REGULATORY DISTORTIONS
IN
TRANSPORTATION AND TELECOMMUNICATIONS

Thesis by

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ABSTRACT

The first of three papers corrects two flaws in the literature on traffic misallocation under rate regulation by the ICC. First, it is shown that, contrary to suggestions in several recent studies, the comparative-cost approach, which determines an efficient allocation by assigning all traffic in a class to the low-cost mode, does not necessarily overstate the welfare loss on misallocated traffic. Second, Levin's modal-split procedure was applied to data for 1963-64. Although the modal-split concept, in which an efficient traffic distribution is derived from the demand function, has been applied several times, the different procedures make comparisons over time difficult. Comparing Levin's results for 1972 with those obtained here indicates that the extent and the cost of the traffic misallocation have declined.

The second paper attempts to determine the pricing and welfare effects of competition and regulation in a transportation network. The pricing and input (car assignment) decisions of a railroad monopolist subject to common carrier and round-trip constraints are determined. Then competition is introduced by shifts in rail demand and regulation as a set of constraints on pricing that are based on costs observed in the network. Both competition and regulation can cause

peak (fully-loaded) directions to change, and the welfare effects can be negative.

The final paper examines the effect of jurisdictional cost separations in telecommunications on input use by the profit-maximizing firm. In an Averch-Johnson formulation of the problem, separations can alter some of the expected factor use relationships. In addition, the firm has an incentive to employ unproductive inputs in a jurisdiction that has no productive input specifically assigned to it. But because the Averch-Johnson model is an unrealistic characterization of the regulatory process, a model is developed in which the regulator explicitly sets prices on the basis of the firm's profitability in a previous period in his jurisdiction. Since the firm can influence future prices by its input choices in the present period, it may choose to hire unproductive inputs. Moreover, the cost separations process distorts factor use relative to a multi-product firm regulated on the basis of overall profitability.

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CHAPTER I

THE EFFECT OF RATE REGULATION ON FREIGHT TRAFFIC ALLOCATION

The Interstate Commerce Commission has long been criticized for maintaining a rate structure for freight transportation that causes a misallocation of traffic among modes and thereby contributes to the financial difficulties of the railroads. The misallocation is said to arise because rates do not coincide with the costs of providing service. The extent of the misallocation has usually been measured by reassigning traffic to the lower-cost carrier in shipment classes defined by commodity, weight, and length of haul, a procedure known as the comparative-cost method. Using this approach, Harbeson found the cost of the misallocation between railroads and trucks in the early 1960s to be as much as $2.9 billion per year, a figure which has become important evidence in the case against regulation.[1]

More recent work, however, indicates that the size of the misallocation has been overstated. In particular, Levin has shown that the cost of this inefficiency is more likely

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[1]Robert Harbeson, "Toward Better Resource Allocation in Transport," Journal of Law and Economics 12 (October 1969): 332.

on the order of $100 million per year.[2] These studies have proceeded by estimating market shares for each mode on the basis of relative rates and service characteristics and then using the regression coefficients to determine a cost-based allocation of traffic. This technique has been labelled the modal-split method.

The modal-split approach embodies a more realistic view of modal choice by shippers and so measures more accurately the cost of the traffic misallocation. This paper, however, corrects two important errors in previous research. First, Levin asserted that the comparative-cost method necessarily overstates the extent of the misallocation, even if the average service differential between railroads and trucks in each shipment class is determined correctly.[3] A simple comparison of the two methods demonstrates that Levin's statement is not true. Second, it is difficult to compare the results of the two approaches because data from two different time periods have been used. That is, comparative-cost results are generally based on statistics from the early 1960s, while modal-split studies have relied on data from the early 1970s. This paper indicates the relative importance of different procedures and time periods by

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[2]Richard Levin, "Allocation in Surface Freight Transportation: Does Rate Regulation Matter?" Bell Journal of Economics 9 (Spring 1978): 38.

[3]Ibid., pp. 19-20.

reporting the results of an earlier update of the comparative-cost method[4] and by applying the modal-split procedures to the 1960s data.

The organization of this paper is straightforward. Section 1 examines the roots of the traffic misallocation. Section 2 reviews previous studies and compares the comparative-cost and modal-split approaches. Section 3 uses the modal-split method to estimate the cost of the misallocation in the early 1960s. Finally, section 4 considers the policy implications of this research.

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[4]Lee Sparling, "Rate Regulation and Freight Traffic Allocation: A Review and Revision," Social Science Working Paper No. 68, California Institute of Technology, March 1975.

1. ICC rate regulation and the efficient allocation of traffic

Regulated freight rates are based on both cost and demand conditions. The proportions by which rates exceed costs are greater for high-value manufactured goods than for low-value bulk commodities, a rate structure known as value-of-service pricing. The purpose of this section is to describe the role of the ICC in maintaining this rate structure and to explain how the Commission's rate policies have produced a misallocation of traffic among modes.

The Interstate Commerce Act in 1887 prohibited railroad price discrimination among shippers but failed to address either discrimination by commodities or the basic problem of monopoly power. The railroads supported regulation because it stabilized the rate level while leaving value-of-service pricing intact.[5] Value-of-service pricing survived because it maximized railroad profits while serving the interest of the government in the development of the West.

Rail transportation demands in 1887 were more elastic

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[5]The period before 1887 was marked by the formation and collapse of several railroad traffic pools. MacAvoy has documented the effectiveness of regulation in eliminating the sharp rate fluctuations that characterized this cycle, and Kolko has shown that the railroads recognized the potential and actual value of regulation in stabilizing the cartel. Paul MacAvoy, The Economic Effects of Regulation: The Trunk Line Railroad Cartels and the Interstate Commerce Commission before 1900 (Cambridge: Massachusetts Institute of Technology Press, 1965) and Gabriel Kolko, Railroads and Regulation, 1877-1916 (New York: W. W. Norton, 1965).

for bulk commodities than for manufactured goods for two reasons. First, barge competition was generally more effective for bulk agricultural and mineral goods, and second, the shares of freight costs in delivered prices were higher for bulk commodities. As a result, low rates on bulk goods and high rates on manufactured products were more profitable than relatively uniform rates.[6] At the same time this rate structure promoted Western development. Low rates on bulk exports increased the settlers' market area, while high rates on manufactured imports speeded the growth of Western industry.

However, railroad pressure for modification of the rate structure arose as growing intermodal competition produced more elastic demands for rail transportation. In addition, an imbalance in cross-country movements caused a shortage of capacity for agricultural shipments that exerted upward pressure on bulk rates. But the ICC and Congress continued to hold bulk rates down and reaffirm value-of-service pricing in order to protect depressed agricultural areas.

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[6]The profit-maximizing condition that marginal revenue equal marginal cost can be written:

$$p(1-\frac{1}{\eta}) = mc \qquad \text{or} \qquad \frac{p-mc}{mc} = \frac{1}{\eta-1}$$

where p = price, mc = marginal cost, and η = elasticity of demand for any market. That is, the profit-maximizing markup varies inversely with the elasticity of demand.

This policy enabled motor carriers to divert lucrative merchandise traffic from the railroads. Motor carriers were able to undercut regulated railroad rates even though their costs were probably higher than the railroads' on all but the shortest hauls. Faced with both chaotic economic conditions in the trucking industry (due primarily to excess capacity) and the railroads' loss of revenue, Congress regulated motor carriers in 1935 but did exempt agricultural commodities from rate regulation. Trucking rates became based on rail rates, as much a matter of expediency as anything else. Barge transportation came under limited regulation in 1940 despite the fact that water carriers forced the railroads to maintain low rates on competitive bulk traffic. But competition by the lower-cost barges could have caused the railroads to reduce service on competitive routes or forced the ICC to allow compensating rail bulk rate increases wherever barge competition was not effective. It appears, therefore, that the Commission has been able to maintain low rates on agricultural and resource goods only by regulating both the trucks that directly threatened the profitable rail traffic in industrial products and the barges that indirectly jeopardized low rail rates on non-competitive bulk shipments.[7]

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[7]This sequence of events is a good example of McKie's "tar-baby effect," the "extension of control in response to perpetually escaping effects of earlier regulation." James

Motor carriers have continued to attract traffic from the railroads because they have provided faster and more reliable service. As a result, the railroad share of intercity ton-miles declined from 62.4 percent in 1939 to 36.3 percent in 1976 while the corresponding motor carrier share increased from 9.7 percent to 23.5 percent.[8]

The railroads have been unable to use their cost advantage to recapture traffic lost to motor carriers or to compete effectively for new shipments of manufactured goods because the ICC has required rate parity for the two modes. Although the Commission has occasionally approved a lower rail rate to account for inferior service, its general policy has been to allow no rail rate reduction below the average cost of motor carrier service, a level which usually exceeds long-run marginal cost for the railroads. The ICC's concern has apparently been to maintain fair shares of traffic by allowing regulated carriers an equal opportunity

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McKie, "Regulation and the Free Market: The Problem of Boundaries," Bell Journal of Economics and Management Science 1 (Spring 1970): 9, 14-17. This is not to say that the other modes were unwilling participants in the process: Nelson has shown that large trucking firms supported the application of entry and rate controls to their industry. James Nelson, "The Motor Carrier Act of 1935," Journal of Political Economy 44 (August 1936): 464-504.

[8]The 1939 shares are reported in, Ann Friedlaender, The Dilemma of Freight Transport Regulation (Washington: The Brookings Institution, 1969), p. 204, and the 1976 shares are given in, Interstate Commerce Commission, 91st Annual Report (1977).

to compete for merchandise shipments and to prevent rate wars that would have undermined value-of-service pricing.[9] Consistent with its support of value-of-service pricing, the Commission has been more willing to let the railroads compete with barges for the transportation of bulk commodities.[10]

Most of the recent studies of the Commission's rate policies have relied on relatively old figures on rail costs and revenues to demonstrate the existence of value-of-service pricing. These figures indicate that the ratio of revenue to variable cost for shipments in 1961 was 1.06 for mine products, 1.18 for farm commodities, and 1.48 for manufactured goods.[11]

However, some skepticism about the extent of value-of-

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[9]The ICC, however, has generally allowed the railroads to reduce rates as low as marginal cost to compete with unregulated carriers. Detailed reviews of the Commission's decisions in intermodal rate cases are given in, Ernest Williams, The Regulation of Rail-Motor Rate Competition (New York: Harper and Brothers, 1958) and George Hilton, The Transportation Act of 1958: A Decade of Experience (Bloomington: Indiana University Press, 1969).

[10]Friedlaender's book offers a more complete discussion of the development of regulation and the apparent motivation for ICC policy decisions. Friedlaender, pp. 7-27.

[11]Interstate Commerce Commission, Bureau of Accounts, Distribution of the Rail Revenue Contribution by Commodity Groups, 1966, (June 1964), reported in, Friedlaender, p. 56. I am not aware that a more recent set of figures for all commodities is available. Most of the traffic misallocation studies focus on manufactured goods and so report revenues and costs for that class. Levin, for example, found that the ratio of revenue to variable costs for shipments in 1972 was 1.4 for his sample of manufactured products. Levin, pp. 39-40.

service pricing has been expressed. Levin has argued that the ICC is now more likely to use a carrier's own variable costs to determine minimum rates.[12] In addition, Boyer has suggested that the markups used to demonstrate value-of-service pricing are misleading because the underlying cost estimates are unreliable. For example, coal moved in 1961 at rates that covered only 86 percent of the fully allocated costs calculated by the ICC, but the Chesapeake and Ohio and the Norfolk and Western railroads were quite profitable even with high concentrations of bituminous coal.[13] Unit-train service was not available until 1963,[14] but the railroads probably experienced lower costs on coal traffic than on other carload shipments in 1961 because coal moved in larger and more regular volumes. The cost-finding procedures used by the ICC did not account for this difference, so the actual ratio of revenue to cost for railroad coal movements almost

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[12]Ibid., pp. 40-41.

[13]Kenneth Boyer, "The Price Sensitivity of Shippers' Mode of Transport Selection and the Intermodal Allocation of Freight Traffic" (Ph.D. dissertation, University of Michigan, 1975), p. 15. Boyer cited Friedlaender's discussion of the coal example. Friedlaender, pp. 24-25. ICC cost-finding procedures are described in more detail in section 3 below.

[14]MacAvoy and Sloss have shown that the introduction of unit-train service was delayed by the Commission's decision that locational discrimination allowed under single carload rates would not be permitted under unit-train rates. Paul MacAvoy and James Sloss, Regulation of Transport Innovation: The ICC and Unit Coal Trains to the East Coast (New York: Random House, 1967).

surely exceeded .86.

This suggests that the ICC has been more concerned about relative rates than about relative markups. That is, while the markup on coal has probably increased because of increases in volume and improvements in service that reduced costs, the Commission has been able to satisfy mining and farming interests by maintaining the historical relationship among rates, a relationship more visible to shippers than relative markups. If markups were the more important concern for shippers and the Commission, then more accurate cost-finding procedures would have been developed.

The basis of all the comparative-cost and modal-split studies, including those of Levin and Boyer, is that a misallocation of traffic exists because rates differ from the long-run marginal costs of providing service and that the extent of the misallocation can be determined by reassigning traffic to the lower-cost carrier. But if a monopoly railroad were unable to cover total costs by pricing at marginal cost and lump-sum transfers were not feasible, then second-best pricing rules require that demand conditions be considered. That is, optimal prices include markups high enough to enable the firm to break even and inversely related to the elasticities of demand in each market. Braeutigam has extended the usual welfare analysis to intermodal competition in transportation and found that the optimal rate structure for the railroads resembles value-of-service pricing.[15] In addition, a model of railroad pricing that focuses on operation in a network indicates that welfare- or profit-maximization requires the adoption of peak-load pricing principles.[16] Consequently, the comparative-cost and modal-split studies address the misallocation of traffic only in a limited sense: they estimate the cost savings associated with pricing at marginal cost and ignore breakeven problems and network effects.

The misallocation studies also assume that it is ICC rate policy that prevents carriers from pricing at marginal cost. That assumption, however, is suspect for at least two reasons. First, many shippers are served by only one railroad, and intermodal competition is not always an effective deterrent to the exercise of market power. Trucks, for example, are not a practical alternative to the railroads on long hauls because of their relatively high line-haul costs. Second, Boyer has argued that existing rate bureau procedures are as much a source of rigidity in the rate structure as the Commission's policies.[17] This view is substantiated to some extent by the apparent failure of the

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[15]Ronald Braeutigam, "Optimal Pricing with Intermodal Competition," American Economic Review 69 (March 1979): 38-49.

[16]This model is developed in chapter II below.

[17]Boyer, p. 19.

railroads to adjust relative prices under the rate provisions of the 4R Act.[18] As a result, the misallocation studies overstate the likely cost saving on current traffic of increased rate freedom for the railroads.[19]

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[18]The Railroad Revitalization and Regulatory Reform Act of 1976 established variable cost as the minimum rate standard and authorized the railroads to increase any rate below variable cost up to that level. The legislation also allowed the railroads to raise or lower rates 7% per year without suspension by the ICC, subject to the minimum rate rule and the absence of "market dominance" by the carrier. The Commission's interpretation of the market dominance provision has been criticized on the grounds that it unduly limits the railroads' rate flexibility and thereby violates the intent of Congress.

[19]It is not unlikely that the antitrust exemption for rate bureaus will survive the current campaign for regulatory reform because there is strong carrier support for rate bureaus and a clear need for railroads to arrange joint routes and rates.

2. The comparative-cost and modal-split procedures in practice and theory

The cost penalty associated with carriage by a higher-cost mode is known as an intermodal loss. The purposes of this section are, first, to review several studies of the intermodal loss that arises in rail and truck transportation of manufactured goods because rates differ from the costs of providing service and, second, to compare the underlying comparative-cost and modal-split approaches.

Three studies have used a comparative-cost procedure, in which an efficient allocation of traffic is determined by assigning all shipments in a particular class to the lower-cost mode. In the earliest and most comprehensive work, Meyer and his associates examined transportation costs, market structures, and demand conditions in determining both an efficient modal distribution of freight traffic and a regulatory policy conducive to such an optimum.[20] In the process, motor carrier costs were computed from ICC formulas, and rail costs were estimated from regressions of expense categories on output and size variables.[21] In addition, the

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[20] John Meyer et al., The Economics of Competition in the Transportation Industries (Cambridge: Harvard University Press, 1959).

[21] This paper focuses more on traffic allocation methods than on costing techniques. ICC cost-finding procedures have been severely criticized, but there is no clear bias in the resulting estimates of intermodal loss. In addition, the studies reviewed here indicate that the intermodal loss estimates are more sensitive to choice of traffic allocation method than to choice of costing procedure.

rail costs were increased to account for the inventory costs of the longer transit time and larger minimum load required for rail shipments. For the rail and motor carriage of high-value manufactured goods, Meyer found that the railroads had "a narrow cost advantage at 100 miles and a clear and increasing cost advantage for traffic moving over 200 miles," while 97 percent of large common carrier truck operations covered more than 100 miles.[22]

In an attempt to determine the social cost of the misallocation identified by Meyer, Harbeson computed costs for both modes from ICC regional cost figures and adjusted them for inventory costs and a deficiency in highway user charges.[23] Specifically, the costs of average loads (16.6 tons for trucks and 33.7 tons for railroads) were compared to determine the low-cost mode at various distances. Using census figures on traffic distribution, the total of the losses from carriage of manufactured goods by the high-cost mode at each distance was found to lie between $1.1 billion and $2.9 billion per year, depending on the regional cost scales employed.[24]

Harbeson's results are difficult to interpret because the cost comparisons are based on different shipment sizes

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[22]Ibid., p. 194.

[23]Harbeson, pp. 321-338.

[24]Ibid., p. 332.

for the two modes. His approach assumes that the relevant choices for the shipper are a truck shipment of a certain size or a rail shipment of approximately twice that size. Certainly the use of the average weights for all shippers demands justification; but more important is the fact that the analysis requires a change in the scheduling and operations of the shipper. Without a more sophisticated model of inventory costs and shipper decisions, it seems more appropriate to shift traffic to the low-cost mode without altering other shipment characteristics. This is the procedure adopted in the Friedlaender book.[25]

In her review of the failures of freight transport regulation and the probable effects of alternative policies, Friedlaender calculated costs for several shipment sizes and determined for each size the distance beyond which the railroads, with higher terminal and lower line-haul costs, were the more efficient carrier. Again, ICC costs[26] were modified by rail inventory charges and increased motor

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[25]Friedlaender, pp. 36-43.

[26]Friedlaender seriously overestimated motor carrier line-haul costs. In effect, she double-counted by computing those line-haul costs from ICC reported figures for both line-haul costs per vehicle-mile and per hundredweight-mile; but these are regional averages calculated as the quotients of total variable line-haul costs and, first, vehicle-miles and, second, hundredweight-miles. The error is implicit in the cost calculations. Ibid., p. 39. The correct interpretation of the cost figures is given in, Interstate Commerce Commission, Bureau of Accounts, Simplified Procedures for Determining Cost of Handling Freight by Motor Carriers (1968), p. 4.

carrier user fees. A comparison of the estimated distances with modal distribution figures by size of shipment and length of haul revealed a misallocation in favor of motor carriers for shipments weighing less than 40 tons and moving more than 200 miles.[27]

What these three studies have in common is that the efficient distribution of traffic was determined by assigning shipments to the low-cost mode in each traffic category. Meyer's two traffic classes consist of shipments moving more or less than 200 miles. Harbeson's categories are defined by average loads moving distances corresponding to the mileage blocks used in available census figures. Finally, Friedlaender's classes are determined by specific shipment sizes and the estimated mileages above which railroads are more efficient than trucks.

Critics of the comparative-cost approach have argued that since shippers have different transportation requirements some will choose a different mode than the average or representative shipper in a traffic category. Shippers differ in access to the modes and in preferences with respect to such modal characteristics as speed and reliability of service. The modal-split approach addresses the problem by using demand functions to determine the distribution of traffic that arises when rates equal the long-run marginal

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[27]Friedlaender, p. 68.

costs of providing service. Moreover, since the demand functions embody shipper judgments about the service attributes of the modes, they can be used to evaluate the welfare gains associated with rate changes.

Figure 1 shows the standard welfare triangle for rail transportation of a particular class of traffic. The modal-split approach assumes first that rates equal marginal (and average) costs for motor carriers, a condition about which there is reason to be skeptical.[28] That assumption leads to an overstatement of the traffic misallocation and its cost: if regulation raises truck rates above costs, then the allocation away from railroads because of rail pricing distortions is reduced.

The downward sloping demand curve for rail service in figure 1 reflects both the shift of traffic from motor carriers and the generation of new shipments as the rail rate falls. For a shipment switched to the railroads in response to a slight decline in the rail rate, it must be the case that the cost to the shipper of using trucks is just below the corresponding cost of using railroads at the

[28]There is evidence that entry restrictions and rate bureau activities have enabled motor carriers to maintain rates above a competitive level. The high value of the certificates required for common carrier operation indicates that the present value of economic profits is substantial. In addition, motor carrier rates fell 20 percent (and service improved) when various commodities were deregulated for a short time in the 1950s.

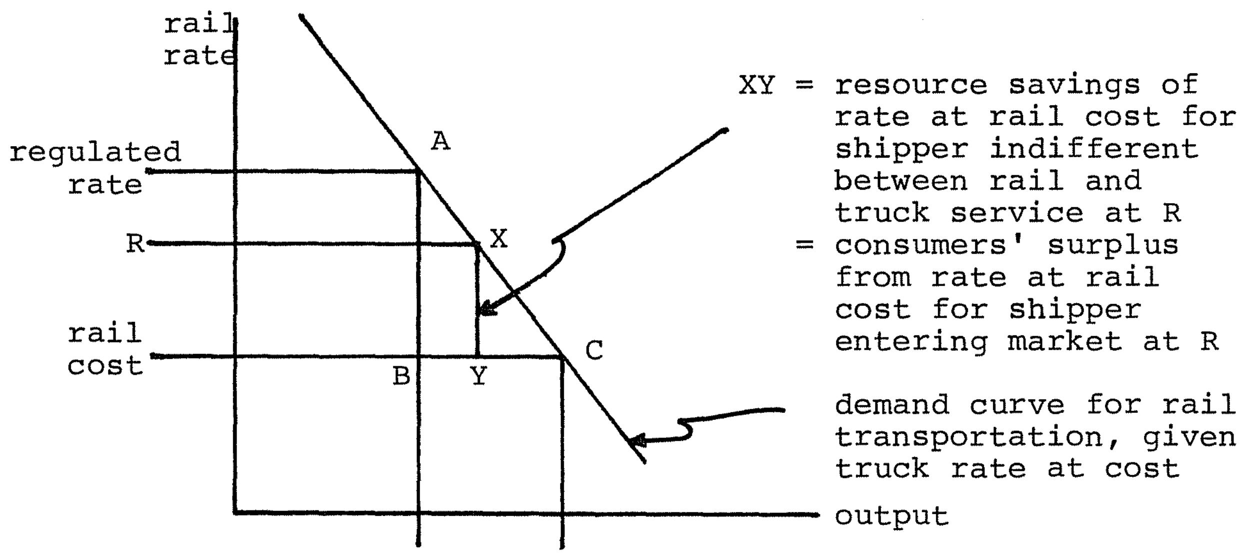

Figure 1

original rail rate. But the private cost of shipping by railroad exceeds the social cost by the difference between the rail rate and rail cost; so that difference measures, for shippers induced to switch by that rail rate, the resource savings of the shift to rail carriage. Similarly, the consumers' surplus associated with new traffic can be measured by the excess of the rate that stimulated the shipment over rail cost. Taken together, the shifted and new traffic generate cost savings and consumers' surplus as the regulated rate falls to rail cost that can be measured by the area of the triangle ABC.[29]

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[29]A more complete discussion of the argument is given in Theodore Keeler, "On the Economic Impact of Railroad Freight Regulation," Department of Economics Working Paper No. SL-7601, University of California - Berkeley, September 7, 1976, pp. 27-30.

Assuming that the demand and cost functions in figure 1 are linear,[30] the area of the welfare triangle ABC is:

$$W_i = \tfrac{1}{2} \Delta p_i \Delta q_i \qquad (1)$$

where Δp_i = difference between the regulated rate (p_i) and rail marginal cost for traffic class i

Δq_i = difference between the competitive and actual (q_i) rail outputs for class i.

With some manipulation of equation 1, the welfare loss for all traffic classes can be expressed as:

$$\frac{W}{R} = \tfrac{1}{2} \sum_i z_i \delta_i^2 \eta_i \qquad (2)$$

where $R = \sum_i p_i q_i$ = total transportation revenue

$z_i = \dfrac{p_i q_i}{R}$ = share of rail revenue accounted for by traffic class i

$\delta_i = \dfrac{\Delta p_i}{p_i}$ = ratio of the difference between the regulated rate and rail marginal cost to the regulated rate for class i

$\eta_i = \dfrac{p_i \Delta q_i}{q_i \Delta p_i}$ = elasticity of demand for rail transportation for class i.[31]

Friedlaender apparently had some reservations about the

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[30] Rail marginal cost, however, need not be constant, as shown.

[31] Friedlaender, p. 71. Equation 2 is often used to evaluate welfare losses. See, for example, F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally and Company, 1970), pp. 401-402.

comparative-cost approach because she also used equation 2 to estimate the welfare loss. She erred, however, by adding the areas of the welfare triangles for both truck and rail demand curves. The rail component of her calculation indicates by itself that the cost of traffic misallocated or not handled at all because of rate regulation was about $150 million for manufactured goods and $170 million for all commodities in 1964.[32]

While Friedlaender used ICC figures on the ratio of revenue to cost for each commodity class, Keeler used his own estimates of rail long-run marginal cost to update the welfare calculation. He found that the welfare loss in 1969 was no more than $180 million for manufactured goods and $400 million for all products.[33]

Levin, however, calculated the welfare loss directly from equation 1 by estimating a modal choice model and

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[32]Friedlaender, pp. 72-74.

[33]The figures reported by Keeler are not correct. Friedlaender used an overall ratio of price to marginal cost of 1.27; Keeler updated the figure to 1.42 and scaled up each δi (the ratio of the difference between price and marginal cost to price for traffic class i) by a factor of 1.55 (= .42/.27). But:

$$\frac{p}{mc} = 1.27 \Rightarrow \frac{p-mc}{p} = .21, \quad \frac{p}{mc} = 1.42 \Rightarrow \frac{p-mc}{p} = .30,$$

and therefore each δ_i should be scaled up by a factor of 1.42 (= .30/.21). This yields annual losses of $180 million for manufactured goods and $400 million for all commodities, not the corresponding $200 and $500 million shown by Keeler. Keeler, p. 32.

using it to determine the rail shares and outputs corresponding to both actual rates and long-run marginal costs.

Levin specified a logit model, in which the probability of a shipper choosing a given mode is a function of differences in prices and service quality among competing modes. The model is consistent with utility-maximization in problems of discrete choice (in general, a shipper selects only one mode to carry a particular class of traffic), and, unlike a linear probability or share model, it constrains market shares to the zero-one interval. The regression model can be written:

$$\ln \frac{f_i}{f_n} = a_{in} + b_1(R_n - R_i) + b_2[V(T_n - T_i)] + b_3[2V(\sigma_n - \sigma_i)] + \varepsilon_i \qquad 3$$

where f_i = market share for mode i, i = 1,2,...,n-1
R_i = rate charged by mode i
V = commodity value
T_i = mean transit time for mode i
σ_i = standard deviation of transit time for mode i
ε_i = disturbance for equation i.

Levin considered three modes: truck, railroad, and piggyback (trailer-on-flat-car service). Because of the symmetry of the logit function, the regression model reduces to two equations; in addition, the requirement that market shares sum to one constrains the coefficient on each independent variable to be the same in both equations. The constant in each equation can be interpreted as a measure of the service difference between modes that is not captured by the speed and reliability variables. The model was estimated with observations in markets defined by commodity, shipment size, and length of haul.[34]

The regression results were then used to predict market shares for both regulated rates and rail costs. Rail outputs were determined by applying the shares to existing freight output in each market; as a result, new traffic generated by lower rail rates is not considered in this procedure except insofar as it affects the regression coefficients and predicted shares. Finally, Levin calculated the welfare loss from equation 1 and found that it was between $53 and $135 million for manufactured goods in 1972.[35]

Boyer estimated a logit model of traffic allocation with a different set of explanatory variables. Using Harbeson's data on costs and traffic distribution and his own figures on rates, he concluded that the annual welfare loss on manufactured goods in the mid-1960s was approximately $125 million;[36] recall that Harbeson found that the cost of misallocated traffic was between $1.1 and $2.9 billion

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[34] Levin, pp. 20-26.

[35] Ibid., p. 37. Different sample sizes and cost assumptions produced different estimates of the welfare loss in the range from $53 to $135 million.

[36] Kenneth Boyer, "Minimum Rate Regulation, Modal Split Sensitivities, and the Railroad Problem," Journal of Political Economy 85 (June 1977): 505.

per year. Levin has criticized Boyer's results for two reasons. First, data from several different years were used to estimate the logit model and compute the welfare loss. Second, Boyer used the observed rail share to calculate the area of the welfare triangle instead of the share predicted for the observed rail rate, thereby leaving in the welfare calculation the unexplained variation in the relation between market shares and rates and service quality. However, the direction of bias introduced by these flaws is not apparent.[37]

Levin has claimed that the comparative-cost approach overstates the misallocation between railroads and motor carriers even if the average service differential in each traffic category is evaluated properly. The reason is simple: the low-cost mode for the representative shipper will not be the low-cost mode for shippers with service requirements or preferences sufficiently different from the average. In Levin's words, "to count such traffic as misallocated is surely to exaggerate the extent of misallocation."[38] A comparison of the comparative-cost and modal-split procedures, however, indicates that Levin's argument is generally correct for the amount of traffic misallocated but not for the corresponding welfare loss.

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[37] Levin, pp. 39-40.

[38] Ibid., p. 20.

In order to compare the two methods, it is convenient to borrow from previous studies the assumption that total rail and truck output in each traffic category is fixed; that is, the overall demand for transportation in each market is completely inelastic. Figure 2 illustrates the demand for rail service at prevailing truck rates (which are assumed to be equal to truck costs); as the rail rate falls, demand increases because shippers switch from motor carriers, not because new traffic is generated. The horizontal axis can be interpreted as rail market share or output. As explained in the discussion of figure 1, the modal-split procedure measures the welfare loss by the area of the triangle ABC.

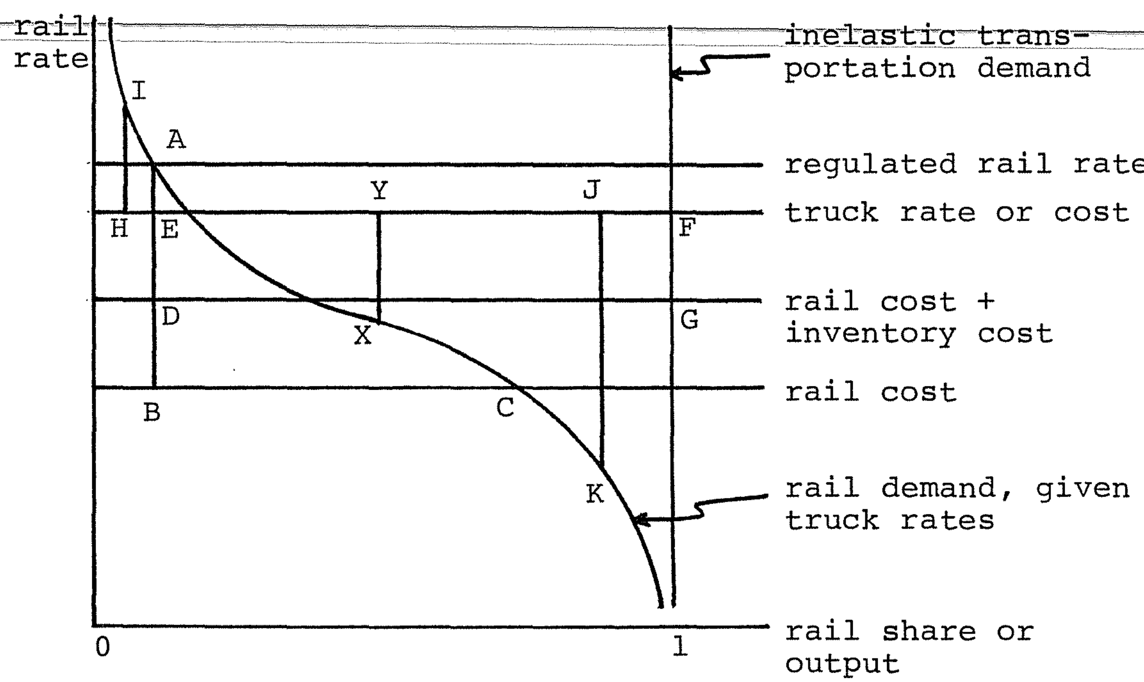

Figure 2

The comparative-cost approach adds inventory costs to rail long-run marginal cost to determine the low-cost mode in each traffic class. This adjustment is intended to capture the additional cost to the average shipper of the inferior service provided by the railroads.[39] In figure 2, the inventory costs are BD, and the rail cost advantage is DE. Since the comparative-cost procedure assigns all of the shipments in a particular class to the low-cost mode, the amount of motor carrier traffic shifted to the railroads is EF, and the associated cost saving is measured by the area of the rectangle DEFG.

Most critics of the comparative-cost method have argued that its practitioners have underestimated the value of superior motor carrier service. Levin has pointed out that the usual inventory cost calculations ignore the greater flexibility and reliability that trucks offer.[40] It is possible, however, to measure the average service difference from the rail demand curve.[41]

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[39]Harbeson and Friedlaender also increased motor carrier costs to account for an apparent deficiency in user charges. Other studies have focused more on the division of traffic that would appear in the absence of rate regulation and do not make such an adjustment.

[40]Levin, p. 19.

[41]The level of service is exogenous in both the comparative-cost and modal-split procedures. Service quality, however, is a decision variable for the firm, and rail service has surely been adversely affected by regulatory constraints on pricing in different markets.

At any point on the demand curve, those shippers who would switch from truck to rail service in response to any decline in the rail rate must be indifferent between the two modes; that is, the perceived cost of using either mode must be the same. Therefore, the difference between the motor carrier and rail rates at that point on the demand curve measures the additional cost to the shipper of using rail transportation. At point I in figure 2, the difference HI is negative, indicating that railroads satisfy the transportation requirements of the marginal shipper better than trucks; at point K, where the difference JK is positive, the opposite conclusion holds. For all shippers, the average service difference can be evaluated from:

$$\int_0^1 [R_t - p_r(f_r)]\, df_r \qquad 4$$

where f_r = rail market share
R_t = motor carrier rate
$p_r(f_r)$ = inverse demand function for rail service

If the underlying distribution of shipper valuations of the service difference is normal, then the average can be determined at the point of inflection. In figure 2, X is the inflection point, and the average value of superior truck service is YX.

If truck costs exceed rail costs by the average service cost YX, as shown in figure 3, then the comparative-cost

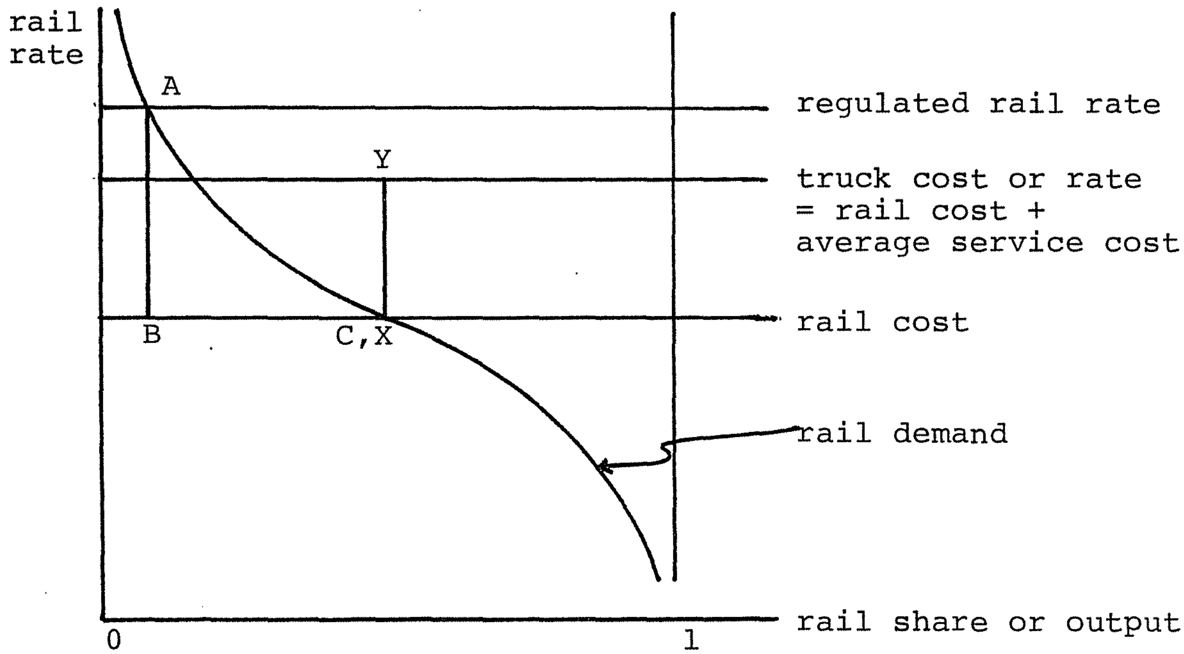

Figure 3

approach finds no difference in the cost to the representative shipper of each mode and therefore no misallocation of traffic. This is the only case in which the comparative-cost approach indicates a smaller amount of misallocated traffic than the modal-split procedure. But the welfare loss will be smaller under the former method if the difference between truck and rail costs is sufficiently close to the average service cost.

This comparison of the two procedures in theory and practice reveals that the comparative-cost approach has two serious deficiencies. First, in assigning all shipments in a traffic class to the low-cost mode, it assumes that rail demand is perfectly elastic at a rate equal to the truck rate less the average service cost. Levin, however, found that the elasticity of rail demand is not more than .35.[42] Second, the value of service differences has not been measured correctly in previous studies. Boyer has shown how difficult it is to identify and compute the various costs associated with rail or truck service instead of using the information on shipper preferences that is embodied in the demand function.[43] The comparison of the two methods, however, demonstrates that the social cost of the misallocation of traffic is not necessarily overstated by the comparative-cost procedure. Consequently, the relationship between contending estimates in any period is an empirical issue.

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[42] The logit model has the property that the response of the market shares to a change in an independent variable is greatest when the traffic is evenly divided. Levin, therefore, obtained an upper bound for the elasticity by assuming an equal share of traffic for each mode. The actual elasticity will be larger to the extent that lower rates generate new traffic. Levin, p. 32.

[43] Boyer, "Minimum Rate Regulation," p. 497.

3. A modal-split estimate of welfare losses in 1963-64

Levin has argued that the great disparity between Harbeson's social cost estimate for 1963 and his own for 1972 can be traced to a decline in the misallocation of traffic as well as to the choice of measurement procedure. Traffic allocation may have improved for two reasons. First, rail costs probably increased relative to rates with a concomitant reduction in the range of the railroads' cost advantage over competing modes. Second, the Commission apparently began to give more emphasis to cost standards in evaluating carrier rate proposals in the late 1960s.[44]

It is difficult to determine whether the welfare loss associated with traffic misallocation changed between 1963 and 1972 because only Harbeson's comparative-cost procedure has been applied to both periods. A recent updating of Harbeson's study to 1970 found the cost of misallocated traffic to be a slightly smaller proportion of the cost of rail and truck transportation of manufactured goods than in 1963.[45] But the deficiencies of the comparative-cost method and Harbeson's questionable assumption about comparable shipment sizes for railroads and motor carriers make any

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[44]Levin, pp. 19, 40-41.

[45]Sparling, "Traffic Allocation," p. 21. The updating of the Harbeson and Friedlaender studies to 1970 is described in the Appendix to this chapter.

conclusion about changes in the misallocation of traffic somewhat suspect. The welfare losses obtained by Boyer and Friedlaender for 1963-64 are quite similar to those reported by Levin for 1972, but differences among their applications of the modal-split approach raise questions about the validity of the comparison.

Levin's conjecture about an improvement in traffic allocation from 1963 to 1972 can best be tested by using the same procedure to estimate the welfare loss in each year. To that end, Levin's modal-split procedure is applied in this section to data for 1963-64.

The first step is to estimate the logit model given by equation 3. Observations were obtained for markets defined by commodity and mileage block; no further classification by shipment size was possible because the required market share and rail rate figures were not available.[46] Levin, however, also estimated the model for markets defined in this manner. His motive was to allow shifts among different shipment sizes because, for example, lower rates for large rail shipments encourage the consolidation and shift of smaller shipments from other modes. Levin found that this modification did not substantially alter the regression results

[46] Commodities were limited in part by the need to use published rail data. More complete figures are probably recorded on the Commission's waybill sample tapes, but the oldest usable tape dates back only to 1972.

for 1972.[47] Complete data were available for 91 markets in 19 three-digit STCC[48] manufactured commodities, ranging from grain mill products to household appliances.

Market shares of freight tonnage were computed for railroads and motor carriers (for-hire and private) only.[49] It was not possible to separate rail traffic into boxcar and piggyback shipments, but the omission does not appear to be serious because trailer-on-flat-car service accounted for only 2 percent of rail carloads in 1963.[50] The regression model consists of just one equation when two modes are considered.

Rail rates were calculated from tonnage and revenue figures in each market that were obtained from the ICC's one-percent sample of railroad waybills.[51] Motor carrier

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[47] Levin evidently believed that markets defined only by commodity and distance more accurately represent the shipper's choice problem because he concluded that "the more disaggregated model is not seriously misspecified." Levin, pp. 34-35.

[48] Standard Transportation Commodity Classification. This grouping is similar to the Standard Industrial Classification used in the Census of Manufactures.

[49] U.S. Department of Commerce, Bureau of the Census, 1963 Census of Transportation, Vol. III, Commodity Transportation Survey, Part 2, Commodity Groups (1966).

[50] Interstate Commerce Commission, 78th Annual Report (1964), pp. 137, 144.

[51] Interstate Commerce Commission, Bureau of Economics, Carload Waybill Statistics, 1964: Mileage Block Distribution (1967). It was necessary to use rail and truck data from 1964 because that was the first year the ICC used the STCC. Before 1964 the Commission used the Freight Commodity Statistics Classification, and it was not possible

rates were not available for the markets defined here, so truck costs were used as a proxy for rates. The calculation of costs from ICC formulas is described below.

The time performance variables were constructed from regression results reported by Levin that give transit time and its standard deviation for each mode as a function of distance.[52] Commodity values were determined from census figures for intercity tonnage and value of shipments.[53]

Cost data were required for motor carriers to estimate the logit model and for both modes to perform the welfare calculation. Most investigators of the traffic misallocation have used the Commission's cost formulas while criticizing

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to reconcile the two codes.

Mileage blocks and lengths of haul were adjusted for differences in distance measures. The Census of Transportation reports distances in straight-line miles, but the Commission uses short-line (shortest carrier route) miles in its waybill statistics and actual miles in its cost formulas. In 1963, short-line or rate-making miles exceeded straight-line miles on average by 24% and 21% for railroads and trucks, respectively, and actual miles exceeded short-line miles by 13% and 6%.

[52]Levin, pp. 28-29.

[53]The intercity tonnage figures were drawn from the Census of Transportation and the value of shipments figures from the Census of Manufactures. The calculated commodity values are subject to some error because the data are reported for commodity classifications that are not identical (STCC and SIC) and because the Census of Manufactures figures include intracity shipments but not imports. U.S. Department of Commerce, Bureau of the Census, 1963 Census of Manufactures, Vol. III, Industry Statistics, Parts 1 and 2, Commodity Groups (1966).

them severely. An evaluation of these cost formulas is, therefore, appropriate.

In the current construction of rail freight service costs by the ICC, each category of operating expense is regressed on the relevant output variable (for example, yard transportation expenses on yard switching hours). Variables are deflated by miles of road as a carrier size measure. That is, the ICC estimates:

$$\frac{E}{S} = a + b_1\frac{Q}{S} + b_2\left(\frac{Q}{S}\right)^2 + \varepsilon \qquad 5$$

where E = expense
S = miles of road
Q = output
ε = disturbance,

and each observation consists of data from one railroad. From the regression results is calculated a percent variable, which is used to calculate variable expenses for each category. The percent variable is equivalent to the quotient of marginal and average cost as well as the elasticity of cost with respect to output:

$$PV = \frac{b_1 + 2b_2\overline{\frac{Q}{S}}}{a\left(\overline{\frac{Q}{S}}\right)^{-1} + b_1 + b_2\overline{\frac{Q}{S}}} \qquad 6$$

$$= \frac{mc}{ac} = \frac{\partial c}{\partial Q}\frac{Q}{c}$$

where $\overline{\frac{Q}{S}}$ = average output per mile of road

PV = percent variable
c = cost or expense

The variable expenses corresponding to a particular final output are totaled to determine terminal costs per carload and per ton and line-haul costs per car-mile and per ton-mile. This last operation requires the conversion of intermediate outputs to final outputs (for example, yard switching hours to carloads) on the basis of industry averages.

Actually, the Commission does not estimate the expense-output relationship each year but instead applies to each expense category the percent variable obtained from a study covering 1966-69. This yields variable expenses for each category, and the calculation of terminal and line-haul costs proceeds in the manner described above. In addition, before 1970 variable costs were simply taken to be 80 percent of total operating expenses (plus a return on equipment and property investment), a figure derived by estimating a variety of linear expense-output models for the 1930s and 1940s.[54]

For the curvilinear relationship between deflated cost and output that the ICC now estimates, both marginal and average cost and, therefore, percent variable, are a function

[54]Current practices are described briefly in, Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales, 1975 (1978), pp. 154-155. A thorough explanation of procedures followed through 1969 is given in, Interstate Commerce Commission, Bureau of Accounts, Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs (1963).

of output, so the level of output chosen is crucial.[55] Griliches found that the ICC produced an overall percent variable in 1958 of 77.6 percent by giving equal weight to the cost conditions of large and small firms alike (by taking average values for marginal and average cost). But if the costs of the industry as a whole are considered by giving equal weight to each ton-mile (by weighting each carrier's marginal and average cost by its share of output), the resulting percent variable is 97.4 percent.[56] The report of an aggregate percent variable for 1975 of 79 percent suggests that this overrepresentation of small road conditions and underestimation of rail freight costs continue.[57]

The Commission's treatment of the size variable has also been questioned. Griliches has pointed out that the ICC specification has no particular statistical efficiency properties. That is, if the disturbance is assumed to be proportional to size, then deflation can stabilize the error

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[55]This is also true for the linear form estimated by the ICC before 1970 because average cost varies with output in such a relationship (if fixed costs are not zero).

[56]Zvi Griliches, "Railroad Cost Analysis," Bell Journal of Economics and Management Science 3 (Spring 1972): 29. Still other weighting procedures could be used. For example, instead of the average carrier value for output per mile of road, the ICC could as well use output per mile of road for the entire network, that is, the quotient of total output and miles of road.

[57]Interstate Commerce Commission, Rail Carload Cost Scales, 1975, p. 154.

variance and improve estimator efficiency. In a linear form, the correct weighted least squares method minimizes:

$$\sum_i \left(\frac{E_i}{S_i} - \frac{a}{S_i} - \frac{bQ_i}{S_i}\right)^2 \qquad 7$$

while the ICC procedure treats:

$$\sum_i \left(\frac{E_i}{S_i} - a - \frac{bQ_i}{S_i}\right)^2 \qquad 8$$

Griliches has also argued that the size variable is irrelevant, a conclusion based on regressions of total carrier cost on output (ton-miles) for alternative specifications of the influence of size.[58] However, this ignores the possibility that size is significant for some individual expense category regressions. In addition, Keeler has argued that Griliches' results are biased toward understating returns to traffic density and the significance of the size variable.[59]

Costs incurred in the provision of both freight and passenger service (for example, maintenance of track expenses) should be allocated to freight service only to the extent that such costs vary with freight output. This can be accomplished by including separate freight and passenger

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[58] Griliches, pp. 32-33.

[59] Keeler, pp. 15-18.

output measures in the regression. The Commission, however, allocates common costs that are variable with an aggregate measure of output (gross ton-miles in freight and passenger service) in the same proportions as costs incurred solely by each service.

Despite these problems, there are two persuasive reasons to use the Commission's cost formulas in determining the extent and cost of the traffic misallocation in 1963-64. First, no other cost estimates allow cost to be calculated for a specific shipment size and length of haul. Keeler, for example, reported only an overall cost per ton-mile for the railroads in his sample.[60] Second, using ICC costs facilitates comparison with other studies, particularly Levin's for 1972.

Rail costs, therefore, were calculated from ICC cost formulas for a carload shipment moving by general service boxcar in an average weight train in Official territory.[61] Motor carrier costs were based on single-line movements in

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[60]Keeler's rail cost estimates are based on a specification of the cost function that was derived from Cobb-Douglas production functions for freight and passenger outputs. Short-run total cost functions were obtained by assuming that a fixed amount of track was to be divided between the two outputs in the cost-minimization problem. Then long-run costs were calculated from the envelope of the short-run functions. Keeler, pp. 20-22.

[61]Interstate Commerce Commission, Bureau of Accounts, <u>Rail Carload Unit Costs by Territories for the Year 1964</u> (1966).

Eastern-Central territory.[62] (The Eastern-Central motor carrier territory and Official rail territory encompass almost identical geographic areas.)

The logit model in equation 3 was estimated by ordinary least squares. Levin noted that the error terms are heteroscedastic because a market share estimate has smaller variance when it is based on a larger number of observed shipments. However, it was not possible to construct the weights for generalized least squares estimation because the Census of Transportation does not provide any data on the underlying observations for each market.[63]

The estimated model is:

$$\ln \frac{f_r}{f_t} = \underset{(.232)}{-.851} \; \underset{(.342)}{+2.323}\,(R_t - R_r) \; \underset{(.691)}{+2.416}\, V(T_t - T_r) \; \underset{(1.567)}{-8.844}\, 2V(\sigma_t - \sigma_r) \qquad R = .456 \tag{9}$$

(standard errors in parentheses)

With the exception of b_3, the coefficient of the reliability variable, the estimated coefficients have the expected signs and are statistically significant at the one percent level.

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[62] Interstate Commerce Commission, Bureau of Accounts, Cost of Transporting Freight by Class I and Class II Motor Common Carriers of General Commodities by Regions or Territories for the Year 1964 (1965). The ICC cost formulas take variable costs for motor carriers to be 90 percent of total costs.

[63] Levin was also forced to use ordinary least squares. Levin, p. 26.

Levin also obtained the wrong sign for the reliability coefficient and blamed the result on deficiencies in the construction of the variable.[64]

The negative sign of the constant term indicates that the representative shipper in 1963-64 placed a higher value on the unmeasured service characteristics (attributes other than transit time and reliability) of motor carriers than on those of railroads. Indeed, if the two modes had offered identical rates, transit time, and reliability, the railroads would have captured only 30 percent of the total traffic because of their poor performance in other service areas of importance to shippers, and truck rates 57 percent higher than existing rail rates would have been required for the railroads to obtain an even division of the traffic.[65]

The rate coefficient, b_1, can be used to estimate the elasticity of demand for rail transportation. That is:

$$\frac{\partial f_r}{\partial R_r} = f_r(1-f_r)\frac{\partial \ln \frac{f_r}{1-f_r}}{\partial R_r} \qquad 10$$

$$= b_1 f_r(1-f_r)$$

[64]Ibid., p. 32.

[65]Both figures were derived from the estimated equation. The second is based on an average rail rate of $12.95 per ton, calculated as the ratio of sample revenue and tons. The revenue per ton for all shipments of manufactured goods by railroad in 1964 was $10.78. Interstate Commerce Commission, Bureau of Accounts, Freight Commodity Statistics, Class I Railroads in the United States for 1964 (1967).

$$\eta_r = -\frac{R_r}{q_r}\frac{\partial q_r}{\partial R_r} \qquad 11$$

$$= -\frac{R_r}{q_r}\frac{\partial f_r}{\partial R_r} q_T$$

$$= -b_1(1-f_r)R_r$$

where η_r = elasticity of demand for rail transportation
q_r = rail output
q_T = total output (rail + truck)

Levin noted from equation 10 that the rail market share is most responsive to rate changes when traffic is evenly divided and evaluated equation 11 by assuming a 50 percent rail share and average rail rates. He obtained an elasticity of .13 for the model specification most similar to the one adopted here.[66] But Levin's calculation ignores the fact that market shares are not independent of rates. Observed shares and rates should instead be used to estimate elasticities from equation 11. Following that procedure yields elasticities of .81 for the sample markets and .70 for all manufactured goods in 1963-64.[67]

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[66]Levin, p. 35. Unless otherwise stated, the figures attributed to Levin in this section are his results for a specification that used variable costs and markets defined only by commodity and length of haul.

[67]The logit model was estimated here with rates and values expressed in dollars per hundredweight, so the rates in footnote 65 required conversion. The rail market shares

Given Levin's rate coefficient, the elasticity of demand for rail shipment of manufactured goods was found to be .20 in 1972.[68] Since the average rail rate was lower and the rail share higher in 1963 than in 1972, the higher elasticity for 1963 can be attributed entirely to the higher estimate of the rate coefficient. For rates expressed in dollars per hundredweight, the estimates of b_1 are 2.32 and .46 for 1963 and 1972, respectively. The logit curve (shown, for example, in figure 2) is flatter for a higher rate coefficient, but there is no obvious explanation for such a shift between the two years.

The regression results can also be used to estimate the welfare loss from rate regulation. Market shares were calculated from the estimated equation for existing rail rates and for rail costs; it was necessary to predict market shares for observed rates in order to control for the unexplained variation in observed shares. Outputs were computed by applying the estimated market shares to existing output, and the

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for the sample and for all manufactures were 46% and 44% respectively. The latter figure was obtained from, U.S. Department of Commerce, <u>1963 Census of Transportation</u>.

[68]Modal shares for 1972 are given in, U.S. Department of Commerce, Bureau of the Census, <u>1972 Census of Transportation</u>, Vol. III, <u>Commodity Transportation Survey</u>, Part 3, <u>Area Statistics, South and West Regions and U.S. Summary</u> (1976). The average railroad revenue per ton for STCC codes 20-39 was drawn from, Interstate Commerce Commission, Bureau of Accounts, <u>Freight Commodity Statistics, Class I Motor Carriers of Property Operating in Intercity Service--Common and Contract in the United States, 1972</u> (1973).

welfare loss in each market was calculated directly from equation 1 as half the product of the differences in prices and outputs.

For the 91 markets considered here, the annual social cost of the traffic misallocation in 1963-64 was $120 million or 1.97 percent of sample revenue. Assuming that this proportion applied to all shipments of manufactured goods, the annual welfare loss on manufactured goods was approximately $228 million.[69] The corresponding figures reported by Levin for 1972 are .43 percent and $75 million, suggesting that the cost of the misallocation declined.

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[69]Total rail and truck revenue on shipments of manufactured goods in 1963 was obtained by applying sample rates to census traffic figures.

4. Assessing the results

The purposes of this concluding section are to compare the various estimates of the cost of the traffic misallocation and to consider the policy and research implications of the result. Table 1 summarizes the welfare loss estimates that have been reviewed or developed in this paper.

The first of two basic conclusions that can be drawn from a comparison of misallocation studies is that comparative-cost procedures have overstated the social cost of rate regulation.

It was shown in section 2 that the comparative-cost approach does not necessarily produce a larger welfare loss estimate than the modal-split method, and updating Friedlaender's comparative-cost procedure to 1970 produced an estimate not completely out of line with modal-split results. Even Harbeson's extreme results can be explained by his comparison of different shipment sizes for railroads and motor carriers. Since Friedlaender's procedure compares costs for the same shipment sizes for both modes but is otherwise similar to Harbeson's method (even in the construction of inventory costs[70]), the difference in results can be attributed to Harbeson's peculiar criterion for

[70] Keeler has argued that Harbeson's estimates of the welfare loss are high because inventory costs were understated. Keeler, p. 30.

Study	Year	Welfare loss*
	Comparative-cost	
Meyer	1958	$1 billion[1]
Harbeson	1963	$1.1 - 2.9 billion
Friedlaender	1963	?[2]
Harbeson (update)	1970	$.7 - 4.2 billion[3]
Friedlaender (update)	1970	$400 - 500 million[3]
	Modal-split	
Friedlaender	1961	$150 million
Keeler	1969	$180 million
Boyer	1963	$125 million
Levin	1972	$53 - 135 million
Levin (revision)	1963	$228 million[4]

*For manufactured goods (except Meyer) and in current dollars

[1]Meyer found that the rail cost advantage for shipments over 200 miles was approximately 2 cents per ton-mile; the cost saving was obtained by applying that figure to all truck traffic moving over 200 miles.

[2]Qualitative estimate only: misallocation in favor of motor carriers for shipments weighing less than 40 tons and moving more than 200 miles.

[3]Procedure described in Appendix.

[4]Procedure described in section 3.

Table 1

determining the low-cost mode in each mileage block.[71]

Nevertheless, the comparative-cost approach has two serious deficiencies. First, it embodies an unrealistic conception of shipper choice because it assumes that rail demand is perfectly elastic at one rate (equal to the truck rate less the imputed cost of inferior rail service) and completely inelastic elsewhere. Second, the comparative-cost method ignores the information on shipper evaluations of service differences that is contained in the demand function and instead relies on a complicated compilation of inventory costs. The modal-split approach is superior in both respects because it derives the welfare loss from an estimated demand relationship.

Therefore, the welfare loss in 1972 was more likely $100 million than $1 billion or more. Even the lower figure is an overstatement because the modal-split procedures have used motor carrier costs as a proxy for rates. The assumption that rates equal costs for motor carriers also conceals any shift of traffic from railroads to trucks that might result from the elimination of rate regulation. Whenever reliable motor carrier rate data become available, modal-

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[71] Boyer used Harbeson's cost figures (and, therefore, Harbeson's assumption about comparable shipment sizes), but his results are not very different from other modal-split estimates. Boyer, "Minimum Rule Regulation," pp. 505-507. The reason is that the difference between rail and truck rates or costs affects the modal-split welfare calculation only through the estimation of the logit model.

split traffic shifts and welfare losses should be refigured because it is important for an understanding of regulation to know the redistribution of traffic that it produces. This point is discussed below in more detail.

The second basic conclusion to be drawn from the misallocation studies is that the welfare loss from regulation of rates fell between 1963 and 1972.

The various modal-split studies cover different years, but differences in model specifications and data sources make comparison of the results somewhat difficult. For that reason, Levin's procedure was applied to 1963 data, and it was found that the welfare loss on rail and truck shipments of manufactured goods declined from 1.97 percent of total revenue in 1963 to .43 percent in 1972.

Levin suggested that the cost of the misallocation has fallen since the early 1960s, but his reasoning is unpersuasive. His conjecture that "rising rail costs have probably narrowed the gap between rates and marginal costs"[72] is belied by his report of a ratio of rail revenue to variable cost for manufactured goods of 1.47 in 1961 and 1.45 in 1972.[73] In the markets examined here for 1963, the ratio was slightly higher at 1.53. These figures also raise some question about the significance of Levin's evidence that the

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[72] Levin, p. 19.

[73] Ibid., p. 39.

Commission is now more inclined to use variable cost as the minimum rate standard.[74] Furthermore, Levin pointed out that the ratio of rail revenue to variable cost did not vary much across his sample of manufactured commodities (which suggested a weakening of value-of-service pricing) and that rail costs have risen faster than truck costs.[75] But these observations do not explain the reduced welfare loss. The relative increase of rail costs and, therefore, rates (because of the constancy of the rail markup), for example, can be depicted as an upward shift of their levels relative to the demand curve shown in figures 2 and 3, but the conditions necessary for the welfare loss over all markets to decline are not apparent. As a result, the reasons for the fall in the welfare loss remain a question for further research.

These conclusions must be interpreted with some caution because of the shortcomings of the analysis. Some of the problems inherent in the Commission's cost formulas were outlined in section 2, and changes in its estimation procedures after 1970 may have contributed to the difference in the welfare loss estimates for 1963 and 1972. There is

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[74]Levin cited both a Commissioner's statement that rate decreases have not been denied when the carrier's proposed rate remained above its variable cost and the low rejection rate for tariff filings. Ibid., pp. 40-41. The second, of course is not very conclusive if carriers have adapted to established policy and practice regarding rate proposals.

[75]Ibid., p. 41.

also an implicit assumption that the aggregate cost and output data reflect the conditions prevailing in individual markets. But with carriers operating routes at different points on different cost curves, it is unlikely that cost relationships estimated from observations of carrier total cost and output hold in particular markets for transport services.[76] However, the alternative of evaluating more precisely the existing misallocations at the market level and then aggregating is obviously impractical because the data requirements are prohibitive and because reallocations in any one market necessarily affect cost conditions in connected or related markets.

In addition, the welfare loss estimates are based on a questionable concept of efficient traffic allocation. As stated in section 1, optimal allocation may require a rate structure similar to value-of-service pricing. Furthermore, the rate structure likely to prevail in the absence of rate regulation cannot be determined without additional study of industry structure and market strategy questions.

Finally, the analysis is a partial equilibrium approach

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[76] For example, estimates of economies of density that are based on the cost and output reported for an entire network will be incorrect. If there are economies of traffic density in a particular operation (for example, line-haul), then aggregating cost and output over all routes will lead to an understatement of those economies. Unfortunately, the ICC figures on which all econometric cost studies have been based are collected at the carrier or firm level.

to the study of regulatory reform. Other modes and commodity groups should be included in the modal-split studies. In addition, the influence of rate regulation on network operations, service levels, and innovation should be ascertained because they, in turn, affect costs and shipper evaluations. This interaction becomes more complex when more extensive regulatory change is contemplated; liberalized licensing requirements for motor carriers and abandonment procedures for railroads, for example, will affect the costs that determine the efficient distribution of traffic. Obviously, a more comprehensive approach is required.[77]

An alternative procedure is to model the pricing and investment decisions that a carrier will make under various

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[77] Another example of a partial equilibrium result with important policy implications is the assertion that "(motor carrier) rates would fall 20 percent generally if regulation of trucking were eliminated." Thomas Moore, "Deregulating Surface Freight Transportation," in Promoting Competition in Regulated Markets, ed. Almarin Phillips (Washington: The Brookings Institution, 1975), pp. 55-98. Also see Friedlaender, p. 74. This figure is drawn from the experience of deregulation of certain agricultural goods in the mid-1950s. Surveys by the Department of Agriculture found that rates fell an average of 33 percent for fresh poultry, 36 percent for frozen poultry, and 19 percent for frozen fruits and vegetables. If the lower rates reflected the opportunities for previously unauthorized regulated and exempt carriers to obtain greater return loads, then it is clear that the reduction cannot be extended to deregulation in all products. However, the USDA studies provide no direct evidence on this point. U.S. Department of Agriculture, Interstate Trucking of Fresh and Frozen Poultry under Agricultural Exemption, Marketing Research Report No. 224 (1958) and U.S. Department of Agriculture, Interstate Trucking of Frozen Fruits and Vegetables under Agricultural Exemption, Marketing Research Report No. 316 (1959).

technological, market, and regulatory constraints. Absent regulation, the firm can be viewed as maximizing some objective function (profits, for example) with respect to the rates it sets and the capital (rolling stock) it assigns to various transportation markets. Here the carrier is a multiproduct firm whose markets are defined by shipment of a commodity from one point to another. Production in these markets is characterized in part by the geographic connection of the markets and the joint product nature of the round trip as the firm's production unit. Regulation can be considered a set of constraints on the pricing (rates conforming to a value-of-service pricing structure) and investment (common carrier obligations in the face of stochastic demand and entry or exit restrictions) policies of the carrier.

In view of the general agreement among economists that regulation adversely affects economic efficiency, the important research questions become "Who benefits from the various regulatory policies?" and "Why are those policies maintained?" The modeling approach is valuable because it can indicate the impact of regulation and regulatory change on both carriers and shippers. It is likely that the model can be more easily analyzed by comparing sets of equilibrium conditions than by explicitly solving for optimal prices and allocations, so the model probably will not yield a more reliable estimate of the welfare loss than those obtained above (although it may identify variables that affect the loss). But since regulatory reform remains a controversial issue, any contribution that the modeling approach can make to an understanding of the regulatory process justifies its consideration.

APPENDIX

The Harbeson and Friedlaender comparative-cost results were updated and revised in the following way. Basic terminal and line-haul expenses were obtained from ICC cost studies for 1970[78] and adjusted to account for user charge deficiencies and service differences related to time in transit, minimum shipment sizes, and pickup and delivery.

User charge increases for motor carriers were set at 1.8 cents per vehicle-mile. This figure was obtained by selecting 1.6 cents per vehicle-mile (the midpoint of the range suggested by Friedlaender[79]) as the relevant figure for 1965 and increasing it to 1970 price levels with the wholesale price index for construction materials and components.

The transit time difference between rail and motor carriage can be approximated by:

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[78]Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territories for the Year 1970 (1973), pp. 114-134, and Interstate Commerce Commission, Bureau of Accounts, Cost of Transporting Freight by Class I and Class II Motor Common Carriers of General Commodities by Regions or Territories for the Year 1970 (1972), pp. 25-193.

[79]Friedlaender, p. 38.

$$T = \left(\frac{mr}{20} - \frac{mt}{37.5}\right) + .1\frac{mr}{20} + \left[\frac{mr}{250}(6) - \frac{mt}{250}(3)\right] + \frac{mr}{140}(8) + 48$$

where T = time in hours
mr = rail miles
mt = truck miles

The first term represents the difference in average speeds of 20 mph for railroads and 37.5 mph for trucks, the second allows for rail time spent on sidings enroute, the third represents the difference in time required for interchanges at 250-mile intervals, the fourth is the rail time related to switching at intermediate terminals, and the last represents slower terminal handling at origin and destination. The cost of the difference in transit time is given by:

$$\text{Inventory cost (transit)} = T\left(\frac{Vi}{H}\right)$$

where V = commodity value
i = interest premium
H = 8760 hours per year[80]

The cost was calculated for:

V = \$1000 per ton
i = 15 percent per year

The value figure was derived from census figures on commodity

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[80]The parameters of the time equation were taken from recent studies. For the basic formulation, see Meyer et al., pp. 192-193.

volumes and from wholesale prices of individual products.[81] The selection of representative goods for each census group reflected a bias toward overestimation of the average value.

The inventory cost associated with different minimum loads can be estimated from:

$$\text{Inventory cost (size)} = \left(\frac{Vi + K}{2Q}\right)(L_r - L_t) + S\left(\frac{1}{L_r} - \frac{1}{L_t}\right)$$

where K = annual storage cost
Q = annual shipment volume in tons
S = ordering charge
L_r = minimum rail load
L_t = minimum truck load

The first term is the working capital and storage cost of the larger inventory required for the larger and less frequent rail shipments, and the second is the additional ordering expense of the more frequent truck shipments.[82] The cost was evaluated for:

V = \$1000 per ton
i = 15 percent per year
K = \$100 per ton
Q = 5000 tons
S = \$10 per order
L_r = 25.6 tons (Harbeson), 15-50 tons (Friedlaender)
L_t = 12.2 tons (Harbeson), 10 tons (Friedlaender)

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[81] U.S. Department of Commerce, Bureau of the Census, 1967 Census of Transportation, Vol. III, Commodity Transportation Survey, Part 1, Shipper Groups (1970) and Interstate Commerce Commission, Bureau of Transport Economics and Statistics, Freight Revenue and Wholesale Value at Destination of Commodities Transported by Class I Line-haul Railroads (1961)

[82] Meyer et al., pp. 190-192.

The result was a small net charge against motor carriers for all but the largest rail shipments, so in the interest of overstating the case for motor carriers, no adjustment of basic costs was made.

Pickup and delivery costs for the Eastern-Central territory in 1970 were added to rail terminal costs because the railroads' terminal service is limited to spotting freight cars on industrial sidings, while motor carriers usually provide complete pickup and delivery on through shipments. Meyer has shown that the expense of maintaining and operating a private siding can exceed the cost of truck pickup and delivery,[83] so it is not unreasonable to include truck pickup and delivery expense as a cost of door-to-door rail service. A maximum truck load of 30 tons was assumed.

Misallocation losses were determined by comparing cost-based allocations with traffic distribution figures classified by length of haul only or by both size of shipment and length of haul for 1967.[84] Distribution figures by size of shipment and length of haul were published only for the individual commodity classes, so it was necessary to prepare the aggregate figures required here.

For Harbeson's procedure, costs were calculated for average loads of 12.2 tons per vehicle for Class I intercity

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[83] Ibid., p. 189.

[84] U.S. Department of Commerce, 1967 Census of Transportation.

motor common carriers and 25.6 tons per car for Class I railroads. Although these figures are averages for all commodity traffic, the motor carrier load should be accurate because manufactures account for more than 80 percent of trucking tonnage. Railroads, however, carry a much larger proportion of bulk commodities, so 25.6 tons per car is probably an overestimate of the average manufactures load. This error is offset to some extent by the fact that the calculated rail costs apply to carload shipments and not all shipments.[85] Motor carrier costs were computed for a single-line movement with no intermediate transfer, while rail costs were based on shipment in a general service, unequipped boxcar in an average weight train. Costs were calculated for distances corresponding to the census mileage blocks. An allowance for circuity was made because the census figures are reported for straight-line miles. Short-line or rate-making miles exceed straight-line miles by 24 percent and 21 percent for railroads and trucks, respectively, and actual miles exceed rate-making miles by 16 percent and 6 percent on average. Therefore, census mileages were increased by 44 percent for railroads and 28 percent for motor carriers.

The welfare loss was then determined by evaluating the

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[85]The average load figures were drawn from, Interstate Commerce Commission, Bureau of Accounts, Transport Statistics in the United States, Year ending December 31, 1970, Part 1, Railroads, and Part 7, Motor Carriers (1973).

savings at each distance of reassigning all traffic to the low-cost mode and then summing the individual components. The steps and results of this computation are shown in table 2 for the lowest regional motor carrier costs and highest regional rail costs and in table 3 for the highest motor carrier and lowest rail cost scales. The lowest regional costs for motor carriers were reported for the Southern (Intra) region for the first seven mileage blocks and the Southwest region for the remaining five; the highest rail costs appeared in the Mountain Pacific and Transterritory for the first mileage block and in the New England region for all others. These costs were used in table 2. For table 3, the highest motor carrier costs were reported for the Transcontinental territory for the first five blocks and the New England region - Group II for the remaining seven; the lowest rail costs appeared in the Southern region for all mileage blocks.

Friedlaender's procedure requires costs for several specific shipment sizes. Motor carrier costs were based on weighted average single and interline movements in Eastern-Central territory and rail costs on average freight car costs in an average weight train in Official territory. Terminal and line-haul costs for a representative freight car were obtained by weighting individual car costs by the proportions of the total in service in the Eastern district at the close of 1970. Following Friedlaender, no

Table 2

Minimum Motor Carrier Costs vs. Maximum Rail Costs
(Harbeson, 1970)

$/Ton \ Mileage Block Midpoint	25	75	150	250	350	450	550	700	900	1100	1350	1750
Motor Carrier Costs												
Terminal + line-haul	5.62	7.81	10.49	14.18	18.05	21.88	25.46	31.13	36.03	43.02	51.76	65.74
Δ user charge	.05	.14	.29	.48	.67	.86	1.06	1.34	1.73	2.11	2.59	3.36
TOTAL	5.67	7.95	10.78	14.66	18.72	22.74	26.52	32.47	37.76	45.13	54.35	69.10
Rail Costs												
Terminal + line-haul	4.20	5.14	6.99	9.45	11.91	14.37	16.84	20.53	25.45	30.37	36.53	46.37
Inventory -- transit time	.88	1.00	1.19	1.44	1.68	1.93	2.18	2.55	3.05	3.54	4.16	5.16
Pickup & Delivery	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
TOTAL	7.80	8.86	10.90	13.61	16.31	19.02	21.74	25.80	31.22	36.63	43.41	54.25
Rail Cost Advantage	-2.13	-.91	-.12	1.05	2.41	3.72	4.78	6.67	6.54	8.50	10.94	14.85
High-Cost Carrier Traffic (thousands of tons)	27167	41444	69027	47825	30930	17845	13259	20041	10095	4899	3570	3357
Net Loss ($1,000)	57,866	37,714	8,283	50,216	74,541	66,383	63,378	133,673	66,021	41,642	39,056	49,851

TOTAL LOSS = $689 millions

Table 3

Maximum Motor Carrier Costs vs. Minimum Rail Costs
(Harbeson, 1970)

$/Ton \ Mileage Block Midpoint	25	75	150	250	350	450	550	700	900	1100	1350	1750
Motor Carrier Costs												
Terminal + line-haul	11.37	13.95	15.95	19.19	22.70	27.05	32.05	39.54	49.54	59.33	72.03	92.02
Δ user charge	.05	.14	.29	.48	.67	.86	1.06	1.34	1.73	2.11	2.59	3.36
TOTAL	11.42	14.09	16.24	19.67	23.37	27.91	33.11	40.88	51.27	61.44	74.62	95.38
Rail Costs												
Terminal + line-haul	2.64	3.28	4.24	5.52	6.80	8.08	9.36	11.28	13.84	16.41	19.61	24.73
Inventory -- transit time	.88	1.00	1.19	1.44	1.68	1.93	2.18	2.55	3.05	3.54	4.16	5.16
Pickup & delivery	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
TOTAL	6.24	7.00	8.15	9.68	11.20	12.73	14.26	16.55	19.61	22.67	26.49	32.61
Rail Cost Advantage	5.18	7.09	8.09	9.99	12.17	15.18	18.85	24.33	31.66	38.77	48.13	62.77
High-Cost Carrier Traffic (thousands of tons)	73474	67326	74193	47825	30930	17845	13259	20041	10095	4899	3570	3357
Net Loss ($1,000)	380,595	477,341	600,221	477,771	376,418	270,887	249,932	487,598	319,608	189,934	171,824	210,719

TOTAL LOSS = $4,213 millions

consolidation of small shipments was made, but her assumption of a 20-ton maximum load for motor vehicles was revised to a 30-ton limit; since the weighted average capacity of all terminal-to-terminal vehicles in the Eastern-Central territory is approximately 20 tons, it was assumed that 30-ton vehicles (at average commodity density) are available for these shipments.[86]

Higher terminal costs and lower line-haul costs for railroads relative to trucks at all shipment sizes indicated a rail cost advantage at longer distances. Therefore, the costs were used to determine the distances beyond which rail shipment is more efficient than motor carriage. Again, circuity adjustments were made by increasing line-haul costs by 44 percent and 28 percent for railroads and trucks, respectively. The estimated distances identified an efficient allocation, and the modal distribution figures were used to determine the potential traffic shifts. Traffic shifts were based on an extrapolation of the traffic statistics that was linear with respect to both weight and distance; that is, a distance of 260 miles required a shift from railroads to trucks of 30 percent of the rail traffic in the 200-399 mileage block for the appropriate weight. Shipment cost components are displayed in table 4 and the calculated distances and resulting traffic shift in table 5. The distances reported are

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[86] Interstate Commerce Commission, Cost of Transporting Freight by Class I and Class II Motor Common Carriers, p. 22.

Table 4

Rail and Motor Carrier Costs by Size of Shipment (Friedlaender, 1970)

Terminal Costs - $/ton
Line-haul Costs - $/ton-mile

	Shipment Size in Tons							
	1	5	10	15	20	30	40	50
Motor Carrier Costs								
BASIC TERMINAL	29.64	14.68	7.84	5.20	4.06	3.62	4.04	3.80
Basic line-haul	.5230	.1073	.0531	.0353	.0260	.0176	.0260	.0210
Δ user charge	.0180	.0036	.0018	.0012	.0009	.0006	.0009	.0007
TOTAL LINE-HAUL	.5410	.1109	.0549	.0365	.0269	.0182	.0269	.0217
Rail Costs								
Basic terminal	98.95	19.79	9.90	6.60	4.95	3.30	2.48	1.99
Inventory-terminal handling time	.82	.82	.82	.82	.82	.82	.82	.82
Pick-up & delivery	14.08	7.66	5.14	4.04	3.08	2.72	3.08	2.86
TOTAL TERMINAL	113.85	28.27	15.86	11.46	8.85	6.84	6.38	5.67
Basic Line-haul	.2935	.0606	.0314	.0217	.0169	.0120	.0096	.0081
Inventory-transit time	.0017	.0017	.0017	.0017	.0017	.0017	.0017	.0017
TOTAL LINE-HAUL	.2952	.0623	.0331	.0234	.0186	.0137	.0113	.0098

Table 5

Minimum Efficient Rail Distances and Traffic Reallocation
(Friedlaender, 1970)

Shipment Size	Minimum Efficient Distance (miles)	Current Traffic Rail (,000 tons)	Current Traffic Truck (,000 tons)	Rail → Truck (,000 tons)	Rail → Truck (%)	Truck → Rail (,000 tons)	Truck → Rail (%)
1 ton	315	5063	41163	859	17	19378	47
5 tons	260	7673	35272	1420	18.5	16221	46
10 tons	355	8243	29994	2734	33.2	9091	30.3
15 tons	482	13293	44990	6644	50	6924	15.4
20 tons	630	27517	89979	17247	62.7	7399	8.2
30 tons	894	48907	64634	36760	75.2	2723	4.2
40 tons	129	61126	9297	9533	15.6	5846	62.9
50 tons	136	252843	25905	61969	24.5	12946	50
TOTAL		424665	341234	137166	32.3	80528	23.6

straight-line mileages.

Friedlaender's procedure was extended by estimating the cost savings of the traffic shifts in table 5. The cost difference between modes was calculated at the midpoint of each census mileage block for each shipment size and applied to the relevant traffic. Mileage blocks in which the cost advantage changed from trucks to railroads were divided into two new blocks at the equal-cost distance and treated in the same way. For example, the 600-999 mileage block was divided for a 20-ton shipment at the minimum efficient rail distance of 630 miles; then cost differences were calculated at the new midpoints of 615 and 815 miles and multiplied by the relevant rail and truck tonnages, respectively. Shipments of less than 7.5 tons were not considered because most such shipments are not carload shipments, for which the ICC reports rail costs. This excluded traffic accounted for about 10 percent of the rail and motor common and contract carrier tonnage given in the census figures. The cost savings of a reassignment of the remaining traffic totaled approximately $400 million per year, so the welfare loss for all manufactured goods is probably less than $500 million per year.

CHAPTER II

INTERMODAL COMPETITION AND RATE REGULATION IN A TRANSPORTATION NETWORK

Most studies of the effects of rate regulation by the ICC have assumed that rates would equal long-run marginal costs in the absence of such regulation.[1] Some attention has been given to unregulated pricing in individual markets characterized by economies of density or served by only one railroad,[2] but the effect of market interdependence in a network has been ignored. This paper focuses on the pricing and input decisions of a railroad operating in a network and examines the pricing and welfare effects of competition and regulation. Competition in particular markets alters the demand conditions faced by the firm, and regulations are imposed as constraints on its behavior.

A network model offers a different perspective on the beneficiaries of regulation, knowledge of which is crucial for understanding why regulation is maintained in its

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[1] For a review of studies addressing the effect of rate regulation on traffic allocation, see chapter I above.

[2] Witness the concern in Congress about the lack of protection for captive shippers in current proposals to reform railroad regulation.

present form.[3] Most evaluations of regulation have focused on its effects on both carriers and relative rates for various commodity groups, as evidenced by the extensive discussion of value-of-service pricing. This formulation of the network model, however, emphasizes rate differences related to market location, a phenomenon that has been neglected beyond the observation that high-density routes subsidize low-density ones.

While the operations research literature examines in detail flows in networks with fixed demands, there have been few previous attempts to analyze pricing with elastic demands. Charnes and his associates have examined the question from the perspectives of the carrier[4] and the regulator[5] but have not gone beyond stating the maximization problem and the first order conditions. Florian and Nguyen have developed a method for computing solutions in a surplus maximization problem.[6] Braeutigam has obtained pricing

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[3]Welfare analysis is a means of totaling the gains and losses associated with a change in regulation; but the net result is not a sure guide to the prospects for change because the affected parties differ in their incentives and abilities to vote or influence policy.

[4]A. Charnes et. al., "Chance Constrained Models for Transport Pricing and Scheduling under Competition," Transportation Science 2 (February 1968): 57-76.

[5]A. Charnes et. al., "Regulatory Models for Pricing and Evaluation of Transport Services," Transportation Science 6 (February 1972): 15-31.

[6]Michael Florian and Sang Nguyen, "A Method for Computing Network Equilibrium with Elastic Demands," Transportation Science 8 (November 1974): 321-332.

and regulatory conditions for welfare maximization under intermodal competition when a multi-product mode faces a break-even constraint.[7] The emphasis here is on the firm's pricing decisions instead of optimal prices, and some structure is added to the problem by considering carrier decisions in a network and by basing rate constraints on the costs observed in the network. Finally, Friedlaender and her associates are incorporating network constraints similar to those used here in a simulation approach to the evaluation of regulatory change in transportation.[8]

This paper is divided into three sections. The first derives the profit-maximizing conditions for a rail monopolist in a general network. Section 2 examines the effect of competition and regulation in a simple three-node, two-link network. Finally, section 3 outlines the policy and research consequences of the network model.

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[7] Ronald Braeutigam, "Optimal Pricing with Intermodal Competition," American Economic Review 69 (March 1979): 38-49.

[8] U.S. Department of Transportation, Alternative Scenarios for Federal Transportation Policy: Second Year Final Report under Contract DOT-RSPA-DPB-50-78-32, 2 vols. (1978).

1. The general model

The network is composed of n nodes and m links. For any node k, θ_k is the set of nodes linked to k; that is, there is a link between k and any member of θ_k.

A market for transportation exists from one node to another. There are n(n-1) markets in the network.

The profit-maximizing problem for the monopoly carrier is:

$$\underset{q_{ij},\, c_{kl}}{\text{maximize}} \quad \pi = \sum_{i}^{n}\sum_{\substack{j \\ i \neq j}}^{n} p_{ij}(q_{ij})q_{ij} - \sum_{i}^{n} g_i\left(\sum_{j \neq i}^{n} q_{ij}\right) - \sum_{k}^{n}\sum_{l \in \theta_k} f_{kl}(c_{kl}) \qquad 1$$

$$\text{subject to:} \quad c_{kl} \geq \sum_{i}^{n}\sum_{\substack{j \\ i \neq j}}^{n} a_{kl}^{ij} q_{ij}, \quad \text{for every } k,\ l \in \theta_k \qquad 2$$

$$\sum_{l \in \theta_k} (c_{kl} - c_{lk}) = 0, \quad \text{for every } k \qquad 3$$

where q_{ij} = number of carloads of product shipped from i to j

c_{kl} = number of cars (loaded and empty) moved from k to l on the link between those nodes; note that c_{kl} is not necessarily equal to c_{lk}

π = profits

$p_{ij}(q_{ij})$ = inverse demand function for transportation from i to j

$g_i(\sum_{j \neq i}^{n} q_{ij})$ = terminal cost for all carloads originating at node i

$f_{kl}(c_{kl})$ = line-haul cost for all cars moved from k to l

a_{kl}^{ij} = 1 if carloads q_{ij} traverse link kl,
0 if not

The first term in the objective function (expression 1) is total revenue over all transportation markets. The second term is the sum of the terminal costs of traffic originating at each node. The third term is the sum of line-haul costs on each link. This specification assumes that there is no difference in the line-haul cost for loaded or empty cars; accounting for the increased cost of moving a loaded car would only introduce a cost term similar to the terminal cost for each carload. The terminal and line-haul costs in this formulation correspond to the usual operating and capacity costs in the peak-load pricing literature.

The 2m constraints given by condition 2 require that the number of carloads of product shipped in either direction on any link not exceed the number of cars moved by the firm. The coefficients a_{kl}^{ij} indicate the routing for any market and are assumed to be given. Since these conditions require that the firm supply enough capacity on each link to satisfy the market demands generated by its prices, they are labelled capacity constraints. The last n constraints expressed by equation 3 are termed conservation constraints because they require that the net flow of cars out of each node be zero.

The first order conditions for a maximum, assuming positive values for all q_{ij} and c_{kl}, are given by:

w.r.t. q_{ij}: $$MR_{ij} - g_i' - \sum_k^n \sum_{l \in \theta_k} a_{kl}^{ij} \mu_{kl} = 0 \qquad 4$$

c_{kl}: $$-f_{kl}' + \mu_{kl} + \delta_k - \delta_l = 0 \qquad 5$$

μ_{kl}: $$\mu_{kl} \geq 0; \quad c_{kl} \geq \sum_{i \neq j}^n \sum^n a_{kl}^{ij} q_{ij};$$

$$\mu_{kl}[c_{kl} - \sum_{i \neq j}^n \sum^n a_{kl}^{ij} q_{ij}] = 0 \qquad 6a,b,c$$

δ_k: $$\sum_{l \in \theta_k} (c_{kl} - c_{lk}) = 0 \qquad 7$$

where MR_{ij} = marginal revenue in market ij

μ_{kl} = capacity constraint multiplier

δ_k = conservation constraint multiplier

' denotes appropriate (partial) derivations

Conditions 6b and 7 are, of course, equivalent to constraints 2 and 3, respectively.

At the solution, some of the capacity constraints will be satisfied as equalities. Then the second order conditions require that a particular sequence of principal minors of the bordered Hessian matrix alternates in sign. It is assumed throughout that these conditions are satisfied.

The μ's in equation 4 can be interpreted as capacity charges and the sum as the cost of moving an extra car on the route required for a market. Condition 4 then is the familiar profit-maximizing rule for a monopolist: marginal revenue equals marginal cost, which here is the sum of incremental terminal and line-haul or capacity costs. If there is excess capacity in one direction on a link, so

$$c_{kl} > \sum_{i \neq j}^{n} \sum^{n} a_{kl}^{ij} q_{ij},$$

then, from equation 6c, $\mu_{kl} = 0$. That is, no capacity charges are incurred when there are empty cars moving in the required direction. It is also possible to show that excess capacity can exist in only one direction on a link. From condition 5 for both directions:

$$-f'_{kl} + \mu_{kl} + \delta_k - \delta_l = 0$$

$$-f'_{lk} + \mu_{lk} + \delta_l - \delta_k = 0$$

Adding these two equations yields:

$$\mu_{kl} + \mu_{lk} = f'_{kl} + f'_{lk} > 0 \qquad 8$$

Therefore, if there is excess capacity from k to l then all cars must be fully loaded from l to k:

$$c_{kl} > \sum_{i \neq j}^{n} \sum^{n} a_{kl}^{ij} q_{ij} \Rightarrow \mu_{kl} = 0 \Rightarrow \mu_{lk} > 0$$

$$\Rightarrow c_{lk} = \sum_{i \neq j}^{n} \sum^{n} a_{lk}^{ij} q_{ij}$$

If there were excess capacity in both directions on a link then it would be profitable to reduce the number of cars in both directions until all cars were loaded in one or both directions. Equation 8 indicates that cars can be fully utilized in both directions with each direction incurring a share of the total capacity charge.

Since markets bear charges based on the existence of excess capacity, prices may not conform to value of service pricing or an inverse elasticity rule. Bailey and White have pointed out the converse in the peak-load pricing models: off-peak rates will exceed peak rates if peak demand is sufficiently elastic.[9]

The profit-maximizing solution for any set of transportation demands is characterized by the capacity conditions (constraint 2) since they determine the μ_{kl} and then the q_{ij} and c_{kl}. It is apparent that the configuration of peak and off-peak (or excess capacity) directions changes when demands change enough. In particular, intermodal competition in some markets alters the demands faced by the monopolist and can cause peak directions to switch, thereby changing the capacity charges applied to both competitive and monopolistic markets. In the next section, a simple model is used to demonstrate that such competition can reduce both output and welfare (as measured by surpluses). The effect of cost-based rate regulation is also explored.

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[9] Elizabeth Bailey and Lawrence White, "Reversals in Peak and Off-Peak Prices," Bell Journal of Economics and Management Science 5 (Spring 1974): 75-92.

2. Competition and regulation in a simple network

Consider a railroad monopolist operating on the three-node, two-link network depicted in figure 1. Assume constant average terminal and line-haul costs so that:

$$g_i = s \sum_{j \neq i}^{3} q_{ij}, \qquad f_{kl}(c_{kl}) = A\, d_{kl}\, c_{kl}$$

where d_{kl} is the length of the link and $d_{kl} = d_{lk}$. The conservation constraints reduce to the requirement that $c_{12} = c_{21}$ and $c_{23} = c_{32}$. Therefore, the problem facing the carrier is:

$$\underset{q_{ij},\, c_{kl}}{\text{maximize}} \quad \pi = R_{12} + R_{21} + R_{13} + R_{31} + R_{23} + R_{32}$$

$$- s[q_{12} + q_{21} + q_{13} + q_{31} + q_{23} + q_{32}]$$

$$- 2A[c_{12}\, d_{12} + c_{23}\, d_{23}]$$

subject to:

$$c_{12} \geq q_{12} + q_{13} \qquad 9$$

$$c_{12} \geq q_{21} + q_{31} \qquad 10$$

$$c_{23} \geq q_{23} + q_{13} \qquad 11$$

$$c_{23} \geq q_{32} + q_{31} \qquad 12$$

where R_{ij} = revenue in market ij; $R_{ij} = R_{ij}(q_{ij})$

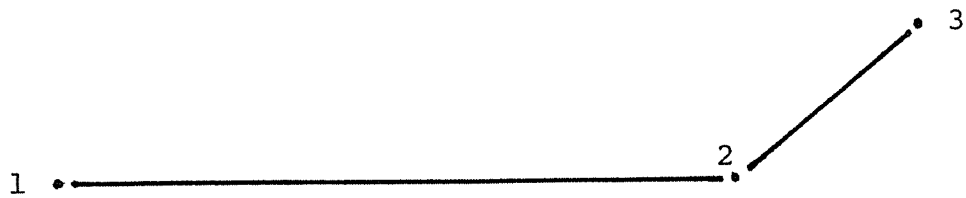


Figure 1

The first order conditions, assuming positive values for all q_{ij} and c_{kl} are:

$$MR_{12} = s + \mu_{12} \qquad MR_{21} = s + \mu_{21}$$
$$MR_{13} = s + \mu_{12} + \mu_{23} \qquad MR_{31} = s + \mu_{21} + \mu_{32} \qquad 13$$
$$MR_{23} = s + \mu_{23} \qquad MR_{32} = s + \mu_{32}$$

$$\mu_{12} + \mu_{21} = 2Ad_{12} \qquad \mu_{23} + \mu_{32} = 2Ad_{23} \qquad 14$$

$$\mu_{12} \geq 0, \quad c_{12} \geq q_{12} + q_{13}, \quad \mu_{12}[c_{12} - (q_{12} + q_{13})] = 0$$
$$\mu_{21} \geq 0, \quad c_{12} \geq q_{21} + q_{31}, \quad \mu_{21}[c_{12} - (q_{21} + q_{31})] = 0 \qquad 15$$
$$\mu_{23} \geq 0, \quad c_{23} \geq q_{23} + q_{13}, \quad \mu_{23}[c_{23} - (q_{23} + q_{13})] = 0$$
$$\mu_{32} \geq 0, \quad c_{23} \geq q_{32} + q_{31}, \quad \mu_{32}[c_{23} - (q_{32} + q_{31})] = 0$$

where μ_{ij} = multiplier for capacity constraint from i to j; $\mu 12$ and $\mu 21$, for example, apply to constraints 9 and 10, respectively

Condition 15 includes the capacity constraints 9 through 12.

Because there is only one route between any two points, this network can be termed a branch line network, in contrast to a main line system in which there are alternate routes between any origin and destination. A circular network, for example, would constitute a main line system. The general model described in section 1 applies to networks with both main and branch lines; the difference in model specification there is the explicit form of the conservation constraints. There is, however, no serious loss of generality in considering the simple branch line network because capacity charges in both models are determined by peak and off-peak (excess capacity) conditions on individual links, as demonstrated by a comparison of equations 8 and 14.

For some demand functions and cost parameters the solution will be characterized by excess capacity from 2 to 1 and from 2 to 3. That is:

$$MR_{12} = s + 2Ad_{12} \qquad MR_{21} = s$$
$$MR_{13} = s + 2Ad_{12} \qquad MR_{31} = s + 2Ad_{23} \qquad 16$$
$$MR_{23} = s \qquad MR_{32} = s + 2Ad_{32}$$

$$\mu_{12} = 2Ad_{12}, \quad \mu_{21} = 0 \qquad \mu_{32} = 2Ad_{23}, \quad \mu_{23} = 0 \qquad 17$$

$$c_{12} = q_{12} + q_{13} > q_{21} + q_{31}$$
$$c_{23} = q_{32} + q_{31} > q_{23} + q_{13} \qquad 18$$

This solution is illustrated in figure 2 for the markets requiring the use of the link between 2 and 3.

Intermodal competition on the link between 2 and 3 changes the demands faced by the railroad and can alter the peak directions and capacity charges associated with rail service. Motor carrier competition might be confined to the markets between 2 and 3 for two reasons. First, since railroads have higher terminal and lower line-haul costs than trucks, the railroad might have a significant cost advantage on the long line between 1 and 2. Second, shippers between 1 and 3 will not use rail-truck service if the cost of transferring freight from one mode to the other at 2 is prohibitive.

If motor carrier service is supplied at a constant average cost per carload (ignoring whatever peak-load pricing might be established by the motor carriers), then demands for rail transportation in the competitive markets between 2 and 3 are given by D*D* in figure 2. At a rail price in either market equal to the cost of motor carrier service, more shippers will use trucks than railroads because of the greater speed and reliability of the former, thereby reducing the inventory cost of goods in transit. The two modes are not perfect substitutes, however, because of differences in shipper location with respect to rail and truck terminals. That is, shippers located on rail lines will not switch to motor carrier service until the railroad rate exceeds the truck rate by more than the cost of delivery to the more distant terminal. Below some price for

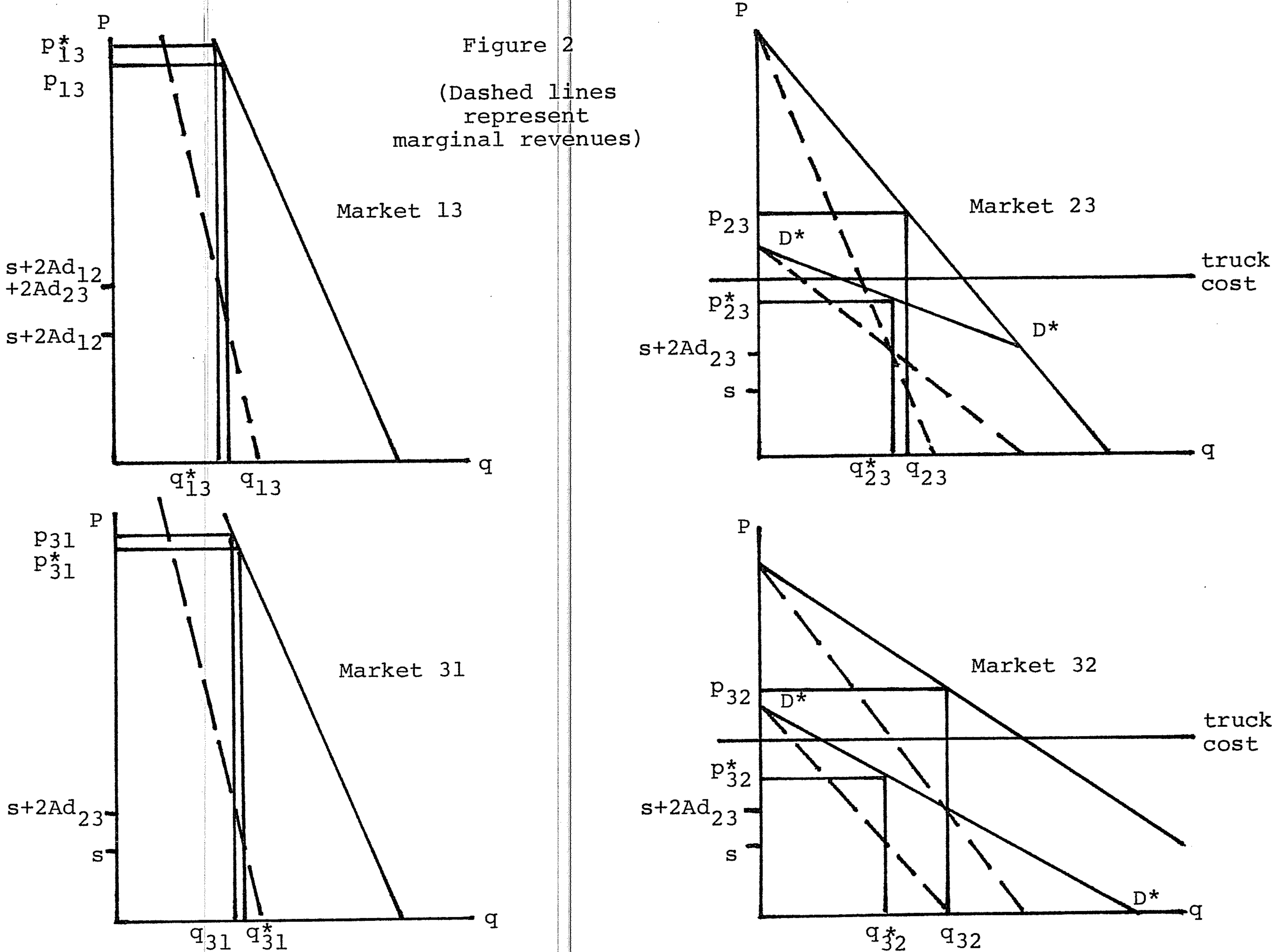


Figure 2

(Dashed lines represent marginal revenues) rail transportation (at the intersection of DD and D*D* in the market from 2 to 3) all shippers prefer rail service.

With new demands confronting the railroad in the competitive markets, the peaks and capacity charges must change: at the capacity charges given in condition 17, the related capacity condition for the link between 2 and 3 in condition 18 no longer holds. If q''_{23} and q''_{32} are the outputs under D*D* determined by the capacity charges in condition 17, then

$$q''_{32} + q_{31} \not> q''_{23} + q_{13}$$

Assume that the capacity relationships on the link between 1 and 2 are not altered by competition on the other link. Then the solution to the railroad's profit-maximizing problem under competition is given by:

$$\begin{aligned} MR^*_{12} &= s + 2Ad_{12} & MR^*_{21} &= s \\ MR^*_{13} &= s + 2Ad_{12} + 2Ad_{23} & MR^*_{31} &= s \\ MR^*_{23} &= s + 2Ad_{23} & MR^*_{32} &= s \end{aligned} \tag{19}$$

$$\mu^*_{12} = 2Ad_{12}, \quad \mu^*_{21} = 0 \qquad \mu^*_{23} = 2Ad_{23}, \quad \mu^*_{32} = 0 \tag{20}$$

$$\begin{aligned} c^*_{12} &= q^*_{12} + q^*_{13} > q^*_{21} + q^*_{31} \\ c^*_{23} &= q^*_{23} + q^*_{13} > q^*_{32} + q^*_{31} \end{aligned} \tag{21}$$

The peak on the link between 2 and 3 has switched; excess capacity exists from 3 to 2. This solution is also shown in figure 2. For some other choices of D*D* the solution requires a joint peak, with capacity charges set so that the same number of carloads of freight moves in both directions on the link between 2 and 3.

From a comparison of the first order conditions 16 and 19:

$$q^*_{12} = q_{12}, \quad q^*_{21} = q_{21} \qquad q^*_{13} < q_{13}, \quad q^*_{31} > q_{31} \qquad 22$$

and for the rail demands D*D* shown in figure 2:

$$q^*_{23} < q_{23}, \quad q^*_{32} < q_{32} \qquad 23$$

(It is possible for rail output to increase in the competitive markets. For example, q_{23} increases if D*D* is sufficiently elastic, despite the higher capacity charges incurred.) In order for peak directions to switch, $q_{13} + q_{23}$ must increase relative to $q_{31} + q_{32}$ even though capacity charges rise in the former markets and fall in the latter. Since $q^*_{13} < q_{13}$ and $q^*_{31} > q_{31}$, inelastic demands in the two markets between 1 and 3 facilitate the switch.

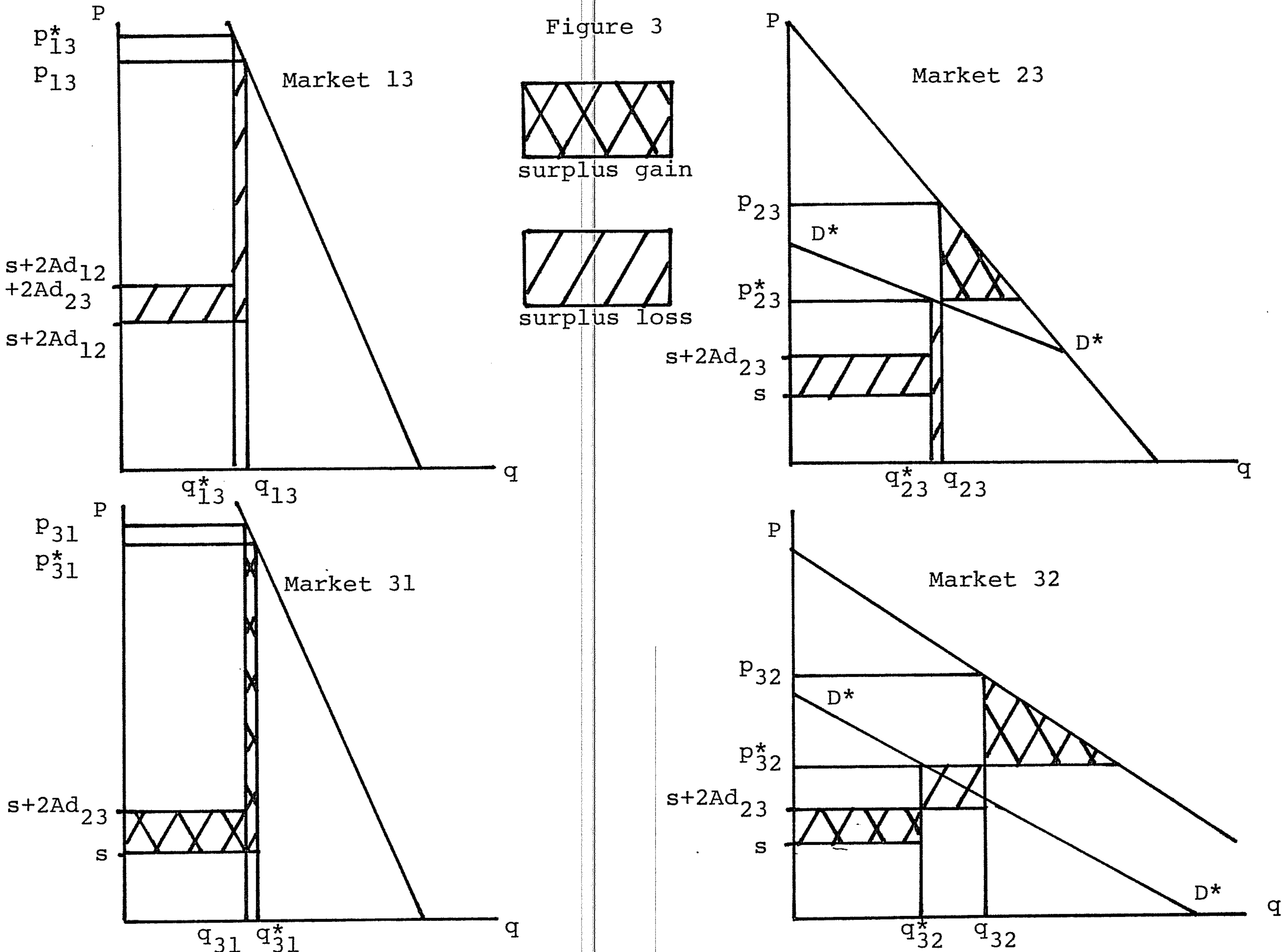
For the solution shown in figure 2, total rail output falls because, from conditions 18, 22, 23 and 21:

$$q_{32} + q_{31} > q_{23} + q_{13} > q^*_{23} + q^*_{13} > q^*_{32} + q^*_{31}$$

In addition, rail (and total) profits decline because the firm could have chosen the competitive outputs before the entry of the motor carriers with higher revenues in the competitive markets.

The effect on welfare is more difficult to determine because the demand for motor carrier service in the competitive markets has not been specified. It is, however, possible to set a lower bound on the welfare gain. Motor carrier output in the competitive markets must be at least the horizontal difference between DD and D*D* at p*. This output, indicated by AB in the market from 2 to 3, would have been demanded from a railroad offering service at p* in the absence of intermodal competition. Some of those shippers who would have entered the market for the rail monopoly's service at rates less than p* may also opt for motor carriage at the trucking cost, but these will be ignored (one way in which the increase in surplus is understated). Since the shippers represented by AB value motor carriage more than rail service by at least the difference between truck cost and p*, the surplus associated with truck transport can be calculated as if the resource cost were p* and not the higher truck cost (another way in which the welfare gain is understated, since some of those shippers value motor over rail carriage by more than the premium paid for the former). The welfare consequences of competition in the markets between 2 and 3 are illustrated in figure 3. That diagram suggests a welfare gain, but it appears that manipulation of the cost and demand conditions could produce an example in which total surplus declines.

Figure 3



Market 13
p
p^*_{13}
p_{13}
$s+2Ad_{12}$
$+2Ad_{23}$
$s+2Ad_{12}$
q^*_{13}
q_{13}
q
surplus gain
surplus loss
Market 23
p
p_{23}
D*
p^*_{23}
D*
$s+2Ad_{23}$
s
q^*_{23}
q_{23}
q
Market 31
p
p_{31}
p^*_{31}
$s+2Ad_{23}$
s
q_{31}
q^*_{31}
q
Market 32
p
p_{32}
D*
p^*_{32}
$s+2Ad_{23}$
s
D*
q^*_{32}
q_{32}
q

Minimum rate regulation in competitive markets can take several forms. The first is a rate floor based on the ICC's calculation of variable costs in each market. The costs recorded in the network are:

$$s \sum_{i \neq j}^{3} \sum^{3} q_{ij} \qquad \text{terminal costs}$$ 24

$$2A(c_{12}d_{12} + c_{23}d_{23}) \qquad \text{line-haul costs}$$

The ICC uses the corresponding system averages as its measures of variable costs:

$$s \qquad \text{per carload}$$ 25

$$\frac{2A(c_{12}d_{12} + c_{23}d_{23})}{\sum_{i \neq j}^{3} \sum^{3} q_{ij}d_{ij}} \qquad \text{per carload-mile}$$

where d_{ij} = length of the route between i and j

The minimum rate constraint in any market is then given by:

$$p_{ij} \geq s + A' d_{ij}$$ 26

where P_{ij} = rate for transportation from i and j

A' = average line-haul cost in expression 25

It is clear that:

$$A \leq A' \leq 2A \qquad (27)$$

The first equality holds when cars are fully utilized in both directions on every link; that is, there are no empty cars in the system. It requires, for example, that:

$$c_{12} = q_{12} + q_{13} = q_{21} + q_{31}$$

The second equality holds when loaded cars move in only one direction on any link. The required condition on the link between 1 and 2 could be:

$$c_{12} = q_{12} + q_{13}, \quad q_{21} = 0, \quad q_{31} = 0$$

Figure 2 indicates that railroad rates in the competitive markets between 2 and 3 satisfy the minimum rate constraints as strict inequalities. In general, however, the constraint can only be effective in the market experiencing excess capacity. The constraint is always satisfied (as a strict inequality if rail demand is not perfectly elastic or $A' \neq 2A$) in the peak market (in figure 2, the competitive market from 2 to 3):

$$p_{ij} \geq MR_{ij} = s + 2Ad_{ij} \geq s + A'd_{ij} \qquad (28)$$

But the constraint can be effective in an off-peak market (in figure 2, the competitive market from 3 to 2)[10] because

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[10]This argument also applies to joint peak markets, in which capacity charges are shared so that the same number of loaded cars moves in each direction.

marginal revenue is set at a level lower than the rate floor:

$$p_{ij} \geq MR_{ij} = s < s + A'd_{ij} \qquad 29$$

Therefore, in markets connected by a single link (primarily short-haul traffic), binding minimum rate regulation raises price and reduces output in markets with excess capacity. It follows that such regulation cannot cause a reversal of peaks.[11]

However, when rate floors based on ICC cost figures are applied to markets requiring transit over more than one link (such as the markets between 1 and 3 in figure 1), peak conditions can change. Since each of the markets in a city pair separated by more than one link normally[12] incurs capacity charges on some links and not others, neither can be designated a peak market. In that case, marginal revenue can be less than the rate floor, and the constraint can be effective in either or both markets. As a result, peaks can switch on any of the connecting links.

The ICC has also restrained intermodal competition by requiring that rail rates be set no lower than motor carrier rates, with a differential sometimes approved to compensate for inferior rail service. The Commission has apparently enforced

[11] Since the rate constraint is based on historical cost figures for regions served by several railroad systems, it is assumed that each firm considers the constraint exogenous.

[12] It is possible that one of the two markets will incur all the capacity charges and the other market none, in which case the earlier single link argument applies.

rate parity in order to protect modal traffic shares. Such a constraint can be effective in any market and therefore can alter peak conditions and the assignment of capacity charges. This is also true for maximum rate regulation as well as rate floors based on various allocations of common costs.

3. Policy implications and research proposals

The primary result of the simple network model is that, for some cost and demand parameters, intermodal competition and rate regulation can alter the peak conditions adopted by the profit-maximizing railroad. Rates in markets not subject to competition or regulation change with capacity charges, and the net effect on total surplus can be negative.

This conclusion suggests that there will be no general shipper support for deregulation of entry and rates. To the extent that individual shippers can estimate the likely capacity charges under deregulation, they will support or oppose the change by location rather than commodity class. Moreover, piecemeal deregulation will be difficult to evaluate as a test of total deregulation and will create new constituencies with respect to further change. (It is quite possible that the new constituencies will judge further deregulation incorrectly: winners are likely to support it and losers to oppose it, when, in fact, peak shifts can reverse their positions.)

At least three other issues should be considered in the network model. First, economies of density in rail service on individual links[13] appear to expand the set of demand functions for which competition and regulation can change peak conditions. Second, entry appears to play the

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[13]Robert Harris, "Economies of Density in the Rail Freight Industry," Bell Journal of Economics 8 (Autumn 1977): 556-564.

same role here as in the sustainability models, which indicate that a multiproduct natural monopoly operating at zero profit will be able to set entry-deterring prices in all markets only under certain conditions.[14] In both formulations, an entrant supplying a subset of the markets can disrupt the monopolist's economies of joint production, here arising from the round-trip constraints. The resemblance ends there, however. Here, the monopolist is not constrained to earn zero profits, the monopolist's cost function is not continuous in the outputs, the entrant employs a technology not available to the railroad, and the railroad's response to entry is more realistic.[15] Finally, since railroad profitability is reduced by both competition and rate regulation, incentives for abandoning individual links are increased.

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[14] John Panzar and Robert Willig, "Free Entry and the Sustainability of Natural Monopoly," Bell Journal of Economics 8 (Spring 1977): 1-22.

[15] Kenneth Baseman, "Open Entry and Cross-Subsidy in Regulated Markets," paper presented at the NBER Conference on the Economics of Public Regulation, December 15-17, 1977.

CHAPTER III

THE INPUT EFFECTS OF COST SEPARATIONS IN TELECOMMUNICATIONS

Separations is the process by which common costs are allocated to different regulatory jurisdictions for rate-making purposes in telecommunications. Separations, however, has received surprisingly little attention in the otherwise extensive economic literature on the behavior of the firm under regulatory constraint. Any effort to remedy that omission is particularly appropriate now because proposed revisions of the Communications Act contemplate significant changes in the separations process. The purpose of this paper then is to determine the effect of cost separations on input use by the firm. Profit-maximizing conditions for a two-product firm regulated in each market are compared to those for an unregulated firm and one operating under an overall constraint. Regulation is characterized by a continuously binding rate-of-return constraint or a pricing rule allowing the regulators to maintain the earned rate of return within certain bounds.

The major element of common cost is the exchange plant used for connecting and switching calls within a city; it is required for the completion of long-distance calls as well as local calls. Exchange plant is provided by one of the

Bell operating companies (which are subsidiaries of AT&T) or independent operating companies. Intercity transmission and switching facilities generally are owned by the Long Lines division of AT&T.

The separations procedures determine the assignment of an operating company's exchange plant to the state and federal jurisdictions. A particular type of equipment is usually divided on the basis of the relative outputs associated with it. After rate base and expenses are assigned to the two jurisdictions, revenue requirements and rates can be computed. The operating company is then entitled to recover from the pool of interstate revenues its expenses incurred in handling interstate calls and a rate of return on the portion of its facilities assigned to the interstate rate base. When the separations rules are amended to allocate a larger share of exchange plant to the federal jurisdiction, the revenue required from state services (local service and state toll) to support the remaining expenses and plant is reduced. As a result, the separations procedures are an important factor in the relationship of interstate rates to local service and state toll charges.

Three periods can be identified in the development of existing separations procedures.[1] Through the 1930s, AT&T

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[1]This history review is based on Richard Gabel, Development of Separations Principles in the Telephone Industry (East Lansing: Michigan State University, 1967) and Gabel's recent draft revision.

advocated the assignment of all exchange facilities to the state jurisdictions. It apparently took this position because of prevailing regulatory practices. The states imposed rate-of-return constraints but were concerned more with valuation issues than separations. Interstate rate regulation was not a factor because the ICC focused on surface transportation and because long-distance costs and rates were falling. Therefore, AT&T could assign as much of the common costs to the state jurisdictions as necessary to justify profit-maximizing local rates under the rate-of-return constraints.

From 1936 to 1941, the FCC obtained five interstate rate reductions, and in 1943, AT&T amended the separations rules in order to shift rate base and expenses to the federal jurisdiction as a means of forestalling further reductions. Until the introduction of competition in terminal equipment and specialized intercity services in the late 1960s, AT&T periodically reclassified rate base and expenses to the interstate jurisdiction.[2] Those changes in the separations procedures were usually made with the uncritical approval of the FCC[3] and the support of the state commissions.

It is instructive to examine the policy of the state commissions more closely. The states generally backed the shift of rate base and expenses to the federal jurisdiction

[2]The major separations changes are listed in the following table:

because it reduced the revenue requirement for state services, but they came to this position somewhat reluctantly. A ruling in 1930 in Smith v. Illinois Bell (282 U.S. 133) supported the assignment of some portion of exchange costs to the interstate jurisdiction, but the states failed to press for its implementation as a means of cutting state revenue requirements because they feared the extension of federal authority.[4] The states

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Year	Separations Change	Estimated Increases in Interstate Revenue Requirement at the Time of the Separations Change ($M)
1947	Simplification	13
1952	Charleston Plan	30
1956	Modified Phoenix Plan	40
1962	Simplification	46
1965	Denver Plan	134
1969	FCC Plan	108
1971	Ozark Plan	131

In 1974, 19 percent or $2.6 billion of local exchange costs were assigned to the interstate jurisdiction under prevailing separations rules: 29 percent of interstate MTS and WATS revenues were required to reimburse those costs. AT&T, "The Impact of Competition for Intercity Services and Terminal Equipment on Separations Assignments and Procedures," Bell Exhibit 45 in FCC Docket 20003, Appendix C.

[3]Between 1942 and 1966, the FCC did not formally address the separations issue or approve any of the principles being used. Its comments on the 1965 Denver Plan are illustrative: ". . . this Commission will interpose no objections to incorporation of the revised procedures into the Separations Manual, and to their use, on an interim basis." The procedures adopted in a 1967 Commission order on separations were codified into the FCC rules so that subsequent changes have required a rule-making proceeding. Gabel, draft Chapter VI, pp. 3, 17.

[4]At FCC hearings on separations in 1942, the counsel for NARUC (now the National Association of Regulatory Utility Commissioners) opposed the assignment of exchange plant to the interstate jurisdiction because it would "offer opportunity

eventually agreed to the separations changes in order to reduce the difference in rates for state and interstate toll calls. Technological change and economies of density had affected long-haul costs more than short-haul costs. The rate disparity arose because long-haul rates subsidized short-haul rates in the interstate rate structure while state toll rates enjoyed no such subsidy and so suffered by comparison with interstate rates for calls covering the same distance. Moreover, with no breakdown of state costs by toll and local service, state regulators usually met increased revenue requirements by raising toll rates. Therefore, the states found in the rising (because of increasing demand and productivity) federal rate of return the opportunity to prevent interstate rate reductions that aggravated the rate disparity as well as to alleviate pressure on local and state toll rates. Nevertheless, the separations changes seldom brought about lower rates: between 1942 and 1965, only 22 percent of the decrease in state revenue requirements associated with separations amendments were translated into rate reductions, and most of the cuts were in toll charges.[5]

In the late 1960s, the FCC authorized competition in the

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for an extension of federal jurisdiction to the field of exchange operations." Another NARUC representative, however, reported that the adoption of the principle in the 1930 decision would reduce state revenue requirements by $50 million! Gabel, p. 39.

[5]Gabel, pp. 128-129.

provision of private line service. Private line is long-distance service over a designated set of points available to the user on demand for a flat monthly charge; the firms supplying the service (besides AT&T) are known as specialized common carriers. AT&T has since resisted the steady transfer of rate base and expenses to the interstate jurisdiction.[6] Since private line services did not until recently bear any common costs under the separations procedures, shifts to the federal jurisdiction would have raised the revenue requirements and rates for public long-distance service and thereby increased the attractiveness of private line vis-a-vis the public services. The states have reacted to AT&T's refusal to reclassify rate base and expenses by opposing competition in private line service. They contend that competition by the specialized common carriers reduces the interstate revenue pool to be divided and, since diversion to private line reduces public toll usage of local exchange facilities, cuts the share of exchange plant assigned to the interstate rate base.

In addition, the states have joined AT&T in opposing competition in the supply of terminal equipment. They argue that when a user obtains a terminal device from an outside

[6] There has been no major revision in the separations procedures since 1971, and AT&T has opposed shifts to the interstate jurisdiction under the so-called California plan. Gabel, draft Chapter VI, pp. 48-49.

vendor instead of the local operating company the company's revenues from equipment rentals and separations fall more than its costs, so that the revenue requirement for basic exchange service increases. Indeed, AT&T has defended its earlier reclassification of rate base and expenses and its current anticompetitive stance by pointing to its "mandate" to provide universal service at reasonable rates and arguing that the subsidy provided to residential customers by the separations process must be improved or at least maintained. But recent studies by several state commissions have revealed that the Bell companies have used the revenue obtained by allocating a share of terminal equipment to the interstate rate base to finance rental rates that do not cover the marginal costs of the equipment.[7] These reports indicate, therefore, that residential service is not subsidized by terminal equipment revenues.

More recently, AT&T has reacted to the authorization of extensive private line networks by imposing charges for access to its local distribution facilities that include a share of common costs. Access charges for all intercity carriers, including AT&T, are being considered in pending leglislation as a means of providing any desired subsidy. Most parties, in fact, have come to view separations more as a political

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[7]Studies by the New York, Vermont, and Massachusetts commissions are cited in, Federal Communications Commission, First Report in Docket 20003 (1977).

process than as a technical costing procedure. In the past, AT&T made its case for separations changes in terms of better measures of relative use or simpler procedures, but its more recent statements have focused explicitly on the subsidy of exchange rates. In addition, the FCC is taking a more active role in the development of the separations rules and has stated that the procedures can be modified to offset any adverse effect of competition on local service rates.

The available evidence indicates that the share of common costs now assigned to interstate services exceeds the welfare-maximizing share. Optimal pricing requires that the common costs be recovered by markups over incremental costs that are inversely related to the price elasticities of demand. But Littlechild[8] has found that the excess of price over marginal cost is greater on the longer routes, which exhibit the higher elasticities of demand.[9] Consequently, it appears that the

[8] S.C. Littlechild, "Peak-Load Pricing of Telephone Calls," Bell Journal of Economics and Management Science 1 (Autumn 1970): 205-206.

[9] Long Lines has estimated daytime elasticities for business and residential services, respectively, to be -0.2 and -0.3 for 500-700 mile routes and -0.1 and -0.2 for 100 mile routes. Nighttime figures are approximately double. The estimated elasticities for local service are not significantly different from zero, and -0.1 is commonly used. Littlechild, p. 207. In a more recent study, Littlechild and Rousseau surveyed the available demand studies and concluded that the best estimates for elasticities of overall demand with respect to constant percentage price changes in all periods of the day are -0.99 for interstate calls, -0.43 for intrastate calls, and -0.4 for local calls. S.C. Littlechild and J.J. Rousseau, "Pricing Policy of a U.S. Telephone Company," Journal of Public Economics 4 (1975): 41-42.

increases in interstate revenue requirements induced by changes in the separations procedures have been exorbitant and that interstate rates exceed efficient levels.[10]

Despite the importance of separations as a regulatory instrument, few attempts have been made to analyze the effects of the separations rules on firm decisions.[11] Braeutigam has demonstrated that a horizontally integrated firm can earn higher profits than its unintegrated counterparts, each of which is separately regulated, if it can control the allocation of common costs.[12] In addition, Hannon has used a simple model to show that the changes in the separations procedures advocated by AT&T were profit-maximizing responses to differences in allowed rates of return and changes in market competition.[13]

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[10]However, it does not follow that state toll and local exchange service are necessarily underpriced. Since the demand for interstate service is more elastic than the demand for state services, a shift to efficient pricing (which would initially lower interstate rates and raise state rates) would increase the use of common facilities. State rates could fall below original levels because increased volume would reduce the markups required to break even and marginal costs would fall if there are economies in the use of common equipment.

[11]Firms operating in more than one jurisdiction have been studied in other settings. For example, MacAvoy and Noll have examined the behavior of natural gas pipelines with both regulated and unregulated sales. Paul MacAvoy and Roger Noll, "Relative Prices on Regulated Transactions of the Natural Gas Pipelines," Bell Journal of Economics and Management Science 4 (Spring 1973): 212-234.

[12]Ronald Braeutigam, "A Comment on ITT v. GTE," paper presented at the Telecommunications Policy Research Conference, Airlie House, Virginia, April 1974.

[13]James Hannon, "The Impact of Cost Allocation in a Multi-

But the effects of separations on input use by the firm have been ignored, a surprising omission in view of the attention (in)efficient production has received in most studies of operation under an overall rate-of-return constraint.

This paper addresses the question of input use for a profit-maximizing, two-product firm regulated in both markets. The decision variables for the firm are specific and common capital and labor. A specific input can be used to produce only one output and is assigned to the corresponding jurisdiction, while a common input can be used to supply both outputs and is apportioned to the two jurisdictions according to the separations rules. Long-distance transmission facilities, for example, are specific to the provision of interstate service. However, inputs specific to the supply of state services are harder to identify. Virtually all facilities required for the supply of local and state toll service are also used to provide interstate service. The telephone, for example, is used for both local and long-distance calls. Therefore, the firm is assumed to produce both outputs with common inputs and inputs specific to the interstate jurisdiction only.

Market Monopoly: Telecommunications" (Ph.D. dissertation, University of Illinois, 1978). Hannon's conclusions, however, are based on the assumption that capital and labor cannot be adjusted in response to a change in the shares of common cost assigned to each jurisdiction. If input levels are allowed to vary, then the effect of separations changes on profits depends on the demand and production functions.

In addition, the firm can employ unproductive inputs; the regulatory commissions are assumed to be unable to distinguish between wasteful and productive inputs in the rate-making process.

The shares of common costs assigned to each jurisdiction are set by the regulatory authorities in some formulations of the problem and by the firm in others. The effect of the separations process on input decisions can be determined by comparing the profit-maximizing conditions for a firm regulated in both markets to those for an unregulated firm and one operating under an overall constraint.

Two models of the regulatory process are considered. The first is a variation of the Averch-Johnson model, in which the firm is subject to a continuously binding rate-of-return constraint in each jurisdiction. The allowed rate-of-return in the federal jurisdiction is assumed to be higher that its state counterpart.[14] But the Averch-Johnson characterization of the regulatory process is unrealistic because it allows the

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[14] If the Averch-Johnson model of rate regulation is accurate, then observed rates of return should mirror allowed rates of return. Reynolds found that from 1954 to 1970 (the last year for which he listed figures) the five-year moving average rates of return for Long Lines exceeded those for the combined Bell companies. However, the number of states with a return (not averaged) greater than Long Lines' increased dramatically in 1970 and remained high through 1972. Robert Reynolds, "Bell," Department of Justice memorandum, February 28, 1974. Hannon also reported that interstate returns were higher than overall state returns in the 1960s. Hannon p. 182.

firm to set prices. It is instead the regulatory commissions that set prices, and the firm is required to satisfy the resulting demands for service.

Joskow has argued that regulators establish procedures that minimize conflict among competing interest groups while meeting statutory requirements.[15] As a result, commissions generally do not initiate rate reviews but instead react to requests for rate changes. When a carrier files for a rate increase, the allowed rate of return used to evaluate the request is likely to be close to the cost of capital because user groups will oppose anything more than a "fair" rate of return and because the average return of other firms will be considered an upper bound. However, earned rates of return somewhat higher than the cost of capital will usually not be discovered and protested by consumers if rates are not rising. Even if the observed return is high enough to provoke complaints from users and review by the commissions, the allowed rate of return will probably exceed the cost of capital because the average industry return will be considered a lower bound in order not to penalize the firm for efficient

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[15]Paul Joskow, "Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation," Journal of Law and Economics 17 (October 1974): 291-328. For a discussion of this theory of agency behavior in the context of the FCC's regulation of television broadcasting, see Roger Noll, Merton Peck, and John McGowan, Economic Aspects of Television Regulation (Washington: The Brookings Institution, 1973), pp. 120-128.

operation.[16]

Therefore, in the second model of the regulatory process, the commissions adjust prices to maintain earned rates of return in a range defined by the cost of capital and some higher allowed rate of return. The firm chooses inputs (specific and common, productive and wasteful) to satisfy demands at prevailing prices and to influence future prices.[17]

This price-adjustment model appears to be consistent with state and federal regulation of telephone rates. The state commissions could have reduced rates after shifts of rate base and expenses to the interstate jurisdiction and faced renewed pressure for increases (because of rising exchange costs) shortly thereafter. But they chose instead to hold rates fixed and allow the carriers a higher realized return in order to postpone the rate increases. In addition, the few cuts that were made affected state toll rates and served to reduce the embarrassing rate disparity between state and interstate calls of the same distance.

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[16]Joskow has found evidence in state regulation of electric utilities to support various hypotheses about commission activity and observed rates of return that are consistent with this description of the rate-making process. Joskow, pp. 299-311.

[17]A similar representation of the rate-making process is used in, Stuart Burness, David Montgomery, and James Quirk, "The Turnkey Era in Nuclear Power: A Case Study in Risk Sharing Arrangements Involving Regulated Firms," Social Science Working Paper No. 175, California Institute of Technology, September 1977.

Until the 1970s, however, the FCC frequently expressed concern that the rate of return earned by AT&T on interstate traffic was too high, but it allowed AT&T to choose between rate cuts and separations changes as a means of solving the problem. This emphasis on the rate of return is somewhat puzzling because there was little support for such a policy outside the Commission. The states favored increases in the interstate share of common costs, but rate reductions only aggravated the rate disparity problem. Moreover, it appears that AT&T did not support all the rate cuts and adopted some separations changes only to prevent them.

One explanation for the FCC's behavior is that with growing demand and technical change in long-distance communications AT&T repeatedly attained rates of return large enough to trigger review by the Commission. That AT&T was allowed to earn a return exceeding the cost of capital is suggested by the higher interstate rate of return.[18] Furthermore, the increases in the number of states with rates of return higher than the federal jurisdiction that occurred after 1970 coincided with the first interstate rate increases in twenty years.[19] This fact indicates that the FCC as well as the

[18]See note 14. However, the relative rates of return are also consistent with regulatory lag and an allowed rate of return always equal to the cost of capital.

[19]Interstate rate and separations changes for the twenty years ending in 1975 are listed in the following table:

state commissions are now concerned with the lower bound on allowed rates of return and are raising prices to provide a return equal to the cost of capital.

The remainder of this paper is divided into three parts. The first two examine the effects of the separations process on input use in the Averch-Johnson and price-adjustment models of regulation. The third considers the policy implications of the results and outlines further research on separations.

Year	Rates ($M)	Separations ($M)
1956	-	+40
1959	-47	-
1960	-3	-
1962	-	+46
1963	-30	-
1965	-98	+134
1967	-104	-
1968	-20	-
1969	-	+108
1970	-237	-
1971	+175	+131
1973	+135	-
1975	+328	-

"-" indicates no change. AT&T, p. 9.

1. An Averch-Johnson approach

In these models, the firm is subject to a rate-of-return constraint in each jurisdiction, but the regulators do not explicitly set rates.

Consider first the case where the shares of common labor and capital assigned to each jurisdiction are determined by the regulatory authorities. Then the problem for the firm can be stated in the following way, where jurisdictions 1 and 2 are taken to be the federal and state jurisdictions, respectively:

$$\underset{\substack{L_1, L, L_1^*, L_2^* \\ K_1, K, K_1^*, K_2^*}}{\text{maximize}} \quad \pi = R^1 + R^2 - w(L_1 + L + L_1^* + L_2^*) - r(K_1 + K + K_1^* + K_2^*) \qquad 1$$

subject to:

$$R^1 - w(L_1 + \beta L + L_1^*) \leq s_1(K_1 + \alpha K + K_1^*) \qquad 2$$

$$R^2 - w[L(1-\beta) + L_2^*] \leq s_2[K(1-\alpha) + K_2^*] \qquad 3$$

K, L = capital and labor inputs common to the provision of service in both jurisdictions; K includes local distribution facilities and L the labor to maintain them

K_1, L_1 = inputs specific to the provision of interstate service; K_1 includes interstate transmission lines and L_1 the required maintenance

$K_1^*, K_2^*, L_1^*, L_2^*$ = unproductive inputs employed in jurisdictions 1 and 2

π = profits

w = wage rate

r = cost of capital

R^1 = revenue in jurisdiction 1; $R^1 = p^1(q^1)q^1$, where p^1 and q^1 are price and output and $q^1 = f^1(L_1, K_1, L, K)$ or $R^1 = R^1(L_1, K_1, L, K)$; $f_i^1 > 0$, where f_i^1 is the marginal product of input i; R^1 is strictly concave in the inputs

R^2 = revenue in jurisdiction 2; $R^2 = p^2(q^2)q^2$, where $q^2 = f^2(L,K)$ or $R^2 = R^2(L,K)$; $f_i^2 > 0$ and R^2 is strictly concave in the inputs

s_1, s_2 = allowed rates of return in jurisdictions 1 and 2; $s_1 > r$ and $s_2 > r$

α, β = shares of common capital and labor assigned by the regulators to jurisdiction 1

The first order conditions for a maximum, assuming positive values for all the productive inputs, are given by:

w.r.t. L_1: $$(R^1_{L_1} - w)(1-\lambda_1) = 0 \qquad 4$$

L: $$R^1_L(1-\lambda_1) + R^2_L(1-\lambda_2) - w + \lambda_1\beta w + \lambda_2(1-\beta)w = 0 \qquad 5$$

K_1: $$R^1_{K_1}(1-\lambda_1) - r + \lambda_1 s_1 = 0 \qquad 6$$

K: $$R^1_K(1-\lambda_1) + R^2_K(1-\lambda_2) - r + \lambda_1\alpha s_1 + \lambda_2(1-\alpha)s_2 = 0 \qquad 7$$

L_1^*: $$L_1^* \geq 0; \qquad -w(1-\lambda_1) \leq 0 \qquad 8a,b$$

$$L_1^*(-w)(1-\lambda_1) = 0 \qquad 8c$$

L_2^*: $L_2^* \geq 0$; $-w(1-\lambda_2) \leq 0$ 9a,b

$$L_2^*(-w)(1-\lambda_2) = 0$$ 9c

K_1^*: $K_1^* \geq 0$; $\lambda_1 s_1 - r \leq 0$ 10a,b

$$K_1^*(\lambda_1 s_1 - r) = 0$$ 10c

K_2^*: $K_2^* \geq 0$; $\lambda_2 s_2 - r \leq 0$ 11a,b

$$K_2(\lambda_2 s_2 - r) = 0$$ 11c

λ_1: $\lambda_1 \geq 0$ 12a,b

$$\lambda_1(s_1[K_1 + \alpha K + K_1^*] + w[L_1 + \beta L + L_1^*] - R^1) = 0$$

λ_2: $\lambda_2 \geq 0$ 13a,b

$$\lambda_2(s_2[K(1-\alpha) + K_2^*] + w[L(1-\beta) + L_2^*] - R^2) = 0$$

where λ_1, λ_2 = constraint multipliers in jurisdictions 1 and 2

R_i^j = marginal revenue product of input i in jurisdiction j

Conditions 10b, 11b, 12a and 13a bound the constraint multipliers:

$$0 \leq \lambda_1 \leq \frac{r}{s_1} \leq 1; \qquad 0 \leq \lambda_2 \leq \frac{r}{s_2} \leq 1$$ 14a,b

From equations 8c and 9c, it follows that labor inputs are never wasted:

$$L_1^* = L_2^* = 0$$

It is also possible to show that $K_1^* = 0$. By equation 4, $R^1_{L_1} = R^1_{q1} \cdot f^1_{L_1} = w$, so that $R^1_{q1} > 0$; that is, the firm operates in the elastic portion of the demand curve in jurisdiction 1. Consequently, $R^1_{K_1} > 0$. But if $K_1^* > 0$, then $\lambda_1 s_1 = r$ from condition 10c and $R^1_{K_1} = 0$ from equation 6, a contradiction. Therefore, $K_1^* = 0$. Without a capital input specific to the provision of state services, however, no such argument can be used to rule out $K_2^* > 0$. The use of unproductive capital in the state jurisdiction will be illustrated and discussed below.

Even if $K_2^* = 0$, so that the firm operates on the production frontier, it does not supply the two outputs at minimum cost. If $\lambda_1 > 0$ the usual Averch-Johnson distortion in the use of K_1 and L_1 occurs. From equation 6:

$$R^1_{K_1} - r = \frac{-\lambda_1(s_1 - r)}{1-\lambda_1} < 0 \qquad \text{6a}$$

Combining this result with equation 4 yields:

$$\frac{f^1_{K_1}}{f^1_{L_1}} < \frac{r}{w}$$

A cost-minimizing firm would equate the ratio of the marginal products of specific capital and labor to the ratio of the input prices $\frac{r}{w}$, but the rate-of-return constraint creates a bias toward the use of K_1.

Equation 7 can be rewritten in the following way:

$$R^1_K + R^2_K - r = \lambda_1[R^1_K - \alpha s_1] + \lambda_2[R^2_K - (1-\alpha)s_2] \qquad \text{7a}$$

Both expressions in brackets are non-positive: the concavity of the revenue function guarantees that the slope (in K) of the profit hill does not exceed that of the constraint plane at their profit-maximizing intersection. Profits in jurisdiction 1 are $R^1 - w(L_1 + \beta L) - r(K_1 + \alpha K)$, and allowed profits are $(s_1 - r)(K_1 + \alpha K)$. The profit hill and constraint plane are shown in figure 1 for given values of L_1, K_1, and L. At point A, the slope of the profit function is $R^1_K - \alpha r$, and the slope of the constraint is $(s_1 - r)\alpha$. Therefore:

$$R^1_K - \alpha r \leq (s_1 - r)\alpha \quad \text{or} \quad R^1_K \leq \alpha s_1 \qquad 15$$

Similarly:

$$R^2_K - (1-\alpha) r \leq (s_2 - r)(1-\alpha) \quad \text{or} \quad R^2_K \leq (1-\alpha) s_2 \qquad 16$$

It is not possible for both conditions to be satisfied as equalities. Equality holds in either case if the profit hill and constraint plane are tangent at the point of intersection,

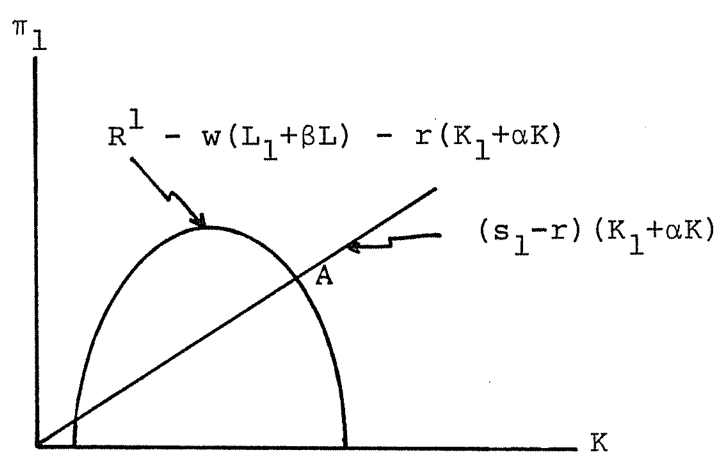


Figure 1

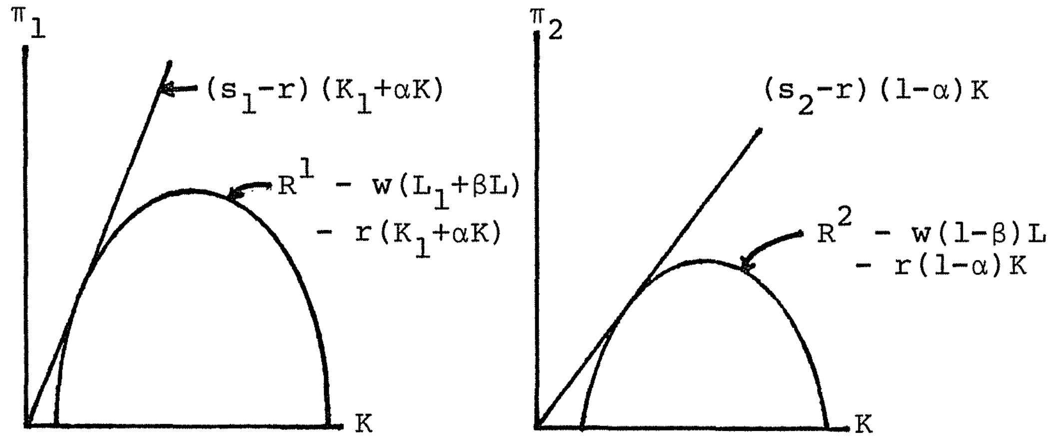


Figure 2

and this can occur only at a point on the left side of the profit hill at a value of K less than that which maximizes profits in that jurisdiction. If the constraint plane were tangent to the profit hill in each jurisdiction, as shown in figure 2, neither constraint would be binding, and the firm could adopt the unconstrained profit-maximizing solution. If either constraint is binding, then the corresponding condition 15 or 16 is satisfied as a strict inequality, and condition 7a becomes:

$$R_K^1 + R_K^2 - r < 0$$

If the firm were unregulated or subject to an overall rate-of-return constraint, it would use capital inputs so that $R_K^1 + R_K^2 = R_{K_1}^1$. Here, however, it is not possible to make such a general statement about the relative use of K and K_1 by comparing the first order conditions 6 and 7. If it is the case that $s_1 > s_2$ and $K_2^* > 0$, then $\lambda_2 s_2 = r$ from equation 11c, and $\lambda_1 s_1 \leq \lambda_2 s_2$ and $\lambda_1 < \lambda_2$ from conditions 14a and 14b. Then:

$$R_K^1(1-\lambda_1) + R_K^2(1-\lambda_2) \quad < \quad (R_K^1 + R_K^2)(1-\lambda_1)$$

$$> \quad (R_K^1 + R_K^2)(1-\lambda_2)$$

and:

$$r - \lambda_1 s_1 \alpha - \lambda_2 s_2 (1-\alpha) \quad = \quad (r-\lambda_1 s_1)\alpha$$

Combining these conditions with equation 6 yields:

$$\alpha \quad < \quad \frac{R_K^1 + R_K^2}{R_{K_1}^1} \quad < \quad \alpha \, \frac{1-\lambda_1}{1-\lambda_2}$$

If α is sufficiently small, then the ratio of marginal revenue products is less than one, indicating that common capital is overutilized. In other cases, the relative use of K and K_1 depends on the parameters of the demand and production functions. However, it will be shown below that common capital is underutilized when the shares assigned to each jurisdiction are decision variables for the firm.

The condition on common labor is also difficult to interpret. Equation 4 can be rewritten as:

$$R_L^1 + R_L^2 - w \quad = \quad \lambda_1[R_L^1 - \beta w] + \lambda_2[R_L^2 - (1-\beta)w] \qquad \text{or} \qquad 4a$$

$$(1-\lambda_1)[R_L^1 - \beta w] + (1-\lambda_2)[R_L^2 - (1-\beta)w] \quad = \quad 0 \qquad 4b$$

If the terms in brackets in equation 4a are not both zero and $\lambda_1 \neq \lambda_2$, then by equation 4b they must be of opposite sign so that $R_L^1 + R_L^2 - w$ is not equal to zero and impossible to sign from the first order conditions. The equilibrium condition for common labor can be examined with the aid of figures 3a and 3b, which illustrate the intersection of the profit hill and constraint plane in each jurisdiction (the equilibrium conditions for specific labor and capital are assumed to be satisfied in jurisdiction 1). Without requiring at first that K and L be the same in both jurisdictions, it follows from the concavity of the revenue functions and the slopes of the constraint planes that the expressions in brackets in equation 4a are both zero at the profit maximum in each jurisdiction. If either were not (as, for example, at point A in figure 3a, where $R_L^1 - \beta w > 0$), then it would be possible to move up the

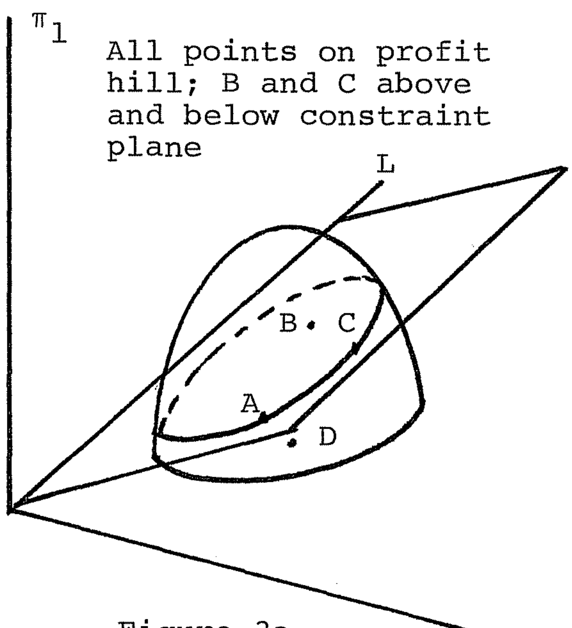


Figure 3a

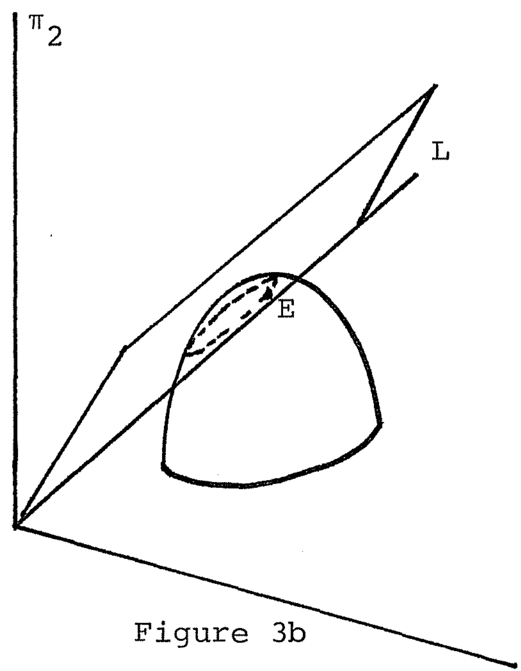


Figure 3b

profit hill by increasing or decreasing labor as the corresponding term in equation 4a is positive or negative (to point B in figure 3a). The constraint would then be violated, but it could be satisfied by increasing capital, resulting in a higher final profit (at point C in figure 3a). In effect, the firm could move along the intersection of the profit function and constraint plane to a higher profit if the expression in equation 4a were not zero. If the profit-maximizing intersections in jurisdictions 1 and 2 occur at the same values of L and K, then $R_L^1 + R_L^2 - w = 0$ for that solution. If the values of L do not coincide, then the firm adjusts them by moving along the intersection of the profit hill and constraint in each jurisdiction until they are identical (at point A in figure 3a and point E in figure 3b). This adjustment, which also reduces K, is preferred to sliding down the profit hill for fixed K because the latter strategy sacrifices more profit because of the concavity of the profit hills (compare points A and D in figure 3a). The equilibrium at which the values of L are the same is characterized by equation 4b, so the sign of $R_L^1 + R_L^2 - w$ in equation 4a depends on the revenue functions.

If the firm were unregulated or subject to an overall rate-of-return constraint, it would employ labor so that $R_L^1 + R_L^2 = w$. When common labor costs are allocated to the two jurisdictions by the regulatory authorities, however, $R_L^1 + R_L^2 \gtreqless w$, and the usual input distortion between capital and labor in the Averch-Johnson models can be increased or decreased.[20]

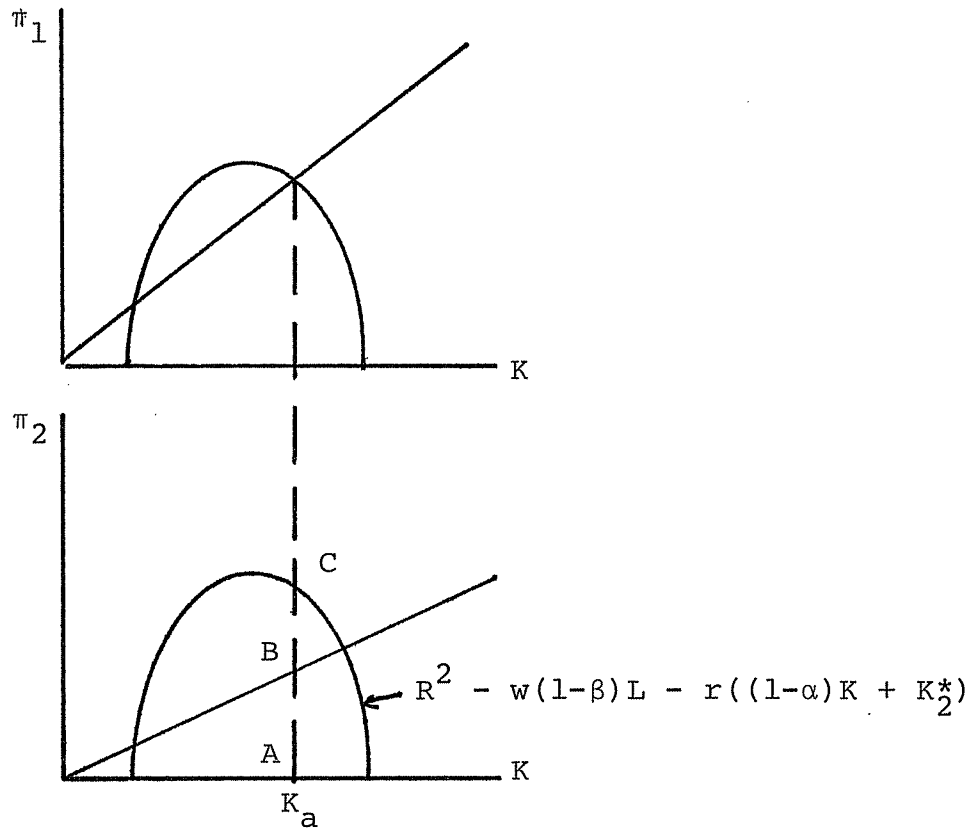
Figures 4a and 4b illustrate a case in which $K_2^* > 0$, that is, waste occurs in jurisdiction 2. The profit hills and constraint planes are drawn in π-K space on the assumption that the productive inputs L_1, K_1, and L take on their solution values. K_a is the level of common capital that maximizes profits in jurisdiction 1, but in jurisdiction 2 the firm earns excess profits BC at $K = K_a$. The firm can eliminate the excess profits by hiring $\frac{BC}{s_2}$ units of the unproductive input K_2^*, which enables the firm to retain $[\frac{s_2-r}{s_2}]BC$.

The firm should increase its use of common capital beyond K_a as long as profits increase. In jurisdiction 2 an increase in K produces at the margin an increase in allowed profits (which equal AB when $K = K_a$) of $(s_2-r)(1-\alpha)$ and a decrease of $[R_K^2 - r(1-\alpha) - (s_2-r)(1-\alpha)][\frac{s_2-r}{s_2}]$ in the excess profits retained by the firm. In jurisdiction 1 the firm loses profits of $R_K^1 - \alpha r$ as common capital is increased. In addition, as K increases beyond K_a the constraint in jurisdiction 1 ceases to be active, and $\lambda_1 = 0$. Summing the profit changes indi-

[20]The second order conditions that certain principal minors of the 7x7 (assuming $K_2^* > 0$) bordered Hessian matrix alternate in sign are not very useful in resolving the ambiguities in relative factor use. Any conclusion obtained from the second order conditions would probably depend on the second partial derivatives of the revenue functions. Comparative statics results are also difficult to obtain because of the interdependence of the first order conditions.

Figure 4a

Figure 4b



cates that the firm should increase K until:

$$R^1_K + R^2_K\left(1-\frac{r}{s_2}\right) - \alpha r = 0 \qquad 17$$

By the concavity assumptions, the left-hand side of equation 17 is decreasing in K. Condition 17, however, is identical to equation 7, the first order condition on common capital, when $\lambda_1 = 0$ and $\lambda_2 = \frac{r}{s_2}$, which holds when $K^*_2 > 0$. If the profit-maximizing value of K is K_a, where $\lambda_1 > 0$, then equation 7 can be rewritten as:

$$R^1_K + R^2_K\left(1-\frac{r}{s_2}\right) - \alpha r = \lambda_1(R^1_K - \alpha s_1) \leq 0$$

(The inequality follows from condition 15.) That is, if the optimal value of K is K_a, then profits must fall as K is increased beyond K_a.

In the standard Averch-Johnson formulation, the firm operates in the elastic portion of the demand curve and prefers to employ an additional productive input instead of an unproductive one because the former adds to revenue as well as the allowed profit. In the separations model, however, the firm wastes inputs because it has no specific input to employ in jurisdiction 2 and because it must consider both jurisdictions when it manipulates common inputs.

Next consider the case where the firm itself determines the shares of common capital and labor assigned to each jurisdiction. Then the first-order conditions 4 through 13b are supplemented by (assuming an interior solution):

$$\text{w.r.t. } \alpha: \quad \lambda_1 s_1 - \lambda_2 s_2 = 0 \qquad 18$$

$$\beta: \quad \lambda_1 w - \lambda_2 w = 0 \qquad 19$$

If $s_1 \neq s_2$, then it is not possible for both $0 < \alpha < 1$ and $0 < \beta < 1$; that is, the firm should assign all common capital or labor to one jurisdiction. For example, if $s_1 > s_2$ and $0 < \alpha < 1$, then $\lambda_1 w - \lambda_2 w < 0$ and $\beta = 0$. If both rate-of-return constraints were satisfied as equalities and β were not zero, then the firm could increase allowed profits by reassigning labor to jurisdiction 2 and capital to jurisdiction 1.

If β were reduced by shifting labor costs δwL to jurisdiction 2, then allowed profits would be less than and greater than earned profits by δwL in jurisdiction 1 and 2, respectively. Increasing α by shifting capital $\frac{\delta wL}{s_2}$ to jurisdiction 1 would restore the constraint in jurisdiction 2 to equality; but in jurisdiction 1 allowed profits would exceed reported profits because $\frac{s_1}{s_2}\delta wL > \delta wL$, thereby enabling the firm to increase revenues and total profits. In general, the firm maximizes profits by assigning common capital to the jurisdiction with the higher allowed rate of return and common labor to the other until α or β is zero or one.

However, it is unlikely that AT&T has ever had the freedom to set α and β independently. The company has long argued that cost separations should be related to state and interstate outputs, and it has been both flexible and creative in defining the relevant outputs. Therefore, a more realistic assumption is that the firm determines the allocation of common costs subject to $\alpha = \beta$. Then the additional first order condition is (assuming $0 < \alpha < 1$):

$$\text{w.r.t. } \alpha(=\beta): \quad \lambda_1(s_1K + wL) - \lambda_2(s_2K + wL) = 0 \qquad 20$$

It is possible to show that now $K_2^* = 0$. If $K_2^* > 0$, then $\lambda_2 s_2 = r$ from equation 11c. As a result:

$$\lambda_1 = \frac{r}{s_2}\left[\frac{s_2K+wL}{s_1K+wL}\right] > \frac{r}{s_2}\frac{s_2}{s_1} = \frac{r}{s_1}$$

which contradicts condition 10b that $\lambda_1 \leq \frac{r}{s_1}$. Therefore, with the ability to manipulate the allocation of common costs, the firm finds it unnecessary to employ unproductive capital in jurisdiction 2.

The Averch-Johnson model, however, is unsatisfactory for at least two reasons. First, the profit-maximizing conditions require that the firm operate in the elastic portion of the demand curve in at least jurisdiction 1, but, as described in the introduction, the empirical evidence is that demands for both interstate and local service are inelastic. Second, the Averch-Johnson characterization of the regulatory process is unrealistic because it allows the firm to set prices. In the next section, therefore, a model is developed in which the regulatory commissions set prices and the firm employs inputs to provide the required services and influence future prices. Again, the problem is to determine the effect of the separations process on input decisions by the firm.

2. A price-adjustment model

Here the commission in each jurisdiction adjusts prices at the beginning of each period to account for the firm's profitability in the previous period. The firm chooses labor and capital in each period subject to the common carrier constraint that it provide the service required by the prescribed prices.

The price in any period is determined by the price and firm input choices of the previous period, according to the regulators' pricing rules. That is:

$$p_1^i = p_1(p_1^{i-1}, K^{i-1}, L^{i-1}, K_1^{i-1}, L_1^{i-1}, K_1^{*i-1}, L_1^{*i-1}) \quad 21$$

$$p_2^i = p_2(p_2^{i-1}, K^{i-1}, L^{i-1}, K_2^{*i-1}, L_2^{*i-1}) \quad 22$$

Superscripts denote time, and subscripts indicate jurisdiction; for example, p_j^i is the price in period i in jurisdiction j. The inputs available to the firm are those considered in the Averch-Johnson formulation in section 1. Since the pricing rules hold for all but the initial period (period 1), p_j^i can be written as a function of p_j^1 and all inputs assigned to jurisdiction j up through period i-1.

The problem for the firm is:

$$\underset{\substack{L^i, L_1^i, L_1^{*i}, L_2^{*i} \\ K^i, K_1^i, K_1^{*i}, K_2^{*i} \\ i = 1,..,T}}{\text{maximize}} \quad \pi = \sum_{i=1}^{T} [R_1^i + R_2^i - w(L^i + L_1^i + L_1^{*i} + L_2^{*i}) - r(K^i + K_1^i + K_1^{*i} + K_2^{*i})] \qquad 23$$

subject to:

$$f^i(L^i, L_1^i, K^i, K_1^i; \; q_1^i, q_2^i) \geq 0 \qquad i = 1,..,T \qquad 24$$

where T = number of periods

R_j^i = revenue in period i in jurisdiction j;

$R_j^i = q_j^i(p_j^i)p_j^i$ or $R_j^i = R_j^i(p_j^i)$

f^i = production function in period i; f^i is increasing in the productive inputs and decreasing in the outputs; f^i is concave in its arguments

Discounting of future costs and revenues is omitted because it does not affect the basic results. Define:

$$A_j^m = \frac{dR_j^m}{dp_j^m} + \lambda^m \frac{\partial f^m}{\partial q_j^m} \frac{dq_j^m}{dp_j^m}$$

Then the first order conditions for a maximum, assuming positive values for the productive inputs, are:

$$\text{w.r.t.} \quad K^i: \quad \sum_{m=i+1}^{T} [A_1^m \frac{\partial p_1^m}{\partial K^i} + A_2^m \frac{\partial p_2^m}{\partial K^i}] - r + \lambda^i \frac{\partial f^i}{\partial K^i} = 0 \qquad 25$$

$$L^i: \quad \sum_{m=i+1}^{T} [A_1^m \frac{\partial p_1^m}{\partial L^i} + A_2^m \frac{\partial p_2^m}{\partial L^i}] - w + \lambda^i \frac{\partial f^i}{\partial L^i} = 0 \qquad 26$$

$$K_1^i: \quad \sum_{m=i+1}^{T} [A_1^m \frac{\partial p_1^m}{\partial K_1^i}] - r + \lambda^i \frac{\partial f^i}{\partial K_1^i} = 0 \qquad 27$$

$$L_1^i: \quad \sum_{m=i+1}^{T} [A_1^m \frac{\partial p_1^m}{\partial L_1^i}] - w + \lambda^i \frac{\partial f^i}{\partial L_1^i} = 0 \qquad 28$$

$$K_j^{*i}: \quad K_j^{*i} \geq 0; \quad \sum_{m=i+1}^{T} [A_j^m \frac{\partial p_j^m}{\partial K_j^{*i}}] - r \leq 0 \qquad 29a,b$$

$j=1,2$

$$K_j^{*i}(\sum_{m=i+1}^{T} [A_j^m \frac{\partial p_j^m}{\partial K_j^{*i}}] - r) = 0 \qquad 29c$$

$$L_j^{*i}: \quad L_j^{*i} \geq 0; \quad \sum_{m=i+1}^{T} [A_j^m \frac{\partial p_j^m}{\partial L_j^{*i}}] - w \leq 0 \qquad 30a,b$$

$j=1,2$

$$L_j^{*i}(\sum_{m=i+1}^{T} [A_j^m \frac{\partial p_j^m}{\partial L_j^{*i}}] - w) = 0 \qquad 30c$$

$$\lambda^i: \quad \lambda^i \geq 0; \quad f^i(L^i, L_1^i, K^i, K_1^i;\ q_1^i, q_2^i) \geq 0 \qquad 31a,b$$

$$\lambda^i[f^i(L^i, L_1^i, K^i, K_1^i;\ q_1^i, q_2^i)] = 0 \qquad 31c$$

where λ^i = constraint multiplier in period i

These conditions demonstrate that the firm considers the value of the productive inputs in satisfying the supply constraint at existing prices (in the marginal product terms for period i in equations 25 through 28) and the effect of all inputs, even unproductive ones, on prices and required outputs in future periods (in the bracketed terms for periods i+1 to T).

In order to explore the question of factor use, it is helpful to assume that the capital or labor inputs assigned to a jurisdiction affect future prices in the same way. That is, if α is the share of common capital assigned to jurisdiction 1, then:

$$\frac{1}{\alpha}\frac{\partial p_1^m}{\partial K^i} = \frac{\partial p_1^m}{\partial K_1^i} = \frac{\partial p_1^m}{\partial K_1^{*i}} \qquad 32$$

$$\frac{1}{1-\alpha}\frac{\partial p_2^m}{\partial K^i} = \frac{\partial p_2^m}{\partial K_2^{*i}} \qquad 33$$

Analogous conditions on the labor inputs are assumed (β is the fraction of common labor assigned to jurisdiction 1). If the firm were instead subject to overall regulation (individual prices adjusted to account for total firm profitability, for example), then common inputs would not be separated and distinguished from specific ones:

$$\frac{\partial p_j^m}{\partial K^i} = \frac{\partial p_j^m}{\partial K_1^i} = \frac{\partial p_j^m}{\partial K_1^{*i}} = \frac{\partial p_j^m}{\partial K_2^{*i}} \qquad j = 1,2 \qquad 34$$

Again, a similar relationship exists among the labor inputs.

If the firm were unregulated or unable to influence future prices, it would produce the required outputs efficiently and employ no wasteful inputs. This can be seen in the fact that the first order conditions for period T reduce to the usual efficiency conditions. From equation 29c, for example, $K_j^{*i} > 0$ would require $r = 0$.

Consider now the possibility of unproductive input use under divided regulatory authority. If it is profitable to waste capital or labor in jurisdiction 1, then the corresponding condition 29b or 30b must be satisfied as an equality, so that $\lambda^i = 0$ from equation 27 or 28 for specific capital or labor. (The importance of assumptions 32 and 33 for this argument is obvious.) Therefore, if inputs are wasted in jurisdiction 1, it must be true that the production constraint is satisfied, in which case any input could be employed for the purpose of altering prices in future periods. (This is also true for overall pricing regulation.) If it is possible that unproductive inputs will be detected and disallowed, then the firm will probably employ productive ones for this purpose.

However, the supply constraint can be binding even if inputs are wasted in jurisdiction 2: K_2^{*i} or L_2^{*i} positive requires the corresponding expression 29b or 30b to be zero, but that does not require $\lambda^i = 0$ in the common input equation 25 or 26. The constraint is binding here because the firm recognizes the effect of all the productive inputs in the pricing rule for jurisdiction 1 and would use less of them in the absence of the production constraint. However, the firm does not have the option of substituting a productive input assigned to jurisdiction 2. Furthermore, adjusting common inputs in order to influence future prices in jurisdiction 2 is not practical because prices in jurisdiction 1 are also affected. Therefore, the firm will in some cases waste inputs in jurisdiction 2 even if there is a possibility of detection. Notice that the argument turns on the lack of a specific input in jurisdiction 2, just as the existence of waste in the Averch-Johnson model did.

The separations process directly affects the relative use of common and specific inputs when there is no waste. For example, from equations 25 and 27:

$$\frac{\dfrac{\partial f^i}{\partial K^i}}{\dfrac{\partial f^i}{\partial K_1^i}} = \frac{r - \Sigma\left[A_1^m \dfrac{\partial p_1^m}{\partial K^i} + A_2^m \dfrac{\partial p_2^m}{\partial K^i}\right]}{r - \Sigma\, A_1^m \dfrac{\partial p_1^m}{\partial K_1^i}} \qquad 35$$

Since specific and common capital assigned to jurisdiction 1 have the same effect on future prices, it is the allocation of some common capital to jurisdiction 2 that makes the ratios in equation 35 greater or less than one, depending on the marginal revenues associated with assigning a unit of capital to one jurisdiction or the other. The shares chosen by the regulators determine the extent of the bias but cannot affect its direction.

The shares of common capital and labor assigned to each jurisdiction also affect the relative use of those inputs. From equations 25 and 26, the marginal products stand in the same relation as the corresponding factor prices if:

$$\frac{\Sigma[A_1^m \frac{\partial p_1^m}{\partial K^i} + A_2^m \frac{\partial p_2^m}{\partial K^i}]}{\Sigma[A_1^m \frac{\partial p_1^m}{\partial L^i} + A_2^m \frac{\partial p_2^m}{\partial L^i}]} = \frac{r}{w} \qquad 36$$

The left side of equation 36 depends on both the pricing rules for a unit of capital or labor assigned to either jurisdiction and the shares α and β. A similar expression for the specific inputs can be obtained by comparing equations 27 and 28, but without a separations problem, only the pricing rules affect relative factor use.

The effect of different pricing rules and assignments of common inputs is not very profound: the firm deviates from efficient factor proportions if inputs differ in their impacts on future revenues (through the A_j^m and the pricing rules). It is useful, however, to examine input use in the context of the specific pricing rule described in the introductory section of this chapter.

That pricing rule can be described in the following way. The regulator raises price if a deficit was incurred in the previous period to a level that would have allowed the firm to break even:

$$p_1^{i+1} = p_1^i + \frac{1}{q_1^i}[w(L_1^i + \beta L^i) + r(K_1^i + \alpha K^i) - R_1^i]$$

$$= \frac{1}{q_1^i}[w(L_1^i + \beta L^i) + r(K_1^i + \alpha K^i)] \qquad 37$$

$$p_2^{i+1} = p_2^i + \frac{1}{q_2^i}[w(1-\beta)L^i + r(1-\alpha)K^i - R_2^i]$$

$$= \frac{1}{q_2^i}[w(1-\beta)L^i + r(1-\alpha)K^i] \qquad 38$$

The existing price is maintained if the firm earned non-negative profits at a rate less than the allowed rate of return. If the firm earned more than the allowed rate of return, then the regulatory authority reduces price to a level that would have yielded that return. In that case, the pricing rules would be those given in equations 37 and 38 with r replaced by s_1 and s_2. These rules assume that the firm operates in the inelastic portion of the demand curve in each jurisdiction.

Since the pricing rules are not continuous, the maximum must be determined by comparing profits for each sequence of increasing, maintaining, or decreasing prices over the firm's horizon. For any such application of the pricing rules, the first order conditions 25 through 28 characterize the profit-maximizing solution.

The effect of the asymmetric treatment of labor and capital on input use can be seen by comparing conditions 27 and 28 on the specific inputs. When the firm acts to raise or maintain prices in the next period, it employs K_1 and L_1 in efficient proportions; but when the firm expects to trigger a rate reduction, it overutilizes K_1 because $s_1 > r$. The bias arises because K_1 is more cost-effective in minimizing the anticipated rate cut.

While the relationship between the common inputs (which is expressed by the left side of equation 36) is similarly affected by operations that precipitate a rate reduction, the allocation of costs can also cause inefficient factor use. That is, even if the firm's profitability will not exceed the allowed rate of return, equation 36 will not be satisfied if $\alpha \neq \beta$ because demand conditions (captured in the A_j^m) are not the same in each jurisdiction. (Obviously, the effects of $s_i > r$ and $\alpha \neq \beta$ can be offsetting.) The same effects determine relative factor use for common and specific capital in equation 35.

3. Conclusion

The separations process affects the proportions in which the firm combines productive inputs in both the Averch-Johnson and price-adjustment formulations of the problem; moreover, it introduces the possibility that unproductive inputs will be employed in the Averch-Johnson model.

Overall regulation eliminates the biases caused by cost separations if prices are marked up or down to account for the firm's total profitability. However, regulation of a multi-product firm by a single authority more often results in the cost allocation task being performed internally so that rates can be tied to costs. In the Averch-Johnson model, allowing the firm to set the shares of common capital and labor assigned to each jurisdiction removes the incentive to employ wasteful inputs; but the other effects of this policy have not been explored, and the Averch-Johnson model is not a very realistic characterization of regulation on which to base policy prescriptions. Since the use of unproductive inputs in the price-adjustment model does not depend on the separations process, making the cost assignments a decision variable for the firm would not have the effect predicted by the Averch-Johnson model. The effect of such a policy change on productive input use remains to be determined.

There are, of course, other modifications and issues that should be studied. Specific inputs in jurisdiction 2, some probability of detecting wasteful inputs, and an explicit investment and depreciation mechanism should be introduced. Furthermore, the effect of the separations process on the firm's pricing decisions should be addressed in more detail.

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