Braniff	-0.053 (0.073)	Air West	-0.026 (0.135)
1972	0.089 (0.032)	Continental	-0.115 (0.083)	Frontier	-0.169 (0.129)
1973	0.091 (0.031)	Eastern	0.092 (0.042)	North Central	-0.037 (0.137)
1974	0.078 (0.030)	National	-0.077 (0.095)	Ozark	-0.074 (0.149)
1975	0.076 (0.030)	Northeast	-0.095 (0.153)	Piedmont	-0.062 (0.143)

Finding 1: Changes in Factor Prices

- Elasticity of total costs w.r.t wage is 0.356, so that as wages increase 1%, total costs will increase 0.356 % (reflects *cost share*)
- Elasticity of total costs w.r.t fuel is 0.166, so that as fuel price increase 1%, total costs will increase 0.166 % (reflects *cost share*)
- so airlines should be much more worried about labor costs (unionization) than fuel costs

Finding 2: Economies of Density

- Increase Y (passenger miles) holding N fixed:
- Elasticity of total costs w.r.t Y is 0.836, so that as Y increase 1%, total costs will increase 0.836 %
- Conclude: There are *economies of scale in density*,
- S_D=1/0.836=1.196.

Finding 3: Economies of Size

- Increase Y (passenger miles) and N together:
- Elasticity of total costs w.r.t Y is 0.836, and w.r.t N is 0.131, so that increasing *both* by 1%, will increase total costs by (0.836+0.131) = 0.967 % (close to unity!)
- Conclude: There are *constant returns in overall size:*
- $S_S = 1/(0.836+0.131) \approx 1$

Finding 4: Changes in other outputs

- Elasticity of total costs w.r.t load factor is -0.277, so that increasing load by 1% reduces total costs by 0.277 %
- Elasticity of total costs w.r.t stage length is -0.135, so that increasing stage length by 1% reduces total costs by 0.135 %
- both these features generate considerable savings for airlines!

Finding 5: Overall technical change?

- The time dummies *fall* over time (at least up to 1980), so this indicates falling costs due to productivity improvements.
- Also, most airlines (except Eastern and American), have lower costs than Delta, due to productivity differences.

Selected Cost Studies of Railroads

Study	***Functional form***	***Data***	***Selected focus or conclusions***[a]
Keeler (1974)	Cobb-Douglas (loglinear)	Panel of 51 firms, 1968-70	CRS, economies of density
Brown, Caves, and Christensen (1979).	Translog	Cross section, 67 firms, 1936	IRS
Caves and others (1985)	Translog	Panel, 43 firms, 1951-75	IRS for some carriers, CRS for large carriers, economies of density
Harmatuck (1979)	Translog	40 firms, 1968-70	Economies of density
Caves, Christensen, and Swenson (1981).	Translog	U.S. railroads, 1955-74	Economies of density but less strong evidence of economies of scale
Braeutigam, Daughety, and Turnquist (1982).	Translog	One large RR, monthly, 1969-77	Economies of density, speed of service are important explanatory variable

Including User Inputs, i.e. Time

- Final output: q=passengers on buses per peak hour. Produced with:
- vehicles per peak hour V, with cost c_p
- waiting time, valued at v_T^W
- Suppose waiting time =1/2V. Then total costs of buses and waiting are,

$$C_B = c_p V, \qquad C_W = \frac{v_T^W q}{2V}$$

The transit authority's problem:

- Choose V to $\min \; C_B + C_W$
- subject to: $q \le NV$ N=bus capacity
- Set up the Lagrangian:

$$L = c_p V + \frac{v_T^W q}{2V} + \lambda(q - NV)$$

- differentiate w.r.t number of buses, V

Solution 1:

- FOC: $$c_p - \frac{v_T^W q}{2V^2} - N\lambda = 0$$
- Two solutions:
- (1) Suppose λ=0 (buses are not full). Then:

$$V^* = (v_T^W q / 2c_p)^{1/2}$$

$$W^* = \frac{1}{2}(q / V^*) = (c_p q / 2v_T^W)^{1/2}$$

$$C_B^* = C_W^* = (c_1 / 2)\sqrt{q}, \quad c_1 = (2v_T^W c_p)^{1/2}$$

Properties:

$$V^* = (v_T^W q / 2c_p)^{1/2}$$

- Number of buses is proportional to the *square root* of passengers on bus (q)
- W and total costs also depend on the *square root* of passengers (q), so there is *increasing returns to scale:* doubling q will increase V, W, and total costs by $\sqrt{2} = 1.4$

Solution 2:

- (2) Suppose $\lambda>0$ (buses are full), so q=VN. Then:

$$V^* = q / N$$

$$W^* = \frac{1}{2}(q / V^*) = N / 2$$

$$C_B^* = c_p q / N, \quad C_W^* = v_T^W N / 2$$

- We will still have increasing returns in q (since C_w acts like a fixed cost)

Transit Pricing:

- The finding of *increasing returns to scale* will substantially affect the "optimal pricing" policy for buses
- I.e., if we charge customers an amount equal to the marginal cost (MC) of transit, this will be *less than* the average cost (AC) of transit, since AC/MC > 1 for increasing returns
- So the total costs of the transit *will not be covered* by passenger fares!