

THE UNIVERSITY OF CHICAGO

A TWO-PART RAMSEY-OPTIMUM RAILROAD TARIFF

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE SOCIAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ECONOMICS

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CHICAGO, ILLINOIS
AUGUST, 1979

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ACKNOWLEDGMENTS

I thank the members of my thesis committee, Professors Arnold C. Harberger, Donald N. McCloskey, Larry A. Sjaastad, and Lester G. Telser for their invaluable assistance and friendly encouragement. I am also grateful to the University of Winnipeg for financial support, and to Professor D. Jane Snidal for expert editing of the manuscript.

INTRODUCTION

Suppose that railroads have increasing returns to scale and are burdened with substantial common costs. Suppose also that an omniscient regulator has the task of setting rates for them that allow their unsubsidized operation and pose the least possible hindrance to internal commerce. This regulator will prescribe a tariff of second-best Ramsey prices that maximizes welfare subject to a budget constraint. It is a tariff which taxes the traffic in a way that brings about an equiproportional reduction of all units from their marginal cost pricing levels.

In this paper we find that an unregulated, profit-maximizing railway monopoly would also set Ramsey prices, in the sense of obtaining its profits in the way least injurious to its patrons. This raises the possibility that some form of competition will nudge unregulated tariffs towards the second-best. Thus we find little difference in the structure of profit-maximizing and regulated rates.

But the budget constraint regulating the second-best tariff makes a difference in its adjustment to cost and demand shifts. This suggests new tests of the significance of regulation. The little evidence we have does not allow us to dismiss the possibility of regulation of natural monopoly by some form of competition. This supports Stigler and Friedland's conclusion that there is little which regulators can regulate, that they cannot be expected to reduce profits or to change the structure of rates.¹

But we find the good thoroughly mixed with the bad: cross-subsidization is inherent to both the profit-maximizing tariff, and to the regulator's prescription. This leads to litigation among non-competing railroads, and exposes every railroad's tax base to erosion by (imperfect) competition with high cost carriers. Therefore the Ramsey tariffs are not sustainable. Not even bankruptcy would be an ironclad deterrent to entry. Since entry cannot eliminate the condition of increasing returns, it creates different shades of transport monopoly. Some of these distort and shrink commodity markets more than others. Since the second-best prices are not sustainable, competition substitutes the least for the most beneficial form of monopoly. The public policy problem appears to be that a sort of Gresham's Law of Transport makes third-best tariffs drive out the second-best ones.

The origin of regulation has recently been explained by Haddock² in terms of a struggle for arbitrary shares in the gross revenue from through traffic, and the allocation of joint costs to exclusive and non-exclusive markets. He prefaced his analysis with a very able discussion of the subtle nature of increasing returns in the railway industry, which permits the existence of several firms. This we take as read to proceed to the analysis of transport price. Its conclusions seem to agree with Haddock's, but they go a little bit further, suggesting that the struggle for distributive shares was not a zero-sum game, because it affected the tariff structure.

The equilibrium of the industry will not represent a first-best condition. That is ruled out by increasing returns and a requirement of unsubsidized operation. The second-best — so-called without bothering too much with the condition of other markets — is not compatible with direct competition in transport. This is so because the second-best tariffs involve cross-subsidization, whose centrifugal force separates those called to pay most of the taxes from those receiving most of the subsidies. Thus the second-best literally tends to fall apart. This is our interpretation of the origin of railway regulation in Illinois, 1871.

Direct competition is viable under a different tariff structure; We found it applied by the Trunk-Line railroad cartel in its competition with canals, lake boats, and new entrants. It is one that avoids cross-subsidization. As such it was less discriminating, and therefore less efficient.

¹ G. S. Stigler and C. Friedland, "What Can Regulators Regulate? Case of Electricity," *Journal of Law and Economics*, 5 (1962) 1-17.

² David D. Haddock, "Regulation of Railroads by Commission," unpublished paper, February 1978.

The difference between the rate structure arrived at by monopolists and cartels does not seem to have been previously recognized. We get at it by paying far less attention than usual to the history of railroad wars, and concentrating instead on the local freight rates assessed on tiny but more tightly monopolized markets.

The plan of this paper is as follows: In Chapter I we describe the freight rates that have to be explained, and briefly consider the problem of distinguishing monopoly tariffs from competitive transport prices. Both may consist of a tonnage charge and a mileage charge. This has created some confusion---often convenient for the monopolist---which we hope to clear up.

Chapter II contains an elementary analysis of the basic principle involved in this paper: that if the demand for transport is normal, the demand for long hauls must be more elastic than the demand for short hauls. This leads to a simple discriminatory scheme and shows the relationship between two-part and marginal cost prices. We find that the part added to marginal cost is a tax on tonnage, less a subsidy on mileage.

In Chapter III we review the previous analyses of the subject that were found useful and relevant, or simply instructive. The most notable is Launhardt's theory of railway rates.³ This is restated in Chapter IV, where we show that Launhardt's profit-maximizing freight is one of many Ramsey prices, all of which involve cross-subsidization on the tax-cum-subsidy plan. This theory is tested in Chapter V. Both unregulated and regulated rates pass the test with good marks. In Chapter VI we analyze the adjustment of tariffs to cost and demand shifts, speculating on the tendency of unregulated rates towards the second-best. The State of Ohio provided some evidence on this point, showing that competition dislocated the transport market, and that its restriction was followed by rate reductions.

In the remaining chapters we go over some problems associated with this type of pricing. The cross-subsidization of one firm by another is explained in Chapter VII, and illustrated with apparently paradoxical effects of merger on prices. Chapter VIII explains why the two-part tariff is not sustainable against direct competition, and that sustainable and competitive tariffs are third-best or worse. The theory is applied in the last chapter to provide an explanation of the origin of regulation in Illinois "Granger Laws."

CHAPTER I A BRIEF DESCRIPTION OF RAILROAD RATES

Railroad tariffs consist of (1) a commodity classification, (2) a schedule of distances between any pair of stations or groups of them, and (3) a price schedule per unit of weight or volume for each length of haul and commodity class. Given a number of goods enumerated in the classification and the number of possible origins and destinations, there is an astronomical number of rates. In 1881 the number of rates was estimated at 6 millions for the Great Eastern Railway of England and 30 millions for the Midland Railway, although the Board of Trade did not think that there were more than 100 million transactions in the transport of railway traffic in the year.⁴

Such an enormous number of rates cannot be explained without drastic simplification. This can be made by reducing the three tariffs down to one generic price per ton: $f_i(x) = t_i + r_i x$, where i denotes the commodity or class, and x is distance in miles. The first term t is called the *terminal charge*, and r is the

³ "Theorie der Tarifbildung der Eisenbahnen," *Archiv für Eisenbahnwesen*, 13 (1890) 1-43, 161-202; reprinted by Springer Verlag, Berlin, 1890. Schumpeter advised that Launhardt's "almost ruthless use of particular forms of functions--by which he produces results of disconcerting definiteness--should be studied and improved rather than condemned *a limine*," in *History of Economic Analysis*, 1954, 948n10.

⁴ United Kingdom, Parliament, Select Committee on Railways (Rates and Fares), *Report*, Part II (1882), testimony of William Birt, Q. 356; of John Noble, Q. 1,952; and of Thomas Henry Farrer, Q. 16,760.

conveyance rate. This tariff line is typical of the *local rates* assessed on traffic between two points served by the same railway company and was the basis for numerous special and preferential rates. In the case of through traffic, in which two or more carriers cooperate to complete a journey, there is a greater likelihood that the mathematical simplicity of the tariff has to be compromised with competitive considerations.

The form of the tariff line is quite universal and durable. It can be obtained by regressing published prices on the corresponding distances, and sometimes it is found explicitly stated as a mathematical function.⁵

Table 1 gives examples of local rates on merchandise, in cents per 100 lbs., in the year 1870. The fit was not always very good, which should not be thought of as a disadvantage, since loose fits provide an interesting piece of information: while conveyance rates are always significantly greater than zero, terminal charges are somewhat nebulous and prone to disappear. The conveyance rate cannot vanish because the marginal cost of hauling must be positive, but the terminal charge can, if it is unrelated to any costly service.

TABLE 1
CLASS I RATES IN 1870

Illinois Central R. R.	26.2618 (4.7387)	+0.24189x, (0.03574)	R ² = 0.8513
Hannibal & St. Joseph R.R.	21.8615 (3.0888)	+0.27211x, (0.02357)	R ² = 0.9434
Chicago & Northwestern R.R.	12.9593 (3.3447)	+0.35774x, (0.02524)	R ² = 0.9617
Union Pacific R.R.	6.7705 (0.5576)	+0.35560x, (0.00423)	R ² = 0.9989
Central Pacific R.R.	3.1912 (4.5245)	+0.17395x, (0.03406)	R ² = 0.7653

Source: From the Report of the Committee on Corporations of the Assembly of the State of California Upon Railroad Rates and Fares, Sacramento, 1871, Exhibit F, 50-51. The number of observations is ten per railroad, determined by the committee's attempt to compare rates for like distances. The figures in parentheses are standard errors of the estimated parameters.

Special rates can fit the same straight line pattern, at least up to a point. In 1861 the Pennsylvania Railroad had a special rate for pig iron which, in dollars per ton of 2,000 lbs. from Pittsburgh to stations between Latrobe and Huntingdon was⁶

$$0.21038 + 0.027892x, \quad R^2 = 0.9724$$

$$(0.19827) \quad (0.001663)$$

⁵ Argentine Republic, Dirección Nacional de Ferrocarriles, *Estadística de los Ferrocarriles en Explotación*, Año 1900, Commercial Appendix, Table V, and Alfred Picard, *Traité des Chemins de Fer*, Paris, 1887, 4, 317-29.

⁶ Committee of Shareholders Appointed Feb. 4, 1861, to Investigate the Condition and Policy of the Pennsylvania Railroad, *Minority Report*, Philadelphia, 1862, p. 44.

The distance to Huntingdon was 151 miles, and the price four dollars and 55 cents. A minority of shareholders had complained that for stations between Newport and Columbia (221 to 277 miles) the price had been reduced to only four dollars and 25 cents. Presumably, this long-and-short-haul discrimination was made to profit from competition with a canal between Huntingdon and Columbia.⁷ This competition obviously spoiled the fit to a straight line tariff. That was also the case of the Central Pacific, which suffered from competition along the California coast.

Government owned railways could apply the same pricing method as private companies, with the advantage of a more secure monopoly position. The South Australian (Government) Railways tariff on 3rd class merchandise--in shillings per long ton--was at one time⁸

$$16.3433 + 0.34567x, \quad R^2 = 0.99077.$$

$$(2.4201) \quad (0.00654)$$

In this case a terminal charge was made even though no variable terminal services were provided, owners having had to load and unload by themselves, and promptly.

The effect of terminal charges was to make long hauls cheaper per ton-mile than short hauls. This is a characteristic that tariffs have retained to this day. However, it is doubtful whether the cost per ton-mile is a declining function of the length of haul.⁹ Instead, railway officers always attempted to justify discrimination among lengths of haul by reference to large fixed costs incurred to provide terminal facilities, installations which were often used midway through the haul. That involved an invalid allocation of fixed and common costs,¹⁰ which the same officers never found convincing enough to set terminal charges payable by passengers.¹¹

Reference to fixed costs became most forceful when it was necessary to justify the higher terminal charges made in London compared to the country. Allegedly this was necessary to recover the higher cost

⁷ The Pennsylvania purchased this canal in 1857. See the *Windom Committee Report*, 43d. Congress, 1st. Session, Senate Report No. 307, vol. 2, 44. The minority shareholders' complaint would have been legitimate, if it was against tariff inertia preventing the maximization of joint railway and canal profits.

⁸ South Australian Railways and Tramways, *Classification, Rates, and Regulations for the Conveyance of Merchandise and Livestock*, August 1st., 1892, Adelaide, 1892. The line was fitted to 28 observations up to 800 miles.

⁹ J. Grierson, General Manager, Great Western Railway denied the declining function, Select Committee, Part I (1881) Q. 13,212. R. G. Harris, "Economics of Traffic Density in the Rail Freight Industry," *Bell Journal of Economics*, 8 (1977) 552-64, estimated average cost per ton-mile of contemporary railways as a function of average length of haul and traffic density in ton-miles per mile. His elasticity of average cost with respect to average length of haul is -1/2, when $x = 200$. That is also the elasticity of a tariff in which $t = 200r$, $x = 200$ miles. Harris' model may suffer from an identification problem, since -1/2 is also the elasticity of square root functions of distance, which modern rates tend to approximate. See I.C.C. Bureau of Transport Economics and Statistics, Statement No. 4,351, *A Description of the Principal Class Rate Scales Prescribed by the Interstate Commerce Commission*, mimeographed, 1943.

¹⁰ J. Allport, General Manager, Midland Railway, made the following quick calculation: Total capital, £20,900,000, of which sunk in stations £4,500,000. Separating the amount due to passenger stations, at 5 percent p.a., the terminal expense for goods traffic is £344,000 p.a., or about 2s.3d. per ton at each end. U.K., Parliament, Royal Commission on Railways, *Evidence Taken Before the Commissioners*, March, 1865, to May, 1867, Q. 13,724-13,726.

¹¹ Capt. W. O'Brien, General Manager, North-Eastern Railway, asked if he would set terminal charges on passenger tickets, replied "that point has never been raised and as it has never been raised I am unable to give an opinion about it. Of course, no terminal is charged for passengers," *ibid.*, Q. 14, 275.

Club arrangements, however, are possible: by purchase of a rebate card a passenger is entitled to deep discounts as in Sweden (*Railway Gazette: Overseas Railways, 1949*, page 128) or with the present-day German *Bahncard* (paragraph added in 2001).

of London real estate occupied by railways.¹² And yet, railway managers did not always do as they said! The Class II rates of the Great Western Railway in 1848, for example, in shillings per ton, including loading and unloading were:¹³

from Paddington (London)	2.9472 (.1700)	+ 0.14582x, (0.00158)	$R^2 = 0.9954$
and from Bristol or Exeter	3.1372 (0.2733)	+ 0.13327x, (0.00353)	$R^2 = 0.9628$

The tariff examples given above all involve local rates. Through rates made for transportation over the lines of several companies at a time should not be expected to fit straight lines very accurately. The reason is that where several railways are involved, there will likely be more than one route between two points, which makes it impossible to pin a number on distance. But that is a practical problem of little theoretical interest. Through rates can still be made, in principle, as straight line functions of distance. Such was, for example, the Normanton scale adopted in 1874 after nine years of discussion between railways and shippers to facilitate the quotation of through rates in a territory East of a line through Chester and London, including all of Scotland. For minerals, per ton, station to station (without terminal services), the scale was set at 1s.6d. plus 5d. for every 5 miles up to 200, and 10d. for every additional 10 miles.¹⁴

The unit of output is the ton carried. The marginal cost of carrying a ton from Here to There may be represented by $c_i + b_i x$, where c_i is the marginal cost of dealing with an additional ton, and $b_i x$ is the total cost of the ton-miles of locomotive work put in to take the marginal ton from Here to There. If c_i were zero, b_i would be the average and marginal cost per ton-mile. These costs may vary among commodities because of differences in loadability and carrier's risk, so that a competitive transport industry would operate at prices that superficially seem similar to railroad monopoly prices, sharing their form, but not their level.¹⁵

The railroad officers' attempts to explain away discrimination in their two-part monopoly price $t_i + r_i x$ by reference to the cost $c_i + b_i x$ and to fixed costs is unsatisfactory. Their efforts fail when we note they sometimes made rates without terminal charges. For example, the Huntingdon iron traders paid no significant terminal charges, and yet they obviously paid more than marginal cost, having paid 30¢ per ton more than Newport and Columbia.

On the other hand, one cannot characterize the railroad's distance rate $t_i + r_i x$ as prima facie discriminatory, unless it is shown to be fundamentally different from two-part costs. This will be done by showing the discriminatory two-part tariff to contain a hidden third part that corresponds to the discriminatory tax in the text-book version of two-part price. The theory producing this third part has testable implications by which one can tell monopoly from competitive prices.¹⁶

¹² It was even suggested to set variable terminal charges corresponding to the ground rent of stations at different locations, *Select Committee*, Part II (1882), Q. 2,402-2, 404.

¹³ U.K., Parliament, *Select Committee (1846) on Railway Acts Enactments*, p. 341. Separate tariff lines estimated for Bristol and Exeter did not turn out to be significantly different from each other, but they were different from London rates at the 0.1 percent level.

¹⁴ U.K., Parliament, *Joint Select Committee on the Railway Rates and Charges Provisional Orders Bills*, 2, 1891, 1370-71.

¹⁵ A. S. DeVany and T. R. Saving, "Product Quality, Uncertainty, and Regulation: The Trucking Industry," *American Economic Review*, 67 (1977) 583-94, showed that the "terminal cost" part of competitive price may be a congestion toll equal to the marginal cost of queueing up for empty vehicles ready to be loaded and depart.

¹⁶ DeVany and Saving thought that their congestion model is an alternative to Josephine Olson's theory and tests of motor transport monopoly (on which see p.20). Their different views have not yet been subjected to an adequate test.

CHAPTER II
MARGINAL COST AND TWO-PART PRICING OF TRANSPORT

"The price charged by a railroad for any service really consists of two parts---a fee and a tax."¹⁷ The function of the tax is to fill the gap between marginal and average cost left by increasing returns to scale.

This fee plus tax is a wedge between the demand for a good Here and its supply There. Suppose that Here the supply of the good is perfectly elastic. Then the portion of the demand that lies above the price is the demand for transportation from There to Here. Figure 1 is an illustration of that demand for transport. Let us tax that traffic at the maximum it can bear. If the marginal cost of transport from There to Here were OK dollars per ton, the revenue maximizing tax would be KM dollars per ton. This is found by making marginal cost equal to marginal revenue. Substituting for marginal revenue the well-known formula $MR = P(1 - 1/E)$, we obtain a deviation of price from marginal cost inversely proportional to the elasticity of demand E : $(P - MC)/P$ equals $1/E$.

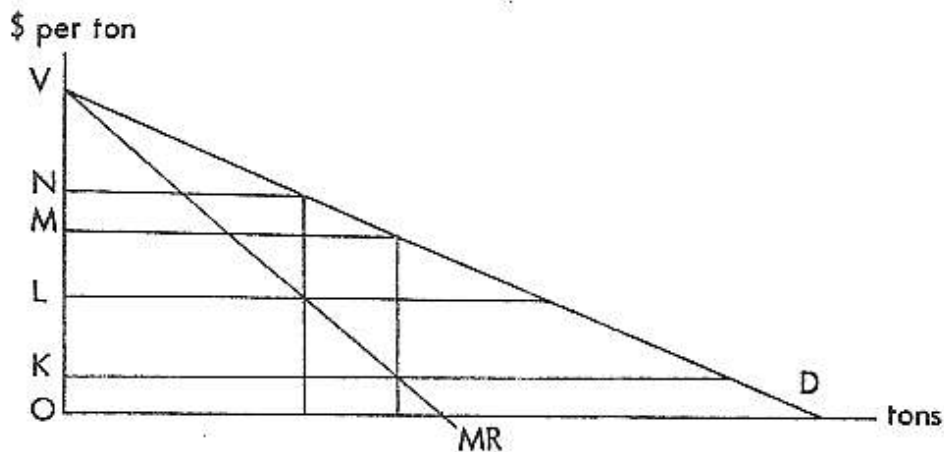


Figure 1.--The demand for transport at a point.

Now consider the trade between Here and some point Further Out There. Because of the greater distance involved, the marginal cost of transport to or from Out There is OL, and the maximum tax that traffic will bear is LN, which is less than KM, because Out There the demand for transport is more elastic. It is so, not because it is a straight line as much as because it is normal. Finally, the traffic with Way Out There, carried on at a marginal cost almost equal to OV, will hardly be taxed at all. The thus established principle that the profit-maximizing "tax" charged by the transport firm is inversely related to distance was discovered and advocated in 1840 by Charles Ellet¹⁸.

This marginal cost plus tax scheme is non-discriminatory in the peculiar sense that the traffic between any two points is reduced by an equal percentage, namely — in this linear case — by one-half of what it would be under marginal cost pricing. In that sense, there is no distortion of normal market relations, and the two-part tariff is equivalent to marginal cost pricing; or better, because it allows a market test of investment in the transport firm.

¹⁷ A. T. Hadley, *Economics, An Account of the Relations Between Private Property and Public Welfare*, New York, 1899, 173 n1.

¹⁸ R. B. Ekelund and D. L. Hooks, "Joint Demand, Discriminating Two-Part Tariffs, and Location Theory: An Early American Contribution," *Western Economic Journal*, 10 (1972) 84-94.

Now consider what happens when this principle of inversely graduated taxes is applied in practice. We have a choice of two tariff schedules, The first one, which follows directly from the geometrical analysis, is a profit-maximizing tariff of marginal cost prices plus a tax on distance:

$$F_1 = t(x) + bx, t'(x) < 0.$$

The other is the actual railroad tariff:

$$F_2 = t + rx.$$

The constant c (the marginal cost of dealing with an additional ton) has been dropped from the marginal cost in F because at this point it is uninteresting and does not affect the result. We have two expressions of discriminatory prices, discriminatory in the sense that they include taxes of varying amounts on different shipments. In the first case, the discrimination is patently obvious, so the second method of quoting the freight would be preferable,¹⁹ if it could be made equivalent to the first for all x . This can be done by first setting $t = t(0)$, so the infinitesimally short haul ($x = 0$) is priced at $t(0)$. But then every positive haul will be priced at $t(0)$ plus, and taxed by more than it ought to contribute. Therefore, a concession will have to be made to shippers, reducing the conveyance rate below marginal cost, which amounts to the "freight absorption" by a spatial monopolist. This we find by setting

$$t(x) + bx = t(0) + rx, \text{ whence } r = b - (t(0) - t(x)) / x$$

Since there is a maximum economically possible length of haul of a miles, for which $t(a) = 0$,

$$F_1 = t(x) + bx = t(0) + (b - t(0) / a) x = F_2.$$

Finally, we take away the brackets around the conveyance rate to smoke out the third part in the two-part railroad tariff:

$$F_2 = \quad bx \quad + t(0) \quad - (t(0) / a) x$$

Freight =	Marginal	+Tonnage	-Mileage
	Cost	Tax	Subsidy

To visualize this in a more familiar setting, suppose the Interstate Highway System were parceled out and auctioned off to the highest bidders. This would raise problems with highway tolls illuminating the nature of railway rates. The profit-maximizing toll that the new owners can levy is $t(x)$, in addition to which highway users incur the cost bx . For a ride on the Interstate from Chicago to Minneapolis the toll would be, say, 100 dollars. From Boston to San Diego ($x = a$?) it could be nil. From Chicago to Winnipeg it may be 50 dollars, with overnight resting privileges. One would pay 100 when turning off the road at a Twin Cities motel, and get a 50 dollar refund on arrival in Winnipeg the following day. For reasons more obvious than sound it would be next to impossible to convince people that this pricing method would raise, at the least possible cost to travelers, just enough revenue to recover the People's profit at the auction. They would not understand that "what the traffic will bear" is "a principle, not of extortion, but of equitable concession to the weaker members of the community."²⁰ A step in that direction would be made if the

¹⁹ This consideration was important to English railways, whose peculiar history compelled them to state terminal charges separately from conveyance rates (Clause 17, Regulation of Railways Act, 1868). The more methodic Prussians had no such problems: they actually had something like a uniform rate per ton-mile plus a charge graduated inversely to length of haul (*Select Committee*, Part I, 1881, Q. 14,178 and Q. 14,196). In the United States, terminal charges were never quoted separately, The Cullom Committee's question whether they should be shown separately produced little useful discussion.

²⁰ W. Acworth, *Elements of Railway Economics*, Oxford, 1905, p. 76.

owners of the road took a fixed toll, and sold gasoline at, say, half the price from pumps accessible only from their highway.

To maximize the net revenue from tolls, the owner of the road must minimize — that is control — the marginal cost of vehicle operation bx . This may be difficult under separate ownership of the road and vehicles. The sale of conveyance at less than marginal cost may require a vertical integration of the road with the carriers.

The first railways chartered in England were assumed to function very much like canals and toll-roads. It was thought they would provide competitive carriers like Pickford's with a public road in competition with canals. That the road's owner was not supposed to have the monopoly of road use made it difficult to maximize the toll taker's profit charging tolls that diminish with distance. The early railway pioneers may or may not have understood this, but they lost very little time in taking over the carriers' business, alleging very pressing technical and safety reasons.²¹

CHAPTER III PREVIOUS ANALYSES OF TWO-PART TARIFFS

There are two types of two-part tariff theories. The first assumes a two-part tariff will be charged and analyses its effects on the equilibrium of the consumer and the firm's net revenue. This type is well known and has found its place in the textbooks. The articles by Gabor²² and by Ng and Weisser²³ belong in this category.

The second type, which is both older and more relevant for our purposes, analyses the profit maximizing problem of the firm and discovers the two-part tariff as its solution. Its XIXth Century precursors were Charles Ellet in America²⁴ and Wilhelm Launhardt in Germany.²⁵ More recently Josephine Olson attacked the same problem with mixed results,²⁶ and Alan Walters came close to rediscovering the second-best road user charges.²⁷

In addition, Baumol and his associates restored the respectability of two-part pricing in the course of their resurrection of Ramsey's principles of optimum taxation.²⁸ They have also shown that a natural monopolist fearful of potential entrants would set Ramsey prices, which may be the only sustainable ones in the industrial conditions that they considered.²⁹ Their work suggested the necessary improvements on Launhardt's theory and its possible applications.

²¹ J. Grierson, *Railway Rates: English and Foreign*, London, 1886, pp.71-73.

²² A. Gabor, "A Note on Block Tariffs," *Review of Economic Studies*, 23 (1955) 32-41.

²³ Y. Ng and M. Weisser, "Optimal Pricing with a Budget Constraint--The Case of the Two-Part Tariff," *Review of Economic Studies*, 41 (1974) 337-45.

²⁴ Charles Ellet, "A Popular Exposition of the Incorrectness of the Tariffs on Tolls in Use on the Public Improvements of the United States," *Journal of the Franklin Institute*, 29 (1840) 225-32, cited by Ekelund and Hooks.

²⁵ Launhardt, *Theorie der Tarifbildung der Eisenbahnen*, Berlin, 1890.

²⁶ J. Olson, "Price Discrimination by Regulated Motor Carriers," *American Economic Review*, 62 (1972) 395-402; 64 (1974) 780-86.

²⁷ Alan Walters, *The Economics of Road User Charges*, Johns Hopkins, 1968.

²⁸ W. J. Baumol and D. Bradford, "Optimal Departures from Marginal Cost Pricing," *American Economic Review*, 60 (1970) 265-83.

²⁹ W. J. Baumol, E. E. Bailey, and R. D. Willig, "Weak Invisible Hand Theorems on the Sustainability of Prices in a Multiproduct Monopoly," *American Economic Review*, 67 (1977) 360-65.

A review of the second type of two-part pricing theories is best begun by considering Olson's model. Suppose there is perfect competition, except in transportation. Commodities are carried from their production points to consumers located in concentric mileage rings around those points. The price charged by the carrier for transportation is a two-part tariff, which is obtained in the following way:³⁰ Let c_j be the manufacturing cost of the j -commodity and r_{ij} the freight on good j and i miles, in dollars per 100 lbs. In perfect competition among shippers and consumers, the price of good j in the i -th mileage ring is $p_{ij} = c_j + r_{ij}$. The demand for the product is $p_{ij} = (x_{ij} T_j)^{-1/a_j}$, where x_{ij} is the number of shipments of commodity j to mileage ring i , T_j is shipment size in hundredweights, and a_j is the constant elasticity of final demand. Substituting cost plus freight for p_{ij} in the final demand equation, one obtains the demand for transport

$$x_{ij} = \frac{1}{T_j} (r_{ij} + c_j)^{-a_j}$$

The joint profit of the cartelized carriers is

$$\sum_i \sum_j (r_{ij} x_{ij} T_j - K_{ij} x_{ij} T_j) = \sum_i \sum_j (r_{ij} - K_{ij}) (r_{ij} + c_j)^{-a_j}$$

where K_{ij} is the cost of carrying good j to mileage ring i . The first order conditions for a maximum of profit with respect to r_{ij} imply the freight rate

$$r_{ij} = \frac{c_j}{a_j - 1} + \frac{a_j}{a_j - 1} K_{ij}; \quad a_j > 1.$$

The first right-hand term is the terminal charge, the second is the conveyance rate. The terminal charge depends on the value of the commodity at its origin, and thus provides a basis for discriminatory commodity classification. The conveyance rate is always greater than the marginal cost of transport.

By regression of 1966 Middle Atlantic Conference general class rates for truckloads under 30,000 lbs., billed for 100-260 miles, on a proxy for transport cost and data on the prices of goods carried, Olson produced the following equation:

$$\text{Rate} = 22.3047 + 1.00244 (\text{Cost} + \text{Price}) - (\text{Price}) \quad R^2 = 0.863.$$

(2.1169) (0.00015)

The elasticity of final demand implied by the regression equation is $a_j = 410$. This is a curious result produced by the specification of the model. The equation for r_{ij} implies a discriminatory tax that increases with distance. There are actually two taxes, one on the tonnage, and another on distance. This double taxation is caused by the assumed constant elasticity of final demand, which implies that there is no outermost mileage ring at which p_{ij} is prohibitive and the tax vanishes.³¹ DeVany and Saving similarly loaded their competitive price with a congestion toll that increases with distance. Both models raise the possibility of long haul shippers evading taxes by making successive short hauls, which is absurd.

Ellet's model is virtually identical to Olson's, except that he assumed a straight line demand curve which limits the radius of the mileage rings. On this basis he made a geometrical analysis of the market area opened up to a town by a railway. The rail-head is at the point where delivered price (Olson's $p_{ij} = c_j + r_{ij}$) is equal to the vertical intercept of demand (point V in Figure 1). Ellet viewed railroad rates as composed of a fee for service at cost plus a toll proportional to distance (similar to a fuel tax) that was the

³⁰ Using her notation.

³¹ Since there is no outermost mileage ring one cannot add the quantities shipped to all rings. Therefore, this model determines no equilibrium quantity, although it may seem to determine a price.

source of profit. He then considered different methods of charging, and produced a numerical example in which a toll inversely proportional to distance both maximized profit and allowed an extension of the railroad beyond its existing terminus, increasing the town's market area.

Launhardt supposed the quantity of goods carried γ to obey a "law of traffic density" $\gamma = \Phi(F)$, where F is the freight per ton. If B is the cost of carrying the good for which the freight is F , then the profit is

$$U = \Phi(F)(F - B)$$

Differentiating with respect to F he obtained the condition for profit maximization³²

$$\frac{\Phi(F)}{\Phi'(F)} = -(F - B)$$

which is the condition that the "tax" be inversely proportional to elasticity of demand, considering B as both the average and marginal cost per ton.

For a further illustration of the inversely graduated tax Launhardt supposed that the "law of traffic density" takes the form

$$\frac{\gamma_0}{v^n} (v - F)^n$$

where v is the difference between the good's prices in two markets and n is any real positive number. If transport cost is bx for the x miles separating the two markets, then profit is

$$U = \frac{\gamma_0}{v^n} (v - F)^n (F - bx)$$

This is maximized if $F = \frac{1}{n+1}v + \frac{n}{n+1}bx$

as is found by differentiation with respect to F . If n equals unity, then the law of traffic density is a straight line demand curve, and the conveyance rate will be one-half of cost. The monopoly absorbs half the freight, a conclusion rediscovered by Singer in 1937.³³

Launhardt's theory was illustrated by M. O. Lorenz, the statistician of the Interstate Commerce Commission,³⁴ In Figure 2, v is a "value of service" that is assumed constant at every point of a line of railroad. Transport cost per ton increases with distance as shown by the ray OQ . A fixed toll per ton plus conveyance at cost would make a price that varies according to the length of haul in the way illustrated by the broken line through point R . This would restrict traffic to movements over distances equal or less than Od . Additional traffic could originate at points between d and a , if the price were lowered to a level more nearly equal to marginal cost. The broken line through R clearly represents inefficient pricing in case there were fixed quantities to be shipped from every point on the road. If these quantities depend on price, a monopolist would reduce the price for long hauls, the demand for which is elastic, and raise the price for short hauls, where demand is inelastic. That would bring about a tariff such as Launhardt's, the line from

³² *Theorie der Tarifbildung*, p, 450.

³³ H. W. Singer, "A Note on Spatial Price Discrimination," *Review of Economic Studies*, 5 (1937) 75-77.

³⁴ M. O. Lorenz, "Constant and Variable Costs and the Distance Tariff," *Quarterly Journal of Economics*, 21 (1907) 283-98, Lorenz's diagram illustrates also Ellet's argument and the one made in the previous chapter.

t to Q . This tariff line could be rotated about Q and placed so the net tax in the two-part tariff brings in as much revenue as the former constant toll per ton.

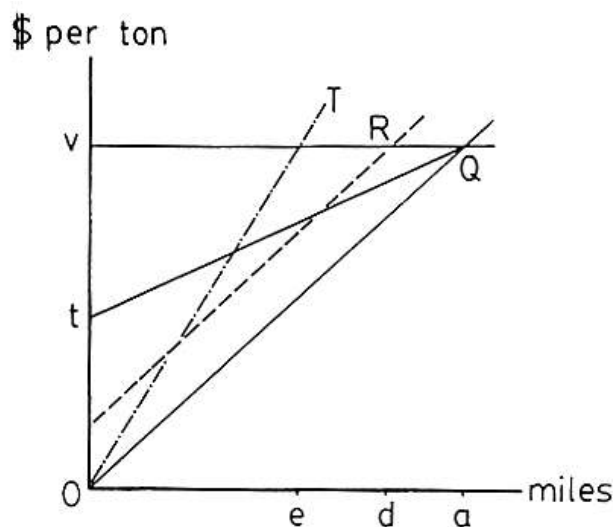


FIGURE 2. ALTERNATIVE TARIFFS

Lorenz thought that the constant toll per ton (the terminal charge) was made to cover terminal expenses (c_j) unrelated to ton-miles, and should therefore not be considered when making a distance tariff. However, an expense that is related to the number of tons carried is not a fixed cost. Considering that expense, the competitive price $c_j + b_j x$ is shown by the broken line, and the monopoly price by a more gently sloped line from, say, t to R (not shown).³⁵

Charles Ellet, in a letter to the editors of the *National Intelligencer* in 1857, volunteered the following advice to railway officers:³⁶

“in arranging the tariff let the first step be to ascertain the true cost of transportation upon the particular road for which the tariff is intended;

The next step in the process should be to ascertain the highest charge which such article will bear, or its equivalent, the least charge which will prohibit its transportation on the road;

the true charge for each article and each position, it must be apparent, will be found somewhere between the actual cost of transportation and the prohibitory charge.”

Finally, the last

“step in the construction of a toll-sheet should then be to form a third tariff, by adding together, for each article and each position, the cost of transportation and the prohibitory charge, and taking half their sum as a near approximation to that charge which will yield the greatest net revenue.”

³⁵ H. W. Hewetson, "The Distance Principle in Railway Freight Rates with Special Reference to Canada," University of Chicago PhD, thesis in Economics, 1951, thought distance rates were related exclusively to cost; that Lorenz's diagram was a different theory from that of Launhardt as expounded by J. M. Clark, and that it assumed completely inelastic demands.

³⁶ Reproduced in *Proceedings of the Convention of Rail Road and Canal Companies of the State of Virginia*, December 8, 1857, pp. 7-18.

Ellet's advice was correct if one can assume, as he did, that demand curves for transportation are straight lines. Then, in Launhardt's formula, $n = 1$ and $F = (v + bx) / 2$. Good advice was worth repeating. Ellet gave it again in a report written for the Virginia Central Railroad in which he also provided an ingenious estimate of the prohibitive toll (or of v), noticing that "fortunately, we are under no necessity to collect and estimate the value of all these facts. The calculations are all made for us; and the practice of the farmer, miller, and merchant, shows the result."³⁷ He looked for the point, somewhat fluctuating at times, where the trade divided between the Virginia Central and its competitors. The prohibitory charge was then the cost of conveying the good from the dividing point to the railway, plus the railway freight charged under the then current tariff.

Alan Walters developed what he called "the Basic Ellet Model," thinking that the problem is "one of choosing between taxes on ton-miles (such as the fuel-tax) and taxes on tonnages (such as the export tax)."³⁸ The result he obtained was that the tonnage tax maximizes revenue, or, for a given revenue, the area of cultivation made possible by the construction of a new road. His recommendation was of a tariff line like the broken one on Figure 2. This is not the Ellet (or Launhardt) model. In that model one can do better, namely by a tonnage tax and a subsidy on fuel, set so the tax raises more revenue than what is paid out in subsidies, enough to maintain and renew the road.

CHAPTER IV A RAMSEY-OPTIMUM TARIFF

Figure 3 shows the demand and supply of a good at some point on a line of railroad x miles from a market M . p_a is the autarky price of the good at that point, and P_m is the price it fetches at M . The freight to M is some function of distance, $F = f(x)$. If transportation were free, AE tons of the good would be shipped to market. This is the quantity g in Figure 4, the demand for transport. But at the given freight for that distance, only BC tons will be shipped, or the amount of q in Figure 4. The vertical intercept of the demand curve, v , is equal to the difference between P_m and p_a . One may call it the "value of service," in the sense of the freight that the traffic will not bear. The value of P_m is of course the same for all points on the line. Assuming a universal application of the same technology, perfect mobility of all factors except land, and homogeneous land, p_a may also be the same all along the line. The value of service would then be constant along the line, and the area under the demand curve for transport, above $f(x)$, is the locational rent of land at a point x miles from M . The incidence of the "tax" in the railroad tariff is on this rent. The quasi-optimum tariff is one that maximizes this rent, subject to a minimum revenue constraint.

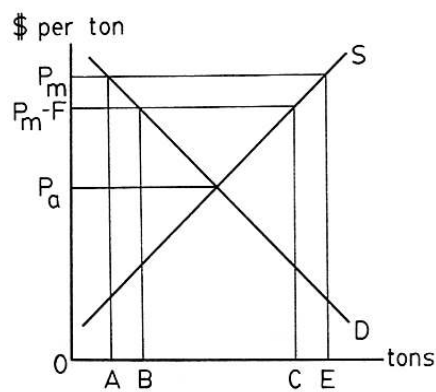


FIGURE 3. DEMAND AND SUPPLY OF A GOOD AT SOME POINT

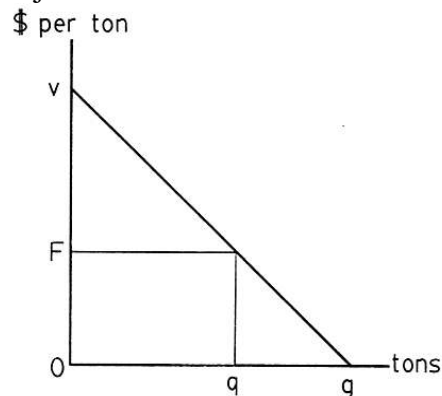


FIGURE 4. DEMAND FOR TRANSPORT AT A POINT

³⁷ Charles Ellet, *Report on the Tariff of Toll for the Virginia Central Rail Road*, Washington, D.C., Aug. 1858, p. 17.

³⁸ *The Economics of Road User Charges*, p. 120. For a more concise exposition, see his "Transport for Economic and Social Development," *American Economic Review*, 58 (May 1968) 360-77.

For the backhaul from M one draws the demand and supply for the backhauled commodity so the autarky price exceeds the price at M . If this were a colonial penetration railway, and the only avenue of commerce, the demand for backhauls would depend on the freight on front-hauls. The demands for transportation in the two directions would be interrelated because the regional balance of trade at each point requires that the value of goods shipped out balance the value of goods brought in. Thus a monopoly railway cannot hope to balance the quantities carried up and down its line, if it also has to balance the payments. Empty backhauls are inevitable.

Front and backhauls are said to be joint products like beef and hides.³⁹ This would raise the interdependence of demands to crisis levels. The railroad would always be in the situation of a butcher who, unable to sell carcasses and hides in equal amounts, has to give away the hides. Since one has yet to see a monopoly railway that gives away backhauls, the interdependence of demands must be weak and unimportant. One reason is that trade is normally triangular, and can follow randomly selected routes, both in space and time.⁴⁰ The real backhaul problem is that competition in transport allows carriers to set their prices as if they could balance their front and backhauls and behave like butchers.⁴¹

All things considered, it seems best to assume that the demands for transportation in different directions are independent of each other. Likewise, it will simplify things to assume that the demand for the transportation of a good from one point on a line is independent of the freight on the same good from any other point. This assumption makes it possible to add up the locational rents at all points on the line to obtain the public utility of the road. The length over which rents are added is a miles, up to where $f(a) = v$.

The demand need not be the straight line in Figure 4. We adopt instead the form suggested by Launhardt:

$$(1) \quad q = g \left[\frac{v - f(x)}{v} \right]^n, \quad n > 0.$$

The quantity demanded g is determined by shippers who take the railway's tariff schedule of distance rates $f(x)$ as given. Our problem is to solve for $f(x)$. We do not wish to complicate this problem by inverting the demand equation and expressing the tariff schedule as a function of both quantity and distance.

The curvature of this demand is given by

$$\frac{d^2q}{d[f(x)]^2} = \frac{n(n-1)g}{v^n} [v - f(x)]^{n-2}.$$

so the demand is concave from below if n is less than unity, a straight line if n equals unity, and convex if n exceeds unity. The constants g and v are the quantity and price axis intercepts of the demand curve. The v follows from the small country assumption made about a region that employs the railway to trade

³⁹ A. C. Pigou, *Wealth and Welfare*, London, 1912, 219n.

⁴⁰ W. J. Stenason and R. A. Bandeen found it impossible to determine the movement of empty cars traceable to the transport of Canadian grain to ports. See their "Transportation Costs and Their Implications: An Empirical Analysis of Railway Costs in Canada," in National Bureau of Economic Research, *Transportation Economics: A Conference of the Universities*, New York, 1965, p. 125.

⁴¹ A sympathetic study of the Trunk Line Railroad Cartel would reveal that it was mainly preoccupied with the maintenance of westbound rates.

at the price set in the distant market. A constant elasticity demand for transport would leave the autarky price in the small region hanging in the air and fail to put a limit on market areas. The maximum possible tonnage g could be made a function of some other variable, say x , but that would not affect the form and properties of the tariff $f(x)$. It would only affect the level of railway profit, and the level of a tariff determined with a constraint on profit. The power n is the constant elasticity of the quantity demanded with respect to the fraction of the value of service v conceded by the railway to the shippers. The price elasticity of demand is

$$(2) \quad E = \frac{-nf(x)}{v - f(x)}$$

The demand is normal, since its price elasticity is zero when the freight $f(x)$ is zero, and it tends to infinity as the freight approaches v and becomes prohibitive. This is the basis for discrimination between lengths of haul by a distance tariff. Discrimination among commodities is caused by the fact that, given $f(x)$, an increase in v per ton of goods reduces the price elasticity of transport demand.

The benefit to all shippers of a good located at any point on the line is obtained by integrating the area under the demand curve and above the freight. A second integration adds the benefits at all points on the line. The integration is made first between the prices $y_1 = f(x)$ and $y_2 = v$, and then---assuming that access to the line can be had at any point on it---from zero to a miles from the market M . The upper limit of the second integration is the maximum length of haul, at which $v = f(a)$ and $q = 0$. This need not be the length of the railway line, since market areas can overlap. North Dakota coal may not be shipped beyond Minneapolis, but Milwaukee beer sells in Montana. For a given commodity, the benefit function is

$$(3) \quad g \int_0^a \int_{f(x)}^v \left[\frac{v - y}{v} \right]^n dy dx = \frac{gv}{n+1} \int_0^a \left[\frac{v - f(x)}{v} \right]^{n+1} dx$$

Next suppose that the average direct and marginal cost per ton-mile is b dollars. This cost is independent of distance; but it may vary among commodities. To make it a function of distance would change the mathematical form but not the economic substance of tariffs. The terminal cost of c dollars per ton is assumed for the time being to be zero, to show that terminal charges do not necessarily depend on it. It is further assumed that the cost of carrying any commodity is independent of the quantities of other commodities carried. This and the assumed independence of demands allow us to deal only with the "representative commodity."

There are also large fixed costs in the amount of K dollars per period of time, independent of both tonnage and ton-miles. They may be thought of as the annualized cost of a lumpy factor, the cost of entry by a potential competitor, or as the sum of unallocated common costs, including the cost of empty back hauls that cannot be traced to any particular front haul.⁴²

The surplus revenue over and above direct cost, S , equals the quantity times the difference between price and direct cost:

$$(4) \quad S = g \int_0^a \left[\frac{v - f(x)}{v} \right]^n [f(x) - bx] dx.$$

Maximization of this surplus is the simplest problem in the calculus of variations, because the partial derivative $\frac{\partial \phi}{\partial f'}$ in the Euler equation

⁴² The text after the comma and beginning with "including" was added in the year 2001.

$$\frac{\partial \phi}{\partial f} - \frac{d}{dx} \left(\frac{\partial \phi}{\partial f'} \right) = 0$$

does not appear in $S = g \int_0^a \phi [x, f(x)] dx$. Thus we can treat $f(x)$ as an ordinary variable, and look upon results at one point of the line as representative for the whole line, so long as we do not fully distribute the fixed cost K over those points.

At any point, for a given length of haul \bar{x} , the freight is $f(\bar{x}) = F$, and the cost is $b\bar{x} = B$. The operating surplus is

$$s = \frac{g}{v^n} (v - F)^n (F - B)$$

$$\text{and } \frac{ds}{dF} = \frac{ng}{v^n} (v - F)^{n-1} [v - (n+1)F + nB].$$

Setting this first derivative equal to zero we find $F = \frac{v + nB}{n+1}$. The second derivative of the surplus is

$$\frac{d^2s}{dF^2} = -\frac{ng}{v^n} (v - F)^{n-2} [(v + nB) + (v - B) - (n+1)F].$$

This second derivative is negative, and the surplus can be maximized, if the value of service exceeds its price and cost ($v > F > B$), and if $\frac{v + nB}{n+1} + \frac{v - B}{n+1} > F$. Substituting the tariff $\frac{v + nB}{n+1}$ for F :

$$\frac{d^2s}{dF^2} = -\frac{ng}{v^n} \left(\frac{n}{n+1} \right)^{n-2} (v - B)^{n-1} < 0, \quad \forall v > B$$

Thus the surplus is a concave function of this tariff. Similarly, the benefit to shippers (the area under the demand curve and above the price) evaluated at the profit-maximizing tariff, is positive when $v > B$, or at all locations worth a transport service. The second derivative of the benefit, at the profit-maximizing tariff, is

$$\frac{gn}{v^n} \left(\frac{n}{n+1} \right)^{n-1} (v - B)^{n-1} > 0.$$

The benefit is a downward-sloping function of price that reaches zero at $v = F > B$. A tariff reduction would raise the benefit and reduce the surplus.

To find the second-best tariff we maximize the concave benefit to consumers subject to a convex budget constraint. This constraint is that marginal cost pricing must avoid deficits:

$$\text{maximize } \frac{gv}{n+1} \int_0^a \left[\frac{v - f(x)}{v} \right]^{n+1} dx, \text{ with respect to } f(x)$$

$$\text{subject to } K - g \int_0^a \left[\frac{v - f(x)}{v} \right]^n [f(x) - bx] dx \leq 0$$

The Lagrangean function is

$$V = \frac{g}{v^n} \int_0^a \left\{ \frac{[v - f(x)]^{n-1}}{n+1} + [v - f(x)]^n [f(x) - bx] \right\} dx - \lambda K.$$

The multiplier λ is the marginal social value of a dollar of railway surplus, equal to the opportunity cost of a dollar's worth of deficit finance. It exceeds one dollar, because of the dead-weight loss of taxation, assuming that elsewhere there are no other distortions. The conditions for a maximum are:

$$\begin{aligned} \frac{\partial \phi}{\partial f} &\leq 0, & f(x) &\geq 0, & f(x) \frac{\partial \phi}{\partial f} &= 0; \\ \frac{\partial V}{\partial \lambda} &\geq 0, & \lambda &\geq 0, & \lambda \frac{\partial V}{\partial \lambda} &= 0. \end{aligned}$$

Unsubsidized operation is possible only if $f(x)$ is greater than zero. This and the complementary slackness condition imply

$$\frac{\partial \phi}{\partial f} = 0 = (\lambda - 1)[v - f(x)] - \lambda n[f(x) - bx],$$

whence

$$(5) \quad f(x) = \frac{m}{m+n}v + \frac{n}{m+n}bx, \quad m = 1 - \frac{1}{\lambda}$$

Substituting this into the equation for surplus over direct cost we have

$$(6) \quad S = \frac{mn^n gv^2}{(m+n^{n+1})(n+2)b}.$$

$K \geq 0$, $K - 1 \leq 0$, and equation (6) imply in turn $\lambda \geq 1$, $0 \leq m < 1$. Therefore, by the second complementary slackness condition, $\frac{\partial V}{\partial \lambda} = S - K = 0$. The budget is balanced exactly.

Given that m varies between zero and unity, there is a continuum of Ramsey tariffs between the limits $f(x) = bx$ for $m = 0$, marginal cost pricing;

and $= \frac{1}{n+1}v + \frac{n}{n+1}bx$, for $m = 1$, profit - maximizing

The choice of one tariff over another depends on K , b , g , n , and v . $K = 0$ is the condition for marginal cost pricing. For a poor railroad, running through an area in which all parameters assume unfavorable values, the second-best tariff may have to be made with $m = 1$, or profit-maximizing.

From (5) and (2), we find the second-best tax rate

$$(7) \quad \frac{f(x) - bx}{f(x)} = -\frac{m}{E}$$

This is one of the formulations of Ramsey's rules of optimum taxation. It means that prices are set as if the monopolist overestimated the price-elasticity of demand by a factor $1/m$.

Substituting (5) into (1) we find the quantity demanded in the second-best situation

$$(8) \quad q = \left(\frac{n}{m+n} \right)^n \left(\frac{v-bx}{v} \right)^n = \left(\frac{n}{m+n} \right)^n q',$$

where q' is the quantity demanded under marginal cost pricing and deficit finance. This is the equiproportional reduction formula, the more general of Ramsey's rules.

Comparison of (5) with Launhardt's tariff (p. 23) shows that the only difference between an unconstrained monopoly and the second-best tariff is in the value of m . Therefore, (7) and (8) apply also to an unconstrained monopoly and qualify it for the second-and-a-half best prize. Whatever level of profit it achieves is extracted in the way least injurious to consumers. Thus we find no structural difference between the pricing policies of an unchallenged, profit-maximizing monopoly and the omniscient regulator.

The tariff in equation (5) is related to the argument in Chapter II, p. 17 in the following way:

$$f(x) = bx \quad + \frac{m}{m+n}v \quad - \frac{m}{m+n}bx =$$

Marginal + Tonnage - Mileage
Cost Tax Subsidy

The revenue raised by the tonnage tax is applied to pay the fixed cost K , after which a balance is left over and returned to shippers in the form of a mileage subsidy. This is a cross-subsidization of long haul shippers by short haul shippers. It is inherent to spatial monopoly, so much so that the Interstate Commerce Commission held that a scale carrying a higher rate per ton-mile for longer compared to shorter distances is illogical and *prima facie* unreasonable.⁴³ Since the factors of v and bx add up to unity, the effect of the tax-cum-subsidy scheme is that a marginal shipper will pay as much in tax as he receives in subsidy and gets service at marginal cost. The marginal shipper is a miles away from his market, where $v = ba$. That the marginal shipper---who has the highest elasticity of demand and is Acworth's "weaker member of the community"---is served at marginal cost is what Ng and Weisser distilled from a more general model: They found that the per unit price in a two-part tariff will be less than marginal cost, if the marginal consumer takes more units than the average consumer. Our marginal consumer is the one most distant from the market, who requires more ton-miles per ton than the average shipper located closer to M .

Consider now the terminal cost of c dollars per ton. Add it to bx , dig through the model again, and emerge with the tariff

$$\frac{m}{m+n}v + \frac{n}{m+n}c + \frac{n}{m+n}bx.$$

Thus all variable costs are absorbed by the monopolist.

If the services of the firm were complementary — like branch line and main-line service, if they were priced separately — the second-best price of one of them could be set above its pure monopoly price. This would exacerbate the sustainability problem.

Launhardt noted that profit-maximizing rates would have such high terminal charges that he could not recommend them for practical application. This raises problems related to the type of competition that is invited. These will be discussed in other chapters, but we should note here that some form of competition

⁴³ In *Thompson v. Louisiana Railroad Commission*, 198 Fed. 691.

may cause the monopolist to surrender a little to the "general welfare" and set rates that mimic the second-best. Normally, the omniscient regulator imposes a constraint on firms, subjecting them to a perfect competition which makes them act as if the demand for the product were perfectly elastic. In this case, the regulator imposes a constraint that makes the firm act as if it overestimated the elasticity of demand by a factor $1/m$. This could be accomplished by potential entry, or by "competition of markets," by means of railways, to which these have to adjust.⁴⁴ The Interstate Commerce Commission disparaged the concept, calling it a "euphemism for railway policy,"⁴⁵ without saying what that policy was. The policy was that of a member in a cartel that assigns customers to firms. These customers compete at a distant market M with those of other transport firms. A railway will find it profitable to grant rate rebates that assist its customers to increase their share of M . Since a railway's customers compete not only with those of other railways, but also among themselves, rebates are governed by a sort of "most favored nation" clause, by which the firm extends to all its customers the rate reduction it grants to any one of them. This clause puts downward pressure on all rates and is implied in the managers' claims---repeated to every investigating committee of Congress or Parliament---that they would not resort to local and personal discrimination, if they could avoid it, and resort to it to meet direct competition between common points.

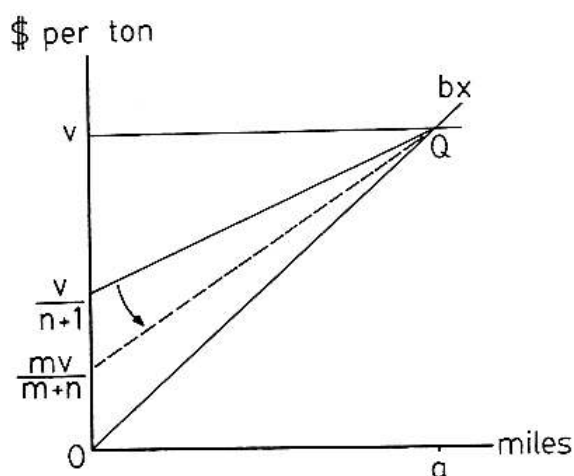


FIGURE 5. MODERATION OF MONOPOLY POWER

The idea of indirect competition putting a constraint on the firm is of course somewhat vague, and could therefore be expressed in many other ways. For example, a former president of the Chicago, Burlington, and Quincy Railroad wrote that "if a man does not like the prices charged by a given railroad, he can move away to some other region, where the railroads charge prices which he likes better."⁴⁶ His policy was to maximize profit, subject to his customers getting rents comparable to what they were elsewhere, and he knew that this was not satisfactory to the public. His more enlightened colleague at the helm of the Northern Pacific was accused by a shareholder of "leaning towards the views entertained by

⁴⁴ Royal Commission on Railways, 1867, Q. 14,795; J. M. Clark, *Standards of Reasonableness in Local Freight Discriminations*, New York, 1910, 51; T. D. Heaver and James C. Nelson, *Railway Pricing Under Commercial Freedom: The Canadian Experience*, Vancouver, 1977, Ch. 5, pp. 157 ff.

⁴⁵ 21 I.C.C., 367.

⁴⁶ C. E. Perkins to G. Frazee, March 3, 1885, in T. C. Cochran, *Railroad Leaders, 1845-1890*, Cambridge, Mass., 1953, pp. 439-40.

the public at large, rather than to those of the corporation," but was convinced that his was "a better judgment as to what is for the real permanent interest of the Company."⁴⁷

An unregulated monopoly railway's reaction to competition of markets, if it exists, is to reduce the tonnage tax and withdraw part of the mileage subsidy. It would cut the terminal charge t , and raise the conveyance rate r , so the tariff line is rotated around the point Q , where marginal cost equals the value of service.

This would reduce the ratio t/r and recommend it as a measure of exercised monopoly power. Across the board cuts are ruled out, because the marginal shipper was already getting service at marginal cost.

A striking example of a tariff's rotation around Q is given by the first fixing of local rates by the South Carolina Railroad Commission in 1883. They did it in the following way:

- 1st. The rates for short distances have been generally reduced below what they were before.
- 2nd. The rates for long distances are about the same as before.
- 3rd. In the case of the Charlotte, Columbia, and Augusta Railroad, short distance rates have been increased and long distance rates reduced.⁴⁸

In the last case, the rates—which had previously been set by the Courts—were revised because they had been strictly proportional to distance, like the cost plus fuel tax condemned by Ellet and Walters.

CHAPTER V A TEST OF THE CROSS-SUBSIDIZATION HYPOTHESIS

On pages 5-6 we were cautioned that competitive and monopoly transport prices are deceptively similar, since both may consist of two parts. In this chapter we test the theory that railroads had a cross-subsidizing monopoly. This test will be carried out on the basis of price information alone. Ordinarily, this would be rather foolish, but not in this case, because two-part prices signal a little more information than uniform prices, just enough more to permit this test.

Consider first the competitive case. Competition would make both parts of the price tend towards their costs. The firms' estimates of these costs suffer from random errors, so there is no reason to suppose that errors in terminal charges will be correlated with those in conveyance rates. A firm overestimating one of them may over- or under-estimate the other, or even get it right. Therefore, if the two parts of the price were plotted on a scatter diagram, one would get a cloud around their means.

However, transport is a spatial industry, and some firms operate in high cost areas while others serve low cost areas. One would then expect a significantly positive correlation between the two parts of a competitive transport price.

A non-discriminating monopoly taxes all its customers at the same rate. If its terminal cost c were zero, then its rates would be like those of the Charlotte, Columbia, and Augusta Railroad, before their revision in 1883. If it had a positive terminal cost, it would mark it up by the same percentage as the line-haul cost. Variance of monopoly power among railways would then again produce a positive correlation of terminal charges with conveyance rates.

⁴⁷ R. Harris to R. Hale, March 12, 1884, in T. C. Cochran, *Railroad Leaders, 1845-1890*, Cambridge, Mass., 1953, p. 356. *Added in the year 2001*: If all else fails, the government granting the railway concession with its rights of public domain will insert in the contract a clause authorizing expropriation at say, cost plus 20 percent. That was a common practice, notably in the Argentine, that opened the way to a potential "entrant of last resort." (Argentine Republic, Law 5315 ("Ley Mitre" of 1907), Section 16).

⁴⁸ Railroad Commissioners for the State of South Carolina, *Fifth Annual Report*, Columbia, 1883, p. 8.

In the case of discriminating monopoly we have seen that one may expect a negative correlation between t and r , if one goes up, then the other goes down. Among profit-maximizing firms, the see-sawing of the tariff parts is brought about by variance of n in the sample. Among constrained firms, variance of b , g , K , n and v causes a variance of profits which the constraint equalizes and grinds into a variance of m . In either case, the hypothesis to be tested is that the coefficient of simple correlation between t and r is negative.

The expected negative correlation is due to cross-subsidization. It was already evident when in Chapter II we set the two parts of the tariff at $t(0)$ and $(b - (t(0)/a))$. In equation (5) these two parts are t and $b(v - t) / v$. They would be perfectly correlated, if both b and v were constant. But they are not, and if their variances speak louder than the cross-subsidization, we will find positive correlations of t and r . This can be verified by looking at the tariffs applied by one and the same railway to different commodities.

Considering the tariffs of different firms for a given commodity or class, one would have to control for cost differences among firms. This we shall not do, and therefore the correlation of t and r will test both the hypothesis of cross-subsidization, and the additional one that this is the strongest and most pervasive element in the determination of railway rates.

The data are local station to station rates and mileage scales that were step functions of distance. In the jargon of the trade, the local rate is one charged for the transportation of goods between points served by one and the same company whereas through rates applied for the interchange of traffic between companies. The geography of railway networks is such that through rates are more likely to have been made competitively than local rates, because the interchange is made at nodes where there is a choice of routes and companies. But the local traffic between nodes is also competitive. There is no such thing as a pure monopoly tariff, but the local one is the closest substitute for it. Therefore we use it to test the model, and the model will fail if local tariffs were made with "too many" competitive considerations.

The prices shown in the tariffs were regressed on the distance between stations, or on the higher of the two distances in each mileage block, to estimate the terminal charge t and the conveyance rate r of each company in the sample. We obtained local rate schedules of one hundred and twenty-one companies, operating in nine states over thirty-three years. Of these schedules we used mostly the Class I rates, because although all companies had different numbers of classes, and many commodity rates, they were not easily comparable among firms, unless they applied a common classification. But Class I is comparable, in the sense of being the highest rate a firm thinks it can charge for any commodity. Class I rates may nowadays be regarded as obsolete, but in the pre-I.C.C. era 25 percent of the west-bound tonnage of six major Trunk Line railroads was rated in Class I.⁴⁹

The tariffs were published at different times by State railroad commissions. Some commissions published the tariffs they found at the time they commenced their work, others published the rates they attempted to enforce. To the extent that these local rates applied to intra-state traffic, they were beyond the reach of the Interstate Commerce Commission. The State commission reports indicate whether or not a State had the power to set rates, and on this basis the tariffs were classified as regulated or unregulated.

A total of 2,030 unregulated prices were fitted to 123 tariff equations, and another 1,095 regulated prices were used to estimate 62 tariffs. A surprisingly large number of rates fit very well to straight line distance tariffs. The simplifying assumptions built into the model to produce these straight lines seem to have done little violence to the facts. The estimates are shown in Tables 9 to 33 in the Appendix. Since the standard errors of the coefficients were omitted from those tables to avoid overcrowding each page with numbers, it should be mentioned here that all but two tariffs had significantly positive terminal charges.

Next analyses of covariance were made to test the hypothesis that the individual tariff lines were all drawn from the same population. If they were, the seesawing of the tariff parts would have been

⁴⁹ New York Railroad Commissioners, *Report for 1885*, 1, 115.

produced by errors in the equation, and not by systematic cross-subsidization. In the cases where this hypothesis could be rejected we proceeded to correlate \hat{t} with \hat{F} to test the cross-subsidization hypothesis.

The test results are summarized on Table 2. The hypothesis that all tariffs in a State are identical can be rejected, even when comparing the local rates applied by one and the same company over its different divisions. The only cases in which it can be accepted are those of the largest railroads in States whose regulating commissions had the power to set rates and set them uniformly for a number of companies at a time. The level of confidence with which the hypothesis of zero correlation between \hat{t} and \hat{F} can be rejected is generally quite acceptable, considering that we are testing a hypothesis which is stronger than necessary. The correlations always have the expected negative sign.

A more direct but statistically less satisfactory test would show the terminal charge to be mushy and tending to disappear in the railways' attempt to obtain competitive business. One needs to show that when competitive price reductions are made, the percentage reduction on short hauls is greater than for long hauls.

The best evidence would be obtained by unearthing secret rebates. Here we only notice the following facts:

(a) Special rates were made more frequently for short hauls than for long ones. For example in England, the Great Western did about 50 percent of its business on the Normanton scale, and 50 percent by special rates, and of these, the majority were for short distances, reaching about 70 to 80 miles.⁵⁰

(b) In America, it was common to make special rates by waving the terminal charges on reconsignments, or after "milling in transit."

(c) Differences between class rates tended to vanish during periods of extremely low rates set by competition among American Trunk Lines.⁵¹ This amounted to the disappearance of v or t from the tariff formula.

(d) The rates set by the Trunk Line cartel for points between Pittsburgh and Chicago were made as percentages of the New York-Chicago rate. The percentage points were initially set strictly proportional to distance (implying $t = 0$), but subsequently altered to reflect an assumed terminal charge in the New York-Chicago rate. This assumed terminal charge became a focus of negotiations between cartel members about the percentage bases.⁵²

The vulnerability of the terminal charge depends on how direct and complete competition is. The charge will disappear completely if competition is over parallel routes, as between road and rail. In America this competition has been prevented by regulation and the assimilation of motor-truck to railway rates. In Argentina, the foreign-owned Central Argentine Railway did not have this protection. Both class differences and cross-subsidization of long hauls were greatly reduced by it in response to the Argentine government's first extensive road-paving program and the consequent appearance of motor-truck

⁵⁰ U. K., Parliament, *Report of the Committee on Railway Rates and Charges Provisional Orders Bills*, Part II, 1891, evidence of Mr. Lambert, General Manager, Great Western Railway, Q. 13,622 and 13,632.

⁵¹ Albert Fink, *Statistics Regarding the Movement of East-Bound and West-Bound Traffic Over the Trunk Lines, &c.*, New York, 1884, p. 39. River navigation caused the Entre Rios Railways of Argentina to throw out value of service pricing and make rates per wagon load of twenty tons of goods of any description, W. C. Holland, "Argentine Railway Rates and Fares," *Journal of the Institute of Transport*, XI (1929) 103-09.

⁵² Trunk Line Association, *Proceedings and Circulars of the Joint Executive Committee*, 1883, New York, 1884, 48, 121-27.

competition over a parallel highway. For the most highly rated goods, Class I, in lots of 100 kilograms, the old and new rates were:⁵³

	Kms.	Rates in 1938		
		OLD	NEW	Percent Reduction
		Ordinary	B200	
Buenos Aires to Santa Fe	477	75.9	71	6.46
Buenos Aires to Rosario	302	59.8	45.5	23.9
Rosario to Santa Fe	177	46	26	43.5

Not only was the reduction greater for short hauls than for long ones, but the terminal charge had virtually disappeared. This charge was the sum of rates for 300 and 177 kilometers, less the rate for 477 kilometers. That was 29.90 pesos under the ordinary rates, and 0.50 pesos under the new special rate. In this way the rate structure was returned to the primitive condition Charles Ellet had condemned.

⁵³ Lino Camaño, "La competencia carretera en la República Argentina: las tarifas proyectadas por el Ferrocarril Central Argentino para contrarrestar sus efectos," *Cuarto Congreso Panamericano de Ferrocarriles*, Bogotá, 1941, 3, 167-85.

TABLE 2.— TESTS OF MONOPOLY ELEMENT IN LOCAL RATES OF RAILROADS

		<i>F</i> -test of deviations between individual tariff equations			Correlation of terminal charges with conveyance rates	
		Degrees of freedom	<i>F</i>	Confidence level	$R_{t,r}$	Confidence level
<i>Unregulated Railroads</i>						
1874 — Illinois	Class D	12/188	3.706	99.9	-0.664	98.6
	Coal	15/250	4.856	99.9	-0.601	98.4
1886 Mississippi — Class I		15/204	11.08	99.9	-0.67	99
1891 North Carolina — Class I		8/160	32.21	99.9	-0.926	99.9
1898 Michigan — Class I		25/206	3.97	99.9	-0.544	99.6
1900 Arkansas — Class I		5/106	22.18	99.9	-0.862 to -0.996	85.0-99.0
1906 Indiana — Class I:		36/670	18.97	99.9	-0.693	99.9
C.C.C. & St.L.R.R.		6/114	2.101	94	-0.51	75
P.C.C. & St.L.R.R.		5/73	22.45	99.9	-0.965	99.8
C.I. & L.R.R.		2/51	10.43	99.9	-0.754	54
Vandalia R.R.		2/69	98.21	99.9	-1.834	60.2
Another 18 railroads		17/363	14.91	99.9	-0.409	90.6
<i>Regulated Railroads</i>						
1897 Florida — Class I		6/100	17.43	99.9	-0.857	98.5
1905 Alabama — Class I						
0-300 miles		2/81	1.794	-	-	-
0-170 miles		6/136	6.47	99.9	-0.253	41.6
0-92 miles		10/99	7.115	99.9	-0.475	85.2
1907 Mississippi — Class I						
0-335 miles		37/168	4.976	99.9	-0.669	84.4
0-200 miles		6/156	6.7	99.9	-0.24	35.2
0-45 miles		5/23	16.6	99.9	-0.108	none
1907 So. Carolina — Class I						
3 Large RRs		2/69	2.649	91	-	-
12 Small RRs		11/41	6.236	99.9	-0.944	99.9

CHAPTER VI

SPECULATION ABOUT THE PRESENCE OF A CONSTRAINT ON PROFIT

In the tariff equation $f(x) = mv / (m+n) + nbx / (m+n) = t + rx$, the ratio of the terminal charge to the conveyance rate, t/r , equals am/n , where a is the maximum economically possible length of haul--determined by demand and cost conditions beyond the firm's control--- m is an index of the constraint on the firm's profit that varies from zero (no monopoly) to unity (no constraint), and n is the elasticity of demand with respect to the proportion of the value of service that the carrier concedes to the shipper. Thus one may say that m measures the firm's power to tax, n measures the revenue that the tax will not raise, so m/n is the railroad's monopoly power, and t/r is a good index of it.

Among profit maximizers, a low n makes a high t/r and a high profit in equation (6). This correlation between t/r and profits is spoiled by the constraint, which only allows high taxes (high t/r) to poor railroads. Therefore, one is tempted to test the presence of the constraint by the significance and sign of the correlation between t/r and company profits.

Such a correlation will likely turn out to be insignificant, both statistically and conceptually. One would first have to make cost allocations to freight and passengers, and correlate the profit from the freight business with an average t/r .

Part of the freight business may have been charged with less discriminating monopoly prices ($t = 0, r > b$). That would mandate further disaggregations and run us into blatant contradictions of the theory to be tested, about the pricing of things produced under joint costs. Therefore it seems advisable to grasp at other but firmer straws.

The previous argument assumed that m reacts to changes in the other parameters of the profit equation. If costs fall, or demand increases, profits would tend to rise. This tendency would be thwarted by a binding constraint which, if it existed, would reduce m and thereby rotate the tariff. This hypothesis may be tested directly by observing tariff shifts and twists without any reference to profits calculated with dubious allocations of joint costs.

One may also ask whether or not government regulation facilitated the railways' exercise of their monopoly power by observing the structure of tariffs before and after regulation.

Finally, one can test a hypothesis advanced by railway officers and shippers: that the discriminatory tax raises a fixed sum, so an improvement in one segment of a railway's market will be used to provide tax relief to other segments. This follows from a constraint on profits, since a profit-maximizing, unconstrained monopoly would derive the full benefit of new opportunities in one market segment, leaving the prices charged in other segments at their previous profit-maximizing levels.

Consider first the effect of a cost reduction. In Launhardt's formula ($m = 1$) only the conveyance rate will be affected by a reduction of the marginal cost b . An unfettered monopolist will leave terminal charges as they were, and use the cost reduction to extend the line and increase his profit. He was admirably suited to assist in stretching the American economy from East to West. But if a constraint is working, it will squeeze out some of the additional profit by cutting down m . This makes a great difference in the response to a cost reduction. The constrained firm would reduce its terminal charge t . And when this tonnage tax is reduced, part of the mileage subsidy will be withdrawn.⁵⁴ If the mileage subsidy were then reduced by more than the hauling cost, the cost reduction would have *increased* the conveyance rate r .

⁵⁴ This is like saying "if the firm makes price reductions only or chiefly by absorbing freight, and never or seldom by reducing prices to customers in its natural territory, it is practicing what I shall term systematic freight absorption. If the firm frequently uses both price reductions in its territory and freight absorption, I shall term its behavior competitive." G. J. Stigler, "A Theory of Delivered Price Systems," *American Economic Review*, 39 (1949) 1143-57.

To see this mathematically, suppose everything in equation (6) to be held constant, except m and b . Then set $dS = dK = 0$, and solve for the elasticity of m with respect to b , when profits are held constant:

$$\frac{dm/m}{db/b} = \frac{m+n}{n(1-m)}, \quad 0 < m < 1.$$

This elasticity is always greater than unity. Therefore, a cost reduction will not only cut t but also t/r , since the latter equals vm/bn , and m falls by a greater percentage than b . Correlation of an index of factor prices with t/r would provide a test of the constraint. This would have to be a time series study of individual firms, because each has its own m . The trouble with that is the number of available tariff schedules may not leave enough degrees of freedom.

The effect of a cost reduction on the conveyance rate r is given by

$$\frac{dr/r}{db/b} = \begin{cases} 1, & \text{if } m = 1, \\ 1 - \frac{m}{n(1-m)} \geq 0 & \text{if } 1 > m \leq \frac{n}{n+1} \text{ else } \leq 0 \end{cases}$$

This means that on a railway operating under a revenue constraint there is no clear-cut relationship between changes in conveyance rates and changes in the marginal cost per ton-mile. Cost reductions could go by undetected, if one looked only at conveyance rates.

Since a cost reduction will cut the terminal charges of a constrained firm $\left(\frac{dt/t}{db/b} = \lambda\right)$ but r may

fall, rise, or stay the same, the cross-subsidization of shippers will vary from case to case. The relative shares in locational rents distributed to producers along the railroad can change in apparently capricious ways.

Next consider an increase in v , the value of service. In Launhardt's pure monopoly case there would be a parallel upward shift of the tariff line. But if there were a constraint on profit, m and t/r would diminish. The relevant elasticities are

$$\frac{dm/m}{dv/v} = \frac{2(m+n)}{n(1-m)} < -2; \quad \frac{dr/r}{dv/v} = \frac{2m}{n(1-m)} > 0; \quad \text{and} \quad \frac{dt/t}{dv/v} = 1 - 2\lambda < 0;$$

when $dS = dK = 0$. The reduction in the terminal charge offsets the increased profitability of long hauls, when the value of service increases.

As an illustration, consider Table 3 of seasonal rates on coal. These rates may have been written into the tariff books by railway officers asking the hypothetical question: what if, everything else equal, the demand for coal is greater in Winter than in Summer?

In Northern States one could have argued that operating costs are higher in Winter than in Summer, and this should be a consideration in making seasonal rates. But that argument would not have held in Mississippi, nor did it apply to most commodities other than coal. What may be argued is that coal was more valuable in Winter than in Summer. However, the railways' ability to exploit seasonal demand shifts seems to have been limited. The hypothesis of unconstrained monopoly producing parallel shifts and a higher t/r in the tariff can be accepted between one season and the next, but not year-round. Only three of the nine shifts were definitely parallel. However, terminal charges were not reduced either. The constraint, if any, was weak because most of the Southern freight traffic was compressed into the winter months.

TABLE 3: SEASONAL COAL RATES IN 1886
IN CENTS PER TON, UNREGULATED

	\hat{t}	\hat{P}	R^2	H_0	P	t / r
Cincinnati Southern						
Summer	51.314	0.69652	0.94710	$r_1 = r_2$	0.829	74
	(5.124)	(0.05487)				
Winter	60.332	0.81995	0.94611	$r_1 = r_2$	0.829	74
	(6.091)	(0.06523)				
New Orleans and Northeastern						
May to August	63.2500	0.76323	0.99309	$r_1 = r_2$	0.999	83
	(1.645)	(0.01701)				
September	64.8750	0.90220	0.99422	$r_1 = r_2$	0.999	72
	(1.777)	(0.01838)				
October to April	70.500	0.96838	0.97064	$r_2 = r_3$	0.812	73
	(4.352)	(0.04501)				
Louisville & Nashville Railroad						
May to August	91.9191	0.59118	0.95283	$t_1 = t_2$	0.999	105
	(1.7406)	(0.03297)				
September	81.9191	0.59118	0.95283	$t_1 = t_2$	0.999	138
	(1.7406)	(0.03297)				
October to April	84.4191	0.84118	0.98698	$r_2 = r_3$	0.999	100
	(1.409)	(0.02582)				
Alabama Great Southern						
May to August	51.500	1.20000	0.80000	$t_1 = t_2$	0.998	43
	(7.794)	(0.42426)				
September	71.500	1.20000	0.80000	$t_1 = t_2$	0.998	60
	(7.794)	(0.42426)				
October to April	80.000	1.00000	1.00000	$r_2 = r_3$	0.337	80
Georgia Pacific						
May to August	58.3093	0.65013	0.95723	$t_1 = t_2$	0.999	90
	(2.651)	(0.06146)				
September	78.3093	0.65013	0.95723	$t_1 = t_2$	0.999	120
	(2.651)	(0.06146)				
October to April	79.3481	0.95428	0.95865	$r_2 = r_3$	0.981	83
	(3.824)	(0.08863)				

Note: H_0 is the null hypothesis tested; P is the confidence level at which it can be rejected.

Sources: Mississippi Railroad Commission, *Second Annual Report*, Jackson, 1887 and Kentucky Railroad Commission, *Seventh Report*, Frankfort, 1887, p. 20.

One may also think the elasticity of demand for the transport of coal changes with the seasons; that it falls as it gets colder. The Winter n would then be smaller than in Summer, and a monopolist unencumbered by public utility considerations would raise t and reduce r in the Fall. This was only once the case.

Next compare local---generally non-competitive---rates before and after regulation. We can do this for the State of Mississippi, for which we already estimated t and r in 1886 and 1907.⁵⁵ Cross-subsidization was more significant in 1907 than in 1886, and the index of monopoly t/r increased over those years, as shown in Table 4.

TABLE 4				
RELATION BETWEEN TARIFF PARTS IN MISSISSIPPI				
1886	$r = 0.85169$	$-0.013549 t,$	$R^2 = 0.4494;$	Mean $t = 25.49$
	(0.10448)	(0.003621)		Mean $r = 0.5063$
				Mean $(t/r) = 73.5$
1907	$r = 1.13982$	$-0.024937 t,$	$R^2 = 0.6521;$	Mean $t = 29.03$
	(0.14182)	(0.004684)		Mean $r = 0.416$
				Mean $(t/r) = 114.5$
Note: the increase in the coefficient of t is significant at the 5 percent level. t : estimated terminal charge; r : estimated conveyance rate.				

Supposing in 1886 the railways of Mississippi did have unused monopoly powers, how could they have justified that extravagance? A possible explanation is that their sacrifice was rewarded by profitable pooling of competitive traffic.⁵⁶ This was done by the Southern Railway and Steamship Association. This stablest of railroad cartels began to crumble in 1894 and ceased its activities in 1897, in consequence of the Supreme Court's ruling on the Trans-Missouri Freight Association case.⁵⁷

If there was a constraint on a firm's profits, the gains reaped by pooling competitive traffic must have been at least partially offset by some relief to shippers in non-competitive markets. This is the basis for railway officers' and some shippers' representations to Congress in favor of pooling.⁵⁸ To the officers

⁵⁵ We cannot enlarge the sample except at great cost. Not all commissions had the power to set rates and published them. Even fewer published the rates they found when starting their work. And in many States the regulatory commissions robbed us of degrees of freedom by prescribing uniform rates for many companies at a time.

⁵⁶ Then why bother with pooling in the first place? First, because price distortions are reduced when all segments of the market are monopolized about equally, and this creates new opportunities for profit. Second, the local markets may be a small tax base on which to support the firms. Third, pooling was partly an attempt to solve the backhaul problem.

⁵⁷ W. H. Joubert, *Southern Freight Rates in Transition*, Gainesville, 1949, pp . 50-51 , 64.

⁵⁸ Gabriel Kolko, *Railroads and Regulations, 1877-1916*, New York, 1970, 77; *Cullom Committee Report*, 49th Congress, 1st. Session, Senate Report No. 46, esp. Appendix, 126-47 ; and the *Report of the Government Directors of the Union Pacific Railroad for the Year 1884*, p. 158: "it is neither beneficial nor expedient that one class of rates should decline to the basis forced by relentless and dishonorable competition, while another class is maintained at exorbitant figures, which competition does not affect, unless very indirectly or remotely. On account of this really unjust feature,

TABLE 5 — CONVEYANCE RATES AND TERMINAL CHARGES ON LOCAL FREIGHT BEFORE REGULATION AND DURING PERIODS OF STRONG AND WEAK REGULATION:
RATIO OF TARIFF PARTS *t/r*

Years	Railway and Point of Origin			
	<u>Michigan Central</u>			
	<u>Chicago</u>	<u>Kalamazoo</u>	<u>Detroit</u>	
1857	--	--	56	
1884	164	253	162	
1887-95	153	58	81	
1896-1902	216	189	202	
	<u>Chicago and Grand Trunk</u>			
	<u>Chicago</u>	<u>Port Huron</u>	<u>Flint</u>	<u>Charlotte</u>
1882	99	162	95	132
1887	102	251	162	245
1890	128	92	44	32
1895	128	114	76	44
1900	172	213	120	120
	<u>Lake Shore & Michigan Southern</u>			
	<u>Chicago</u>		<u>Toledo</u>	
1886	184		89	
1887-95	150		70	
1896-1902	196		120	

Source: Calculated from rate tables in Interstate Commerce Commission, *Railways in the United States, 1902, Part II, A Forty-Year Review of Changes in Freight Rates*, Washington, D.C., 1903; and rates, Detroit to Niles, published in Michigan Central Railway, *Annual Reports of the Directors, 1850-1857*.

it had the advantage of changing the competition's character, making it less direct and more vague, as by potential entry and rivalry of markets. Their arguments implied an inverse correlation of through rates set by cartels with the (more nearly non-competitive) local rates of cartel members. Some information on this point is shown in Table 5. The Michigan Central, Grand Trunk, and Lake Shore were members of a cartel strengthened by the Interstate Commerce Act, especially by its Section 4, the long-and short-haul clause.⁵⁹ This clause was increasingly disregarded as time wore on, challenged in the courts, and rendered ineffective by the Supreme Court's decision on the Alabama Midland case in 1897.⁶⁰ Note that this clause

the Union Pacific, as are other roads, is compelled, in order to secure the revenues necessary to its requirements, to fix and impose rates at points where they may be arbitrarily maintained which embrace every feature of extortion. This fact is recognized and deprecated by none more fully and earnestly than the present management itself."

⁵⁹ Haddock, "Regulation of Railroads by Commission," p. 55.

⁶⁰ Kolko, p. 83.

did not order a reduction of terminal charges and an increase in conveyance rates, and could have been observed by revising only the latter (e.g., by "blanketing"). Nevertheless, three cartel members tended to charge their local traffic with a lower t/r during the period of strong regulation around 1890 than either before or after it.

Evidence on the relative adjustment of local and through rates is hard to obtain, and we shall have to restrict ourselves to the case of Ohio, from July 1, 1881, to June 30, 1888.⁶¹ Table 6 shows the relationship between freights per ton and lengths of haul in cross-sections of Ohio railways. Two things may be noticed there: first, local terminal charges were higher and statistically more significant than those assessed on through traffic. And secondly, local rates did not fit functions of distance as well as through rates did.

TABLE 6				
LOCAL AND THROUGH FREIGHT RATES IN OHIO: CROSS-SECTION ESTIMATES OF FREIGHT AS A FUNCTION OF DISTANCE IN CENTS PER TON, DEFLATED				
Year to June 30	Constant	Rate per ton per mile	R ²	Average per ton-mile
Local Rates ¹				
1882	61.587	0.38056	0.43691	1.217
	(-9.429)	(-0.01115)		
1883	46.641	0.525	0.80327	1.157
	(-5.71)	(-0.0567)		
1884	53.808	0.41598	0.56025	1.161
	(-6.586)	(-0.07523)		
1885	49.843	0.56419	0.53766	1.287
	(-9.305)	(-0.10679)		
1886	52.762	0.52672	0.49646	1.283
	(-8.41)	(-0.1061)		
1887	45.349	0.59875	0.69802	0.992
	(-6.077)	(-0.07858)		
1888	41.402	0.57176	0.80318	1.153
	(-4.842)	(-0.06034)		
Through Rates ¹				
1882	35.494	0.33384	0.81066	0.559
	(-8.564)	(-0.04166)		

⁶¹ Few companies reported their through and local traffic separately, and even fewer railroad commissions asked them to do so. The Ohio Commissioner published tons, ton-miles, and revenue of through and local traffic from 1885 to 1888. The data for 1882, 1883, and 1884 were obtained by solving appropriate systems of equations with other available information. Ohio had 89 railways in 1882, and 71 in 1888. Forty-two of these made useable reports at one time or another; we used at most 27 in any one year. Not all of these were independent competitors. In 1886, for instance, 9 were leased to or owned by some of the other 18.

TABLE 6

LOCAL AND THROUGH FREIGHT RATES IN OHIO: CROSS-SECTION ESTIMATES OF FREIGHT AS A FUNCTION OF DISTANCE IN CENTS PER TON, DEFLATED

Year to June 30	Constant	Rate per ton per mile	R ²	Average per ton-mile
1883	28.696	0.53124	0.9003	0.735
	(-7.259)	(-0.03858)		
1884	19.918	0.51482	0.91551	0.663
	(-5.477)	(-0.03192)		
1885	23.884	0.47636	0.89297	0.646
	(-6.443)	(-0.03366)		
1886	22.075	0.50358	0.88904	0.647
	(-6.681)	(-0.03558)		
1887	10.222	0.66642	0.91777	0.738
	(-7.091)	(-0.03989)		
1888	9.5852	0.69339	0.9259	0.76
	(-7.575)	(-0.04182)		

Note: figures in parentheses are standard errors of coefficients.

¹Source of rate variance:

	Local Rates		Through Rates	
	D.F.	Mean squares	D.F.	Mean squares
Between r and \bar{r}	1	0.8618	1	91.76
Of group means	5	2.9643	5	5.0221
Between individual lines	6	2.5169	6	47.1746
About individual lines	156	3.2024	156	4.6773

Local rates were stable, but varied greatly between firms. While through rates had significantly different slopes---following the cartel's fortunes up and down---there were no significant differences in local rates.⁶² Given a stable tariff structure, railway officers would have applied it to set rates with some margin of error. But why did Mr. Traffic Manager---who did an almost flawless job fitting through rates to functions of distance---set local rates with such great errors? Suppose the cartel regulating the traffic through Ohio, although it attracted entry and made price chiseling profitable,⁶³ was unable to maintain

⁶² In 1882-86 the ratios of mean squares of deviations between individual slopes to the mean squares about individual lines were $F = 5.89$ for through rates, and 0.29 for the local, with 4 and 109 degrees of freedom.

⁶³ P. W. MacAvoy, *The Economic Effects of Regulation: The Trunk-Line Railroad Cartels and the Interstate Commerce Commission Before 1900*, Cambridge, Mass., 1965, pp. 200-01.

through rates far above marginal cost.⁶⁴ If X is ton-miles of through traffic, and s is the corresponding surplus revenue over marginal cost, then total profit from through and local traffic is, as per equation (6) on page 17:

$$S = sX + \frac{mZ}{(m+n)^{n+1}}; \quad Z = \frac{n^n g v^2}{(n+2)b}; \quad 0 < m < 1.$$

If indirect competition creates a constraint on S , then $S = K$ and

$$dK = s dX + Z \frac{(m+n-mn)}{(m+n)^{n+1}} dm = k dX.$$

If increased through traffic can be handled without any increase in common costs, then $k = 0$. The experience of railways was, however, that K rose *pari passu* with output. Their increasing returns to scale arose not out of a simple constancy of K , but have the subtler reasons explained by Haddock.⁶⁵ Now if $k > 0$, then the change in a railroad's power to tax allowed by a change in its through traffic is

$$\frac{dm}{dX} = \frac{(k-s)(m+n)^{n+1}}{Z(m+n-mn)}; \quad m+n-nm > 0.$$

The sign of this derivative is the same as the sign of $(k-s)$. If competition should drive s towards zero, an increase in through traffic will mean a heavier tax on the local. If a cartel raises s above the level of k , m will be reduced by the constraint and the through traffic will subsidize the local. Therefore we can test the allegations made by the proponents of pooling by correlating the tax on local traffic with ton-miles of through traffic. Their theory must be rejected if this correlation is not significantly different from zero.

Let Y be the ratio of the average revenue per local ton-mile relative to the average revenue per ton-mile of through freight. Assuming the denominator to have been close or proportional to marginal cost, Y is a rough measure of the tax on local traffic and a proxy for m . Let X_2 be the ratio of through ton-miles to local ton-miles. This corresponds to the X in the constraint and is measured in ratio form to avoid spurious correlation with the sizes of firms in a cross-section, and because all variables that determine local ton-miles except m (that is v , g , n , and b) are supposed constant. Since Y measures an average tax that depends not only on m , but also on the distribution of g (the tonnage shipped when price is zero) along the line, we must expect Y to be relatively low when the demand for transport of a good is concentrated at points far away from its market. In that case even a high m would produce a low average tax Y . To catch the effect of the distribution of g on each firm in the cross-section we add the variable X_1 , the average length of the local hauls. And finally we add also X_3 , the gross revenue from freight per dollar of passenger revenue, and write

$$Y = c_0 + c_1 X_1 + c_2 X_2 + c_3 X_3 + u.$$

If c_2 and c_3 are significantly different from zero, that will be evidence of cross-subsidization and a constraint. If they are equal to zero, no conclusion can be reached, because there could still be a constraint with $k = s$. The coefficient of X_1 is expected to be negative.

⁶⁴ Through rates were as a rule prorated among cooperating railroads in proportion to mileage. Thus if a railway accepts all traffic that pays marginal cost or better, most traffic will be carried at more than marginal cost. For instance, freight from St. Louis reached the Erie Railroad through 16 different channels, leading through different routes at the West. Rates being the same by all routes, the proportion accruing to the Erie was different in every case, varying with the distances over which the freight passed before it reached the Erie, See G. R. Blanchard's *Argument Before the Committee on Commerce of the House of Representatives in Opposition to the Pending Bill for the Regulation of Interstate Commerce*, New York, 1882, pp. 109-10.

⁶⁵ Haddock, "Regulation of Railroads by Commission," pp. 10-27.

The estimates of the coefficients in the regression equation may suffer from an identification problem, since substitution in consumption causes positive correlation of Y with X_2 , but in this case it is difficult to argue that the traffic of Western States with the Eastern Seaboard through Ohio was a close and statistically significant substitute for local traffic in the State. Also, the coefficient of X_2 will be biased downwards, because Y equals X_2 times the ratio of gross revenues from local and through traffic.

The estimates are shown in Table 7. The coefficient of the average length of haul has the expected sign. The signs of the other coefficients indicate that the local freight subsidized every other line to the business. In 1886-87 this was so bad that the Cincinnati, Hamilton, & Dayton; Cincinnati, Richmond, & Chicago; Cincinnati, Hamilton, and Indianapolis, and the Dayton & Michigan railroads withdrew their participation in through traffic.⁶⁶ The numerical values of c_2 and c_3 do not mean as much as their signs, since they are functions of m , the constraint gave each firm its own m , and different firms are represented in each cross-section.

TABLE 7— LOCAL FREIGHT RATES IN OHIO					
Year to June 30	c_0	c_1	c_2	c_3	\check{R}^2
1882	1.9328	-0.002288	0.28794	-0.094538	0.71925
		(-1.136)	-5.168	(-2.099)	
1883	1.7968	-0.003367	0.132217	-0.0015	0.55124
		(-2.559)	-3.86	(-0.022)	
1884	2.207	-0.004644	0.035519	-0.023848	0.39016
		(-2.820)	-2.042	(-0.560)	
1885	2.4618	-0.004776	0.08757	-0.1346	0.36802
		(-2.811)	-2.077	-2.04	
1886	2.5096	-0.003514	0.12841	-0.2047	0.3574
		(-1.928)	-2.443	(-2.921)	
1887	1.9369	-0.006698	0.28023	-0.30573	0.72702
		(-3.861)	-6.84	(-5.212)	
1888	2.0532	-0.005624	0.13506	-0.008514	0.42425
		(-2.952)	-2.696	(-1.701)	
<i>Note: t-ratios are shown in parentheses</i>					
Y: Average revenue per local ton-mile ÷ Average revenue per ton-mile carried through					
X_1 : Average length of the local haul, in miles.					
X_2 : Ton-miles of through traffic ÷ Local ton-miles					
X_3 : Freight revenue ÷ Passenger revenue					

⁶⁶ Cincinnati, Hamilton, & Dayton Railroad Co., *Annual Report of the Directors for the Year Ended March 31, 1887*, p. 11.

The argument of the last part of this chapter may be related to Peltzman's theory of regulation, according to which regulators buy votes with cross-subsidization.⁶⁷ The interests of state railroad commissioners dictated that they favor pooling of interstate through traffic, which would have created revenues that could be dissipated in rate reductions ("subsidies") for the local traffic in their constituencies. The Kansas commissioner urged the Senate to allow pooling in 1885, and the Cullom Committee agreed.⁶⁸ A National Convention of Railroad Commissioners received a favorable report on pooling in 1894, and passed a resolution urging Congress to make a suitable amendment to the Interstate Commerce Act.⁶⁹ The Act was passed to facilitate collusion but had outlawed pooling as a compromise with the rival House Bill for the regulation of interstate commerce.⁷⁰

CHAPTER VII EXTERNALITIES IN RATE MAKING

Here is a problem for the theory of second-best posed by the theory of second-and-a-half best: Suppose two pairs of railroads, one operating as unconstrained monopolists, the other under an effective revenue constraint. They may be located in different States, one with and another without a railroad regulating commission. Within each pair there is a large amount of interchange traffic. This through traffic poses a rate-making problem which may find its best solution in a merger of the cooperating companies. So let there be two mergers, one in each State. Then the paradox is this: the merger of unregulated roads will definitely lead to a reduction of through rates,⁷¹ whereas the merger of the constrained firms may (just may) result in tariff increases. If a merger should prove more expensive than an agreement on through rates by companies retaining their separate identities, the profit-maximizing ones will have a greater incentive to reach such an agreement on reduced through rates than a pair of firms constrained by competition.

Consider a route from A to C through B, and suppose it is worked by two railways, one running only from A to B, the other making the connection from B to C. The distance from A to B is x_1 miles; from B to C it is x_2 miles. The freight per ton from A to C is either $f(x_1) + f(x_2)$, if railroads operate independently of each other, or $f(x_1 + x_2) = f(x)$, if they set through rates and deal with shippers as if they were a single company.

If they make rates independently of each other, the tonnage shipped from A to C is

$$q = g \frac{[v - f(x_1) - f(x_2)]^n}{v}$$

and the profit of the railroad from A to B is

⁶⁷ Sam Peltzman, "Towards a More General Theory of Regulation," *Journal of Law and Economics*, 19 (1976) 211-40, and "Pricing in Public and Private Enterprises: Electric Utilities in the United States," *Journal of Law and Economics*, 14 (1971) 109-48.

⁶⁸ *Cullom Report*, Appendix 7.

⁶⁹ Interstate Commerce Commission, *Proceedings of a National Convention of Railroad Commissioners*, Washington, D. C., 1894, pp. 9-34.

⁷⁰ G. W. Hilton, "The Consistency of the Interstate Commerce Act," *Journal of Law and Economics*, 9 (1966) 87-114.

⁷¹ This is a familiar problem in monopoly and has a very long history. Ellet knew it in 1840 (see Ekelund and Hooks). Launhardt discussed it in his *Mathematische Begründung der Volkswirtschaftslehre*, 1885, p. 196, and thought it was a reason to favor nationalization, while Haddock used it to explain the drive towards government regulation.

$$S_1 = \frac{g}{v^n} [v - f(x_1) - f(x_2)]^n [f(x_1) - bx_1]$$

Treating $f(x_2)$, the rate set by the other railway, as a constant, S is maximized when

$$\frac{dS_1}{d[f(x_1)]} = 0 \text{ or when } (n+1)f(x_1) = v - f(x_2) + nbx_1.$$

Similarly, for the other railway's profit-maximizing rate

$$(n+1)f(x_2) = v - f(x_1) + nbx_2.$$

Solving these two equations for the equilibrium tariffs we obtain

$$f(x_1) = \frac{nv + nb[(n+1)x_1 - x_2]}{(n+1)^2 - 1}; f(x_2) = \frac{nv + nb[(n+1)x_2 - x_1]}{(n+1)^2 - 1}$$

and for the entire haul

$$f(x_1) + f(x_2) = \frac{2nv + n^2bx}{(n+1)^2 - 1}$$

The corresponding profit of each of the two railroads is

$$S_1 = S_2 = \frac{gn^{2n+1}(v - bx)^{n+1}}{v^n[(n+1)^2 - 1]^{n+1}}.$$

This is a curious equilibrium in which a short line makes as much profit as a long one. The advice to investors must have been to build branch lines, only to sell them to the main line at inflated prices, or it exchange for "watered stock."

If the two railroads act as one company, their joint profit is

$$S = \frac{g}{v^n} [v - f(x)]^n [f(x) - bx],$$

which is maximized at

$$S = \frac{n^n g(v - bx)^{n+1}}{v^n (n+1)^{n+1}}$$

by the through rate $f(x) = \frac{v}{n+1} + \frac{nbx}{n+1}$.

The difference between the through rate and the sum of local rates is

$$f(x) - f(x_1) - f(x_2) = \frac{bx - v}{3 + n + \frac{2}{n}} < 0,$$

and the joint profit is always greater than the sum of independently arrived at profits. Thus it is profitable to internalize through traffic, and it is in the public interest that separate railroads act as one in certain respects. The cooperation can extend even further, as when export rates are made lower than domestic

rates.⁷² But the division of through rates poses a bilateral monopoly problem in whose solution the short line may not be interested. Both Parliament and Congress had more than their fair share of shipper complaints about their inability to get through rates made for them.

Now suppose the line from A to B had made its tariffs with a factor m_1 , and the line from B to C had m_2 in its tariff equation. If they merge, the market, or the regulators, will work out a new average m . If there is going to be a large increase in profits from through traffic, the new m may fall below the old. If not, it will stay between them, so some rates will rise and others will fall. Room for rate increases exists, because rates are not assumed to have been at their profit maximizing level before. There is no sure way to predict the effect of merger on prices, whereas if we started from unmitigated monopoly, the new rates would definitely be lower.

If instead of merger we had a traffic agreement, profit-maximizing firms would reduce their rates on through traffic, pocket the additional profits from it, and leave their local rates at their previous and profitable levels. But constrained firms would find the increase in profits from through traffic mandates a decrease in their m , and a reduction of all their local rates. That makes agreement with the other lines more expensive and recommends the simpler practice of booking through by the addition of local rates. Companies refused to furnish through cars at stations between competing points, and the through traffic was developed by separate fast freight lines.⁷³

In England the authors of the *Report from the Joint Select Committee of the House of Lords and the House of Commons on Railway Companies Amalgamations*, 1872, found that

“The case of the North Eastern is a striking illustration. That railway, or system of railways, is composed of 37 lines, several of which formerly competed with each other. Before their amalgamation they had, generally speaking, high rates and fares and low dividends. The system is now the most complete monopoly in the United Kingdom, from the Tyne to the Humber, with one local exception; it has the country to itself, and it has the lowest fares and the highest dividend of any large English railway. It has had little or no litigation with other companies. Whilst complaints have been heard from Lancashire and Yorkshire, where there are so-called competing lines, no witness has appeared to complain of the North Eastern, and the general feeling in the district it serves appears favorable to its management” (p xxvii).

They added

“much of the evidence against the proposed amalgamations is directed against alleged general defects in the existing railway system, rather than against any new evils to arise from the extension of monopoly” (p, xxxi),

and concluded that

“the result (of amalgamations) to the railway companies would be unmixed good, whilst to the public they would not be unmixed evil” (pp, xli-xlii).

Unmixed good fell on the citizens of New Hampshire in 1884, when the Boston and Lowell leased the Concord and Montreal and the Northern. Through rates from Boston to points in New Hampshire, and local rates from Concord, were reduced by 34 percent: They were also made to correspond more closely to distance, thus eliminating the more objectionable discriminations.⁷⁴ At about the same time, the lease

⁷² *Royal Commission on Railways*, 1867, Q. 13,277-13,283.

⁷³ *Windom Committee Report*, Part II, 277, and 128-131.

⁷⁴ George F. Page, *Argument on Behalf of the Business Interests of New Hampshire, Before the Railroad Committees of the New Hampshire Legislature, In Favor of the Passage of House Bill No. 28*, Concord, 1887.

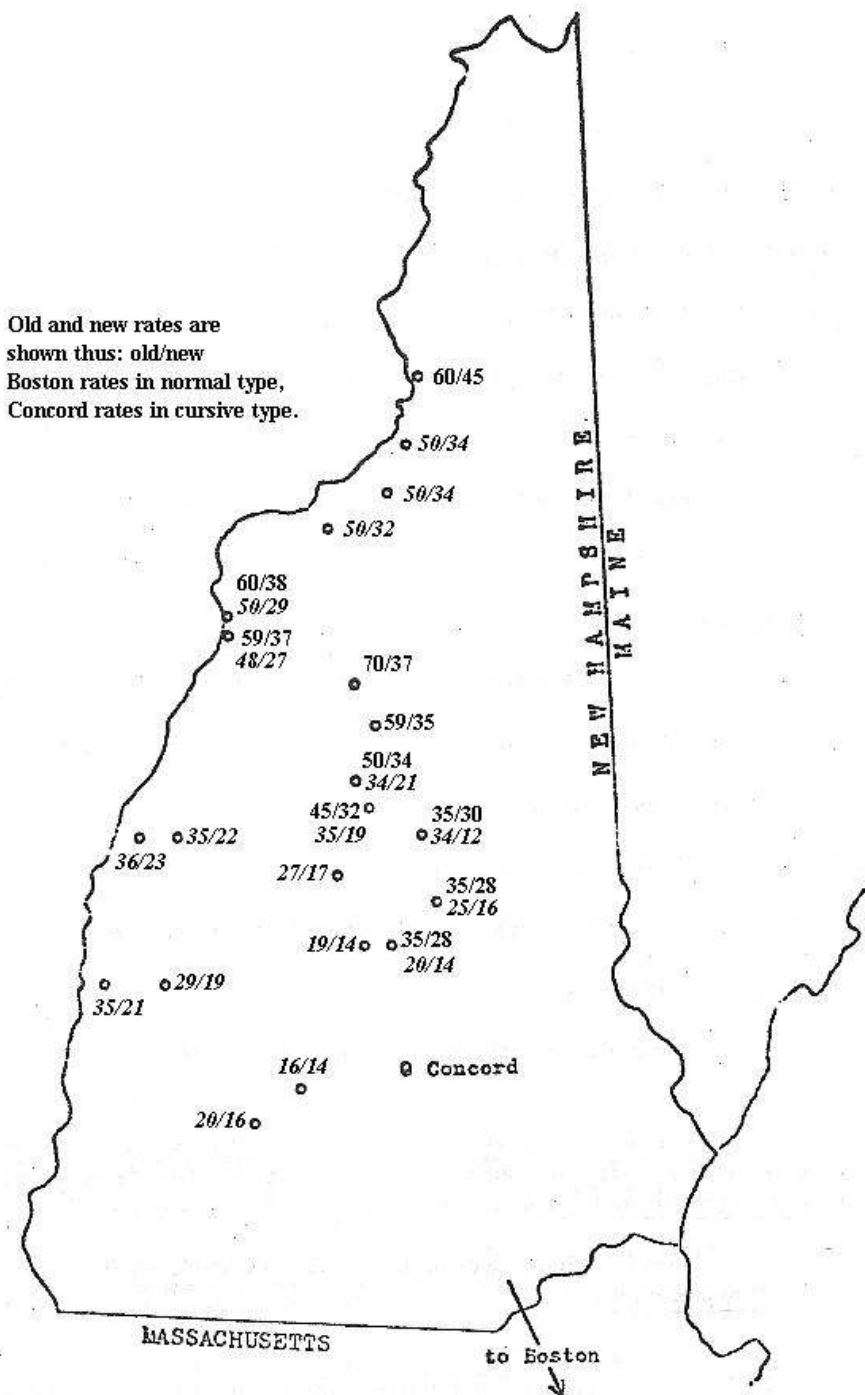


Figure 6.—New Hampshire: Class I rates in effect in 1884 and reduced on 18 May 1885.

of the Eastern Railroad by the Boston and Maine brought about similar, but less pronounced rate reductions.⁷⁵

Around the turn of the century a wave of mergers swept the South, by which railroads sought a substitute for the outlawed Southern Railway and Steamship Association pool. Under the pool's basing point pricing system, through traffic was charged with the addition of local rates.⁷⁶ In Mississippi, the mergers should have reduced these rates by, say, 34 percent, especially since they had the assistance of 21 years' cost reductions and entry. Since this didn't happen, it strengthens the impression that there was unused monopoly power looking for employment in 1886. The relative importance of through traffic, and the extent of problems that may be expected from it, can be measured by the ratio of the total tonnage transported to the number of tons originating. This is a measure of the extent to which traffic is double-counted when a ton originated on one railway is carried to its destination by two or more other railroads. In the year 1911, after many consolidations, this was 1.78, but only 1.4 in the West, 1.42 in the South, and 2.13 in the East.⁷⁷ In Argentina this statistic was 1.34 in 1905, and only 1.23 after deduction from that year's interchange traffic of the business internalized by mergers effected between 1906 and 1913.⁷⁸ The companies operating there used informal controls on entry to divide the territory and develop networks that minimized the number of competitive points and the volume of interchange traffic. This different organization of the industry did not have obvious effects on tariffs. A comparison of Argentine and North American freight rates on wheat showed Argentine rates higher for long distances, but lower for short hauls.⁷⁹ Their higher marginal cost pulled up the Argentine rates on long marginal hauls. Being more tightly monopolized, the Argentine railway industry could look for a profit on every intra-marginal shipment. However, the comparison with American rates implied a lower ratio of terminal to conveyance rates (t / r). In 1905, the highest Argentine t / r on first class freight was 114.⁸⁰ This compares favorably with the ratios found on the previous pages.

⁷⁵ James F. Briggs, *Speech Before the Railroad Committee of the House of Representatives*, Concord, July 20, 1887, pp. 32- 3.

⁷⁶ W. H. Joubert, *Southern Freight Rates in Transition*, Ch. II, and James F. Doster, *Alabama's First Railroad Commission*, University of Alabama, 1949.

⁷⁷ Interstate Commerce Commission, *Statistics of Railways in the United States for the Year Ended June 30, 1911*, Washington, D.C., 1913, pp. 45-47. That was the first time that the Commission published tons originated.

⁷⁸ Argentine Republic, Dirección Nacional de Ferrocarriles, *Estadística de los Ferrocarriles en Explotación*, Tomo XIV, Año 1905, Buenos Aires 1906, Tables 19, 20, and 21.

⁷⁹ R. R. Kuczynski, "Freight Rates on Argentine and North American Wheat," *Journal of Political Economy*, 10 (1902) 333-60.

⁸⁰ Argentine Republic, *Estadística*, 14 , Table VI, 224. The highest t / r was that of the Entre Rios Railways, which were in competition with river navigation. To interpret the rate comparison, it must be mentioned that Argentine railways were not regulated in earnest until 1907, when a number of threats of entry had materialized and the federal government took over the entry controls.

cost indicated by OT (T for trucks). Although their cost is higher, they can quote lower prices up to a certain distance and divert traffic from several points on the railroad. The traffic diverted involves the shorter hauls, those that pay most of the tax graduated in concession to "the weaker members of the community," many of whom would not get road service because its cost exhausts v long before a can be reached.

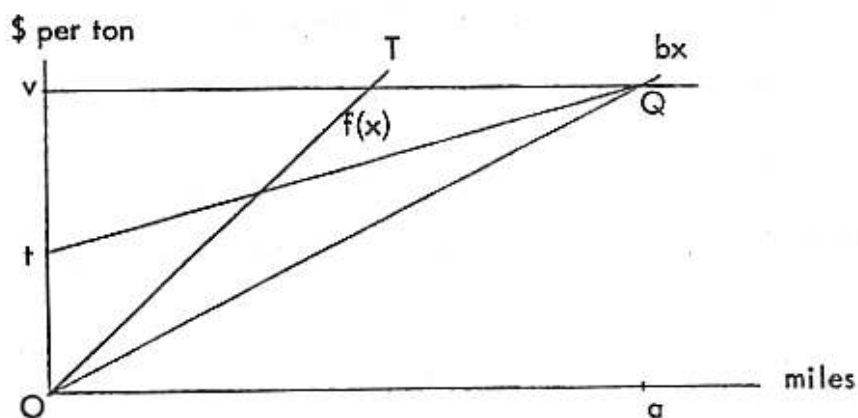


Figure 7.--Skimming the cream.

This is the "skimming off the cream of the traffic" that railroad officers used to complain of. The erosion of the railroad's tax base has nothing to do with the question of whether its two-part tariff is optimal or not. The criteria for an optimum are not the same as those for sustainability. The optimum railroad rate is made with reference to costs and demands alone, while sustainability depends on the comparison of tariffs with the cost of alternative arrangements.

The problem is older than trucks. There never was a two-part passenger fare. Fares were made proportional to distance, at so many cents per mile, and class discrimination was limited, because passengers had too many alternatives.⁸⁴

More important however is the assumption of a fixed entry cost K . The entrant does not have to pay it in full; he does not have to duplicate the existing firm's plant or offer identical services. He can develop an alternative route, find a short-cut, or build branch lines into the other fellow's territory. In the previous ADB example, he can charge his K to the trade at D and handle the competitive business at marginal cost. From the individual point of view, this is two-part pricing equivalent to marginal cost pricing. The AB traffic does not need the line through D . Therefore the ADB company will carry it at anything equal to or better than marginal cost. Only the traffic with D requires that additional capital be sunk into the new line, and therefore it alone must pay the fixed and common costs.⁸⁵

This type of marginal cost pricing produces local discriminations and long-haul rates lower than short-haul prices.⁸⁶ From the point of view of general welfare, it was objectionable because it restricted

⁸⁴ The directors of the Charleston and Hamburg Railroad claimed in 1836 that at the rates established "it is cheaper to owners of Negroes to pay their passage on the Railroad than to make them walk on the common road," U. B. Phillips, *A History of Transportation in the Eastern Cotton Belt to 1860*, New York, 1908, p. 155.

⁸⁵ *Cullom Committee Report*, App., 126-47, argument of H. S. Haines in favor of pooling the AB traffic.

⁸⁶ Nowadays one finds this when flying from A to B through an airline hub at C , turning there at an angle of less than 180° , and yet paying the same fare as another passenger flying direct along the arc from A to B with an airline that has its hub at either A or B . Neither of the two "competitive fares" is likely to signal costs or provide a guide to resource allocation. (Note added in 2001)

construction.⁸⁷ Tax revenue available at A and B is dissipated and construction is stopped short of the point at which an unchallenged monopoly would have equated marginal investment expenditures with marginal tax revenues. This is especially true considering the AB line as a marginal addition to a larger network. In this sense competitive output is less than monopoly output; which is not surprising, if one accepts the analogy with banking.

When competition erodes the tax base one can paraphrase Mr. Vanderbilt's "let the public be damned:" set a sustainable tariff, proportional to distance, like the line *OT* in Figure 7. That will make a third-best tariff and bring out the full meaning of Mr. Vanderbilt's outburst.

If this tariff is equal to marginal cost and there are increasing returns to scale, it will be inferior by failing to put a price on some factors of production. If it satisfies a minimum revenue constraint, it will cut traffic short at some point inwards of *a*, like the marginal cost plus fuel tax rejected by Ellet and Walters. Market areas will shrink; a lessened competition between markets is the price of greater competition in transport.

The Trunk Line cartel that pooled the traffic between Midwestern States and the Northeastern seaboard made through rates between competitive points proportional to distance.⁸⁸ This McGraham formula of rate-making was sustained from 1874 to 1931, until the Interstate Commerce Commission--strengthened by successive revisions of the Act--condemned it and prescribed what amounts to a two-part tariff for that territory.⁸⁹ Paul MacAvoy showed that the cartel prices invited entry; that new entrants profited by their action. Therefore, the proportional price exceeded marginal cost, although it fluctuated widely. The cartel rates were like the line *OT* in Figure 7. East of Chicago the scheme was modified a little, making the percentages of the New York-Chicago rate for points between Pittsburgh and Chicago reflect a small terminal charge. But for points West of Chicago, where the absolute deviation of price from cost was greatest, and the Mississippi River magnified the competitive pressure of lakes and canals, the rates were kept absolutely proportional.

By setting through rates proportional to distance, the cartel withdrew the cross-subsidies. Whatever taxes it continued to impose were assessed mostly on the traffic with Illinois. Even as late as 1880 there was very little traffic with more Western states. Of the tonnage carried from Western termini to points East of Trunk Line termini, 27 percent originated in Illinois, 21 percent in Ohio, and only 15 percent in Wisconsin, Iowa, and Missouri taken together.⁹⁰

One can understand that a battered pool would seek to avoid making any more waves by setting proportional, sustainable tariffs. But these rates were sustainable only in the abstract, not in Illinois, 1874, in an area between Lake Michigan, the Mississippi River, and the Ohio. How could the Trunk Line pool collect a heavy tax from an area with such magnificent alternatives? In the next and last chapter we shall see how Illinois shippers combined to give all power to the Eastern roads.⁹¹

⁸⁷ *Royal Commission on Railways*, 1857, Q, 14,873-76.

⁸⁸ The best description of the Trunk Line rate system is W. Z. Ripley's "The Trunk Line Rate System: A Distance Tariff," *Quarterly Journal of Economics*, 20 (1906) 183-210.

⁸⁹ Stuart Daggett, "Mileage Rates and the Interstate Commerce Commission," *Quarterly Journal of Economics*, 46 (1932) 295-99.

⁹⁰ Albert Fink, *Report Upon the Adjustment of Railroad Transportation Rates to the Seaboard*, New York, 1882, Statement E. There was a similar geographical distribution of backhauls.

⁹¹ *Addendum dated 2001*: We often had occasion to cite articles with the words "distance tariff" in their title. Such a choice of title seems peculiar to the American economists. Their fascination with distance tariffs may be symptomatic of dissatisfaction with competitive transport prices that did not reflect resource costs and thus failed as signals pointing to cheap routes and accessible markets.

CHAPTER IX AN INDUSTRY IN SEARCH OF REGULATION

We have seen that railways tended to set rates according to a two-part tariff. Their freight rates consisted of a terminal charge and a conveyance rate which determined the mileage charge. This could be interpreted as marginal cost pricing plus a tax, the terminal charge being a tonnage tax discriminating among varying lengths of haul after the deduction of a mileage subsidy. This type of discrimination was unobjectionable. An omniscient regulator would recommend it as the means to maximize public utility without resorting to deficit finance of an increasing returns industry.

The more common explanation of terminal charges by reference to terminal costs was found unsatisfactory. It is inconsistent with the fact that terminal charges could be competed away, and with substantial evidence of negative correlation between the two parts of the tariff implied by the tax-cum-subsidy theory.

We also saw bits and pieces of evidence suggesting that indirect competition could have regulated two-part tariffs. But even if this had qualified for the second-best, it created more problems than it solved.

A railway's terminal charges invite entry and a more direct competition between common points or along parallel lines. But this competition could not reasonably be expected to reduce prices to marginal cost. Instead, its effects were, first, to make rates proportional to distance, disregarding the omniscient regulator's prescription; and, second, to create new and more objectionable discriminations that redistributed the incidence of the tax with some unspecified welfare cost. Unsatisfactory as it was, this direct competition was inevitable, and it may have been necessary to back up the credibility of the indirect one.

Another effect of competition was to make railways less willing to solve the joint monopoly problem created by their interchange traffic. The refusal to agree on a joint through rate is one line of defense of the regulator's prescription against erosion by competition, and it is made cheaper by competition and regulation. For the regulator, this creates a dilemma since he would just as much grant railways the right of refusal to make joint rates, as he would like to force them to an agreement whenever it should be in the public interest.

Thus a competition that made the prices of flour and cloth and shoes equal and reasonable made fares and freights unequal and unreasonable. And there was no abstract law that could solve the problem.⁹² This was probably most evident in Illinois, and may explain why railroad regulation by commission began in that State.

First, railroads were not extended from East to West as continuous lines. The Lake at Chicago and the great rivers in the Midwest produced a break. Of course the traffic went through, but the very same reasons that made Chicago a magnet for railroads prevented their agreement on joint through rates between East and West. Instead, through rates were made by combining a Western line's local rate with the Eastern cartel price.⁹³ This was inefficient, but competition among Eastern roads---governed by Lake rates---made it impossible to adhere to agreed through rates and their division. Western railroads simply refused to furnish through cars to the East at stations between competing points. The Burlington made rates jointly with its Western connections at Burlington, Quincy, and Keokuk, but not with Lake boats to Buffalo. But in the 1860's and 1870's pro-rated joint rates were made by the Erie and Pennsylvania railroads with Lake

⁹² Charles Francis Adams, *Railroads, their Origin and Problems*, New York, 1878, p. 128.

⁹³ Albert Fink, in *Cullom Committee Report*, 14 .

boats from Buffalo, by the Baltimore and Ohio with river boats, and by the Illinois Central with Mississippi River boats and Southern railways.⁹⁴

The lack of through rates was not a serious problem in the 1860's, since even in 1871 there was little freight sent through Chicago by rail, virtually all the grain having been transported East by Lake.⁹⁵ But the problem was soon highlighted by the consolidation of lines East of Chicago---begun by the Lake Shore in 1869---⁹⁶ and the ensuing rate reductions and agreements on through rates between common points and the Eastern Seaboard.

That joint rates were not made would not have mattered to shippers, if the Eastern roads had charged marginal cost prices for the connection. But they did not. They taxed the Illinois traffic, and the Western roads, having alternative connections by Lake and rivers, did not see fit to internalize the externalities created by the interchange traffic. In the early 1870's they were the short lines that profited from through traffic as much as the longer lines to the seaboard. That is why Eastern roads built or acquired extensions into the West, bypassing Chicago.⁹⁷

The unresolved joint monopoly problem allowed Western roads to raise their rates whenever Eastern rates fell. Contrary to what is usually expected of competitive industries, a price reduction in one market---the East, on the opening of navigation in Spring---did not increase supply to the adjacent market and reduce prices there as well. Instead, a rate reduction in the East had the effect of an increased v of the local tariff in the West:

"Under ordinary circumstances, the comparatively low cost of lake and canal transportation, of which we take advantage during the season of navigation in forwarding freight to the Atlantic cities, enables us to obtain fair rates upon our part of the through route; but during the past year the capacity of lake vessels was found to be quite inadequate to meet, in addition to the ordinary demands, the very extraordinary one for transporting materials for the rebuilding of Chicago. The result was an advance of from 2 to 300 percent in lake freights, which compelled us to accept very much less than our usual proportion of the through rate."⁹⁸

This was annoying because most of the East-bound traffic was collected from branch lines under local tariffs.⁹⁹

Second, railway rates were liable to undergo gyrations that threatened the shippers' acquired positions. The average revenue per ton-mile had been falling steadily since the Civil War and complaints about the level of rates were becoming rare.¹⁰⁰ But cost reductions mirrored in the declining revenue per ton-mile brought about changes in the relative sizes of terminal charges and conveyance rates. These

⁹⁴ *Windom Committee Report*, Part II, pp. 44, 266, 277, 366, 898, and 939; and Chicago, Burlington, & Quincy Railroad Company, *Annual Report of the Directors*, 1866-1874.

⁹⁵ Paul MacAvoy, *The Economic Effects of Regulation*, p. 6.

⁹⁶ *Ibid.*, 13 ff.

⁹⁷ "A Change in the Course of Traffic," *Railroad Gazette*, 6 (15 June 1872) 252; G. H. Miller, *Railroads and the Granger Laws*, Madison, 1971, shows the new extensions on a map on page 60.

⁹⁸ Chicago and Alton Railroad, *Report for 1871*, p. 7. Albert Fink noted the same thing happening at Atlantic ports. Ocean rates increased in summer, and fell when canals froze over. *Report Upon the Adjustment of Railroad Transportation Rates to the Seaboard*, 1882, p. 25.

⁹⁹ Albert Fink, *Report Upon the Adjustment of Railroad Transportation Rates to the Seaboard*, p. 21.

¹⁰⁰ Complaints were about discrimination. Illinois Railroad and Warehouse Commission, *First Annual Report*, 1871, Springfield, 1872, p. 19.

changes meant that shippers did not benefit equally from cost reductions in the way that purchasers of, say, flour, benefit equally from a decline in the cost of flour. Only marginal shippers could be sure of getting the full benefit, which was small consolation for being marginal. In Illinois, short-haul shippers got the worst deal, whether the general rate level went up or down.

The rates of the Illinois Central, for instance, were raised during wartime inflation. But the increase was proportionately greater for short hauls than for long hauls, because the Civil War had reduced the demand for transport to Cairo and points South of it. After the War, merchandise rates were reduced, but more for longer than for shorter hauls, and not at all for the shortest. At the same time rates were actually increased on some bulky goods such as coal, whose market was improving.

TABLE 8			
EXTRACT OF ILLINOIS CENTRAL RATES			
	July 1859	Sept. 1864	Nov. 1874
CLASS I, in cents per 100 lbs.			
13 miles - Chicago to Calumet	10	22	22
352 miles - Cairo to Calumet	70	90	77.5
365 miles - Chicago to Cairo	60	90	77.5
COAL, in dollars per ton			
10 mile haul	0.5	0.6	0.85
140 mile haul	2.35	2.05	2.5
<i>Sources:</i> Illinois Central Railroad, <i>Local Freight Tariff</i> , July 1, 1859, and September 1, 1864; Illinois Railroad and Warehouse Commission, <i>Fourth Annual Report</i> , 1874, pp. 378 and 394.			

Further West the contrast between rates for long and short hauls was not so great. Western railroads did not have the same opportunity as those in Illinois to exploit through traffic by setting high terminal charges. Compare, for example, the 1870 merchandise rates of the Illinois Central and Union Pacific Railroads (on p. 8 above).¹⁰¹

Third, the railroads of Illinois---since the Western extension of Eastern Trunk lines---ran at right angles, from East to West and from North to South. They were torn between their junctions with Eastern roads, the Lake at Chicago, and the Mississippi River. Competition among right-angled railroads trying to attract traffic to three markets at once did not eliminate price discrimination; rather, it created a plague of long and short haul discriminations. Neither did it break local monopolies, although it could bankrupt them. When it did, the bankrupt's terminal charges could still attract selective entry, which shifted increasing tax burdens onto the remaining non-competitive points. The diversion of trade from Chicago was a constant source of editorial comment in 1869.¹⁰² It would have been greater than it was, if the Eastern cartel had not maintained its rates at artificially high levels, and if the North-South roads had not

¹⁰¹ See also *Windom Committee Report*, 1874, Part I, p. 96.

¹⁰² Miller, *Railroads and the Granger Laws*, pp. 78-82.

abandoned the distance principle when making rates for the transport of goods from competing points to Chicago.

Thus shippers in Illinois had three complaints: (1) impossibility of getting through rates to the East; (2) unfavorable distribution of tax burdens by a high t / r in local rates and a third-best tariff on their Eastern trade; and (3) many long haul rates being absolutely lower than short haul rates. But not everybody in Illinois had all three complaints at once. In the Northern parts of the State they were still fighting battles lost by the anti-monopoly leagues, they were in an area not penetrated by Eastern roads. The merchants of Chicago complained about the diversion of their trade. Farmers in the South complained about long and short haul discriminations, but would have liked more railroads and more competing points. The new State Constitution of 1869 included inter-alia an article subjecting railroad property "to public necessity." The vote was six to one in favor of this article, with the most solid support given in the northern third of the State. In the South it was feared that regulation would keep railroads from coming.¹⁰³

The first attempt to regulate railroads was inevitably inept. By strictly enforcing an Act outlawing short and long haul discrimination, the Illinois legislature made it difficult for the North-South railways to route East-bound traffic through Chicago, and the East-West roads were strengthened. It was as if the value of Lake Michigan had been knocked off the locational rent of lands close to competing points.

After a revision of the Act in 1873 to remove a legal defect, the Rock Island raised its rate from Chicago to Peoria from 35 cents per hundred pounds of first class goods to 67 cents; and the fourth class rate went up from 20 to 34 cents. The fourth class rate from Chicago to Rock Island was increased from 25 to 39 cents, all to remove long and short haul discriminations. It was better for them to give up the competitive traffic, than to reduce all rates to the competitive level. The Indianapolis, Bloomington, and Western changed its rates so it could take goods from Cincinnati to Lincoln for 33 cents a hundred, which was about half what the Chicago and Alton charged from Chicago to Lincoln, although the distance from Chicago to Lincoln was less than half the mileage from Cincinnati.¹⁰⁴ Traffic on the Chicago and Alton fell, since they actually let the East-West roads take all the business of competing points,¹⁰⁵ and raised the local rates between non-competing points.¹⁰⁶ The Illinois Central management concluded that Chicago had ceased to be the great entrepot for the grain products of the country West and South of it. They reduced their rates for grain to Chicago from local stations on their line from twenty to thirty percent, and lumber rates at most points were cut by fifty percent and over.¹⁰⁷ The Chicago and Northwestern had no such problems, because it possessed the shortest routes and was therefore able to adhere to a distance tariff.¹⁰⁸ This made it somewhat impervious to regulation, and may explain also its continued profitability in spite of Federal regulation, which had puzzled Haddock.¹⁰⁹

¹⁰³ *Ibid.*, p. 74.

¹⁰⁴ *Railroad Gazette*, 7 (7 June 1873) 231.

¹⁰⁵ Chicago and Alton Railroad Company, *Report of the President and Directors for the Year Ended December 31, 1874*, p. 14.

¹⁰⁶ *Railroad Gazette*, 7 (7 June 1873) 231.

¹⁰⁷ Illinois Central Railroad Company, *Annual Report for 1876*, p. 2.

¹⁰⁸ *Railroad Gazette*, 7 (21 June 1873) 250.

¹⁰⁹ Haddock, "Regulation of Railroads by Commission," p. 66. But the C & N.W. soon came to regret Wisconsin's and Iowa's version of regulation.

Thus it was no accident that the first Trunk Line cartel was organized in 1874.¹¹⁰ The cartel was made viable by the Illinois regulations of 1873. Neither was it an accident that the Baltimore and Ohio Railroad rushed to complete its extension to Chicago in 1874. That extension crossed all the feeder lines from southern Illinois.

The Illinois Legislature's second attempt at regulation was worse than its first. The Commission had been empowered to set maximum rates as standards of reasonableness, and set them at levels that allowed most railroads to raise terminal charges, but forced all of them to lower conveyance rates.¹¹¹ This bill was opposed by farmers, who called it a sell-out to railroads.¹¹² But the farmers did not know what railroads, and had no proposals of their own.

The Grangers had their eyes fixed on local discriminations caused by direct competition, and on the difference between average revenues per ton-mile on short and long hauls. They had little time to reason about anything else. Grain prices had been falling during 1865-71; farmers---many of them new settlers---were unable to pay their debts. With transportation charges reduced by competition from the East, the worst offenders among the railroads could not pay theirs. "There was a loss to be divided, instead of a profit. It was beyond the power of any law to divide this loss in such a way as to give a profit to both parties."¹¹³

One of the things the Grangers needed were cross-subsidizing through rates with the East, which no State law could prescribe. Instead, the law assisted the creation of the Eastern Trunk Line cartel and the maintenance of its peculiar pricing system. In this way an unresolved local problem was carried over to be dealt with at the Federal level.¹¹⁴

¹¹⁰ Paul MacAvoy, *The Economic Effects of Regulation*, pp. 13 and 39.

¹¹¹ Their first schedule of maximum rates is shown in their *Fourth Annual Report*, and compared it with rates then in force, pp. 378-94. Their policy was opposite to that of the South Carolina commission noted on p. 41 above.

¹¹² Miller, *Railroads and the Granger Laws*, p. 93.

¹¹³ A. T. Hadley, *Railroad Transportation, Its History and Its Laws*, New York, 1892, p. 131.

¹¹⁴ Carried over by, among others, Shelby Cullom, ex-Governor of Illinois, who was elected to the Senate just at the time when the Supreme Court struck down the State's attempt to regulate interstate commerce in *Wabash Railroad v. Illinois*. Hurt because the Senate would not give him a committee job as inflated as his ambition, he made one for himself drafting an interstate commerce bill. See his *Fifty Years of Public Service*, Chicago, 1911, p. 302 ff.

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APPENDIX

TABLE 9

ILLINOIS, CLASS D RATES— 1874
DOLLARS PER CARLOAD
0-200 MILES

	Railroad	t	r	R ²	i
1	Illinois Central	10.5608	0.12516	0.94016	19
2	Western Union	9.9604	0.13340	0.94440	20
3	Rockford, Rock Island, & St. Louis	9.7079	0.11104	0.98116	20
4	Chicago and Alton	9.5986	0.14221	0.96838	19
5	Ohio and Mississippi	9.4737	0.12709	0.88508	20
6	Chicago, Burlington, and Quincy	9.1756	0.14189	0.99202	20
7	Toledo, Peoria, and Warsaw	8.2369	0.14876	0.96276	20
8	Chicago, Danville, and Vincennes	8.0801	0.18237	0.97855	15
9	Peoria, Pekin, and Jacksonville	8.0132	0.16789	0.98517	13
10	Chicago, Rock Island and Pacific	7.9877	0.13592	0.99748	8
11	St. Louis, Vandalia & Terre Haute	7.9562	0.10963	0.96650	20
	Springfield & Illinois Southeastern				
	Paris and Decatur				
12	St. Louis and Southeastern	7.4213	0.13152	0.96819	8
13	Chicago, Pekin & Southwestern	6.0003	0.23017	0.88427	12
	Overall	9.1188	0.13250	0.92093	214

Source: Illinois Railroad and Warehouse Commission, *Fourth Annual Report*, Springfield, 1874, p. 393.

TABLE 10

ANALYSIS OF COVARIANCE OF ILLINOIS CLASS D RATES

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	63.597	1	63.5970
Deviations of the group means	280.362	11	25.4870
Between the individual slopes	107.173	12	8.9310
About the individual lines	453.026	188	2.4097
About the overall line	904.160	212	
Due to regression on overall line	10,530.260	1	
Total	11,434.420	213	

TABLE 11

ILLINOIS, COAL RATES— 1874
DOLLARS PER TON
0-200 MILES

	Railroad	t	r	R ²	i
1	Chicago, Burlington and Quincy	1.01810	0.0090408	0.98088	20
2	Illinois Central	0.89363	0.1063100	0.97906	19
3	Springfield & Illinois Southeastern	0.86057	0.0100140	0.93864	20
4	Chicago, Pekin, and Southwestern	0.83536	0.0082120	0.91119	11
5	Ohio and Mississippi	0.82854	0.0094790	0.99559	20
6	Peoria, Pekin, and Jacksonville	0.81133	0.0071600	0.66209	13
7	Chicago and Alton	0.79815	0.1034400	0.99289	19
8	Toledo, Wabash, and Western	0.78195	0.0103720	0.96382	19
9	Gilman, Clinton, and Springfield	0.73969	0.0117550	0.95918	15
10	Indianapolis, Bloomington, & Western	0.67607	0.0099690	0.95096	20
11	Toledo, Peoria, and Warsaw	0.66275	0.0111580	0.96614	20
12	Rockford, Rock Island, & Pacific	0.64994	0.0106270	0.97278	20
13	St. Louis, Vandalia & Terre Haute and Paris and Decatur	0.60056	0.1040600	0.99460	20
14	Western Union	0.58133	0.0128230	0.96722	20
15	Cairo & St. Louis	0.50889	0.0111150	0.99994	18
16	St. Louis and Southeastern	0.39299	0.0116610	0.93890	8
	Overall	0.72629	0.0105890	0.92747	282

Source: Illinois Railroad and Warehouse Commission, *Fourth Annual Report*, Springfield, 1874, p. 393.

TABLE 12

ANALYSIS OF COVARIANCE OF ILLINOIS COAL RATES

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	0.208	1	0.20800
Deviations of the group means	3.402	14	0.24300
Between the individual slopes	0.751	15	0.05007
About the individual lines	2.578	250	0.01031
About the overall line	6.940	280	
Due to regression on overall line	88.231	1	
Total	95.171	281	

Note: The hypothesis that the variance around the separate lines could be regarded as homogeneous can be rejected, and the correlation between t and r can be calculated at -0.60131, significantly different from zero at the two percent level.

TABLE 13

CLASS I RATES IN MISSISSIPPI, 1886
IN CENTS PER 100 LBS, UNREGULATED

	Railroad	t	r	R ²	i
1	Vicksburg and Meridian	62.0000	0.20000	1.00000	14
2	Illinois Central	40.9628	0.27398	0.94052	34
3	New Orleans and Northeastern	38.0500	0.32583	0.78786	16
4	Mobile and Ohio	37.3706	0.29793	0.92412	27
5	Yazoo and Mississippi Valley and Canton, Aberdeen & Nashville	32.3476	0.35731	0.91324	15 14
6	Natchez, Jackson, and Columbus	25.8515	0.38123	0.92025	24
7	Georgia Pacific, 3rd. Section	25.5000	0.50000	0.99206	4
8	Mobile and Northwestern	24.5479	0.50137	0.97152	6
9	Ship Island, Ripley & Kentucky	20.0207	0.68898	0.89989	4
10	Mississippi and Tennessee	19.2421	0.53729	0.99223	20
11	Kansas City, Memphis & Birmingham	18.5454	0.53202	0.98355	22
12	Georgia Pacific	16.2150	0.61579	0.99101	7
13	Memphis and Charleston	15.6571	0.54857	0.96807	6
14	East Tennessee, Virginia & Georgia	14.6667	0.40000	0.75000	3
15	Louisville and Nashville	10.1250	0.50000	0.97132	16
16	Alabama Great Southern	6.8000	1.44000	0.98182	4
	Overall	30.5627	0.34157	0.86057	236

Source: Mississippi Railroad Commission, Second Annual Report, Jackson, 1887, pp. 25-29.

TABLE 14			
ANALYSIS OF COVARIANCE OF MISSISSIPPI TARIFFS, 1886			
Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	1,512.140	1	1512.1400
Deviations of the group means	10,559.720	14	754.2700
Between the individual slopes	3,680.900	15	245.3900
About the individual lines	4,516.600	204	22.1400
About the overall line	20,269.360	234	
Due to regression on overall line	125,108.670	1	
Total	145,378.030	235	

TABLE 15					
CLASS I RATES IN NORTH CAROLINA, 1891 IN CENTS PER 100 LBS, UNREGULATED					
	Railroad	t	r	R ²	i
1	Georgia, Carolina and Northern	26.9720	0.23100	0.88259	20
2	Cape Fear and Yadkin Valley	24.1960	0.19641	0.88669	25
3	Marietta and North Georgia	19.4948	0.35397	0.99088	31
4	Charleston, Cincinnati & Chicago	19.4718	0.33835	0.96698	22
5	Western N. Carolina, Paint Rock Division	19.3263	0.29752	0.96710	21
6	Atlantic and North Carolina	16.7544	0.33544	0.97605	19
7	Chester and Lenoir	14.8571	0.49643	0.94599	7
8	Lynchburg and Durham	10.6008	0.47115	0.98448	23
9	Roanoke and Southern	10.3382	0.53643	0.89800	10
	Overall	20.9282	0.28580	0.86704	178

Source: Railroad Commission of North Carolina, First Annual Report, Raleigh, 1892, pp. 80-96.

TABLE 16

ANALYSIS OF COVARIANCE OF NORTH CAROLINA TARIFFS, 1891

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	58.820	1	58.8200
Deviations of the group means	2,175.590	7	310.8000
Between the individual slopes	3,360.500	8	420.0600
About the individual lines	2,086.400	160	13.0400
About the overall line	7,681.300	176	
Due to regression on overall line	50,090.840	1	
Total	57,772.140	177	

Note: This sample excludes railroads that already applied the commissioners' Standard Tariff, and several very small companies.

TABLE 17: CLASS I RATES IN MICHIGAN, 1898
IN CENTS PER 100 LBS, UNREGULATED

	From	Via	t	r	R ²	i
1	Allegan	D.T. & M.	11.9140	0.13401	0.93694	10
2		C. & W.M.	10.4215	0.16994	0.89706	15
3		L.S. & M.S.	12.8650	0.08199	0.88572	21
4	Adrian	L.S. & M.S.	10.9380	0.10074	0.93031	21
5	Cadillac	G.R. & I.	12.5081	0.13398	0.97469	15
6	Detroit	D.G.H. & M.	14.4993	0.10656	0.96651	5
7		M.C. Ry.	14.1264	0.08221	0.60361	7
8		D. G. R. & M.	12.0965	0.12933	0.97416	7
9	Grand Rapids	M.C. Ry.	13.2839	0.11011	0.89375	6
10		C. & W.M.	10.9866	0.16011	0.99561	6
11		D.G.R. & W.	12.9885	0.12102	0.94464	6
12		G.R. & I.	11.5153	0.15731	0.97974	10
13		D.G.H. & M.	13.8454	0.11738	0.95015	6
14		L.S. & M.S.	12.4132	0.08030	0.75727	9
15	Jackson	L.S. & M.S.	9.3034	0.17225	0.67605	5
16		M.C. Ry.	10.4576	0.15860	0.86775	12
17	Kalamazoo	M.C. Ry.	11.7219	0.13152	0.96371	9
18		G.R. & I.	11.0847	0.10455	0.97541	10
19		L.S. & M.S.	10.4748	0.16659	0.97352	6
20	Lansing	L.S. & M.S.	10.0414	0.08647	0.99436	3
21		D.G.R. & W.	11.3190	0.15412	0.96500	6
22		M.C. Ry.	14.9746	0.09727	0.70714	5
23		C. & G.T.	12.9706	0.11392	0.93942	11
24	Manistee	F. & P.M.	15.5929	0.09245	0.95462	15
25	Mackinaw City	G.R. & I.	15.4348	0.10733	0.98233	19
26	Saginaw	F. & P.M.	12.4712	0.13929	0.83477	13
	Overall		13.2998	0.10353	0.87121	258
	<i>Outliers:</i>					
	Marquette	D.S.S. & A.	18.4676	0.17390	0.73345	11
	Mackinaw City	D.S.S. & A.	20.7995	0.14973	0.91360	13

Note: These were local intra- and inter-state rates, unregulated insofar as the Michigan Railroad Commission lacked interest in the matter and the Interstate Commerce Commission had been emasculated by the Courts.

Source: Railroad Commission of Michigan, *Twenty-Sixth Annual Report*, Lansing, 1899, pp. ccxxvii-ccxxxvii

TABLE 18

ANALYSIS OF COVARIANCE OF MICHIGAN TARIFFS, 1898

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	84.300	1	84.3000
Deviations of the group means about their regression lines	788.020	24	32.8340
Between the individual slopes	381.310	25	15.2520
About the individual lines	792.140	206	3.8450
About the overall line	2,045.770	256	
Due to regression on overall line	13,838.880	1	
Total	15,884.660	257	

Note: the coefficient of simple correlation between tariff parts $R_{t,r}$ is -0.59416.

TABLE 19

CLASS I RATES IN ARKANSAS, YEAR 1900
IN CENTS PER 100 LBS, UNREGULATED

	Railroad	t	r	R ²	i
1	St. Louis and Southwestern, and St. Louis, Iron Mountain, & Southern	19.4000	0.44353	0.98334	25
	do. do. from Little Rock:				
2	Main Line	18.1198	0.45006	0.98432	13
3	Main Line North	16.0024	0.57866	0.98138	15
4	Fort Smith Branch	28.5783	0.19412	0.91894	16
5	Kansas City, Fort Scott & Memphis	23.0571	0.35681	0.89487	25
6	Choctaw and Memphis	28.2402	0.68095	0.98491	25
	Overall	22.8470	0.37391	0.86001	118

Source: Arkansas Railroad Commission, *First Annual Report*, Little Rock, 1901, Exhibits Nos. 1-7.

Note: Taking the tariff lines in pairs, one finds that equations (1) and (2) have the same slope, and the equality of slopes in equations (5) and (6) can be denied with only 80 percent confidence. The coefficient of correlation between *t* and *r* in any four unequally sloped tariff lines ranges from -0.862 to -0.996, significantly different from zero at from 15 to one percent.

TABLE 20

ANALYSIS OF COVARIANCE OF ARKANSAS TARIFFS, 1900

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between <i>r</i> and \bar{r}	172.820	1	172.8200
Deviations of the group means about their regression line	1,947.700	4	486.9200
Between the individual slopes	1,044.860	5	208.9700
About the individual lines	999.100	106	9.4200
About the overall line	4,164.490	116	
Due to regression on overall line	26,014.630	1	
Total	30,177.120	117	

TABLE 21

CLASS I RATES IN INDIANA, 1906
IN CENTS PER 100 LBS, UNREGULATED

	Railroad	t	r	R ²	i
	Cleveland, Cincinnati, Chicago and St. Louis R.R.:				
1	Peoria and Eastern Division, West	15.1313	0.15079	0.75061	15
2	do. do. do. do., East	9.6911	0.14098	0.86043	13
3	St. Louis Division	13.5962	0.17324	0.75195	17
4	Chicago Division, East	10.1548	0.17273	0.86049	21
5	do.do. West	7.1886	0.22228	0.87700	19
6	Indianapolis Division	9.6765	0.18039	0.89339	17
7	Michigan Division	9.4596	0.15432	0.88542	16
	Overall	11.7800	0.14730	0.76546	128
	Pittsburgh, Cincinnati, Chicago and St. Louis R.R.:				
1	Logansport Division	10.5574	0.12336	0.96272	19
2	Effner Branch	10.5334	0.12563	0.94257	11
3	Indianapolis Division	4.6813	0.16088	0.89632	14
4	Louisville Division	3.3557	0.20141	0.97947	23
5	Richmond Division	2.9444	0.21007	0.99252	8
6	Madison Division	0.7500	0.24000	0.99435	10
	Overall	4.9596	0.17277	0.96230	85
	Chicago, Indianapolis and Louisville R.R.:				
1	"Monon Route"	19.5945	0.08013	0.94769	8
2	Chicago-Indianapolis Division	13.4824	0.13258	0.88854	28
3	Second Division	15.6851	0.07810	0.81812	21
	Overall	17.7970	0.07628	0.78884	57
	Vandalia Railroad:				
1	Michigan Division	18.7058	0.05875	0.89593	35
2	St. Louis Division	14.4546	0.16668	0.76685	16
3	Vincennes Division	3.8626	0.19212	0.96070	24
	Overall	13.6920	0.08689	0.72127	75

Source: Railroad Commission of Indiana, *First Annual Report*, Indianapolis, 1906, Appendix V.

TABLE 22

CLASS I RATES IN INDIANA, 1906
IN CENTS PER 100 LBS, UNREGULATED

	Railroad	t	r	R ²	i
1	Chicago and Wabash Valley	18.6805	0.16885	0.87285	30
2	Evansville and Indianapolis (from Terre Haute)	17.1460	0.11033	0.74232	24
3	Chicago and Eastern Illinois	14.9326	0.11921	0.96320	30
	Evansville and Terre Haute:				
4	From Terre Haute	14.6378	0.14247	0.90000	23
5	From Evansville	13.2178	0.17927	0.84099	15
	Cincinnati, Hamilton & Dayton:				
6	Springfield Division, West	12.2952	0.20260	0.92064	15
7	do. do., East	4.0864	0.18337	0.92530	17
8	Wabash	12.2686	0.12016	0.95220	21
9	Lake Erie and Western	10.9308	0.13336	0.95525	33
10	Grand Trunk Western	10.8526	0.16996	0.95976	14
11	Grand Rapids and Indiana	10.3579	0.18205	0.97675	19
12	Lake Shore and Michigan Southern	10.0085	0.13221	0.98430	30
13	Baltimore and Ohio	8.7846	0.15518	0.97634	26
14	Pittsburgh, Fort Wayne and Chicago	8.5429	0.17704	0.96230	24
15	New York, Chicago and St. Louis	8.1320	0.20156	0.95945	22
16	Central Indiana	7.2437	0.16528	0.98945	12
17	Baltimore and Ohio Southwestern	7.1290	0.15448	0.97000	32
18	Indianapolis Southern	1.7866	0.39033	0.96619	12
	Overall	9.0815	0.17451	0.63453	399

Source: Railroad Commission of Indiana, *First Annual Report*, Indianapolis, 1906, Appendix V.

TABLE 23

ANALYSIS OF COVARIANCE OF INDIANA TARIFFS, 1906

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Cleveland, Cincinnati, Chicago and St. Louis R.R.:			
Between r and \check{r}	142.950	1	142.9500
Deviations of the group means	406.840	5	81.3670
Between the individual slopes	57.870	6	9.6460
About the individual lines	523.330	114	4.5910
About the overall line	1,130.990	126	
Due to regression on overall line	3,691.030	1	
Total	4,822.020	127	
Pittsburgh, Cincinnati, Chicago and St. Louis R.R.:			
Between r and \check{r}	0.436	1	0.4360
Deviations of the group means	22.130	4	5.5320
Between the individual slopes	81.264	5	16.2530
About the individual lines	52.875	73	0.7240
About the overall line	156.704	83	
Due to regression on overall line	3,999.950	1	
Total	4,156.650	84	
Chicago, Indianapolis and Louisville R.R.:			
Between r and \check{r}	205.370	1	205.3700
Deviations of the group means	39.910	1	39.9100
Between the individual slopes	98.660	2	49.3280
About the individual lines	241.440	51	4.7280
About the overall line	585.380	55	
Due to regression on overall line	2,185.860	1	
Total	2,770.940	56	
Vandalia Railroad:			
Between r and \check{r}	0.162	1	0.1620

Deviations of the group means	533.680	1	533.6800
Between the individual slopes	473.110	2	236.5600
About the individual lines	166.210	69	2.4088
About the overall line	1,173.160	73	
Due to regression on overall line	3,035.700	1	
Total	4,208.860	74	
The Remaining 18 Railroads:			
Between r and \check{r}	2,308.620	1	2308.6200
Deviations of the group means	8,011.596	16	500.7200
Between the individual slopes	537.980	17	31.6460
About the individual lines	846.740	363	2.1220
About the overall line	11,704.940	397	
Due to regression on overall line	20,321.920	1	
Total	32,026.860	398	

TABLE 24			
ANALYSIS OF COVARIANCE OF INDIANA TARIFFS, 1906 CLASS I RATES OF 37 RAILROADS			
Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	1,315.040	1	1315.0400
Deviations of the group means about their regression lines	8,064.330	35	230.4100
Between the individual slopes	1,865.910	36	51.8310
About the individual lines	1,830.290	670	2.7318
About the overall line	13,075.570	742	
Due to regression on overall line	27,727.470	1	
Total	40,803.040	743	

TABLE 25		
COEFFICIENTS OF SIMPLE CORRELATION BETWEEN TERMINAL CHARGES AND CONVEYANCE RATES OF RAILROADS IN INDIANA, 1906 CLASS I RATES		
Railroad	$R_{t,r}$	Significance level
Cleveland, Cincinnati, Chicago and St. Louis	-0.50976	25%
Pittsburgh, Cincinnati, Chicago and St. Louis	-0.96491	0.2%
Chicago, Indianapolis and Louisville	-0.75423	46%
Vandalia	-0.83383	40%
The Remaining 18	-0.61628	0.8%
do. do. do. after eliminating an outlier (the 18th.)	-0.40894	10%
All 37	-0.69334	0.1%

TABLE 26: CLASS I RATES IN ALABAMA, 1905
IN CENTS PER 100 LBS, REGULATED

	Railroad	t	r	R ²	i	
Range of x: 10-300 miles						
1	Alabama Great Southern	31.6816	0.19764	0.82321	21	
2	Southern	31.6713	0.23846	0.97346	30	
3	Louisville and Nashville	26.2861	0.23679	0.84418	36	
	Overall	28.6725	0.23420	0.87732	87	
Range of x: 5-170 miles						
1	Mobile and Ohio	29.7905	0.28710	0.91547	23	
2	Kansas City, Memphis, and Birmingham	27.4343	0.36065	0.95317	17	
3	Central of Georgia:	Columbus & Andalusia	29.5347	0.31331	0.87769	25
4		Columbus & Western	27.3466	0.30430	0.84056	26
5	Northern Alabama	26.2521	0.18046	0.92772	19	
6	Western Alabama	21.8705	0.35791	0.94829	23	
7	Atlanta and Birmingham Air Line	20.8015	0.32770	0.98733	17	
	Overall	27.0353	0.29446	0.81283	150	
Range of x: 5-92 miles						
1	Mobile, Jackson & Kansas City	19.3818	0.62364	0.98583	11	
2	Birmingham and Atlantic	19.2000	0.48000	0.97297	5	
3	Central of Georgia:	Montgomery & Eufaula	18.1571	0.53428	0.96425	15
4		Chattahoochee & Gulf	17.7000	0.54235	0.99572	16
5		Eufaula & Ozark	17.0454	0.56783	0.99460	12
6		East Alabama	15.4286	0.68095	0.99456	8
7	Carrollton Short Line	16.8000	0.80000	0.98280	5	
8	Chattanooga Southern	15.5053	0.44995	0.96654	18	
9	Seaboard Air Line	14.6470	0.50200	0.97385	17	
10	Chattahoochee Valley	10.7949	0.91639	0.82959	6	
11	Nashville, Chattanooga & St. Louis	7.6022	0.67153	0.81291	8	
	Overall	17.2012	0.50606	0.89251	121	

Source: Alabama Railroad Commission, *Twenty-Fourth Annual Report*, Montgomery, 1905, pp. 1191-1325.

TABLE 27: ANALYSIS OF COVARIANCE OF ALABAMA RATES, 1905

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Range of x: 10-300 miles			
Between r and \bar{r}	615.670	1	615.6700
Deviations of the group means	24.704	1	24.7040
Between the individual slopes	181.420	2	90.7100
About the individual lines	4,094.660	81	50.5510
About the overall line	4,916.460	85	
Due to regression on overall line	35,158.260	1	
Total	40,074.710	86	
Range of x: 5-170 miles			
Between r and \bar{r}	322.940	1	322.9400
Deviations of the group means	2,107.350	5	421.4300
Between the individual slopes	774.610	6	129.1000
About the individual lines	2,713.870	136	19.9550
About the overall line	5,918.770	148	
Due to regression on overall line	25,702.520	1	
Total	31,621.290	149	
Range of x: 5-92 miles			
Between r and \bar{r}	32.016	1	32.0160
Deviations of the group means	1,592.690	9	176.9600
Between the individual slopes	181.540	10	18.1540
About the individual lines	248.640	99	2.5516
About the overall line	2,054.890	119	
Due to regression on overall line	17,062.280	1	
Total	19,117.170	120	
	$R_{t,r}$	Significance level	
10-300 mile size group	-	-	tariffs are parallel lines
5-170 mile size group	-0.253	-	virtually all tariffs have the same constant
5-92 mile size group	-0.475	15%	
19 railroads, excluding the Alabama Great Southern Ry.	-0.816	0.1%	

TABLE 28

CLASS I RATES IN FLORIDA, 1897
IN CENTS PER 100 LBS, REGULATED

	Railroad	t	r	R ²	i	
1	Atlantic, Suwanee River, and Gulf Carrabelle, Tallahassee & Georgia Florida Central and Peninsular Florida East Coast Gainesville and Gulf Jacksonville, Tampa & Key West Live Oak and Gulf Tavares and Gulf	Same as Plant System of Railways				
	Plant System of Railways	42.2590	0.20622	0.92836	39	
2	Plant System: Baker's Mill to Gainesville, and Boulogne to Jacksonville	21.6050	0.42752	0.97174	20	
3	Louisville and Nashville	Pensacola and Atlantic Div.	27.5950	0.33322	0.97280	25
4		Pensacola Division	7.0240	0.60848	0.98969	10
5	Georgia Southern and Florida	25.0300	0.32517	0.96576	12	
6	Florida Midland	19.4000	0.64000	0.98651	5	
7	Pensacola, Alabama and Tennessee	9.0000	0.90000	0.87097	3	
	Overall	30.5090	0.25463	0.91930	114	

TABLE 29

ANALYSIS OF COVARIANCE OF FLORIDA TARIFFS, 1897

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Between r and \check{r}	909.740	1	909.7400
Deviations of the group means	1,570.600	5	314.1200
Between the individual slopes	2,099.450	6	349.9100
About the individual lines	200,764.000	100	20.0800
About the overall line	6,587.430	112	
Due to regression on overall line	75,045.060	1	
Total	81,632.490	113	

Note: The above rates were not very different from those applied before the creation of the Florida Railroad Commission. See their *First Annual Report*, March 1, 1898, page 10.

TABLE 30

CLASS I RATES IN MISSISSIPPI, 1907
IN CENTS PER 100 LBS, REGULATED

	Railroad	t	r	R ²	i
Range of x: 10-335 miles					
1	Mobile, Jackson and Kansas City	40.4833	0.16963	0.92386	66
2	Yazoo and Mississippi Valley	39.5109	0.14118	0.78094	42
3	Mobile and Ohio	38.9001	0.18591	0.91001	54
4	Illinois Central	36.9452	0.18942	0.89438	42
5	Mississippi Central	34.9462	0.21330	0.89065	35
6	Alabama Great Southern	32.9706	0.19012	0.84444	39
	Overall	37.6728	0.17898	0.86468	278
Range of x: 10-200 miles					
1	New Orleans and Northeastern	36.7076	0.34011	0.72948	26
2	Gulf and Ship Island	35.2664	0.19514	0.76520	5
3	Southern	32.7231	0.25051	0.92278	40
4	New Orleans Great Northern	32.1545	0.25623	0.91183	32
5	Alabama and Vicksburg	30.0163	0.30094	0.91546	25
6	Kansas City, Memphis, & Birmingham	27.8968	0.33856	0.90084	23
7	Louisville and Nashville	11.2210	0.47158	0.97914	19
	Overall	31.0654	0.27942	0.77466	170
Range of x: 5-45 miles					
1	Natchez, Columbia and Mobile	25.0000	1.00000	1.00000	7
2	Mississippi Eastern	22.8056	0.59000	0.98850	9
3	Alabama and Mississippi	21.0000	0.74000	0.96749	4
4	Brookhaven and Pearl River	19.5000	0.66000	0.96201	5
5	Fernwood and Gulf	18.4286	0.67143	0.96547	7
6	Sardis and Delta	15.0000	1.00000	1.00000	3
	Overall	20.9697	0.73494	0.70942	35

Source: Railroad Commission of Mississippi, *Eleventh Biennial Report*, Nashville, 1908, pp. 284-744.

TABLE 31

ANALYSIS OF COVARIANCE OF MISSISSIPPI RATES, 1907

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Range of x: 10-335 miles			
Between r and \check{r}	81.115	1	81.1150
Deviations of the group means	1,156.790	4	289.2000
Between the individual slopes	821.180	5	164.2350
About the individual lines	8,779.640	266	33.0060
About the overall line	10,838.720	276	
Due to regression on overall line	69,258.160	1	
Total	80,096.890	277	
Range of x: 10-200 miles			
Between r and \check{r}	0.080	1	0.0800
Deviations of the group means	4,411.990	5	882.4000
Between the individual slopes	1,177.690	6	196.2800
About the individual lines	4,569.900	156	29.2940
About the overall line	10,159.660	168	
Due to regression on overall line	34,925.960	1	
Total	45,085.620	169	
Range of x: 5-45 miles			
Between r and \check{r}	9,926.000	1	9.9260
Deviations of the group means	798.763	4	199.6908
Between the individual slopes	86.453	5	17.2910
About the individual lines	23.958	23	1.0416
About the overall line	919.100	33	
Due to regression on overall line	2,243.870	1	
Total	3,162.970	34	

All railroads in the State			
Between r and \check{r}	61.790	1	61.7900
Deviations of the group means	8,444.240	17	496.7200
Between the individual slopes	6,405.470	18	355.8600
About the individual lines	13,373.500	445	30.0500
About the overall line	28,284.000	481	
Due to regression on overall line	127,906.460	1	
Total	156,190.460	482	
	R_{tr}	Significance level	
10-335 mile size group	-0.669	16%	
10-200 mile size group	-0.73	7%	
do. do. excluding an outlier (No. 7, L&N)	-0.24	none	
5-45 mile size group	-0.108	none	
all	-0.791	0.1%	

TABLE 32

CLASS I RATES IN SOUTH CAROLINA, 1907
IN CENTS PER 100 LBS, REGULATED

	Railroad	t	r	R ²	i
1	Atlantic Coast Line	33.0662	0.15868	0.83702	26
2	Southern	30.1518	0.19102	0.87297	25
3	Seaboard Air Line	29.6400	0.20941	0.85492	24
	Overall	31.2227	0.18332	0.83728	75
1	Charleston and Western South Carolina	25.3332	0.27408	0.83120	14
2	Georgetown and Western	23.4627	0.45244	0.99537	4
3	Alcolu	19.7049	0.38524	0.97873	3
4	Hampton and Branchville	17.1356	0.57627	0.97966	4
5	Northwestern	15.2615	0.53961	0.90644	7
6	Carolina and Northwestern Lancaster and Chester Catawba Valley	13.0984	0.70492	0.87227	3
7	Raleigh and Charleston	11.7500	0.57000	0.96696	9
8	Greenville and Knoxville	9.1066	0.93033	0.94702	3
9	Bennetsville and Cheraw	7.6896	0.83990	0.99274	5
10	Chesterfield and Lancaster	7.4458	0.87328	0.99489	7
11	Conway Coast and Western	7.0000	0.95000	0.99176	3
12	Charlotte, Monroe and Columbia	0.1264	0.13681	0.99610	3
	Overall	18.9425	0.36527	0.82250	65

Source: Railroad Commissioners for the State of South Carolina, *Twenty-Ninth Annual Report*, Columbia, 1908, pp. 220-34.

TABLE 33

ANALYSIS OF COVARIANCE OF SOUTH CAROLINA TARIFFS, 1907

Source of variance	Sum of squares	Degrees of freedom	Mean squares
Atlantic Coast Line, Southern and Seaboard Air Line			
Between r and \check{r}	124.390	1	124.3900
Deviations of the group means	0.376	1	0.3760
Between the individual slopes	173.100	2	86.5500
About the individual lines	2,254.720	69	32.6770
About the overall line	2,552.590	73	
Due to regression on overall line	13,143.760	1	
Total	15,696.350	74	
The twelve shorter lines			
Between r and \check{r}	8.192	1	8.1920
Deviations of the group means	514.320	10	51.4320
Between the individual slopes	785.980	11	71.4520
About the individual lines	469.760	41	11.4570
About the overall line	1,778.250	63	
Due to regression on overall line	8,240.000	1	
Total	10,018.250	64	

Note: The tariff lines of the three first railroads are parallel lines, and those of the Southern and the Seaboard Air Line coincide. For the other twelve, the coefficient of correlation between terminal charges and conveyance rates $R_{r,\check{r}}$ is -0.944.

TABLE 34: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1882

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Cincinnati, Indianapolis, St. Louis, and Chicago	1.48	97	1.82	1.95	1.45	1.23	122
2	Cincinnati and Muskingum Valley	2.04	54	0.31	1.72	0.92	0.45	53
3	Cincinnati and Springfield	2.16	44	2.05	1.74	0.74	0.47	60
4	Cleveland, Columbus, Cincinnati, and Indianapolis	2.15	103	3.61	2.99	1.12	0.97	191
5	Columbus, Chicago & Indiana Central	2.00	156	1.87	3.08	1.43	0.90	197
6	Ashtabula and Pittsburgh	1.34	59	1.06	8.79	0.76	1.38	142
7	Dayton and Union	3.13	36	4.64	0.80	1.11	0.57	42
8	Lake Erie and Western	1.79	106	0.79	2.81	1.16	1.17	190
9	Lake Shore & Michigan Southern	1.82	160	0.53	2.46	1.07	1.98	540
10	Little Miami	1.86	65	1.64	1.45	0.92	0.74	96
11	New York, Pennsylvania & Ohio	3.43	39	5.69	2.98	0.59	0.93	210
12	Northwestern Ohio	2.52	63	1.79	2.53	0.73	0.38	84
13	Pittsburgh, Cincinnati & St. Louis	1.72	86	1.59	2.79	0.78	0.94	179
14	Pittsburgh, Fort Wayne & Chicago	1.89	102	2.18	2.65	1.02	2.19	415
15	Pittsburgh and Lake Erie	1.68	41	2.01	4.60	0.64	0.56	61
16	Toledo, Ann Arbor, and Grand Trunk	2.99	28	3.41	2.41	0.82	0.58	59
17	Valley	1.60	36	0.12	1.71	0.86	0.29	19
	MEANS	2.09	74	2.06	2.79	0.95	0.92	156

Source: Ohio Commissioner of Railroads and Telegraphs, *Annual Report for 1882*.

Y	Revenue per local ton-mile, relative to revenue per ton-mile carried through.
X ₁	Average length of local haul, in miles.
X ₂	Ton-miles of through traffic relative to local ton-miles.
X ₂	Freight revenue per dollar of passenger revenue.
R ₁	Average revenue per local ton, in dollars.
R _t	Average revenue per ton of through traffic, in dollars.
X _t	Average length of haul, in miles.

TABLE 35: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1883

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Chicago and Atlantic	2.81	88	8.08	3.75	1.46	1.66	283
2	Cincinnati, Hamilton and Dayton	2.05	16	1.08	1.55	0.65	0.40	45
3	Cincinnati, Hamilton and Indianapolis	1.34	68	0.26	1.47	0.73	0.63	78
4	Cincinnati, Richmond and Chicago	1.71	49	1.20	1.49	1.02	0.38	32
5	Cincinnati & Springfield	2.17	44	1.66	1.67	0.81	0.51	61
6	Cincinnati and Muskingum Valley	1.89	49	0.38	1.67	0.86	0.52	55
7	Cleveland and Pittsburgh	1.42	58	1.11	3.91	0.75	1.28	141
8	Cleveland, Columbus, Cincinnati, and Indianapolis	1.76	109	3.84	3.30	1.22	1.24	195
9	Cincinnati, Indianapolis, St. Louis and Chicago	2.11	64	5.76	1.87	1.28	1.25	120
10	Cleveland, Mt. Vernon & Delaware	2.81	22	2.22	1.84	0.61	0.59	61
11	Cleveland, Youngstown & Pittsburgh	1.52	12	0.08	2.99	0.45	1.50	60
12	Lake Erie and Western	1.11	144	0.47	2.94	1.21	1.06	141
13	Lake Shore & Michigan Southern	1.26	168	0.37	2.78	1.24	3.15	535
14	Little Miami	1.64	68	1.70	1.47	0.91	0.78	95
15	New York, Chicago & St. Louis	1.04	334	0.35	6.89	2.35	2.24	330
16	Painesville and Youngstown	2.25	30	4.43	2.80	0.82	0.73	60
17	Pittsburgh, Cincinnati & St. Louis	1.38	86	1.77	3.16	0.78	1.18	181
18	Pittsburgh, Fort Wayne & Chicago	1.44	100	1.81	2.66	1.00	2.71	387
19	Pittsburgh and Lake Erie	1.69	41	1.86	4.60	0.60	0.56	64
20	Northwestern Ohio	1.88	64	0.54	3.02	0.71	0.50	85
21	Toledo, Ann Arbor, and Grand Trunk	2.04	32	1.85	2.93	0.60	0.57	61
22	Valley	2.08	14	0.04	2.36	0.30	0.66	64
23	Wheeling and Lake Erie	1.71	59	2.47	1.59	0.75	0.72	97
	MEANS	1.79	75	1.88	2.73	0.92	1.08	140

Note: For explanation of symbols see Table 34.

TABLE 36: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1884

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Chicago and Atlantic	2.24	81	18.00	2.80	0.89	1.30	264
2	Chicago, St. Louis & Pittsburgh	1.43	162	1.89	2.97	1.07	1.23	214
3	Cincinnati, Hamilton and Dayton	1.77	35	1.26	1.44	0.54	0.41	46
4	Cincinnati, Hamilton and Indianapolis	1.86	72	0.52	1.46	0.77	0.56	96
5	Cincinnati and Muskingum Valley	2.00	50	0.25	1.44	0.87	0.50	58
6	Cincinnati, Richmond & Chicago	1.83	38	2.03	1.43	0.80	0.52	45
7	Cincinnati & Springfield	1.97	44	1.29	1.36	0.71	0.49	60
8	Cincinnati, Indianapolis, St. Louis and Chicago	2.08	73	4.65	1.73	1.35	1.12	126
9	Cleveland and Pittsburgh	1.54	55	1.59	3.94	0.69	1.17	143
10	Cleveland, Columbus, Cincinnati, and Indianapolis	1.82	103	3.72	3.06	1.10	1.15	197
11	Cleveland, Mt. Vernon & Delaware	2.80	35	1.65	1.66	0.74	0.69	92
12	Dayton and Michigan	1.60	86	0.54	1.98	0.91	0.74	112
13	Dayton and Union	2.83	29	3.95	1.19	0.86	0.46	43
14	Lake Erie and Western	1.45	102	0.95	2.65	1.09	1.38	187
15	Little Miami	1.55	67	1.69	1.37	0.84	0.77	96
16	New York, Chicago & St. Louis	1.08	264	2.00	10.66	1.45	2.09	412
17	New York, Pennsylvania and Ohio	2.38	49	4.77	3.14	0.59	1.16	229
18	Northwestern Ohio	2.03	66	0.64	2.80	0.69	0.43	84
19	Pittsburgh, Cincinnati & St. Louis	1.38	81	1.52	2.86	0.67	1.07	179
20	Pittsburgh, Fort Wayne & Chicago	1.38	108	1.35	2.58	0.93	2.48	399
21	Pittsburgh, Cleveland and Toledo	2.02	11	5.30	5.28	0.14	0.55	92
22	Pittsburgh and Lake Erie	1.64	39	2.67	5.11	0.52	0.50	63
23	Toledo, Canada Southern & Detroit	2.30	46	0.88	1.90	0.48	0.21	46
24	Toledo, Cincinnati & St. Louis	1.97	88	0.41	2.65	0.98	1.10	194
25	Valley	1.91	35	0.08	2.82	0.67	0.71	70
26	Wheeling and Lake Erie	2.37	59	3.45	2.67	0.78	0.54	98
	MEANS	1.89	72	2.58	2.81	0.81	0.90	140

Note: For explanation of symbols see Table 34.

TABLE 37: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1885

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Chicago and Atlantic	1.68	121	6.68	2.67	0.83	1.10	269
2	Chicago, St. Louis & Pittsburgh	1.63	166	1.84	2.74	1.06	1.00	221
3	Cincinnati, Hamilton and Dayton	2.12	35	1.13	1.36	0.53	0.33	47
4	Cincinnati, Hamilton and Indianapolis	2.38	64	0.71	1.44	0.76	0.44	96
5	Cincinnati and Muskingum Valley	1.62	54	0.23	1.40	0.68	0.52	54
6	Cincinnati, Richmond & Chicago	1.78	36	2.11	1.34	0.76	0.52	44
7	Cincinnati & Springfield	2.30	43	1.25	1.35	0.70	0.44	61
8	Cleveland and Pittsburgh	1.20	8	0.67	3.48	0.78	0.78	97
9	Cleveland, Columbus, Cincinnati, and Indianapolis	2.06	109	3.39	2.83	1.10	0.98	201
10	Cleveland, Mt. Vernon & Delaware	2.81	38	1.29	1.27	0.66	0.57	91
11	Dayton and Michigan	1.68	90	0.54	2.00	0.88	0.70	120
12	Dayton and Union	2.73	28	3.39	1.16	0.84	0.48	43
13	Lake Shore & Michigan Southern	1.71	132	1.64	3.11	1.32	1.17	200
14	Lake Erie and Western	1.52	161	0.36	2.38	1.07	2.37	537
15	Little Miami	1.68	65	1.62	1.27	0.79	0.68	94
16	Michigan and Ohio	2.08	83	0.55	1.90	0.92	0.77	143
17	New York, Lake Erie, and Western	2.46	56	4.44	2.73	0.58	0.94	221
18	Northwestern Ohio	2.06	66	0.77	2.94	0.64	0.40	85
19	Pittsburgh, Cincinnati & St. Louis	1.59	87	1.42	2.82	0.87	0.84	179
20	Pittsburgh, Fort Wayne & Chicago	1.52	104	1.96	2.59	0.83	2.12	405
21	Scioto Valley	2.07	53	0.75	1.90	0.66	0.70	116
22	Toledo, Ann Arbor & North Michigan	1.62	37	1.32	5.04	0.48	0.39	48
23	Toledo, Cincinnati & St. Louis	1.36	95	0.65	3.08	1.09	1.10	130
24	Valley	1.94	35	0.07	3.84	0.54	0.61	76
25	Wabash, St. Louis & Pacific	2.02	124	3.38	3.18	1.70	1.88	277
26	Wheeling and Lake Erie	2.09	70	3.44	3.94	0.65	0.48	109
	MEANS	1.94	76	1.78	2.43	0.87	0.85	148

Note: For explanation of symbols see Table 34.

TABLE 38: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1886

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Chicago and Atlantic	1.92	126	4.27	2.46	0.87	0.97	270
2	Chicago, St. Louis & Pittsburgh	1.60	164	1.93	3.05	1.17	0.98	220
3	Cincinnati, Hamilton and Dayton	2.34	33	0.93	1.43	0.54	0.31	45
4	Cincinnati, Hamilton and Indianapolis	1.81	68	0.58	1.52	0.76	0.50	81
5	Cincinnati and Muskingum Valley	1.66	53	0.43	1.77	0.70	0.48	60
6	Cincinnati, Richmond & Chicago	0.94	32	2.09	1.44	0.70	0.50	45
7	Cincinnati & Springfield	2.55	40	1.94	1.53	0.70	0.40	58
8	Cleveland, Akron & Columbus	2.53	42	1.78	1.24	0.71	0.62	94
9	Cleveland, Columbus, Cincinnati, and Indianapolis	2.07	106	3.68	3.22	1.11	0.99	196
10	Cleveland and Pittsburgh	1.34	72	0.85	3.68	0.66	0.83	121
11	Dayton and Michigan	2.83	82	0.96	2.18	0.85	0.65	175
12	Dayton and Union	2.81	27	3.45	1.35	0.75	0.43	43
13	Lake Erie and Western	2.31	87	1.81	2.61	1.07	1.12	213
14	Lake Shore & Michigan Southern	1.50	162	0.32	2.44	1.06	2.36	537
15	Little Miami	1.52	71	1.44	1.49	0.75	0.64	92
16	Michigan and Ohio	1.77	73	0.66	2.68	0.60	0.62	132
17	New York, Pennsylvania & Ohio	2.30	58	4.22	3.08	0.57	0.93	219
18	Northwestern Ohio	1.84	67	0.59	2.86	0.63	0.43	84
19	Pittsburgh, Cincinnati & St. Louis	1.61	81	1.56	3.37	0.60	0.80	174
20	Pittsburgh, Fort Wayne & Chicago	1.40	94	1.69	2.65	0.73	2.20	398
21	Pittsburgh & Lake Erie	1.42	43	3.06	5.23	0.42	0.42	62
22	Scioto Valley	2.02	53	0.53	2.38	0.62	0.67	118
23	Toledo, Ann Arbor & North Michigan	1.52	34	0.97	3.00	0.49	0.58	62
24	Toledo, Columbus and Southern	2.37	18	1.33	1.26	0.73	0.53	32
25	Valley	1.97	30	0.23	4.12	0.44	0.57	76
26	Wabash, St. Louis & Pacific	2.05	105	4.32	2.98	1.42	1.82	277
27	Wheeling and Lake Erie	2.11	68	3.44	3.72	0.55	0.38	101
	MEANS	1.97	70	1.82	2.54	0.75	0.80	148

Note: For explanation of symbols see Table 34.

TABLE 39: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1887

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _t	X _t
1	Chicago and Atlantic	1.97	124	5.85	4.16	1.00	1.10	269
2	Chicago, St. Louis & Pittsburgh	1.40	160	1.80	3.70	1.21	1.14	213
3	Cincinnati, Hamilton and Dayton	2.24	34	0.58	1.38	0.49	0.27	42
4	Cincinnati, Hamilton and Indianapolis	1.86	71	0.64	1.59	0.71	0.50	93
5	Cincinnati and Muskingum Valley	1.28	54	0.45	2.04	0.67	0.55	58
6	Cincinnati, Richmond & Chicago	1.85	33	1.71	1.36	0.65	0.48	45
7	Cincinnati & Springfield	2.39	41	2.16	1.65	0.68	0.40	6
8	Cincinnati, Washington & Baltimore	1.97	68	1.11	2.33	0.77	1.12	195
9	Cleveland, Akron & Columbus	1.98	47	1.75	1.40	0.69	0.62	84
10	Cleveland, Columbus, Cincinnati, and Indianapolis	1.87	104	3.13	3.48	1.12	1.10	192
11	Cleveland and Pittsburgh	1.37	70	0.70	3.96	0.64	0.78	117
12	Columbus and Cincinnati Midland	4.13	39	4.74	1.78	0.76	0.33	71
13	Columbus and Eastern	1.82	37	0.06	3.78	0.39	0.38	65
14	Dayton and Michigan	1.73	89	0.32	2.32	0.86	0.62	112
15	Lake Erie and Western	1.44	89	1.44	2.04	1.07	1.28	153
16	Lake Shore & Michigan Southern	1.12	164	0.28	2.73	1.14	3.31	537
17	Little Miami	1.46	70	1.48	1.74	0.76	0.72	95
18	New York, Pennsylvania & Ohio	2.11	58	4.50	3.53	0.57	0.98	209
19	Northwestern Ohio	1.53	66	0.50	3.29	0.60	0.49	84
20	Pittsburgh, Cincinnati & St. Louis	1.36	79	1.52	4.07	0.60	0.97	174
21	Pittsburgh, Fort Wayne & Chicago	1.27	97	1.29	2.93	0.78	2.50	396
22	Pittsburgh & Lake Erie	1.56	39	3.55	4.73	0.43	0.41	59
23	Scioto Valley	2.01	49	0.52	2.54	0.49	0.70	118
24	Toledo, Ann Arbor & North Michigan	1.54	45	0.21	2.31	0.54	0.58	76
25	Toledo, Columbus and Southern	1.22	20	1.27	1.59	0.68	0.69	26
26	Valley	2.11	31	0.23	4.34	0.48	0.56	76
27	Wheeling and Lake Erie	2.11	70	3.44	4.22	0.58	0.41	103
	MEANS	1.80	68	1.65	2.78	0.72	0.85	138

Note: For explanation of symbols see Table 34.

TABLE 40: FREIGHT RATES IN OHIO, YEAR TO JUNE 30, 1888

	Railroad	Y	X ₁	X ₂	X ₃	R ₁	R _i	X _i
1	Chicago and Atlantic	1.59	128	3.28	3.84	0.92	1.21	269
2	Chicago, St. Louis & Pittsburgh	1.29	163	1.68	3.41	1.21	1.21	211
3	Cincinnati, Hamilton and Dayton	1.86	35	0.70	1.34	0.46	0.29	41
4	Cincinnati, Hamilton and Indianapolis	1.54	77	0.94	1.47	0.72	0.53	89
5	Cincinnati and Muskingum Valley	1.21	52	0.46	1.90	0.66	0.58	55
6	Cincinnati, Richmond & Chicago	1.47	36	1.54	1.25	0.61	0.48	42
7	Cincinnati & Springfield	2.18	43	2.05	1.43	0.67	0.42	58
8	Cleveland, Akron & Columbus	1.90	48	2.29	1.44	0.61	0.71	107
9	Cleveland, Columbus, Cincinnati, and Indianapolis	1.76	101	3.56	2.96	1.05	1.13	192
10	Cleveland and Pittsburgh	1.35	70	0.73	3.65	0.64	0.81	120
11	Columbus and Cincinnati Midland	2.57	43	2.07	1.54	0.63	0.41	71
12	Columbus and Eastern	1.43	50	0.04	4.45	0.54	0.48	63
13	Dayton and Michigan	1.36	92	0.70	2.29	0.80	0.66	103
14	Dayton and Union	2.60	28	3.66	1.16	0.67	0.39	43
15	Lake Shore & Michigan Southern	1.13	165	0.32	2.58	1.15	3.28	536
16	Little Miami	1.37	69	1.48	1.72	0.77	0.80	98
17	Northwestern Ohio	1.47	68	0.42	2.87	0.58	0.49	84
18	Pittsburgh, Cincinnati & St. Louis	1.36	78	1.58	3.51	0.62	1.03	175
19	Pittsburgh, Fort Wayne & Chicago	1.28	100	1.28	2.68	0.82	2.58	402
20	Pittsburgh, Youngstown and Ashtabula	1.06	45	<i>a</i>	7.35	0.37	0.09	12
21	Scioto Valley	1.98	51	0.45	2.35	0.59	0.71	120
22	Toledo, Ann Arbor & North Michigan	1.06	54	0.02	2.47	0.57	2.01	199
23	Valley	2.32	31	0.21	3.91	0.47	0.50	76
24	Wheeling and Lake Erie	1.66	80	5.76	4.59	0.71	0.60	112
	MEANS	1.62	71	1.47	2.76	0.70	0.89	137

Note: For explanation of symbols see Table 34.

$a = 0.0004$.