4. FIRM PRODUCTION AND COST IN TRANSPORTATION

The long run

4.1. Theory

Productivity curves

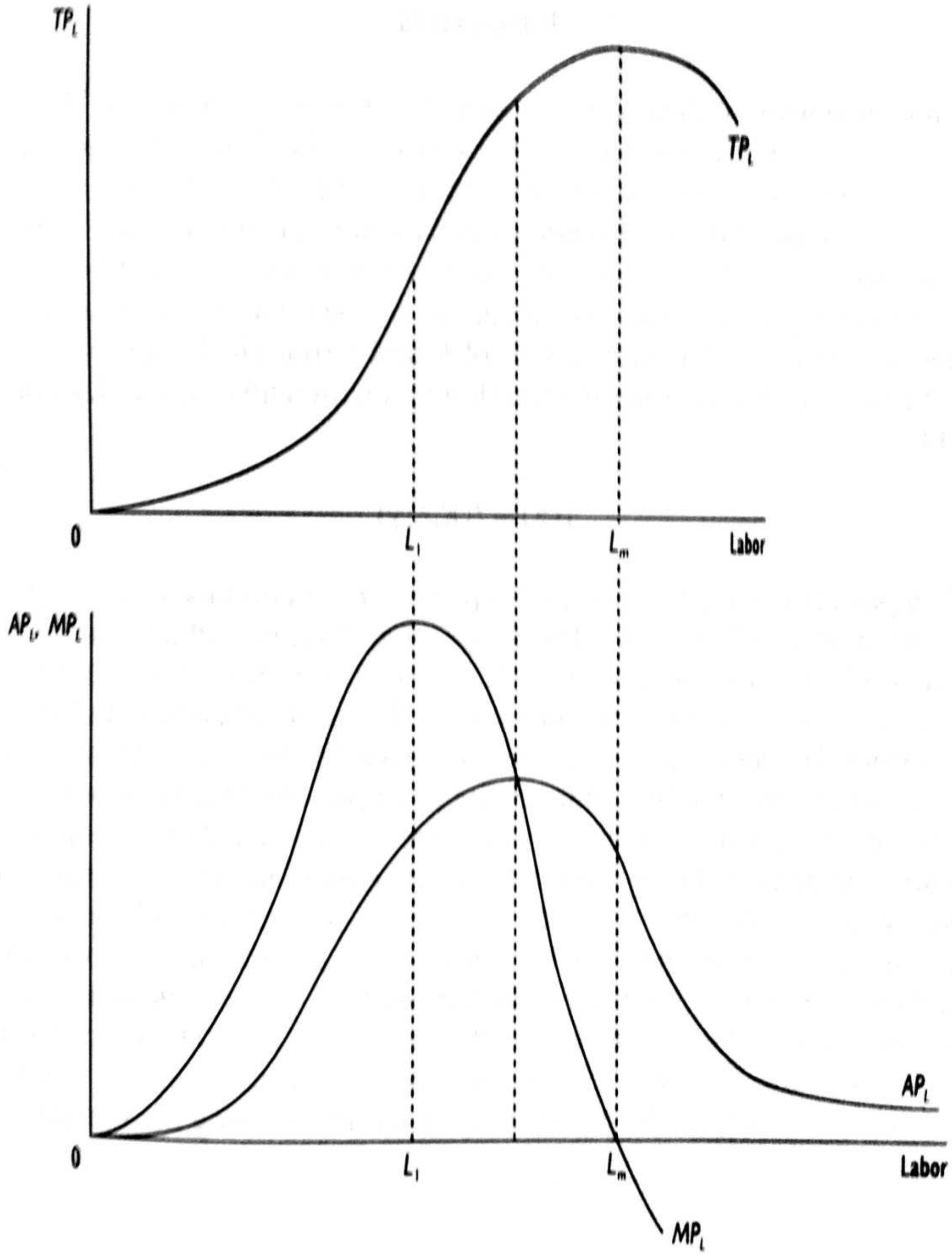

Figure 5.1 Productivity curves.

Isoquants

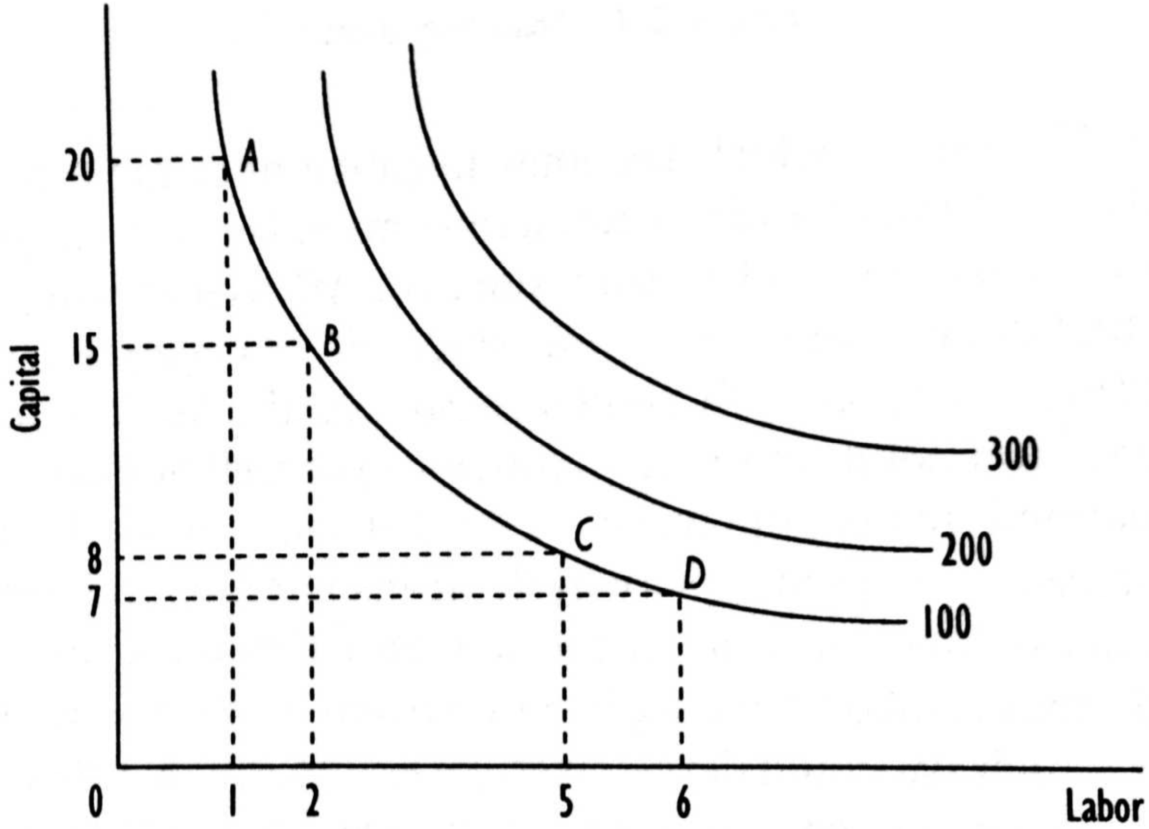

Figure 5.2 Isoquant curves.

$$0 = \square\square\square_{\square}\Delta\square + \square\square\square_{\square}\Delta\square$$

$$\Rightarrow -\frac{\Delta\square}{\Delta\square} = \frac{\square\square\square_{\square}}{\square\square\square_{\square}}$$

$$= \text{marginal rate of technical substitution}$$

Elasticity of substitution

The elasticity of substitution is defined as:

$$\sigma_{L,K} = \frac{\%\Delta\left(\frac{K}{L}\right)}{\%\Delta(MRTS_{L,K})}$$

and interpreted as the percentage change in he capital/labor ratio that results from a 1% increase in the marginal rate of technical substitution.

Returns to scale

$$sT = MP_L L + MP_K K$$

where s is a return to scale parameter (RTS). For s=1, the firm is operating under constant RTS; s >1 implies increasing RTS and s < 1 decreasing RTS.

$$s = MP_L(L/T) + MP_K(K/T) = MP_L/AP_L + MP_K/AP_K = E_{T,L} + E_{T,K}$$

RTS in production is the summation of individual output elasticities with respect to labor and capital.

Long run costs curves

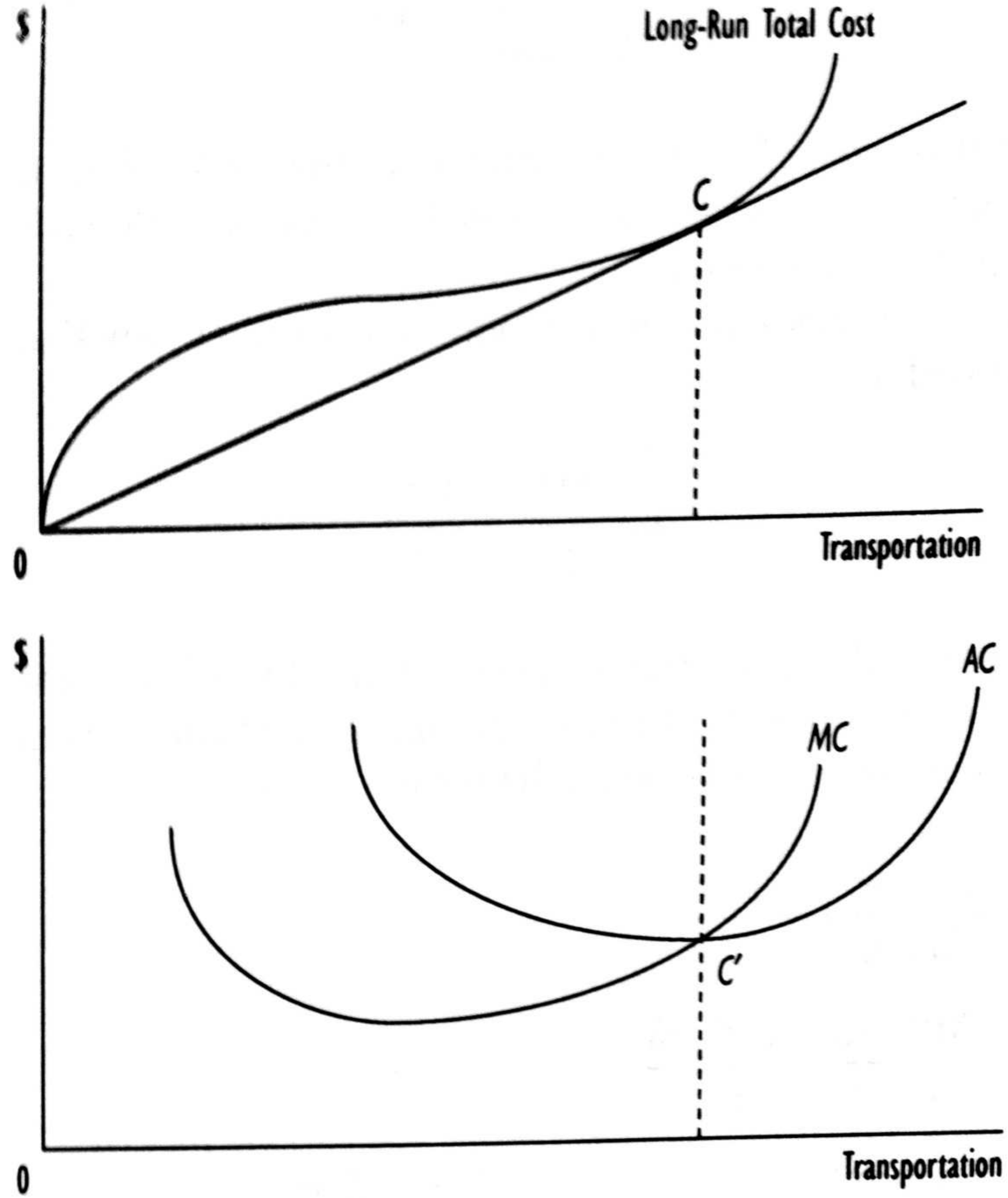

Figure 5.4 Total, average, and marginal cost curves.

Returns to scale and long run costs

[illegible] $=$ [illegible] $+$ [illegible]

$=$ [illegible] $+$ [illegible]

$= \frac{1}{[\text{illegible}]}\left([\text{illegible}]\right)$ (since [illegible] $=$ [illegible] in equilibrium)

$= \frac{[\text{illegible}]}{[\text{illegible}]} = \frac{1}{[\text{illegible}]}$

where $E_{C,T}$ is the elasticity of total cost with respect to output $E_{C,T} = \Delta C/\Delta T * T/C$

The relationship between economies of scale and cost elasticity

Former equation tells us that, for constant input prices, there is an inverse relationship between production RTS and elasticity of total cost with respect to output:

Returns to Scale	Value of s	Value of $E_{C,T}$
Increasing	> 1	< 1
Constant	= 1	= 1
Decreasing	< 1	> 1

Therefore, analysis of firm cost s provides economically relevant information on a firm's production technology without having to separately estimate a firm's production function.

Input demands and Shephard's lemma

$$E_{C,w} = \frac{w}{C(T;w,r,\gamma)}\frac{\Delta C(T;w,r,\gamma)}{\Delta w} = \frac{wl(T;w,r,\gamma)}{C(T;w,r,\gamma)}$$

$= \text{conditional optimal } \textit{share} \text{ of labor expenditures in total costs}$

$$E_{C,r} = \frac{r}{C(T;w,r,\gamma)}\frac{\Delta C(T;w,r,\gamma)}{\Delta r} = \frac{rk(T;w,r,\gamma)}{C(T;w,r,\gamma)}$$

$= \text{conditional optimal } \textit{share} \text{ of capital expenditures in total costs}$

Elasticity of substitution and long run costs

In equlibrium, the marginal rate of technical substitution equals the input price ration. Thus the elasticity of substitution between capital and labor σ_{KL} can be expressed as:

$$\sigma_{KL} = \frac{\%\Delta\left(\frac{K}{L}\right)}{\%\Delta\left(\frac{w}{r}\right)}$$

Alternative measures of cost elasticities in transport

- Economies of scale
- Economies of capital stock utilization
- Economies of traffic density and generalized economies of scale

The long run market supply function

Assuming that there are F firms in the industry and summing over each of these firms gives the long run market supply function:

$$?^{\mathrm{lr}}_{?}(?, ?, ?, ?) = \sum_{?=1}^{?} ?^{\mathrm{lr}}_{?}(?, ?, ?, ?)$$

Changes in long run market supply

Increase in Supply from $S_T^{\mathrm{lr}}(p)$ to $S_T''^{\mathrm{lr}}(p)$ due to:	Decrease in Supply from $S_T^{\mathrm{lr}}(p)$ to $S_T'^{\mathrm{lr}}(p)$ due to:
Increase in the number of firms	Decrease in the number of firms
Decrease in the prices of inputs	Increase in the prices of inputs
Increase in subsidies given to T	Decrease in subsidies given to T
Decrease in taxes on T	Increase in taxes on T
Improvements in technology γ	

Estimating long run cost functions

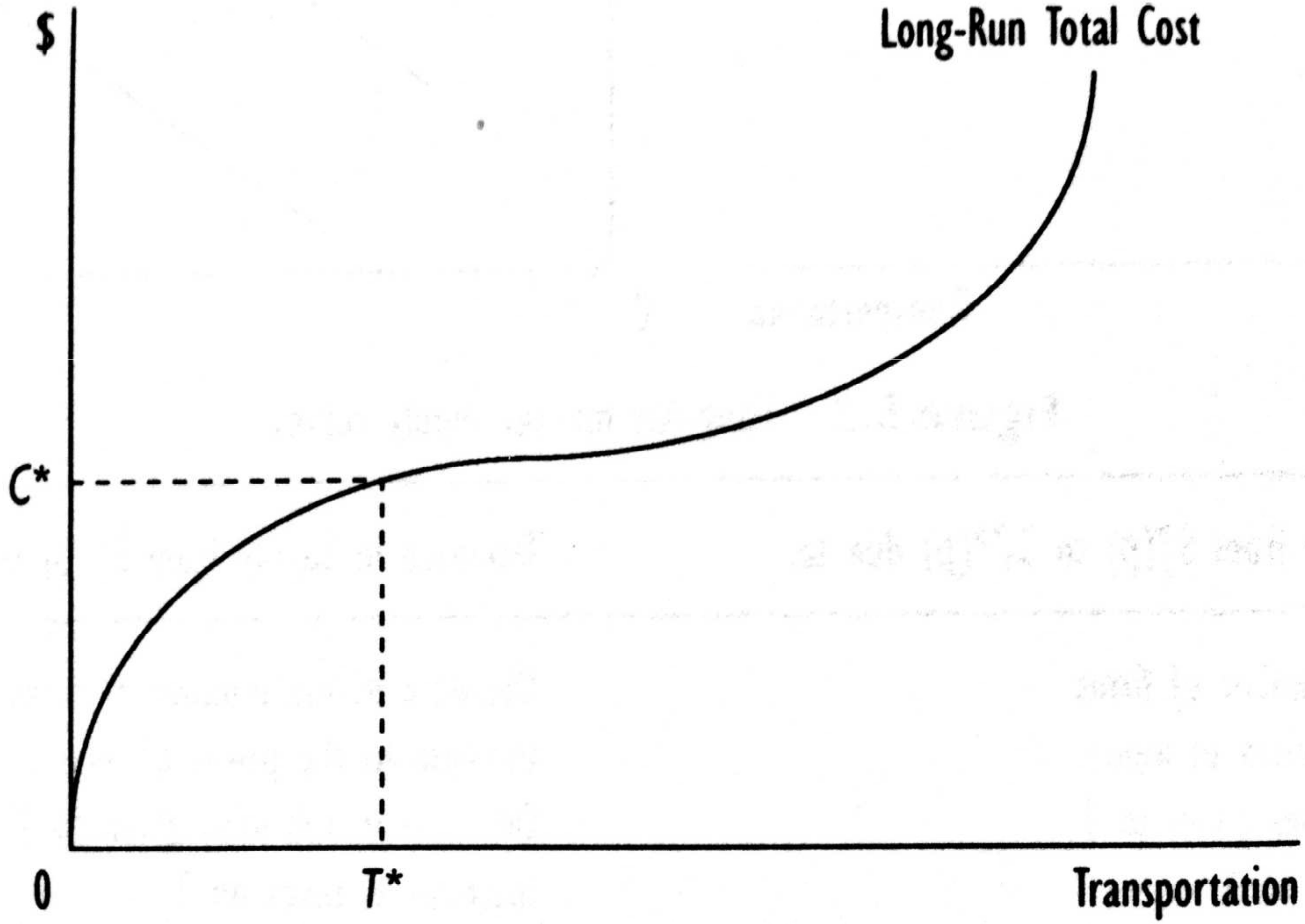

Figure 5.6 Predicted cost–output combination.

Leontif (fixed proportions) cost function

$$T = \min\left(\frac{L}{a}, \frac{K}{b}\right), \quad a, b > 0$$

$$C(T; w, r, \gamma) = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \varepsilon$$

Cobb Douglas cost function

$$T = AL^a K^b, \quad a, b > 0$$

$$\ln C(T; w, r, \gamma) = \alpha_0 + \alpha_1 \ln T + \alpha_2 \ln w + \alpha_3 \ln r + \varepsilon$$

Leontief and Cobb-Douglas isoquants

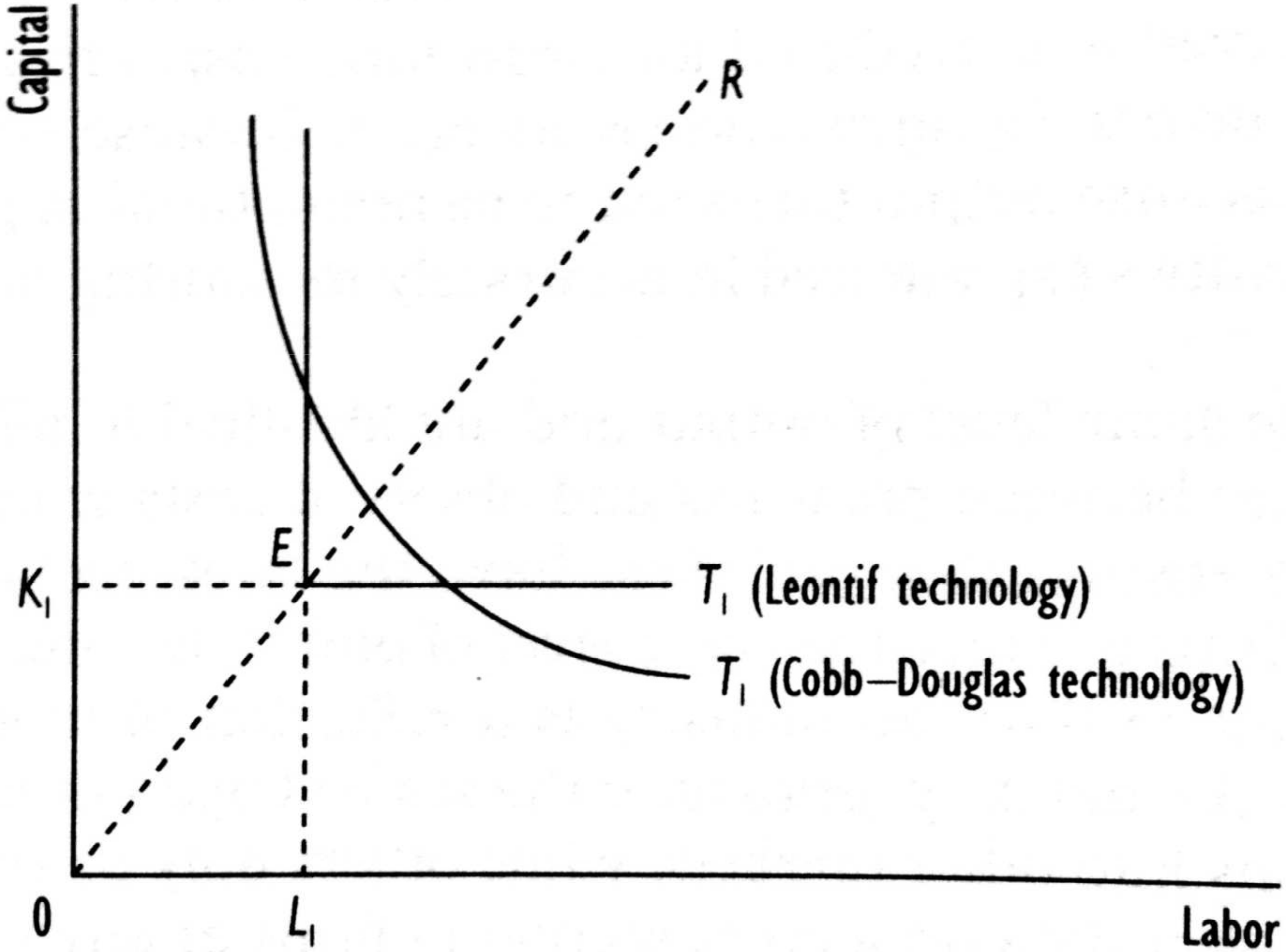

Figure 5.7 Leontif and Cobb–Douglas isoquants.

Flexible cost functions (translog)

Regressor	Coefficient	Interpretation
Constant term	α_0	Logarithm of total cost at the sample mean
$(\ln T - \ln \bar{T})$	α_1	Elasticity of total cost with respect to output T at the sample mean
$(\ln w - \ln \bar{w})$	α_2	Share of labor in total costs, evaluated at the sample mean
$(\ln r - \ln \bar{r})$	α_3	Share of capital in total costs, evaluated at the sample mean
$(\ln \gamma - \ln \bar{\gamma})$	α_4	Percentage change in total cost from a 1% change in technology, evaluated at the sample mean

$$\ln C(T; w, r, \gamma) = \alpha_0 + \alpha_1(\ln T - \ln \bar{T}) + \alpha_2(\ln w - \ln \bar{w})$$
$$+\alpha_3(\ln r - \ln \bar{r}) + \alpha_4(\ln \gamma - \ln \bar{\gamma})$$
$$+\text{“second– order and interaction terms”} + \varepsilon$$

Flexible cost functions (translog)

$$\ln C(T; w, r, o, t) = \alpha_0 + \alpha_1(\ln T - \ln \bar{T}) + \alpha_2(\ln w - \ln \bar{w})$$
$$+\alpha_3(\ln r - \ln \bar{r}) + \alpha_5(\ln o - \ln \bar{o}) + \alpha_6(\ln t - \ln \bar{t})$$
$$+\text{“second– order and interaction terms”} + \varepsilon$$

Regressor	Coefficient	Interpretation
$(\ln o - \ln \bar{o})$	α_5	Elasticity of total cost with respect to operating characteristic o at sample mean
$(\ln t - \ln \bar{t})$	α_6	Productivity growth rate period of time (e.g. per year) at the sample mean

Intercity freight movements in the US

Year	ICC Truck	Non-ICC Truck	Rail	Air	Water	Pipeline
1940	21 (3.4)	41 (6.6)	379 (61.3)	0.02 (0)	118 (19.1)	59 (9.5)
1950	66 (6.2)	107 (10.1)	597 (56.2)	0.3 (0.03)	164 (15.4)	129 (12.1)
1960	104 (7.9)	181 (13.8)	579 (44.1)	0.9 (0.07)	220 (16.7)	229 (17.4)
1970	167 (8.6)	245 (12.6)	771 (39.8)	3.3 (0.17)	319 (16.5)	431 (22.3)
1975	200 (9.7)	254 (12.3)	759 (36.7)	3.7 (0.18)	352 (16.6)	507 (24.5)
1980	242 (9.7)	313 (12.6)	932 (37.5)	4.8 (0.19)	407 (16.4)	588 (23.6)
1985	250 (10.2)	360 (14.6)	895 (36.4)	6.7 (0.27)	382 (15.5)	564 (22.9)
1990	311 (10.9)	424 (14.8)	1,071 (37.4)	10.4 (0.36)	464 (16.2)	584 (20.4)

Note: The numbers in parentheses are modal shares.
Source: ENO Transportation Foundation (1993)

Motor carriers costs and production technology under regulation

- Economic regulation of motor carrier activities during 1935 – 1980
- Two types of cargo: truckload (TL) carriers and less than truckload carriers (LTL)
- LTL find it advantageous to invest in terminal facilities (no need in TL sector)
- Underlying technologies and costs different in TL and LTL sector
- Two analyses of motor carrier cost and technology in regulated environment.
- The first study focus upon TL sector, while the second upon LTL sector

4.2. Regulated truckload carriers

Specification

McMullen and Stanley (1988) estimated a translog flexible cost function for specialized commodity (TL) motor carriers. In abbreviated form, their empirical cost function is:

$$
\begin{aligned}
\ln \square(\square, \square, \square) = \square_0 + \square_1(\ln \square - \ln \bar{\square}) \\
+ \square_2(\ln \square_l - \ln \bar{\square}_l) \\
+ \square_3(\ln \square_k - \ln \bar{\square}_k) \\
+ \square_4(\ln \square_f - \ln \bar{\square}_f) \\
+ \square_5(\ln \square_{pt} - \ln \bar{\square}_{pt}) \\
+ \square_6(\ln \square_{ald} - \ln \bar{\square}_{ald}) \\
+ \square_7(\ln \square_{alh} - \ln \bar{\square}_{alh}) \\
+ \square_8(\ln \square_{ins} - \ln \bar{\square}_{ins}) \\
+ \text{“second– order and interaction terms”} \\
+ \square
\end{aligned}
$$

Hypotheses

1. The truckload sector operates under constant returns to scale $\longrightarrow \alpha_1 = 1$
2. An increase in the price of any input increases all else constant, long-run total costs. Thus, we expect: $\alpha_2 > 0; \alpha_3 > 0; \alpha_4 > 0; \alpha_5 > 0$. From Shephard's lemma: $\alpha_2+\alpha_3+\alpha_4+\alpha_5 = 1$
3. Average load per vehicle reflects increased capacity utilization; longer hauls are expected to have lower costs and higher insurance is a proxy for high value or perishable goods. Therefore we expect: $\alpha_6 < 0; \alpha_7 < 0; \alpha_8 > 0$.

Estimation results

Regressor	Coefficient Estimate (t-statistic)	Interpretation
Constant term	8.32 (46.1)	Logarithm of total cost at the sample mean
Output	0.721 (4.6)	Elasticity of total cost with respect to output T at the sample mean
Price of Labor	0.387 (9.8)	Share of labor in total costs, evaluated at the sample mean
Price of Capital	0.308 (12.5)	Share of capital in total costs, evaluated at the sample mean
Price of Fuel	0.127 (6.7)	Share of fuel in total costs, evaluated at the sample mean
Price of Purchased Transportation	0.178 (2.7)	Share of purchased transportation in total costs, evaluated at the sample mean

Estimation results

Average Load Per Vehicle	–0.674 (–3.6)	Elasticity of total cost with respect to average load, at the sample mean
Average Length of Haul	–0.093 (–0.77)	Elasticity of total cost with respect to average length of haul, at the sample mean
Insurance Cost Per Ton-Mile	0.076 (0.35)	Elasticity of total cost with respect to per ton-mile insurance cost, at the sample mean
$R^2 = 0.99$		
Number of observations = 81		

Note: The estimated translog cost function has the following form:

$$\ln C(T; p, o) = \alpha_0 + \alpha_1(\ln T - \ln \bar{T}) + \sum_{i=2}^{5} \alpha_i(\ln p_i - \ln \overline{p_i}) + \sum_{i=6}^{8} \alpha_i(\ln o_i - \ln \overline{o_i})$$
$$+ \text{“second– order and interaction terms”} + \varepsilon$$

Source: McMullen and Stanley (1988), table II, p. 306

Interpretation

1. Firms are operating under increasing rather than constant RTS
2. Each of the price coefficients is positive and significant.
3. The results for firm operating characteristics are mixed.

Elasticities

	Labor	Capital	Fuel	Purchased Transportation
Own-Price Elasticity	–0.566	–0.682	–0.582	–1.92
*Elasticity of Substitution**				
Labor	–	0.590	0.177	2.30
Capital	0.590	–	0.514	2.19
Fuel	0.177	0.514	–	2.78
Purchased Transportation	2.30	2.19	2.78	–

* Note that the estimated elasticities of substitution are symmetric. The elasticity of substitution of labor for capital, for example, is the same as that of capital for labor.
Source: McMullen and Stanley (1988), table IV, p. 310

Discussion

1. What are long-run total costs?
2. Increasing RTS under regulation and constant RTS after deregulation?
3. The elasticities of substitution are neither equal to zero or one, therefore use of flexible cost function is appropriate (unlike Leontif or Cobb-Douglas)
4. The relationship between output and long run total cost reflects a movement along the long run total cost curve. Changes in any of the other variables reflects change in the location of the curve.

4.3. Regulated general freight carriers

Introduction

- The results presented for the TL sector characterize specialized commodity motor carriers firms as operating under increasing RTS and whose underlying technology enables firms to substitute between their owned inputs and purchased transportation.
- Would we expect to see similar cost and technological characteristics for general freight services? – No, since general freight services require a network of origin and destination terminals.

Hypotheses

- H_0: LTL and TL motor carriers have identical cost structures and production technologies
- H_1: LTL and TL motor carriers have different cost structures and production technologies

Estimation results

Regressor	Coefficient Estimate (*t*-statistic)	Interpretation
Constant term	0.556 (6.62)	Logarithm of total cost at the sample mean
Output	1.025 (25.6)	Elasticity of total cost with respect to output *T* at the sample mean
Price of Labor	0.624* (–)	Share of labor in total costs, evaluated at the sample mean
Price of Capital	0.244 (34.9)	Share of capital in total costs, evaluated at the sample mean
Price of Fuel	0.040 (21.3)	Share of fuel in total costs, evaluated at the sample mean
Price of Purchased Transportation	0.092 (6.1)	Share of purchased transportation in total costs, evaluated at the sample mean

Average Load Per Vehicle	−0.282 (−2.4)	Elasticity of total cost with respect to average load, at the sample mean
Average Length of Haul	−0.407 (−5.8)	Elasticity of total cost with respect to average length of haul, at the sample mean
Average Shipment Size	−0.114 (−1.3)	Elasticity of total cost with respect to average shipment size, at the sample mean
Percentage of LTL Traffic	0.254 (2.1)	Elasticity of total cost with respect to percentage of LTL traffic, at the sample mean
Insurance Cost Per Ton-Mile	0.121 (1.7)	Elasticity of total cost with respect to per ton-mile insurance cost, at the sample mean

$R^2 = 0.95$

Number of observations = 412

Note: The estimated translog cost function has the following form:

$$\ln C(T; p, o) = \alpha_0 + \alpha_1(\ln T - \ln \overline{T}) + \sum_{i=2}^{5} \alpha_i(\ln p_i - \ln \overline{p_i}) + \sum_{i=6}^{10} \alpha_i(\ln o_i - \ln \overline{o_i})$$
$$+ \text{“second– order and interaction terms”} + \varepsilon$$

* The coefficient for labor was derived from the constraint that input coefficients sum to 1. The *t*-statistic was not reported.

Source: Reprinted from Ying (1990b), Appendix, p. 1006, with the permission of the Southern Economic Association

Interpretation

- In contrast to specialized commodity carriers, firms in the LTL sector operate under constant RTS
- What is the effect of deregulation?
- The share of labor is much higher in LTL sector due to more handling
- Operating characteristics in both sectors have same signs but different magnitudes

Elasticities

	Labor	Capital	Fuel	Purchased Transportation
Own-Price Elasticity	–0.372	–0.762	–0.724	–0.973
*Elasticity of Substitution**				
Labor	–	0.968	0.766	0.947
Capital	0.968	–	0.762	1.44
Fuel	0.776	0.762	–	0.856
Purchased Transportation	0.947	1.44	0.856	–

* Note that the estimated elasticities of substitution are symmetric. The elasticity of substitution of labor for capital, for example, is the same as that of capital for labor.
Source: Ying (1990b), table II, p. 1002

Final comments

1. At the sample mean, the TL sector operated under increasing RTS, whereas LTL sector under constant RTS.
2. On average capital, fuel and purchased transportation were more important in the production of TL than LTL transportation services. On the other hand, labor played a more important role in providing LTL services.
3. For both sectors, all inputs were substitutes in production. However demand for purchased transportation was more elastic in TL, whereas labor, capital and fuel were more easily substitutable in LTL.
4. Technological differences reflected by firm operating characteristics differed between the two sectors.

4.4. Airline cost and production under regulation

Introduction

- After WWII, rapid growth in airline passenger traffic
- From the beginning of government involvement in the airline industry, an explicit aim was to foster the industry's growth
- The main provision of the regulation dealt with market access, route restrictions, rate-setting and subsidization.

Control of entry/exit

- The regulators tightly controlled entry into and exit from the market
- The carriers that provided intercity air service in 1938 were granted operating authority and between 1938 – 1975 there was no new allowance to entry
- Exit from the industry was as difficult as entry because air carriers were mandated to provide adequate service
- Over time firms found, that mergers were the quickest way to effectuate entry and exit.
- Of the 16 trunk lines granted authority, 11 remained at the beginning of 1970.

Route and rate restriction

- The regulation aimed to stabilize the indsutry by equalizing profitability across firms.
- There was a regulation of non-stop services and opening new markets (new routes)
- Rates were requied to be just, reasonable and non-discriminatory
- Rates were deemed to be too high if they led to inordinately high rates of return on investment and unjustly low if they affected the financial health of a competing carrier.

Subsidization

- Although the regulation severely restricted entry and exit into the major trunkline routes, it experimented with entry info feeder markets, giving temporary operating authority to local carriers to provide subsidized short-haul service from smaller communities to the larger markets served by the trunk carriers
- During time, temporary authority became permanent and sometimes overlapped with the more profitable trunkline routes in order to stem the growing level of subsidies paid to local carriers.
- As a result, in the period after permanent certification, local carriers evolved into a group of larger regional carriers that competed with trun carriers.

US providers of air transport services, 1970

Carrier Type	Number of Carriers	Revenue Ton-Miles* (millions)	Percentage of Total
Trunk	11	12,288.7	88.1
Local	9	851.5	6.1
All Cargo	2	301.5	2.2
Commuter	179	47.1	0.3
Other**	22	458.1	3.3

* A revenue ton-mile is one ton of revenue traffic (passenger and cargo) transported one mile.
** Other includes 13 supplemental carriers (providing nonscheduled charter service domestically), two carriers operating within Hawaii, four carriers within Alaska, and three helicopter services.
Source: Douglas and Miller (1974), table A-2, p. 193

Specifications of costs for regulated air carriers

- Becuse differences in the markets, the size if aircraft used, average stage length and average load, local carriers may face different cost strucutres, and hence technologies, than trunk carriers
- Consistent with this is the belief that the trunk carriers operate under constant RTS, whereas the local carriers operate under increasing RTS.
- If true, the implicationis that larger size of operations of trunk carriers gives them competitive advantage and that local carriers will be able to reduce unit costs if allowed to increase their scale of operations.

Specification

- Caves, Christiansen and Tretheway (1984) estimated a general model of total airline costs based upon trunk and local carriers operating from 1970 through 1981, a total of 208 observations.
- The empirical cost model is a flexible translog model which includes translog transformations of Output, Prices of inputs, operating characteristics and network characteristics.

Hypotheses

1. Air carriers operate under constant RTS
2. There exist increasing returns to traffic density where the size of the carrier’s network is held fixed.
3. The coefficients of the input prices will be positive.
4. It is expected that increases in Average Stage Length and Average Load will decrease long run total costs.

Estimation results

Regressor	Coefficient Estimate (t-statistic)	Interpretation
Constant	13.243 (294.3)	Logarithm of long-run total cost, evaluated at the sample mean
Revenue Output-Miles	0.804 (23.6)	Elasticity of total cost with respect to output T at the sample mean
Average Number of Points Served	0.132 (4.2)	Elasticity of total cost with respect to average number of points served, at the sample mean
Price of Labor	0.356 (178.0)	Share of labor in total costs, evaluated at the sample mean
Price of Capital	0.478 (239.0)	Share of capital in total costs, evaluated at the sample mean
Price of Fuel	0.166 (166.0)	Share of fuel in total costs, evaluated at the sample mean

Estimation results

Average Stage Length	–0.148 (–2.7)	Share of purchased transportation in total costs, evaluated at the sample mean
Average Load Factor	–0.264 (–3.8)	Elasticity of total cost with respect to average load, at the sample mean
Number of observations = 208		

Note: The authors did not report the R^2 for this study. The estimated translog cost function has the following form:

$$\ln C(T;p,o) = \alpha_0 + \alpha_1(\ln T - \ln \bar{T}) + \sum_{i=2}^{5} \alpha_i (\ln p_i - \ln \overline{p_i}) + \sum_{i=6}^{10} \alpha_i (\ln o_i - \ln \overline{o_i})$$

$$+ \text{“second– order and interaction terms”} + \text{“time dummy effects”} + \text{“first dummy effects”} + \varepsilon$$

Source: Caves et al. (1984), table A1, p. 484

Elasticities

	Labor	Capital	Fuel
Own-Price Elasticity	–0.17	–0.21	–0.01
*Elasticity of Substitution**			
Labor	–	0.46	–0.29
Capital	0.46	–	0.24
Fuel	–0.29	0.24	–

* Note that the estimated elasticities of substitution are symmetric. The elasticity of substitution of labor for capital, for example, is the same as that of capital for labor.
Source: Caves and al. (1984), table 5, p. 479

Trunks versus local carriers under regulation

	Trunk Carriers	Local Carriers
Returns to Scale*	1.025	1.101
Returns to Density	1.253	1.295
Operating Characteristics		
Average Number of Points Served	61.2	65.2
Average Stage Length	639	152
Average Load Factor	0.520	0.427

* For both trunk and local carriers, the null hypothesis of generalized constant returns to scale could not be rejected at the 0.05 level.
Source: Caves et al. (1984), table 4, p. 478

Policy implications

- It is possible for the smaller local carriers to compete with the much larger trunk carriers?
- The uit costs of local carriers are 44% higher than those of trunk carriers.
- The reasons are density of service and stage length.
- The implication from these results is that local carriers want to exploit economies of traffic density and economies of distance.

4.5. Summary

Summary (1)

- Given the existing technology, a firm‘s production function is the maximum amount of output that a firm can produce from a given quantity of inputs. If all inputs to the firm are variable, the firm is in the long run; if some inputs are fixed, the firm is in the short run.
- The elasticity of substitution, defined as the percentage change in an input ratio due to a percentage change in the marginal rate of technical substitution, reflects the ease with which a firm can substitute among inputs in the production process. If a proportional increase in all variable inputs raises output (less than, more than) proportionately, then the firm is operating under constant (decreasing, increasing) returns to scale.

Summary (2)

- A firm minimizes its cost of production by using inputs up to the point at which the marginal rate of technical substitution equals the input price ratio. A firm‘s total cost function is the minimum cost necessary to produce a given amount of output. A firm‘s minimum efficient scale is that level of output corresponding to the minimum point on a firm‘s average cost curve. At this point, the firm is operating under constant returns to scale.

Summary (3)

- Knowing a firm‘s cost function provides information on the firm‘s underlying production technology. The inverse of the elasticity of total cost with respect to output measures a firm‘s economies of scale. By Shepard‘s lemma, the elasticity of total cost with respect to input price is the conditional optimal share of the input‘s expenditures in total costs. The long-run total cost function also provides information on the elasticity of substitution among inputs.
- In addition to economies of scale, transportation firms also experience economies of traffic density, economies of capital utilization, and economies of network size.

Summary (4)

- Empirically, there exist several cost function models to characterize transportation activities. The most restrictive is the Leontif cost function model, which assumes constant returns to scale and no substitutability among inputs. The Cobb-Douglas cost function model allows for nonconstant returns to scale and input substitutability, but the elasticity of substitution is constrained to equal one. The least restrictive cost function model is the translog cost function, which allows for nonconstant returns to scale and places no restrictions on substitutability among inputs.

Summary (5)

- The motor carrier industry comprises two basic sectors, the truckload or specialized commodity carrier and the less-than-truckload or general freight carrier sector. By having to consolidate and break-bulk shipments, the less-than-truckload sector has a different production technology than the truckload sector.
- Economic regulation of the motor carrier industry began with the Motor Carrier Act of 1935, which regulated firm entry, rates, routes, and goods carrier. Many of these regulations were significantly relaxed in the Motor Carrier Act of 1980.

Summary (6)

- A case study of the truckload sector of the motor carrier industry under economic regulation found that truckload firms operated under increasing returns to scale, which is inconsistent with the competitive nature of this sector but consistent with regulatory-based economies of network size. This sector was less labor intensive and relied more on purchased transportation. Input demands for labor, capital, and fuel in this sector were inelastic. But the demand for purchased transportation was elastic. The elasticities of substitution indicated that all inputs were substitutes. The greatest opportunities for input substitution occurred with purchased transportation.

Summary (7 – 1/2)

- A case study of the less-than-truckload sector under regulation confirms that differences in production technology exist between this sector and the truckload sector. Less-than-truckload firms operated under constant returns to scale, holding network size constant. However, there was also evidence of generalized returns to scale in this sector, which indicated that a proportional increase in output and network size increased costs less than proportionately. This sector was more labor intensive than the truckload sector and relied much less on purchased transportation. Firms' costs in this sector were sensitive to shipment size, length of haul, and value of commodity shipped. (…)

Summary (7 – 2/2)

- (...) Factor demands, including purchased transportation, were inelastic. Similar to the truckload sector, all inputs were substitutes. However, in contrast to the truckload sector, there were greater substitution possibilities among fuel, capital, and labor inputs, but fewer opportunities for substitution between each of these inputs and purchased transportation.
- Economic regulation of the US airline industry began with the Civil Aeronautics Acts of 1938, which controlled firm entry and exit, route operating authority, and fares. Economic regulation continued until passage of the Airline Deregulation Act in 1978

Summary (8)

- A case study of trunk and local airline costs during the 1970s indicated that air carriers operated under economies of density. Further, during this period, air carriers operated under general constant returns to scale; that is, a proportional increase in output and network size, all else constant, increase costs proportionately. Air carrier operations were relatively capital intensive, with 48 % of total cost expended on capital. In the form of lower costs, air carriers benefited from high average loads and longer stage lengths. Factor inputs were price inelastic, and relatively few possibilities appeared to exist for input substitution between capital and labor or capital and fuel. Labor and fuel were complements in production.

Summary (9)

- A comparison of trunk and local air carriers during the transition to deregulation indicated that local carriers experienced unit costs that were more than 40 % higher than those of trunk carriers. This can be attributed to significant differences in traffic density between the two sectors, as well as to the longer stage length of the trunk carriers.