AN EVALUATION OF ALTERNATIVE TRANSPORT PRICING RULES:

ARGENTINE RAILWAYS CA. 1905

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ABSTRACT

This paper reports transport pricing simulations that show the effects on carrier revenues, land rents and social welfare of the application of different pricing principles. Differential or Ramsey pricing is compared with non-discriminatory markups over marginal cost and with marginal cost pricing. Revenue-pooling in collective rate-making is also simulated. The conclusion is that the imposition of a revenue constraint is the source of most of the benefits from Ramsey pricing. Beyond that, observance of inverse-elasticity rules adds little to aggregate welfare gains. However, it can make or break the fortunes of individual carriers and shippers.

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In this paper we apply the theory developed in [9] to construct a simulation model for evaluation of railway tariff systems, including Ramsey pricing. This evaluation is based on estimates of :

(a) the economic gain by diversion of traffic from other modes of transport to railways;

(b) the potential contribution of railways to economic welfare by marginal cost pricing;

(c) the potential loss due to monopoly behavior of railways;

(d) the gain from railway rate regulation by either government or potential entry;

(e) the gain from differential Ramsey pricing in place of fully distributed cost pricing; and

(f) the effect of revenue pooling.

The estimates under (a)-(f) show benefits from Ramsey pricing over alternative competitive, monopoly, and regulated monopoly solutions. The last one involves also a comparison of stand-alone pricing with tariff uniformity. This is related to a question posed by the Interstate Commerce Commission (ICC) in *Ex-Parte 347* about the merits of stand-alone Ramsey pricing and of Ramsey pricing on a segment by segment basis [14].

The subject I have chosen for a concrete application is the early 20th Century Argentine railway tariffs. The data for the analysis are primarily the Argentine freight classifications, the distribution of traffic by tariff class and by commodity as published by the Argentine counterpart of the ICC, their analysis of freight rate mileage schedules and annual reports by the companies that operated in the country at the time. The discussion may contribute to evaluations of new transport projects in foreign countries and to further understanding of Ramsey pricing as a response to pricing opportunities offered by deregulation in the United States.

The model used in this paper is a simplified, sparse simulation model that needs few data and has very few parameters. The key variable is λ, the ratio of price to marginal cost when the elasticity of demand is unity. This is an indicator of the general level of rates for heterogeneous services. Mathematically speaking, λ is a Lagrange multiplier that measures the change in public utility per dollar reduction in railroad revenue requirements. Thus it will be used to measure the welfare cost of second-best pricing to finance the excess of average over marginal cost of railway services produced under increasing returns to scale.

A crucial assumption is that demand and cost curves are linear and that there are no cross-elasticities. This assumption makes it possible to calibrate the model parameters to a small set of data.

The principal conclusion is that the contribution of Ramsey pricing to economic efficiency is small compared to that of an alternative constraint on the level of railway profits. When Ramsey pricing made a large contribution, it was a subtle one: firstly, it permitted profitable operation of railways in circumstances where no other tariff system -- not even an extortionary one -- would have been remunerative. Secondly, where alternative tariff systems were feasible, it produced with equal profit a different spatial pattern of higher economic activity. These last two effects of Ramsey pricing, however, are peculiar to the monopoly position of early 20th Century railways. They have little or no relevance to competitive railroads in late 20th Century America for which it would be impossible to apply Ramsey's rules on a wide scale. That need not be regretted, as the economic loss is small compared to realistic alternatives.

I *Analysis Railway Traffic and Rates*

The analyses of railway traffic and rates by Charles Ellet [13], Wilhelm Launhardt [15] and Alan Walters [19] are extended to encompass William Baumol's [3] theory of Ramsey pricing as a strategy followed by firms that have contestable monopoly rights.

The analysis is couched in terms of pricing the transport of a single commodity although a tariff system must be adequate for the transport of a multitude of commodities and passengers, and for the provision of other services. It is however assumed that the demand for one type of service is independent of the demands for and the prices of other services. It is likewise assumed that variable costs are independent. These assumptions allow us to deal with the pricing of the transport of a "representative commodity," and the results obtained are extensive to all other commodities and types of traffic. Tariffs are similar except for obvious differences between parameter values related to different types of traffic. Total quantities carried, revenues, and benefits to users are summations over all types of traffic. Theoretical results for any traffic item are representative of the whole so long as one does not distribute fixed costs over each item.

Let m be the market price of a product carried by rail and p its production cost at the point of origin, on or off the railway line. If off the rail line, the product is carted to a railway station over a distance of r miles at a cost of c dollars per ton-mile. The distance from the station to the market is x miles and the railway freight is a function of this distance, $f(x)$ dollars per ton. In addition to this freight, the shipper may suffer a cost proportional to the time taken by the railway to transport his goods. Given the speed of transport by rail, this cost is proportional to distance and equal to wx. For economical production in the area served by the railway, the market price must be at least equal to the cost of supplying the market. Thus

$$m = p + rc + wx + f(x)$$

or

(1) $v >= rc + wx + f(x)$

where v is the "value of service" or the "difference between terminal values" m-p.[1]

The maximum distance over which goods can be carted to the railway is

$$r' - (v - f(x) - wx)/c.$$

This distance is zero at the railhead, which is a miles away from the market and where $v = f(a) + wa$. Letting g be the annual production in tons per unit of land area and supposing this to be constant everywhere in the area served by the railway line, the amount of traffic originating from any fraction of land on both sides of the line is

(2) $\mathrm{d}q = \int_{-r}^{r} g\mathrm{d}x\mathrm{d}z.$

Let the railway's variable cost be a constant b dollars per ton-mile. The surplus revenue over variable cost generated by traffic originating at any point on the line is then

(3) $\mathrm{d}s = (f(x) - bx)\,\mathrm{d}q$

[1] The equation of "value of service" with the "difference in terminal values" was made by the California Commissioners [4].

so the total surplus revenue over variable cost for the entire line is, supposing that access can be had to the line at every point on it

$$(4)\ S = \int_0^a \int_{-r}^{r} g(f(x)\text{-}bx)\mathrm{d}x\mathrm{d}z = (2g/c)\int_0^a (v\text{-}f(x)\text{-}wx)\ (f(x)\text{-}bx)\mathrm{d}x.$$

Those shippers for whom $wx + f(x) < v$ reap another surplus, analogous to Marshallian consumers' surplus. As it is a producers' surplus dependent on location close to a railway, it is also a locational rent of land that can be capitalized to measure the value of the improvement of land by railway construction. At $x = a$ or $r = (v\text{-}f(x)\text{-}wx)/c$ this rent is zero. Everywhere else inside the area opened up to commercial production by the railway, the locational rent of land, the economic gain to the population served, or the public utility of the railway is

$$(5)\ U = \int_0^a \int_y^{v-wx} \int_{-r}^{r} g\mathrm{d}x\mathrm{d}y\mathrm{d}z = (g/c)\int_0^a (v\text{-}\mathrm{f}(x)\text{-}wx)^2\ \mathrm{d}x.$$

The public utility U can be maximized by marginal cost pricing. That, however, may not meet the railway's revenue requirements and thus may not permit unsubsidized operation of privately-owned railways. Suppose total cost is K dollars more than the revenue that can be raised by charging b dollars per ton-mile. The surplus revenue S over variable cost must then be at least equal to K and the public policy problem is to find the tariff schedule $f(x)$ that maximizes U subject to $S = K$. By definition, the rates determined by such a tariff schedule are Ramsey prices. An established railway may have to be regulated to produce this public-minded break-even result.

Actually, railways adopted value-of-service pricing but this is indistinguishable in practice from Ramsey's inverse elasticity rule. The theoretical difference between value-of-service and Ramsey pricing is that the former admits profit maximization and the latter does not. In practice, however, the historical record contains few railways that reaped abnormal profits and even fewer that enjoyed them for significant lengths of time. Consequently, the conceptual difference between value-of-service and Ramsey pricing is swamped by their similarity in price discrimination according to elasticities of demand.

This is a basis for Baumol's theory of contestable markets according to which a railway that serves a market that can be contested by potential entrants would set Ramsey rates voluntarily. Its best pricing strategy is to maximize U subject to its surplus over variable cost being no greater than a potential competitor's entrance cost K. Markets that are not contestable may have to be made so, perhaps following the suggestion by Harold Demsetz [12] or the earlier one by Chadwick [7] according to which railway legislation makes railways compete for the field but does not allow them to compete within the field for service. In the Argentine, government was a "contestant of last resort". It reserved to itself the right to construct and operate railways and exercised it by inviting locally promoted and foreign-financed companies to act as "concessionaires" on contract with the government. Under these contracts government usually had the right to expropriate the lines for a little over original cost, thus effectively acting as "entrant of last resort" and controlling the entry of private companies.

While it cannot be claimed that railways can find exact Ramsey prices, a study of both regulated and unregulated railway rates charged in the United States between 1867 and 1907 showed that railways did tend to set rates in the manner dictated by Frank Ramsey [17], provided that these rates did not have to meet point-to-point competition within the field. The structure of rates was Ramsey's and their level was below the profit-maximizing one although not necessarily at the break-even point (see [9], Sec. II, III).

Competition within the field was much less in the Argentine than in the United States. Argentine railways succeeded in staking out "zones of influence" in which they were the only carriers. Point- to-point competition was limited mostly to points on the border of these zones of influence and to competition with coastal and interior navigation. There was very little of the latter, as no canals were ever built.

In this context, then, the railway tariff is the solution to a constrained maximization problem for which the Lagrangean function is

(6) $L = U - \lambda(K-S)$ and the solution is

(7) $f(x) = (\lambda -1)v/(2\lambda -1) + (\lambda b - (\lambda-1)w)x/(2\lambda -1)$; and $S = K$

which is a two-part tariff consisting of a terminal charge that is a fraction of the value of service and independent of cost, plus a conveyance charge that is a fraction of variable cost independent of the value of service.[2]

Inserting $f(x)$ into the equation for S one finds that the Lagrangean multiplier depends on g, v, c, b and w. These parameters can assume unfavorable values so that there is no value of λ-- however high -- for which $S = K$. In that case $f(x)$ has to be set at the level of profit-maximizing rates:

$$\lim_{\lambda \to \infty} f(x) = v/2 + (b-w)x/2$$

As g, v, c, b and w vary among railways depending on the type of territory traversed by them and the commodities produced in it, λ also varies to maintain the break-even condition in each of the different circumstances. This variation of λ among railways causes a negative correlation between terminal charges and conveyance rates that is typical of Ramsey prices and would not be observed without them ([9], Sec. II). In perfect competition, however, $\lambda = 1$ and terminal charges are nil.

II *Sustainable Rates*

Terminal charges tend to zero if there is competition along close and parallel lines. Competition erodes the surplus revenue over variable cost. The terminal charge is the source of this surplus by Ramsey pricing and therefore a victim of competition. Thus it was found in the 1930s that

[2] If there was a variable terminal cost the terminal charge would include only a fraction of it ([10], p. 38). Frequent failure of such a cost to show through competitive rates suggests that it can be disregarded (Cf. Section II below and [10], Tables 9-32 and pp. 7-9, 13, 46, 49).

> "the old railway tariff in this new competitive world will not do at all ... the old per mile tariff was based on high rates for short haulage and low rates for long haulage, the two averaging out with a fair result. Motor lorries, however, ... are able to go for our high-rated traffic, leaving us to our long-distance and lower-rated trade. Therefore, to regain our position, we have to turn our tariffs upside down, or, in other words, take far less for short haulage and endeavour to find compensation by a relative increase tor long haulage whenever possible."[3]

Thus competition imposes a further constraint on rate-making in addition to the break-even constraint. The latter made for Ramsey-pricing in the sense of a "second-best" price subject to a single constraint without predetermining the functional form of the tariff.[4] The former produces third-best pricing by imposing a zero intercept on the tariff to make it sustainable against competition. In America some of this competition had been prevented by regulation and the assimilation of motor-truck to railway rates. In the Argentine, the foreign-owned railways did not have this protection. Both class differences and terminal charges were greatly reduced in response to the Argentine government's first extensive road-paving program and the consequent appearance of truck competition over parallel highways. For the most highly rated goods, Class I, in lots of l00 kilograms, the old and the new Central Argentine Railway rates per metric ton in 1938 were:[5]

Origin and Destination	Kms.	OLD	NEW	Percent Reduction
		Ordinary tariff	Tariff B200	
Buenos Aires to Santa Fe	477	$75.90	$71.00	6.46
Buenos Aires to Rosario	302	$59.80	$45.50	23.90
Rosario to Santa Fe	175	$46.00	$26.00	43.50

Not only was the reduction greater for the short haul than for the longer hauls, but the terminal charge had virtually disappeared. This charge was the sum of rates for 302 and 175 kilometers, less the rate for 477 kilometers. That was 29.90 pesos under the old ordinary rates and only 0.50 pesos under the new special rate B200.

Rates sustainable against competition are proportional to mileage. Their functional form is

(8) $f(x) = kx$

like that of a passenger tariff, at so many cents per mile. Passengers have always been charged one-part rates because for short distance trips they had many alternatives to railway travel. For example, "it was cheaper to owners of Negroes to pay their passage on the railroad than to make

[3] Sir Follett Holt, Chairman of the Buenos Ayres Western Railway Co., Ltd., at the annual general meeting (AGM) of shareholders, London, October 23, 1932.

[4] The economists' "first best" is marginal cost pricing. Other solutions rank lower depending on the number of constraints put on them.

[5] Source: [6].

them walk on the common road,"[6] or "if a man was too poor to travel second-class, he buys a horse and rides."[7]

Substituting kx for $f(x)$ in (5) the Lagrangean function becomes

$$(9)\ L = U - (K - S) = gv^3(k + w + (k-b))/(k + w)^2 - \lambda K,$$

and the condition for a constrained maximum, which is d L/dk = 0 implies

$$(10)\ k = (2\lambda b + (\lambda - 1)w)/(\lambda + 1).$$

In the limiting case where λ approaches infinity the sustainable rate is $kx = 2bx + wx$ so that a railway would ask a passenger for double the marginal and average variable cost plus his (not the company's) cost of time, an expense which the poor fellow would already have incurred without being asked to pay for it.

Although the one-part tariff can be consistent with a constraint on surplus revenue, it is not a second-best Ramsey price. This can be seen by looking at the relationship between elasticity of demand and price. The elasticity is

$$(11)\ E = f(x)\mathrm{d}q \,/\, q\mathrm{d}f(x) = -f(x) \,/\, (v - f(x)),$$

so that under the two-part tariff the elasticity is

$$E(2) = -((1 - 1/\lambda)v + bx) \,/\, (v - bx)$$

while under the one-part tariff it is

$$E(1) = -bx \,/\, ((1 + 1/\lambda)v \,/\, 2 - bx).$$

The percentage increase in price over average variable and marginal cost is $(f(x) - bx)/f(x)$ which, under the two-part tariff equals

$$-(1 - 1/\lambda) \,/\, E(2)$$

and will be recognized as Ramsey's inverse elasticity formula , whereas with the one-part tariff the percentage markup is $(1 - 1/\lambda) / 2$. Since this is independent of elasticity the one-part tariff cannot qualify as a Ramsey price. Instead, the price is at the level of fully distributed cost.

III *Traffic and Tariff Formulae*

The evaluation of tariff systems requires a comparison of the actual with the potential public utility of the railway. For this purpose I show in this section a number of utility measures corresponding to different tariff systems, namely marginal cost-pricing, fully distributed cost, and Ramsey pricing.

Neglecting the need to pay for the overhead expenses K, the public utility is maximized by marginal cost pricing which makes the consumers' surplus equal to

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[6] The directors of the Charleston and Hamburg Railroad in 1836, quoted in [16] .

[7] J.W. Batten, Chairman of the Buenos Ayres, Ensenada and Port Ry. Co. Ltd., AGM, London, May 9, 1885, replying to a shareholder’s question about the absence of third class accommodation.

$$(12)\ B^* = (g/c)\int_0^a (v - (b + w)x)^2\, dx = gv^3/(3(b + w)c)\ .$$

Whenever the railway rates exceeded the cost of carting or travelling by road in an era before motor transport and in a place with little opportunity for river navigation, all traffic is assumed to have gone by road and the benefit to shippers from exclusive reliance on animal traction at its marginal cost would have been

$$(13)\ B' = (b + w)\ B^* / c.$$

The maximum potential increase in the rent of land with which railways can be credited is the difference between the utility of using railways at marginal cost or animal traction, $B^* - B'$. This potential cannot be reached if railways have a monopoly and charge more than marginal cost. If they set profit maximizing rates -- as if λ were infinitely large -- the loss due to this exercise of monopoly power is the reduction in consumers' surplus less the railway surplus over variable cost. Denoting the sum of consumers' and producers' surpluses when $\lambda = \infty$ by $B(\lambda = \infty)$, the loss from profit-maximizing railway operation is $B(\lambda = \infty) - B^*$. Not all railways maximized profits however. Their profits were constrained resulting in a finite value of λ. The benefit to shippers from this moderation of monopoly power had two components: the reduction in λ and the two-part Ramsey pricing . The surplus then reaped by the users and the companies can be denoted by $B(2)$, which includes S(= K), and the gain in public utility is $B(2) - B(\lambda = \infty)$. An alternative to Ramsey pricing was fully distributed cost pricing sustainable against point-to-point competition. The total benefit from this is denoted by $B(1)$ and thus the benefit from imposition of the constraint alone can be measured by $B(1) - B(\lambda = \infty)$ while the additional benefit from Ramsey pricing is measured by $B(2) - B(1)$.

These different benefit measures will be tabulated in the following manner:

Benefit from animal traction	B'
Gain due to transport cost reduction and traffic diversion	$B^* - B'$
Loss due to monopoly	$B(\lambda = \infty) - B^*$
Gain due to profit constraint	$B(1) - B(\lambda = \infty)$
Gain due to price discrimination	$B(2) - B(1)$
Total railway surplus	$B(2)$

Figure 1 provides an illustration of the different benefits. The downward-sloping curve is a demand for transport from some point on the line. Supposing for simplicity that $w = 0$, the vertical intercept of the demand curve with the price axis is at \$$v$ per ton since nothing will be shipped if the freight equals all that the traffic will bear. The horizontal intercept is at $2gv / c$ tons that would be shipped if the freight were zero. If only carting is possible at a cost cx, the surplus over variable cost is the triangular area KEv (= B'). If a railway is available at marginal cost bx, carting is displaced completely, with a resource saving $MLEK$. The total surplus from marginal cost pricing is MAv (=

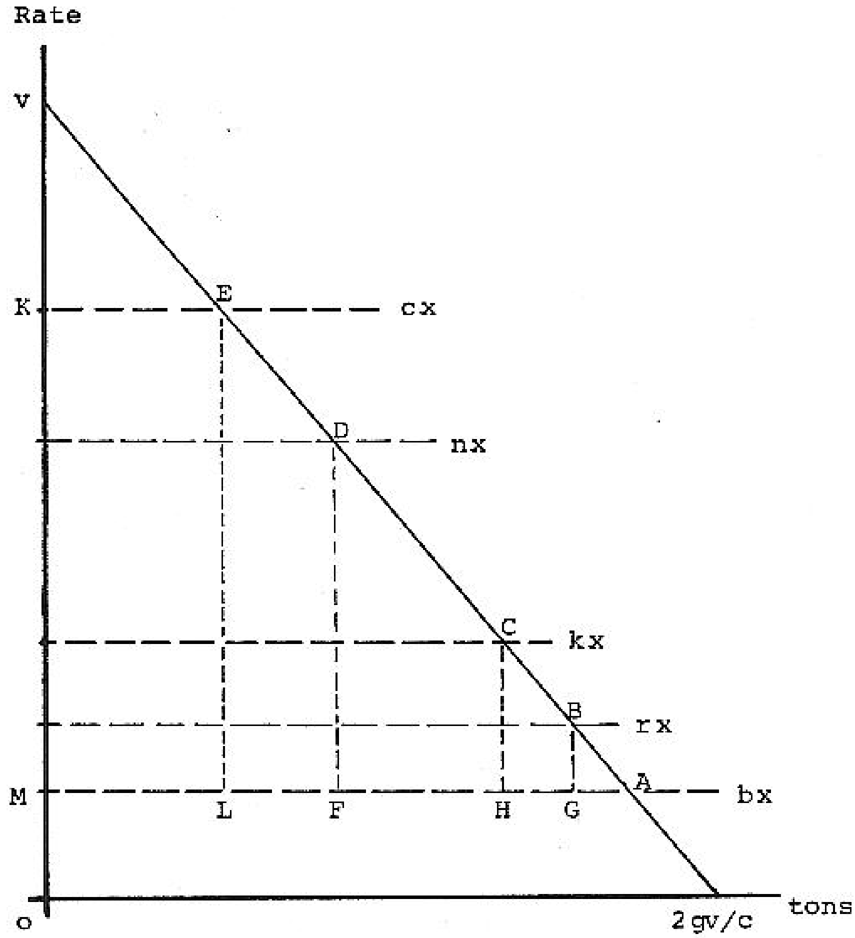

FIGURE 1

Demand for and benefit from transport of goods originating at a point that is x miles away from the market.

B^*) and the welfare gain from the diversion to the railway and the increase in total traffic is *MAEK* (= $B^* - B'$). With monopoly pricing or a rate *nx*, however, there is a loss equal to *FAD* (= $B(\lambda = \infty) - B^*$). This loss is reduced by the imposition of a constraint on the surplus revenue. This results in the rate *kx* and the gain from the profit constraint is the area HCDF (= $B(1) - B(\lambda = \infty)$). Price discrimination in inverse proportion to elasticities of demand being a more efficient revenue raising technique compared to simple monopoly, rates may be reduced further without financial loss to the level *rx*. The gain from that is the area *GBCH* (= $B(2) - B(1)$). The final Ramsey price being *rx*, the total surplus is the area *MGBv* (= *B*).

The different benefit measures are functions of the Lagrange multiplier λ and of the cost *b*. Their values have to be deduced from available operating statistics. To make that deduction one needs formulae that relate traffic and revenues to the functional form of the tariff.

The quantity carried (in number of passengers or tons of goods) is

$$Q = (2g / c) \int_0^a (v - f(x) - wx)\mathrm{d}x$$

where the upper limit of integration under a two-part tariff is $a(2) = v / (b + w)$, while under a one-part tariff it is $a(1) = v / (k + w)$ and $a(2) > a(1)$ for all $\lambda > 1$.

The quantities obtained under each tariff are then
$Q(1) = 3(\lambda + 1) B^*/2\lambda v$; and $Q(2) = 3\lambda B^*/((2\lambda - 1) v)$.
Note that $Q(2) > Q(1)$ for all $\lambda > 1$.

Ton-miles or passenger-miles are given by

$$N = (2 g/ c) \int_0^a (v - f(x) - wx)x\mathrm{d}x$$

so $N(1) = (3\lambda +1)B^*/\{4\lambda^2 (\lambda + 1)(b + w)$ and $N(2) = \lambda B^*/((2\lambda - 1)(b + w))$

and the average length of haul N/Q is less with one-part than with two- part tariffs, for all $\lambda > 1$.
Total revenue is given by

$$(14)\ R = (2g / c) \int_0^a (v - f(x) - wx) f(x)\mathrm{d}x,$$

so $R(1) = kN$

and if $w = 0$, then $R(2) = (4\lambda^2 - 3\lambda) B^* / ((2\lambda -1)^2)$.

Under two-part tariffs, the revenue from terminal charges is

(15) $T = (\lambda - 1) vQ /(2\lambda -1) = (3\lambda-3)R / (4\lambda - 3)$

whence
(16) $\lambda = 3(\mathrm{R}-T)/(3R - 4T)$

and the maximum possible value of T is

$$\lim_{\lambda\to\infty} T = 3R / 4$$

The surplus over variable cost is

$$(17)\ S = (2g / c) \int_0^a (v - f(x) - wx) (f(x) - bx)\mathrm{d}x,$$

so $S(1) = (\lambda + 1)(\lambda - 1)B^* / (4\lambda^2)$

and $S(2) = (2\lambda^2-2\lambda) B^*/((2\lambda - 1)^2) = 2T / 3$ and of course $S =< 0$ under marginal cost pricing.

Given S, the average variable cost can be measured by $b = (R - S) / N$ and the per cent variable cost equals $100(R - S) / R$.

Finally, the total users' and producers' surplus over variable cost is

$$(18)\ B = (2g / c) \int_0^a ((((v - f(x) - wx)^2) / 2) + (f(x) - bx))\mathrm{d}x$$

so $B(1) = (3\lambda - 1)(\lambda + 1)\, B^* / (4\lambda^2)$ and $B(2) = R - T / 3$.

In case of profit-maximizing monopoly the total-benefit criterion cannot be used to choose one tariff system over another. The form of the tariff can be a matter of indifference since

$$(19)\quad \lim_{\lambda\to\infty} \mathrm{B}(1) = \lim_{\lambda\to\infty} B(2) = 3B^* / 4$$

Thus there is no special merit to profit-maximizing Ramsey prices. Profit-maximization cannot be made more palatable by adorning it with the virtues of Ramsey's inverse elasticity rule. Ramsey-pricing is valuable only when the surplus over variable cost is constrained to fall below its maximum possible level, when λ is finite. In that case, the same surplus can be obtained with the two-part tariff and a lower λ than with a one-part tariff and a higher λ.

The value of λ can be estimated in function of total revenue from traffic carried under two-part rates and the terminal charges on the same traffic. The formula was given by equation (16). Since λ measures the marginal value of a dollar of surplus revenue, an efficient internal allocation of resources by a railway company to its different traffics demands that all its tariffs be made as functions of the same value of λ. Thus it may be assumed that the value of λ discovered in two-part tariffs of a given railway company is implicit also in the one-part tariffs of the same company. The different benefit measures can then be estimated as per the above equations. The principal task prior to an evaluation of a two-part tariff system and its alternatives is, therefore, to obtain an estimate of the revenue derived from terminal charges on freight. Next one obtains an estimate of λ and then, given the revenues from passengers, baggage, parcels and freight, one estimates the alternative benefits using the formulae corresponding to the functional form of the tariff applied to each of the four kinds of traffic. B^* is obtained from (14), $B(1)$ and $B(2)$ from (18), and $B(\lambda = \infty)$ from (19).

IV *Data and Results*

All data and results pertain to private companies, mostly foreign-owned. Federal and provincial government railways are excluded from the analysis.

Appendices to the Argentine government's official railway statistics [1] showed the terminal charges per ton and conveyance rates per ton and per kilometer for different classes of freight, commodities, parcels, and excess luggage. Charges for loading and unloading freight were additional to terminal charges. Some companies had zero terminal charges for parcels, excess luggage, or livestock. Passengers were always charged one-part fares. Legislation, company reports, and minutes of shareholder meetings make it appear that traffic was carried at published rates. Argentine economic history texts make no mention of rate wars. The press reported some localized rate wars in 1899 and 1908. [8]

Goods traffic statistics were published in double detail, showing both the tonnage of principal commodities carried and the distribution of traffic by tariff class. A first approximation to the revenue from terminal charges T could therefore be made by adding over all classes the product of tons per class times the terminal charge for the class. Shipment size did not have to be considered. Shipments in small lots were rated in higher classes and special commodity rates applied only to wagon loads. The value of time w was ignored for lack of a suitable measure. Besides, most traffic consisted of primary commodities for which w would have been negligible. In the cases were livestock was carried at one-part rates the estimate of λ was made after subtracting livestock revenue from total freight revenue. This first approximation to T was reduced by adjustment for rate reductions on interline traffic. Some of this was carried at special joint rates and the rest was charged with the sum of local rates. Terminal charges on interline traffic at special rates were divided according to customary rate divisions: by two in the case of joint traffic and by three for traffic in transit. The volume of jointly rated traffic was held at no more than the total shown to have been carried at special rates less the company's own materials. Government materials and company materials carried on capital account were carried at one-half the published rates. This required further adjustments to the first approximation to T. Separate estimates of T were made for the years 1901 to 1906. In 1905 and 1906 terminal charges constituted one-quarter of the whole revenue from goods and livestock.[9] The corresponding values of λ were quite stable from year to year.

Table 1 shows the values of λ implied by average freight revenues and average revenues from terminal charges on freight in 1905 and 1906, as per equation (16). It shows also the values of the Lagrange multiplier λ that would have produced the same surpluses over variable cost if all traffic had been carried at one-part rates. This other value of λ is that which, given B^*, makes $S(1)$ in equation (17) equal to $S(2)$. In some cases this could not be computed; no sufficiently high λ exists and the railway in question would not have been able to obtain the same net revenue without Ramsey pricing. Since such companies had depressed securities and poor dividend records they do not seem to have been viable without Ramsey pricing.

Table 1 also shows the per cent variable cost of each company's entire traffic. On average, this is higher than the 80 per cent figure used by the Interstate Commerce Commission before World War I. The difference corresponds to recent downward revisions of estimates of the degree to returns to scale of railroads. Note also that the figures in Table 1 show that large railways tend to have a higher ratio of variable to total costs than small railroads.

The main thing to notice in Table 1 is the variance of λ. Such a variance can be a cause of resource misallocation. Consider, for example, two railways carrying wheat to a port at freight rates made with different values of λ. If their rates are equal, their marginal costs must be different. If their marginal costs were equal, the rates would be different. In either case, wheat would not be carried

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[8] **South American Journal**, December 16, 1899, p. 693; June 27, 1908, p. 732; September 19, 1908, p. 302.

[9] In England terminals have been roughly estimated as constituting one-fifth of the whole revenue from goods. Cf. **Great Britain, Select Committee on Railways, 1881**, *Minutes of Evidence*, Part I, Q. 12484.

to port over the least cost route from the least cost farm. Variance of λ means that although each railway may have maximized the public utility of its service, the utility of the railway system was not maximized [11].

To passengers, *w* is their foregone wage income per kilometer of travel depending on regional wages and train speeds. The average speed of passenger and mixed trains was last published in the official statistics for the year 1899. Similar speeds were found from timetables in a 1910 guide [8]. Wages paid per 10-hour day to skilled and unskilled railway workshop workers are proxies for the value of time to first and second class passengers.[10] A minimum estimate of the rent of sleeper berths was excluded from passenger revenue for the purpose of estimating passengers' benefits. Adjustments were also made to take account of return fares and of 50 per cent fare reductions for soldiers, based on published data on the number and mileage travelled by soldiers.

The price of travelling by diligence on certain routes is given by [8] . The daily mileage made by diligences on dry, flat land was found in [5] and [18]. The cost of carting goods, parcels, and luggage is assumed equal to Department of Agriculture estimates of the cost of carting grain in different provinces. This completes the data requirements.

Table 2 shows the estimated annual benefits in excess of variable cost of services of privately owned and operated railways in Argentina during 1905 and 1906. The value of railway transport was many times larger than that of animal traction. The total benefit from Ramsey pricing of most freight and one-part pricing for passengers was very close to the potential benefit from hypothetical marginal cost pricing. The contribution made by Ramsey pricing apart from that by a constraint on profit was small in the aggregate but large for individual companies that would not have been viable without two-part pricing.

The value of λ varied among railway companies according to their different revenue requirements. Differences in λ meant that a dollar of surplus revenue reaped by one line was worth more than the profit of another. As was mentioned before, this kind of stand-alone pricing causes inefficient allocations of railway resources if the welfare loss exceeds the cost of centralized pricing by merger or regulation. Neglecting this last cost, total benefit is not maximized unless the consumers' surplus lost per dollar of surplus revenue is the same on all lines. The frequent clamor for nationwide tariff uniformity thus made some sense: shippers and travellers as a whole might have been better off if all railways had made their rates with the same value of λ, as if maximizing national welfare subject to a system-wide revenue constraint and with compulsory revenue-pooling.[11] A further loss was suffered by the inevitable failure to set two-part Ramsey prices for all traffic on the same line. The total loss from stand-alone and incomplete Ramsey pricing was, however, small. The total benefit from the existing tariff system was already close to the benefit from marginal cost

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[10] Regional data on Argentine wages are difficult to obtain. Those derived from railway accounts are perhaps the most reliable. The wages of skilled workmen exceeded the average railway wage which in turn is likely to have been above the average income level in the country. They may thus represent the value of time to the less affluent first-class passengers.

[11] Revenue-pooling was made illegal by Section 5 of the Interstate Commerce Act, 1887, and by a similar Argentine railway Law Number 2873 of 1891, Chapter IV, Section 67. However, some measure of back-door pooling can be achieved by manipulating *per diem* charges and through rate divisions. See [11] for a theoretical analysis of pooling as a Ramsey-pricing tool.

pricing. Table 3 shows total benefits and surplus over variable cost assuming a nation-wide revenue constraint and a single value for λ. The table shows estimates of the actual benefits, the benefits that would have been obtained if a single value of λ (= 1.10) had been used by a monopoly to make one-part fares and two-part rates for excess luggage, parcels and freight, and the benefit from thorough-going Ramsey pricing of all traffic (with λ = l.07). In every case the system-wide surplus revenue over variable cost was held at its actual level, assuming that it was an adequate level and one that would be challenged neither by a new entrant nor by a regulator. The losses from stand-alone and incomplete Ramsey pricing were very small; the redistribution of surplus revenue among railway companies was more substantial. The bulk of simulated results from pooling, measured by the simulated change in surplus over variable cost, appear among railways that combined during the period studied. The Buenos Ayres & Rosario acquired the Central Argentine at the end of 1901 and their merger was completed in 1907, when the B.A. & Pacific obtained the Argentine Great Western in a perpetual lease. Thus events appear to confirm the tenor of the simulations.

V. *Evaluation*

The merits of alternative tariff systems depend on the point of view. From a global point of view, that is regarding the fortunes of both shippers and carriers or of Argentina and the foreign owners of her railways, the tariff structure mattered much less than the level. The profit constraint alone brought *total benefits close to the theoretical maximum hypothetically achievable with marginal cost pricing*. Little was or could have been added to global benefits by differential pricing and pooling.

The distribution of benefits between Argentina and the foreign-owned railways matters from a nationalistic point of view. If that were taken one could ask how much the country could have gained by nationalizing the railways at a fair price. The maximum gross gain would have been the surplus revenue *S* plus the increase in benefits *B* due to marginal cost pricing and deficit finance. The cost is interest on new Argentine government bonds issued in consideration for the railways. A fair price would have been the present value of surplus revenue discounted at the yield of railway bonds. Since the gain from tariff changes was small, the yield of Argentine bonds was about 5 per cent, and the yield of high-grade railway securities was about 4½ per cent, the net result would have been negative. Consequently, *foreign ownership was to the benefit of Argentina.*

From the point of view of shippers the choice of tariff structure makes little difference in the aggregate if railway surplus is held constant. However, the tariff structure can make a large difference to individual shippers. As was shown in Section III, the average length of haul is increased by differential pricing. This affects the location of industry and the rent gradient along a railway line. Differential pricing increases the radius of a shipper's market area and may thus stimulate greater competition in commodity markets.

From the point of view of the carriers, tariff structure and pooling can make a great difference. They can be as important as the general level of tariffs or issues of regulation vs. competition. We have seen that *some carriers* could not have raised the same surplus revenue and *may not have been viable without differential pricing*. The revenue-pooling simulation resulted in large percentage changes in the surplus revenue of individual carriers.

VI *Conclusion*

The value of Ramsey pricing can be exaggerated. There is no net gain from profit-maximizing Ramsey pricing over the alternative one-part pricing. The benefit from Ramsey pricing at a less than profit-maximizing level can be very small. The cases where Ramsey pricing was indispensable because no other tariff formula could have raised the same amount of surplus revenue are the exception.

For the same reason that Ramsey's principles did not apply to passenger fares in the past, present day railways may find that competition makes Ramsey pricing less practical than the more primitive one-part pricing.

What is the lesson of this for transport pricing in the contemporary United States? There are two important differences between the Argentine of 1905 and America in the 1980's. First, the greater degree of intermodal and intramodal competition in the US requires greater reliance on sustainable one-part rates. As illustrated in Table l, that would boost the value of λ and the ratio of price to marginal cost. Secondly, there is a much larger number of carriers in the US than there was in the Argentine and there is correspondingly more scope for reducing λ by revenue pooling, as was illustrated in Table 3. Thus the benefits from Ramsey pricing may be both greater and harder to achieve in the US than they were in Argentina, given the current organization of the US transport industry and the legislation that governs it.

TABLE 1:---LAGRANGE MULTIPLIERS AND PER CENT VARIABLE COST ARGENTINE RAILWAY, AVERAGE OF 1905 AND 1906.

RAILWAY	LAGRANGE MULTIPLIER		VARIABLE COST AS A PER CENT OF THE TOTAL
	ONE PART PRICING	TWO-PART PRICING	
Buenos Ayres Great Southern	1.38560	1.17293	86.9156
Buenos Ayres Western	1.45949	1.15729	86.1000
Buenos Ayres and Rosario	1.17492	1.06530	92.7900
Central Argentine	1.48690	1.14448	85.7644
Buenos Ayres and Pacific	1.23108	1.11290	91.5873
Argentine Great Western	1.19246	1.06865	92.4230
Bahia Blanca and North-Western	5.94741	1.71091	73.1234
Entre Rios Railways	1.59223	1.19472	84.0376
East Argentine	2.56338	1.26989	78.7015
Argentine North-Eastern	1.68461	1.21868	82.2462
Central de Buenos Aires	1.39468	1.11989	85.8034
Province of Santa Fe Railways	1.52074	1.12036	86.1597
Cordoba Central (Original Line)	not feasible	1.26205	75.9611
Cordoba Central (Northern Section)	1.24269	1.06848	91.0498
North-West Argentine	14.7741	1.34834	74.3530
Cordoba and Rosario	2.22226	1.17067	81.0044
Cordoba and North-Western	1.81540	1.27892	80.1845
Argentine Transandine	1.14808	1.10341	93.4798
Central of Chubut	not feasible	1.75725	64.4005
TOTAL	-	-	87.6761

NOTE: the multiplier for one-part pricing was calculated to yield the same surplus as by two-part pricing without reducing rates for goods carried on capital account and Government traffic

TABLE 2:---WELFARE CHANGES DUE TO COST REDUCTION AND TARIFF DESIGN ARGENTINE RAILWAYS, 1905 AND 1906, in thousands of paper pesos per year						
DUE TO:	PASSENGERS		EXCESS BAGGAGE	PARCELS	GOODS	TOTAL
	1st. Cl.	2nd Cl.				
ANIMAL TRACTION	7,870	4,620	459	2,099	9,130	24,177
REDUCED COST	20,590	18,477	126	2,764	97,519	139,477
MONOPOLY	-7,115	-5,774	-146	-1,216	-26,662	-40,913
CONSTRAINT	6,467	5,211	133	1,115	23,889	36,816
DISCRIMINATION	523	459	6	38	1,434	2,459
TOTAL	28,334	22,993	578	4,800	105,309	162,015
"SURPLUS" REVENUE	610	182	98	897	17,508	19,296
NOTE: figures may not add up due to rounding						

TABLE 3:---SIMULATION OF POOLING AND RAMSEY PRICING, ARGENTINE RAILWAYS, 1905 AND 1906, in thousands of paper pesos per year

RAILWAY	LAMBDA	SOCIAL BENEFIT			SURPLUS OVER VARIABLE COST		
		ACTUAL	REVENUE POOLING		ACTUAL	REVENUE POOLING	
			STANDARD	COMPLETE		STANDARD	COMPLETE
			RAMSEY PRICING			RAMSEY PRICING	
B.A. GT. SOUTHERN	1.173	44,672	44,996	45,041	5,417	4,931	5,332
B.A. WESTERN	1.157	20,634	20,758	20,787	2,768	2,470	2,461
B.A. & ROSARIO	1.065	21,057	20,996	21,027	1,454	2,524	2,489
CENTRAL	1.144	26,208	26,325	26,362	3,624	3,108	3,121
B.A.& PACIFIC	1.113	15,713	15,734	15,760	1,346	1,947	1,866
A. GREAT WESTERN	1.068	8,922	8,897	8,914	664	1,153	1,055
B.B. & N.W.	1.711	1,358	1,461	1,463	357	185	173
ENTRE RIOS	1.195	2,260	2,281	2,285	347	275	271
EAST ARGENTINE	1.270	731	745	746	159	88	88
N.E. ARGENTINE	1.219	1,081	1,094	1,095	178	116	130
B.A. CENTRAL	1.120	1,422	1,424	1,426	174	154	169
SANTA FE	1.120	7,781	7,799	7,816	1,113	1,057	925
CORDOBA CENTRAL	1.262	1,779	1,816	1,820	464	247	215
NORTHERN SECTION	1.068	4,229	4,217	4,225	374	535	500
N.W. ARGENTINE	1.348	1,220	1,256	1,257	314	143	149
CORDOBA & ROSARIO	1.171	2,125	2,144	2,148	430	297	254
CORDOBA N.W.	1.279	351	357	357	62	31	42
A. TRANSANDINE	1.103	401	401	401	24	25	47
CHUBUT CENTRAL	1.757	71	76	77	27	10	9
TOTAL	n.a.	162,015	162,775	163,006	19,296	19,296	19,296
LAMBDA	n.a.	n.a.	1.0996	1.0720	n.a.	1.0996	1.0720

NOTE: figures may not add up due to rounding
Complete Ramsey pricing means two-part tariffs for passengers as well as goods.

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COMPUTER CODES (MODIFIED TRS-80 MODEL I BASIC)

Basic computations

```
10 PRINT "ESTIMATION OF SOCIAL BENEFITS"
   INPUT "RAILWAY COMPANY"; F$
   DEFDBL B,F,L,P,R,T, X-Z
   DEFINT G,H,I,J,K
   INPUT "NUMBER OF YEARS' DATA"; JH
   DIM B(8,6)
   INPUT "NUMBER OF GOODS CLASSES"; HK
   DIM A$(19), C$(10)
30 INPUT "PROPORTION CHARGED FOR COMPANY MATERIALS"; S
   INPUT "FOR SERVICE TRAFFIC"; SS
50 FOR I = 1 TO 19
       READ A$(I)
   NEXT I
   FOR I = 1 TO 10
       READ B$(I)
   NEXT I
   FOR I = 1 TO 4
       READ N(I)
   NEXT I
   FOR I = 1 TO 10
       READ C$(I)
   NEXT I
   FOR I = 1 TO 6
       READ K(I)
   NEXT I
60 FOR I = HK+1 TO 41
       PRINT "PRODUCT CARRIED AT SPECIAL RATES (ENTER 99 TO
STOP)"
       INPUT B$(I)
70     IF B$(I) = 99 THEN H= I-1: GOTO 90 ' gets No. of specials
80 NEXT I
90 DIM X(19, 6, 2), Y(H, 2, 2), W(2,2)
100 JJ= JJ+1
    INPUT "YEAR"; G$
    T(1) = 0
    F = 0
    Z = 0
    Y = 0
    IF JJ = JH+1 THEN 160
105 FOR I = 1 TO 19
        PRINT "QUANTITY OF "; A$(I);
        INPUT X(I,1,1)
    NEXT I
    M = 0.44             ' gold value of paper currency
    FOR I = 1 TO H
```

```
        PRINT "TONNAGE OF "; B$(I);
        INPUT Y(I,1,1)
    NEXT I
110 FOR I = 1 TO 8
        PRINT "KILOMETRES OF "; A$(I);
        INPUT X(I,3,1)
    NEXT I
    INPUT "WAGE OF WORKERS"; W(1,1)' the data are in gold pesos
    INPUT "WAGE OF PEONS"; W(2,1) ' the data are in gold pesos
    FOR I = 1 TO 2
        W(I,1) = W(I,1)/M)          ' wages are converted to paper
    NEXT I
    IF JJ > 1 THEN 130
120 FOR I = 1 TO 5
        PRINT "RATE FOR" A$(I);
        INPUT X(I,4,1)
    NEXT I
    FOR I = 6 TO 7
        GOSUB 124
    NEXT I
    I = 11
    GOSUB 124
    FOR I = 16 TO 19
        GOSUB 124
    NEXT I
    INPUT "RATE PER KM. OF COMPANY MATERIALS"; X(11,4,1)
    GOTO 126
124 PRINT "TERMINAL CHARGE FOR " A$(I);
    INPUT X(I, 5, 1)
    RETURN
126 FOR I = 1 TO H
        PRINT "TERMINAL CHARGE FOR "; B$(I);
        INPUT Y(I, 2, 1)
    NEXT I
130 CLS
    PRINT "REVENUES:"
    INPUT "PASSENGERS"; X(1,6,1)
    INPUT "BAGGAGE"; X(6,6,1)
    INPUT "PARCELS"; X(7,6,1)
    INPUT "GOODS AND LIVESTOCK"; X(8,6,1)
    FOR I = 1 TO 8
        X(I,6,1) = X(I,6,1)/M
    NEXT I
135 PRINT "REVENUE IN STERLING"
    INPUT "GOVERNMENT TRAFFIC"; X912,6,1)
    INPUT "CAPITAL ACCOUNT"; X(11,6,1)
    INPUT "SERVICE TRAFFIC"; X(10,6,1)
    E = 11.04 ' paper value of £ Sterling
```

```
    FOR I = 10 TO 12
        X(I,6,1) = X(I,6,1)*E
    NEXT I
136 IF X(12,6,1) = 0 THEN
            X(12,6,1) = X(12,1,1)*X(8,6,1)/(X(8,1,1,)*2)
    END IF
137 IF SS > 0 AND X(10,6,1) = 0 THEN
        X(10,6,1) = X(10,1,1)*X(10,5,1)*SS +
            + X(10,1,1)*X(8,3,1)*X(11,4,1)*SS/X(8,1,1)
    END IF
138 IF X(11,6,1)=0 THEN
        X(11,6,1) = X(11,6,1)*X(11,5,1)*(1-S) +
            + X(11,1,1)*X(8,3,1)*X(11,4,1)*(1-S)/X(8,1,1)
    END IF
139 IF JJ > 1 THEN 160
140 INPUT TRAIN SPEED"; V(1)
    INPUT "KMS. PER DILIGENCE PER DAY"; V(2)
    INPUT "COST BY CART"; C
    INPUT "DILIGENCE FARE"; D
150 INPUT "SHEEP PER WAGON"; G(1)
    G(2) = G(1)
    G(3) = G(1)/6 ' compute heads of other livestock per car
    G(4) = G(3)
    FOR I = 1 TO 4
       X(15+I,5,1)= X(15+I,5,1 *N(I)/G(I) ' compute carloads
    NEXT I
160 FOR I = 1 TO 4
       X(15+I,2,1) = X(15+I,1,1)/N(I)
    NEXT I
    GOSUB 1000
    IF X(16,5,1) = 0 THEN GOSUB 1200
170 FOR I = 1 TO HK
       T(1) = T(1) + Y(I,1,1,)*Y(I,2,1)
       F = F + Y(I,1,1)
    NEXT I
    F = F + X(9,2,1)-X(10,2,1)
    X(1,6,1) = X(1,6,1) +X(1,4,1)*X(2,3,1) + X(3,4,1)*X(4,3,1) -
                          X(5,4,1)*X(5,1,1)
175 IF H > HK THEN
       FOR I = HK+1 TO H
          Z = Z + Y(I,1,1,)*Y(I,2,1)
          Y = Y + Y(I,1,1)
       NEXT I
    END IF
180 FOR I = 16 TO 19
       Z = Z + X(I,2,1)*X(I,5,1)
       Y = Y + X(I,2,1)
    NEXT I
```

```
190 T(1) = T(1) + Z*(9,2,1)/Y - Z*X(10,2,1)/Y - Z*X(11,2,1)/Y +
                X(11,2,1)*X(11,5,1)
    X = T(1)/F
    RP = X(1,4,1)*X(1,3,1) + X(3,4,1)*X(3,3,1)
    RP = X(1,6,1)/RP
200 IF X(13,2,1)+X(14,2,1)>X(9,2,1) - X(10,2,1) - X(11,2,1) THEN
        T = (X(9,2,1)-X(10,2,1)-X(11,2,1)/(X(13,2,1)+X(14,2,1)
    ELSE
        t = 1
    END IF
220 T(2) = 0
    IF X(13,2,1) > 0 AND t > 0 THEN
         T(2) = T(1)-X(13,2,1)*X*T/2 - X(14,2,1)*X*2*T/3
    END IF
230 X(8,6,1) = X(8,6,1) + X(1,6,1) + X(12,6,1) - X(10,6,1)
    B(6,1)-X(1,4,1)*X(2,3,1)
    B(6,2)=X(3,4,1)*X(4,3,1)
    B(6,5) = X(12,6,1)
    B(7,5) = X(11,6,1)
    M = 3*X(8,3,1)/X(8,2,1)
240 P1 = (RP*X(1,4,1)+W(1,1)/(10*V(1))*X(1,3,1)
    P2 = (RP*X(3,4,1)+W(2,1)/(10*V(1)))*X(3,3,1)
    K=0
    IF X(16,5,1,) = 0 THEN
       X(8,6,1)=X(8,6,1)-X(16,6,1)
    END IF
250 K = K + 1
    L2 = 3*(T(K)-X(8,6,1))/(4*T(K)-3*X(8,6,1))
    FOR I = 0 TO 5
       FOR J = 1 TO 6
           B(I,J) = 0
    NEXT J, I
260 L = (3*L2-1)/(2*L2)
    B(5,1) = P1*L
    B(5,2) = P2*L
    B(5,3) = X(6,6,1)*L
    B(5,4) = X(7,6,1)*L
    B(5,5,) = X(8,6,1)-T(K)/3
    R2 = X(16,6,1)*L
270 L = 4*L2*L2/(3*L2*L2 + 2*L2-1)
    FOR I = 1 TO 4
       B(2,I) = B(5,I)*L
    NEXT I
    R0 = R2*L
280 L = (L2*L2-1)/(4*L2*L2)
    FOR I = 1 TO 4
       B(8,I)=B(2,I)*L
    NEXT I
```

```
    B(8,5)=2*T(K)/3
    BL = R0*L
290 MC(1) = (RP*X(1,4,1)*X(1,3,1)-B(8,1))/X(1,3,1)
    MC(2) = (RP*X(3,4,1)*X(3,3,1)-B(8,2))/X(3,3,1)
    L = (4*L2*L2-4*L2+1)/(4*L2*L2-3*L2)
    B(2,5) = L* X(8,6,1)
    IF X(6,5,1) = 0 OR X(7,5,1) = 0 THEN GOTO 420
300 FOR I = 3 TO 4
       T = (3*L2-3)*X(I+3,6,1)/(4*L2-3)
       B(8,I) = 2*T/3
       B(5,I) = X(I+3,6,1)-T/3
       B(2,I)=X(I+3,6,1)*L
       A(I-2)=T/X(I+3,2,1)
    NEXT I
420 MC(5) = (X(8,6,1)-B(8,5))*X(8,2,1)/(X(8,3,1)*X(8,2,1)-
            X(8,3,1)*X(10,2,1))
    FOR I 3 TO 4
       MC(I) = (X(I+3,6,1)-B(8,I))/(X(I+3,3,1)
    NEXT I
    B(2,6) = 0
    B(8,6) = 0
    FOR J = 1 TO 5
       B(3,J) = 3*B(2,J)/4
    NEXT J
430 IF X(16,5,1) = 0 THEN
      B(5,5,) = B(5,5) + R2
      B(2,5) = B(2,5) + R0
      B(8,5) = B(8,5) = BL
      MC(5) = (X(8,6,1)+X(16,6,1)-B(8,5))*X(8,2,1)/
                (X(8,3,1,)*X(8,2,1)-X(8,3,1)*X(10,2,1)
      B(3,5) = B(3,5) + 3*R0/4
530 FOR J = 1 TO 2
      B(1,J) = B(2,J)*(MC(J)+W(J,1)/(10*V(1))/D+W(J,1)/V(2))
    NEXT J
    FOR J = 3 TO 5
      B(1,J) = B(2,J)*MC(J)/C
    NEXT J
540 B(8,1) = B(8,1) - X(1,4,1)*X(2,3,1)
    B(8,2) = B(8,2)-X(3,4,1)*X(4,3,1)
    B(8,5) = B(8,5) - X(11,6,1)-X(12,6,1)
570 FOR J = 1 TO 8
       B(J,6) = 0
    NEXT J
    FOR J = 1 TO 8
       FOR I = 1 TO 5
          B(J,6) = B(J,6) + B(J,I)
    NEXT I, J
    Y = B(2,6)/(B(2,6)-4*B(8,6))
```

```
    IF Y > 0 THEN
       L = SQR(Y)
    ELSE
       GOTO 630
    END IF
610 L = (3*L1*L1 + 2*L1 - 1)/(4*L1*L1)
    FOR J = 1 TO 6
       B(4,J) = L* B(2,J)
    NEXT J
    GOTO 675
630 L1 = 0
    FOR J = 1 TO 5
       B(4,J) = B(3,J)
    NEXT J
    B(4,6) = B(3,6)
675 CLS
    PRINT “POSITION PAPER TO PRINT”
    GOSUB 3030
    FOR I = 0 TO 4
       FOR J = 1 TO 6
          B(I,J) = B(I+1,J) - B(I,J)
    NEXT J, I
680 LPRINT
    LPRINT F$
    LPRINT “WELFARE CHANGES DUE TO COST REDUCTION AND TARIFF
  DESIGN: “ ; G$; “ (IN PESOS M/N)”
    LPRINT
    U$ = “#########”
690 LPRINT “DUE TO:”; TAB(25" :PASSENGERS”; TAB(43) A$6); TAB(56)
      A$7); TAB(70) “FREIGHT”; TAB(84) “IN TOTAL”
    LPRINT
    LPRINT TAB(22) “FIRST”; TAB(2) “SECOND”
    LPRINT
720 FOR I = 1 TO 9
        LPRINT C$(I);
        FOR J = 1 TO 6
           LPRINT TAB(K(J)); USING U$; B(I-1,J);
        NEXT J
        LPRINT
    NEXT I
865 LPRINT
    LPRINT C$(10);
    FOR J = 1 TO 5
       LPRINT TAB(K(J)); MC(J);
    NEXT J
    LPRINT
870 LPRINT
    LPRINT “L1(“;k;”) =”;
```

```
    LPRINT; USING "#######"; L1
    LPRINT "    "; "L2("; K;) =";
    LPRINT; USING "##.#####"; L2;
    LPRINT "      REVENUE FROM TERMINAL CHARGES:";
    LPRINT; USING U$; T(K)-X(11,2,1)*X(11,5,1)*S-X(12,2,1)*X/2
    LPRINT
872 IF X(6,5,1) > 0 THEN
       LPRINT "ESTIMATED TERMINAL CHARGE FOR" A$(6) ":"; A(1)
    END IF
875 IF X(7,5,1) > 0 THEN
       LPRINT "ESTIMATED TERMINAL CHARGE FOR" A$(7) ":"; A(2)
    END IF
876 LPRINT "MAX. LENGTH OF HAUL BY RAIL: A ="; M; " ";
               "BY CART:"; M*MC(5)/C
    LPRINT
    IF t(2) = 0 THEN GOTO 880
871 IF K = 1 THEN GOTO 250
880 PRINT "POSITION PAPER TO PRINT DATA"
    GOSUB 3030
    LPRINT "DATA: " F$; "; "; G$
    LPRINT
890 LPRINT TAB(29) "NUMBER"; TAB(44) "TONS"; TAB(54)
"KILOMETRES"; TAB(67) "$ PER KM"; TAB(81) "TERMINAL";
TAB(98) "REVENUE"
    LPRINT
    FOR I = 1 TO
       U$(I) = "#####,####"
    NEXT I
    U$(3) = "#######,####"
    FOR I = 4 TO 5
       U$(I) = "##.#####"
    NEXT I
    U$(6) = "####,######"
895 X(1,6,1) = X(1,6,1)-X(1,4,1)*X(2,3,1)-X(3,4,1)*X(4,3,1)+
                 X(5,4,1)*X(5,1,1)
    X(8,6,1) = X(8,6,1)-X(11,6,1)-X(12,6,1)+X(10,6,1)
    IF X(16,5,1) = 0 THEN
       X(8,6,1)- X(8,6,1) + X(16,6,1)
    END IF
910 FOR I = 1 TO 19
       LPRINT A$(I);
       FOR J = 1 TO 6
          IF X(I,J,1,> O THEN
             LPRINT, TAB(11+14*J); USING U$(J); X(I,J,1);
920    NEXT J
       LPRINT
    NEXT I
922 FOR I = 1 TO H
```

```
       LPRINT B$(I);
          FOR J = 1 TO 2
             IF Y(I,1,1) > 0 THEN
                  LPRINT TAB(42*J-3); USING U$(J*2); Y(I,J,1);
             END IF
          NEXT J
          LPRINT
925 NEXT I
930 LPRINT
    LPRINT "WAGES OF WORKERS AND PEONS:" W(1,1); " "; W(2,1);
950 LPRINT A$(16)"PER WAGON:"; G(1); "   "; A$(18) "PER WAGON: ";
      G(3)
    LPRINT "PROPORTION CHARGED FOR " A$(11) " MATERIAL:"; S;
    FOR A$(10) " TRAFFIC:" SS
980 LPRINT "FARE BY DILIGENCE: "; D;"   "; COST OF CARTING: "; C;
      " TRAIN SPEED: "; V(1); "KM/H"; "   "; "KMS. BY DILIGENCE
      PER DAY: "; V(2)
990 IF(16,5,1 > 0 THEN
        GOTO 100
    ELSE
        LPRINT
        LPRINT "NOTE: WELFARE CHANGES FROM LIVESTOCK TRAFFIC:";
        LPRINT; USING U$(6); R0*MC(5)/C; R0*(1-MC(5)/C);
             -R/4; (3*L2*L2+2*L2-1)*R0/(4*L2*L2)-3*R0/4;
             R2-(3*L2*L2+2*L2-1)*R0/(4*L2*L2); R2; BL
             GOTO 100
    END IF
1000 IF JJ < JH THEN
       GOTO 1010
     ELSE
       GOTO 1020
     END IF
1010 FOR I = 6 TO 15
        X(I,2,1) = X(I,1,1,)
        X(I,1,1) = 0
     NEXT I
     FOR I = 1 TO 19
        FOR J = 1 TO 6
           X(I,J,2) = X(I,J,2) + X(I,J,1)
     NEXT J, I
     FOR I = 1 TO 2
        W(I,2) = 2(I,2)+W(I,1)
     NEXT I
1015 FOR I = 1 TO H
        FOR J = 1 TO 2
           Y(I, J, 2) = Y(I,J,2)+Y(I,J,1)
     NEXT J,I
     RETURN
```

```
1020 FOR I = 1 TO 19
        FOR J = 1 TO 6
           X(I,J,1)-X(I,J,2)/JH
     NEXT J,I
     FOR I = 1 TO 2
        W(I,1) = W(I,2)/JH
     NEXT I
1030 FOR I = 1 TO H
       FOR J = 1 TO 2
          Y(I,J,1) = Y(I,J,2)/JH
     NEXT J,I
     RETURN
1200 IF JJ < JH THEN
        INPUT "LIVESTOCK REVENUE, IN STERLING"; X(16,6,1)
        X(16,6,1) = X(16,6,1)*E
     END IF
1210 RETURN
3030 INPUT "HIT ENTER WHEN READY"; Q
     RETURN
4000 DATA 1ST CL PASSENGERS, 1ST CL SOLDIERS, 2ND CL PASSENGERS,
       2ND CL SOLDIERS, SLEEPER BERTHS SOLD, BAGGAGE, PARCELS,
     TOTAL FREIGHT, SPECIALS, SERVICE, CAPITAL ACCOUNT,
GOVERNMENT, COMMON, TRANSIT, LOCAL, SHEEP, PIGS, CATTLE,
HORSES
4010 DATA CLASS I, CLASS II, CLASS III, CLASS IV, CLASS V, CLASS
        VI, CLASS VIII, CLASS VIII, CLASS IX, CLASS X
4020 DATA 20, 10, 2, 2.5
4030 DATA ANIMAL TRACTION, RESOURCE SAVING, MONOPOLY, CONSTRAINT,
          DISCRIMINATION, TOTAL, GOVERNMENT, CAPITAL ACCOUNT,
          'SURPLUS', VARIABLE COST
404 DATA 18, 29, 41, 54, 68, 82
```

Simulation Program

```
10 CLS
   CLEAR 1000
   DEFDBL B, L, S, X, Y, Z
   DEFINT I, J, K, N
20 DATA FIRST, SECOND, BAGGAGE, PARCELS, FREIGHT, TOTAL, ANIMAL
          TRACTION, RESOURCE SAVING, SURPLUS
30 FOR I = 1 TO 9
     READ A$(I)
   NEXT I
   INPUT "YEAR"; G$
   INPUT "NUMBER OF COMPANIES"; N
   DIM R$(N), B(N,5,3), S(N+1,6), L(N+2)
40 FOR I = 1 TO N
      INPUT "RAILWAY, LAMBDA"; R$(I), L(I)
      FOR J = 1 TO 5
         PRINT A$(J)
         FOR K = 1 TO 2
             PRINT A$(6+K)
             INPUT B(I,J,K)
      NEXT K, J
50    PRINT A$(6);
      INPUT S(I,1)
      PRINT A$(9);
      INPUT S(I,4)
   NEXT I
60 FOR I = 1 TO N
      FOR J = 1 TO 5
         FOR K = 1 TO 2
            B(I,J,3) = B(I,J,3)+B(I,J,K)
   NEXT K, J, I
   FOR J = 1 TO 5
      FOR I = 1 TO N
         BA(J) = BA(J) + B(I,J,3)
   NEXT I,J
70 B1 = BA(1)+BA(2)
   B2 = BA(3) + BA(4) + BA(5)
   B3 = B1 + B2
   FOR I = 1 TO N
      S(N+1,1) = S(N+1,1)+S(I,1)
      S(N+1,4) = S(N+1,4)+S(I,4)
   NEXT I
   S = S(N+1,4)
   CLS
80 INPUT "TRIAL LAMBDA", L
90 X =0
   GOSUB 410
   X = B3*Y
```

```
   PRINT @256, X-S;"       "
   PRINT @384, L; "         "

100 IF ABS(X-S)>0.0001 THEN
       L = L-(X-S)/10E08
       GOTO 90
    ELSE
       L(N+1) = L
       CLS
    END IF
110 INPUT "TRIAL RAMSEY #"; L
120 X = 0
    GOSUB 410
    X = B3*Y
    PRINT @256, X-S;"        "
    PRINT @384, L; "        "
130 IF ABS(X-S)>0.0001 THEN
       L = L-(X-S)/10E08
       GOTO 120
    ELSE
       L(N+2) = L
    END IF
140 CLS
    L = L(N+1)
    GOSUB 400
    GOSUB 410
    FOR I = 1 TO N
       S(I,5) = B(I,1,3)*Z+B(I,2,3)*Z
       FOR J = 3 TO 5
          S(I,5) = S(I,5)+B(I,J+3)*Y
    NEXT J,I
150 Y = (3*L*L+2*L-1)/(4*L*L)
    GOSUB 420
    FOR I = 1 TO N
       S(I,2) = B(I,1,3)*Y + B(I,2,3)*Y
       FOR J = 3 TO 5
          S(I,2) = S(I,2)+B(I,J,3)
    NEXT J,I
160 L = L(N+2)
    GOSUB 410
    GOSUB 420
    FOR I = 1 TO n
       FOR J = 1 TO 5
          S(I,6) = S(I,6)+B(I,J,3)*Y
          S(I,3) = S(I,3)+B(I,J,3)*Z
    NEXT J,I
170 CLS
    PRINT @384, "READY TO PRINT";
```

```
    INPUT q
    FOR I = 1 TO N
       FOR J = 2 TO 3
          S(N+1, J) = S(N+1,J)+S(I,J)
          S(N+1,J+3)=S(N+1,J+3)+S(I,J+3)
    NEXT J,I
180 LPRINT "SOCIAL BENEFIT FROM ALTERNATIVE TARIFFS, ARGENTINE
                    RAILWAYS IN"G$
    LPRINT
190 LPRINT TAB(31) "LAMBDA"; TAB(57) "SOCIAL BENEFIT"; TAB(94)
      "SURPLUS OVER VARIABLE COST"
    LPRINT
200 LPRINT TAB(44) "ACTUAL"; TAB(57) "MONOPOLY"; TAB(74)
"RAMSEY"; TAB(80) "ACTUAL"; TAB(102) "MONOPOLY"; TAB(119);
 "RAMSEY"
    LPRINT
210 FOR I = 1 TO N
        LPRINT R$(I);
        LPRINT TAB(30); USING "#.####"; L(I);
        FOR J = 1 TO 6
           LPRINT TAB(25+15*J); USING "#####,####"; S(I,J);
        NEXT J
        LPRINT
    NEXT I
    LPRINT
220 LPRINT A$(6);
    FOR J = 1 TO 6
       LPRINT TAB(25+15*J); USING "#####,####"; S(N+1,J);
    NEXT J
    LPRINT
    LPRINT
230 LPRINT "Value of Lambda for monopoly value-of-service
                 pricing:" l(N+1); "for Ramsey pricing:" L(N+2)
    END
400 Z = (L*L-1)/(4*L*L)
    RETURN
410 Y = (2*L*L - 2*L)/(4*L*L - 4*L + 1)
    RETURN
420 Z = (3*L*L - 2*L)/(4*L*L - 4*L + 1)
    RETURN
```