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Marginal Cost and the General Welfare in Relation to Problems of Transport Pricing and Investment Choice

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The search for an efficient principle of transportation and utility rate-setting has a long and checkered history which has variously embraced average cost, marginal cost, and value of service, as well as variations and combinations thereof. Obviously, the principle adopted by regulatory agencies can have a decisive impact on molding future transportation requirements and regional development patterns, and the matter assumes greater urgency as planners from less developed economies attempt to establish pricing policies for their public sector projects, and, in this, look to the western economic literature for guidance. Today, cost appears to enjoy greatest favor among economists writing on the subject in the area of transportation and, although there are differences of opinion in this literature regarding the correct cost criterion, we can detect a growing presumption that marginal cost represents a goal to be striven for in setting transportation prices.

The plan of the paper is as follows. In the first section we define marginal cost pricing for decreasing cost industries. The second section contains an analysis of discriminatory pricing, which has at times been

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proposed as a superior pricing criterion. Under welfare maximization in conditions of homogeneous product, which are, or course, the conditions assumed when speaking of the optimality of marginal equivalences, this is shown to lead to the same output and welfare levels as marginal-cost pricing. Section II then goes on to suggest application of recently developed peak-load pricing principles to transportation pricing problems and concludes that discrimination, in which each activity or product may be priced differentially with respect to its "true" cost, has undeniable merit. In Section III we review some recent examples purporting to represent applied or easily applicable marginal cost pricing. However, we will see, rather, that in reality, either these are examples of average cost pricing or of increasing cost industries and shed no light on normative rules for industries with increasing returns, or else they are simply wrong, their error lying in their reliance on something like short-run rather than long-run marginal cost. These considerations show that attempts at marginal cost pricing in transport generally result in the use of an inappropriate cost category which leads to serious divergences from optimal economic policy. Finally, in Section IV we propose a new DERIVATION FOR A COST ~~cost concept~~ to serve as the basis for pricing on existing systems ~~and on systems being expanded, the latter relating primarily to the highway sector~~.

I. Characteristics of Marginal Cost Pricing

Industries such as power generation, transportation, and other public utilities are generally declining-cost industries over a long range of output. Over this range the long-run marginal cost curve lies below the average cost curve. Since capital costs are usually high, these industries are frequently characterized by local or regional monopolies, facilitating the attainment of scale economies. The downward sloping demand curve facing the monopolist cuts the average cost curve at a lower price than the price at which it cuts the average-cost curve and at a greater volume of output. If such industries produced at the higher level (lower price) their revenue would not cover their cost. To avoid this, therefore, they would tend to produce at the lower level of output where price equals average cost. It has often been argued that such industries should be required to produce at the higher level since, as long as people are willing to pay for a service a price in excess of its marginal production cost, there is a net contribution to social welfare. The firm would then be reimbursed for the resulting deficit through a transfer of public funds. If the enterprise providing the service were a public agency, the deficit would simply be paid out of general tax revenues.

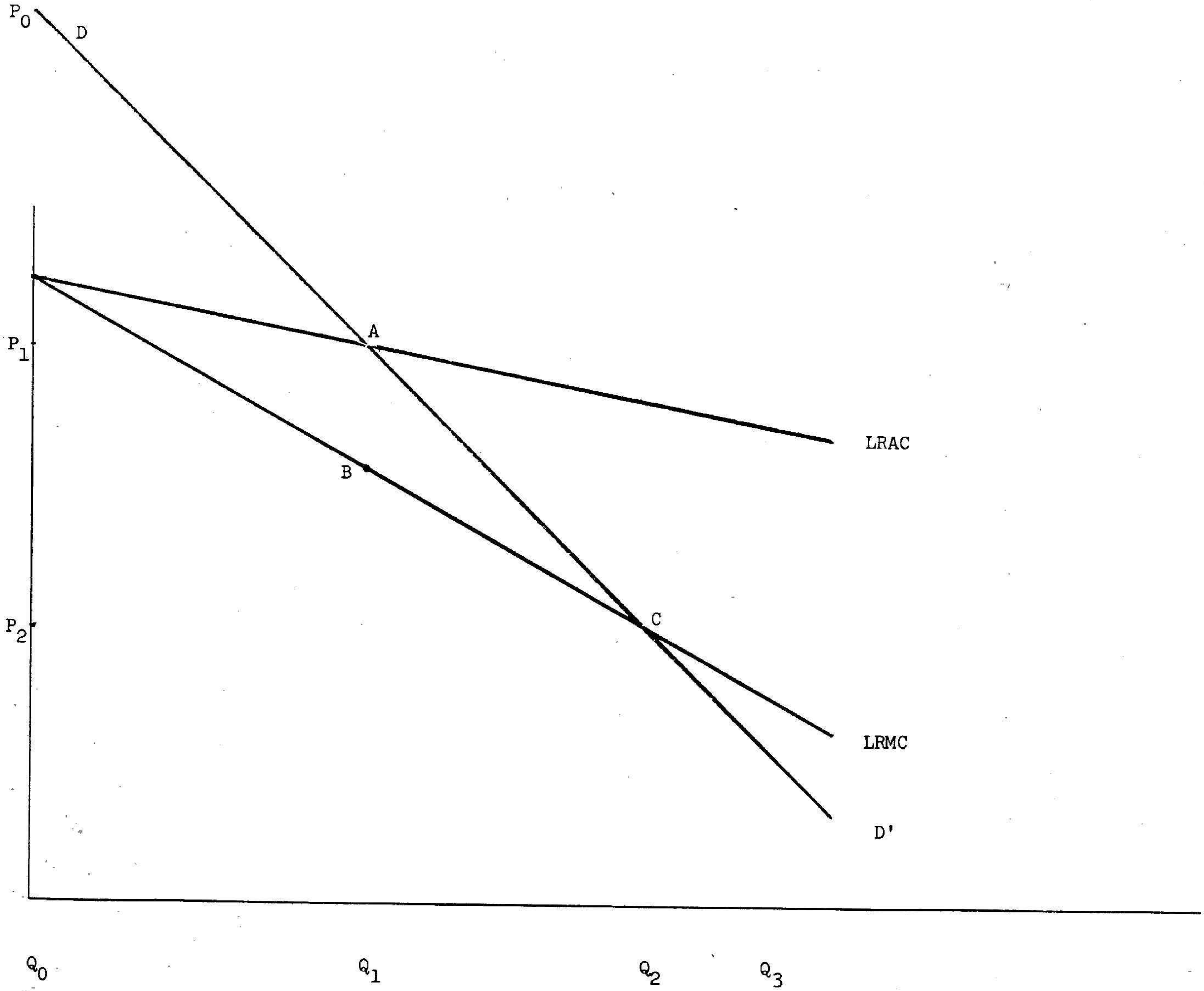
The theory just outlined is usually associated with the names of Jules Dupuit, a 19th century French engineer, and Harold Hotelling, who reintroduced Dupuit's work to modern audiences. The situation is shown graphically in Figure 1.

Figure 1 shows a demand curve, DD', a downward-sloping long-run average cost curve, and a falling long-run marginal cost curve. The integral of the demand function beyond the price-average cost intersection exceeds the area under the marginal cost curve by an amount shown by the triangle ABC, with the point C representing the intersection of price and marginal cost, which clearly shows the desirability of extending production beyond average cost-price equality. The graph also shows the inefficiency of expanding output further, to e.g. Q_3, since here the integral $\int_{Q_2}^{Q_3} (u(Q)-MC)\,dQ$ is negative. This is very obvious. But it is forgotten with disturbing frequency both in the urgings of special interest groups and in the writings of serious scholars. In particular, it is often suggested that price be equated to something akin to short-run marginal cost, which would lead to an output higher than Q_2 and, hence, a lower level of social welfare.

We have restricted our definition of marginal cost pricing to the case of declining marginal cost. If marginal cost is rising the firm will, of course, produce at the intersection of demand and marginal cost, as called for by standard theory. There is no point in considering the latter case, about the optimality of which there can be no controversy, as an example of marginal cost pricing, about which there has been much dispute. As we see in Section III, some examples which purport to demonstrate the desirability of MCP really belong to the class of rising marginal cost and provide no vindication for pricing at declining marginal cost, the situation to which we will limit our definition.

Marginal cost pricing has been objected to on several grounds. One objection is that revenues will fall short of costs since the price to be charged is below average cost, whereas other pricing principles -- especially average cost and value-of-service -- are adequately equipped to handle this problem. The latter has been the criterion traditionally applied in transportation and utility pricing. In these areas an effort is made to offer any service whose price exceeds variable cost and to set prices higher for those services with inelastic demand. This approach answers the objections which may be raised against a proposed public project which it is planned to operate and price at levels at which "it won't cover its costs", which MCP requires. Thus both value-of-service and average cost pass the acid test --

FIGURE 1 Demand and Cost Functions



planners need not rely on conjectual demand curves but, rather, their revenue is proof of the project's worth.

Value-of-service was usually adjudged rational in the earlier literature. More recently it has reemerged in greatly modified form in many writings concerned with the power industry.* In these writings the problem has been more sharply defined in peak-load terms and solved in a social welfare framework leading to a discrimination which is quite the reverse of that usually pursued. These factors -- the earlier tradition of discrimination together with the results of the recent rigorous welfare analysis -- lead us now to inquire into the welfare potentials of discriminatory pricing in transportation.

II. Marginal Cost vs. Discrimination

By value-of-service or discriminatory pricing we mean a system of pricing in which the price/cost ratios of consumers are unequal. This could occur in two situations. The first is the case of a homogeneous good or service. The cost function in Figure 1 presupposes homogeneity, as this sort of curve always does. Discrimination may also be practiced in an industry producing different goods or services where it would be characterized by different costs and, perhaps, different prices as well. By different products we could mean, e.g. vegetable oil and animal feed, or less obvious output pairs such as peak and off-peak energy production, northbound and southbound cargo traffic, iron ore cargo and consumers durables traffic, and so on. We now consider discrimination in the two kinds of situation.

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* See, for example, O.E. Williamson, "Peak-Load Pricing and Optimal Capacity", AER, Sept. 1966, and the references to Boiteux, Hirshleifer, Houthakker, and Steiner there cited.

II.1. Price Discrimination under Product Homogeneity

Average cost pricing leads to a less than optimal output; pricing at marginal cost, on the other hand, results in an optimal production level, but at the cost of a lingering suspicion that the project may not really have been warranted in the first place. As one writer has put it,

> "Thus we must choose between subsidized operation at the best level of output - with some uncertainty as to whether it would not be better to shut down completely - and self-supporting operation in which we know not only that the project is, on the whole, worth while operating but also that we are not operating the project at the best level.
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> "It is sometimes thought that discriminatory pricing offers a way out of this dilemma. Indeed, the defense of discriminatory ratemaking is a familiar part of railroad and public utility literature: that discrimination can at times yield a better allocation of resources than can flat rates that must cover total costs appears to be a well-accepted doctrine. But it is something else again to show that discriminatory pricing can yield revenues covering all costs while producing as good an allocation of resources as a policy of uniform prices at marginal cost."*

The lines seem to be clearly drawn. Can discrimination improve in any way on marginal cost pricing?

By discriminatory pricing we here mean a system of pricing in which some consumers pay more than others for the same good or service the cost of which is the same. Some consumers are willing to pay this differential since their desire is greater -- the utility of the service is greater for them than for others. The homogeneous good may be annual ton-miles of agricultural products movements, the average length of haul being constant. If $U = u(Q) = P$ gives the utility of consumption with respect to quantity consumed, and price $P = g(Q)$, the consumer at quantity Q_n would be willing to pay any price up to and including $P_n = g(Q_n)$, since for any price less

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* William Vickrey, "Some Objections to Marginal-Cost Pricing", Journal of Political Economy, June 1948, pp. 218-219.

than or equal to P_n, there would be an increase in his utility. For example, in Figure 1 the consumer of the first unit would pay any price up to P_o. All consumers of output up to Q_1 would be willing to pay amounts up to at least P_1, and all but the last consumer in this class would be prepared to pay higher prices. Since the supervisory costs of charging each consumer up to the maximum that he would be willing to pay are non-negative, the pricing authority would probably want to set prices over intervals rather than discriminate perfectly. Thus, in our analysis we permit the pricing authority to set constant prices over intervals $(Q_n - Q_{n-1})$, if so desired, rather than set a separate price for each unit. This does not at all affect the result and is more realistic.

We also assume for the activity a cost function, $C = h(Q)$, with declining average cost over the range of possible exploitation. Thus, $\frac{h(Q_1)}{Q_1} > \frac{h(Q_2)}{Q_2} >$ for $Q_2 > Q_1$. This curve and the related marginal cost curve are shown in Figure 1. In such a situation, we will now show, any system of price discrimination in which total costs must be covered by total revenues, together with utility maximization, will lead to the identical welfare level, and the activity will be operated at the same level as would result under marginal cost-price equalization. That is, suppose:

(1) $P = g(Q)$, is an arbitrary, single-valued and decreasing function, giving the relationship between price and quantity consumed with consumption going to zero at infinite price;

(2) $(Q_n - Q_{n-1})$ is the interval of consumption over which the price P_n is to be charged;

(3) $U = \int u(Q)dQ$ is a monotonic, single-valued total welfare function with $u(Q_1) > u(Q_2)$ for $Q_1 < Q_2$;

(4) $C = h(Q)$ is the relationship between total production cost and total output, with $\frac{h(Q_1)}{Q_1} > \frac{h(Q_2)}{Q_2}$ for $Q_1 < Q_2$;

and

(5) $\sum_n P_n (Q_n - Q_{n-1})$, total revenue, is required to be equal to total cost, $C = h(Q)$;

then any system of prices $P_1, \ldots, P_N$, with its corresponding division of total output Q_N into intervals $(Q_n - Q_{n-1})$ will yield the identical net social utility, and the activity will be operated at a level at which $P = \left|\frac{d[h(Q)]}{dQ}\right|$.

Proof: Maximization of welfare means maximization of consumer surplus, the latter being given by

(6) $$W = \int_0^{Q_N} [u(Q) - P]dQ.$$

To allow for the possibility of varying P between intervals while holding it constant within intervals we may write

(7) $$W_n = \int_{Q_{n-1}}^{Q_n} [u(Q) - P_n]dQ,$$

and

(8) $$W = \sum_n W_n.$$

The maximization is constrained by the side condition (5) that total costs be covered out of revenues, i.e., that

(9) $$\sum_n P_n(Q_n - Q_{n-1}) = C = h(Q).$$

We define

(10) $L = \sum_n P_n(Q_n - Q_{n-1}) - h(Q)$

and form the Lagrangean expression

(11) $Z = W + \lambda L,$

differentiate Z with respect to the P_n, λ, and Q, and set the derivatives to zero:

(12) $$\frac{\partial Z}{\partial P_n} = \frac{\partial W}{\partial P_n} + \frac{\partial \lambda L}{\partial P_n} =$$

$$= \frac{\partial \left(\sum_n \int_{Q_{n-1}}^{Q_n} [u(Q) - P_n] dQ \right)}{\partial P_n} + \frac{\partial \left(\lambda \sum_n P_n(Q_n - Q_{n-1}) - h(Q) \right)}{\partial P_n} = 0$$

for n = 1,...,N;

(13) $$\frac{\partial Z}{\partial \lambda} = \frac{\partial \lambda L}{\partial \lambda} = \frac{\partial(\lambda \sum_n P_n(Q_n - Q_{n-1}) - h(Q))}{\partial \lambda} = 0$$

(14) $$\frac{\partial Z}{\partial Q} = \frac{\partial W}{\partial Q} + \frac{\partial \lambda L}{\partial Q} =$$

$$= \frac{\partial \left(\sum_n \int_{Q_{n-1}}^{Q_n} [u(Q) - P_n] dQ \right)}{\partial Q} + \frac{\partial \left(\lambda \sum_n P_n(Q_n - Q_{n-1}) - h(Q) \right)}{\partial Q} = 0$$

Now, the utility function u(Q) was equal to g(Q) = P, an arbitrary, single-valued decreasing function of Q. Therefore,

(15) $$W = \sum_n \int_{Q_{n-1}}^{Q_n} [u(Q) - P_n] dQ = \sum_n \int_{Q_{n-1}}^{Q_n} [g(Q) - P_n] dQ.$$

Denoting the antiderivative of g(Q) by G(Q), the total utility over any interval $(Q_n - Q_{n-1})$ may be written

(16) $$W_n = \int_{Q_{n-1}}^{Q_n} [g(Q) - P_n] dQ = G(Q) - P_n Q \Big]_{Q_{n-1}}^{Q_n}$$

$$= G(Q)\Big]_{Q_{n-1}}^{Q_n} - P_n Q\Big]_{Q_{n-1}}^{Q_n}$$

(17) $$= G(Q_n) - G(Q_{n-1}) - P_n Q_n + P_n Q_{n-1},$$

(18) $$\text{whence } W = \sum_n W_n = G(Q_1) - 0 - P_1 Q_1 + 0 + G(Q_2) -$$

$$G(Q_1) - P_2 Q_2 + P_2 Q_1 \,\ldots\ldots\ldots$$

$$\ldots\ldots\ldots + G(Q_N) - G(Q_{N-1})$$

$$- P_N Q_N + P_N Q_{N-1}.$$

~~We note that in the foregoing expansion we use the fact that $\lim_{P\to\infty} G(Q_{\ }) = 0$.~~
IN THE FOREGOING EXPANSION WE USE THE FACT THAT $G(Q_0) = 0$ (Q_0 WAS DEFINED AS ZERO AND THE ANTIDERIVATIVE WILL CONTAIN A FACTOR Q_0).

We see that each successive integral within the summation over W_n yields a negative antiderivative of $g(Q)$ which cancels out the positive antiderivative remaining from the preceding integral, with $G(Q_N)$ being all that finally survives. The terms in P_n and Q_n, on the other hand, all remain. Collecting these terms we get

(19) $$W = G(Q_N) - [P_1 (Q_1) + P_2 (Q_2 - Q_1) \ldots + P_N (Q_N - Q_{N-1})] =$$

$$= G(Q_N) - \sum_n P_n (Q_n - Q_{n-1})$$

Substituting this expression into (12), (13), and (14) and solving then gives:

(20) $$\frac{\partial Z}{\partial P_n} = + Q_{n-1} - Q_n + \lambda (Q_n - Q_{n-1}) = 0$$

and $\lambda = + 1;$

$$(21) \quad \frac{\partial Z}{\partial \lambda} = \sum_n P_n \, (Q_n - Q_{n-1}) - h(Q) = 0$$

or $\sum_n P_n (Q_n - Q_{n-1}) = h(Q)$, which was the original constraint; and

$$(22) \quad \frac{\partial Z}{\partial Q} = \frac{\partial \, [G(Q_N) - \sum_n P_n (Q_n - Q_{n-1})]}{\partial Q} - \frac{\partial \lambda h(Q)}{\partial Q}$$

$$= G'(Q_N) - \lambda h'(Q) = 0,$$

and $G'(Q_N) = \lambda h'(Q) = h'(Q)$ since $\lambda = 1$.

The first of the three final equations (20) shows that total welfare Z is invariant with respect to price changes. This is so because in the constrained maximization one man's loss must equal another's gain in order to cover total cost. Thus any system of price discrimination will yield the same welfare.

The last expression (22) shows that when welfare is maximized ~~marginal~~ G'(Q) WHICH IS EQUAL TO PRICE P=g(Q) IS EQUAL TO MARGINAL ~~revenue, G'(Q), is the negative of the rate of change of the cost function,~~ COST. ~~h(Q), i.e., marginal cost~~. Thus, these two results together prove that any system of price discrimination which recoups total cost is as good as any other, from an allocational standpoint, and no matter what system is chosen, the production level will be the same as that under marginal cost pricing, i.e., the point where the demand function cuts the marginal cost curve.

Although we have just seen that discrimination and marginal cost pricing yield the same solution, it should be stressed that this is so only in a static framework. In fact, this framework is disturbed when scale economies of competing transport modes -- highway vs. rail, for example -- or of alternative production location variants combine to alter the demand elasticities of different user classes. As this occurs discrimination starts to deflect demand from the service in question and the breakeven constraint is violated. And it should not be thought that the generally low income level of underdeveloped countries helps to make transport users grateful even for the little they have and obviates the pressures for alternative means of transport when the existing mode discriminates or is inefficient -- special interest groups can exert quite as much force in poor countries as in rich, perhaps even more since countervailing power is less. The ultimate result of discrimination then is overinvestment and duplication of capital stock.

II.2. Price Discrimination under Product Heterogeneity

The cost functions in Figures 1 and 2 and in the proof just presented refer to different levels of output of the same good or service. But any transport system or subsystem offers many services and we now consider whether price discrimination among the various services would be economically desirable. We consider discrimination in connection with two kinds of service differences -- direction of flow and kind of traffic. As we will see both are essentially peak-load type situations for which the discrimination of recently developed theory appears to be applicable.

i. Directional Discrimination. When there is a sizable directional imbalance in traffic, we may think of the problem as a peak-load situation.

Since backhauls must be run in any event, a given volume of traffic will require a much smaller basic facility if a given cargo is shared equally between the two directions. This is analogous to electricity supply where a given power can be generated with much smaller plant if generation is spread evenly throughout the day. In this case, then, a variant of the optimal peak-load solution of Williamson, Boiteux, and others would apply. Their solution is to adjust prices to spread out the peak, charging the peak demand something greater than long-run marginal cost (of all activities considered together), and the off-peak demand a price greater than short-run marginal cost, and high enough to make up the difference between long-run average cost of all users considered together and the average contribution of peak users.* Our variant consists in replacing long-run marginal cost by "permanent facility variable cost", a concept to be explained in Section IV.**

In the case described discrimination by the owner of the basic facility should be introduced when administratively feasible. It is administratively feasible on the railroads, for example, but not on highways.

The effect of a peak-load policy in this situation would be substantial. It would confront firms with the real social costs of their location decisions and help disperse industry <u>if this is rational</u>. Of course, it might not be rational -- it might not be cheaper to disperse -- external economies might be such as to promote concentration efficiently; but the correct decision can be rationally reached only when all the true social costs are clearly known.

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* Williamson, <u>op.cit</u>., p. 882.

**By SRMC, which is to serve as a floor for off-peak users, is meant the concept as used in Section IV.

ii. Vehicle-Size Discrimination. It is not so obvious that the other kind of product heterogeneity can be cast into the peak-load mold, but a moment's reflection should convince us that this is indeed so. Consider a railroad. The main determinants of the construction cost of the basic facility are the maximum train size and the annual traffic. However, for any given annual volume, the main cost-determining characteristics of construction of the basic facility -- turning radius, rail gauge, grade angles, signaling equipment, and so on -- may be the more modest, the more uniform is the train size distribution. On the other hand, for any given maximum train size, the annual volume may be increased at negligible cost by running more small trains; to do this would require only some slight additional operating costs rather than the high costs associated with construction of a more ambitious basic permanent facility. These considerations suggest that train size is the chief determinant of decisions on capacity and construction costs. Application of the peak-load pricing criterion in this case would suggest, then, that the heavy traffic for which the facility is designed should be charged no less than the long-run marginal cost calculated at the output level equal to total traffic; the upper bound on the price for heavy traffic should be the long-run marginal cost calculated at an output equal to the traffic generated by the heavy train class, which is given by the product of large train size multiplied by frequency of such trains. The "off-peak" users, the small trains which do not use the facility to its capacity, i.e., which do not need such high specifications regarding gauge, turning radius, grade, etc., which are the primary determinants of investment cost, should be charged only their short-run marginal cost plus whatever contribution is necessary to cover total costs, the amounts actually extracted being determined by the demand elasticities of the various user classes.

The same principles should apply in highway pricing, although in the highway sector the results may be expected to differ more substantially from one economy to another than in railroad transport. For example, in Brazil where over 90 percent of the interurban traffic consists of trucks, and most of the balance of bus movement, and well over half of the truck tonnage moves in heavy vehicles, the indicated solution would be to charge the heaviest trucks for all of the costs of highway construction and maintenance if necessary. The heavy-truck ton-mile charge would then be much higher than it is now and much higher than the charge on small trucks; auto users should be charged only for the short-run marginal cost -- administration and maintenance -- associated with their use plus anything else that could be extracted from them. The point is, however, that their contribution should be a residual rather than the major component of highway finance which it is today. This is not to say that auto users should pay lower taxes. Gasoline demand being inelastic, they could and should pay even more than their present contribution, which is one of the lowest gasoline tax rates outside of the United States. But this contribution should be spent where the cars go -- on urban streets. Major indicated expenditure items: better streets, lights, police, and other forms of traffic control. Alternatively, it might be construed simply as an income redistribution tool and spent on schools or urban amelioration. But there is no good reason that, under the cloak of mitigating interregional income maldistribution or attainment of scale economies, the automobile-using public should subsidize the trucking industry.

In the United States, however, the situation is more complicated. Here highway construction cost is related significantly to both size and number of vehicles. For example, a recent study by Allen Ferguson,* whose pricing recommendations will be considered in Section III, suggests that in one major state about 37 percent of the cost is associated with trucks of varying size, constituting around 18 percent of traffic volume. The fact that autos constitute over 80 percent of traffic suggests a sort of two-peak situation -- the peak activity on the modest part of the construction specifications being automobile use, while the trucks should be regarded as the peak or full-capacity user of the heavier-duty part of the plans. In this case, the pricing implications of Ferguson's analysis may be appropriate. As we explain below, however, notwithstanding the testimony of the title to the contrary, Ferguson's analysis is most certainly not an application of marginal-cost pricing.**

Peak-load pricing applied to vehicle size is, of course, exactly the reverse of the pricing policies generally pursued in rich as well as poor countries. Motor vehicle fuel taxes generally give sizable scale economies to big trucks, and the railroad rates set for basic commodities such as iron ore, which move in larger trains, are generally much lower than those with low demand elasticities. And the effects can be disastrous. Even now, Brazil is witnessing a scheme to rebuild a railroad line to permit very

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* Allen Ferguson, "A Marginal Cost Function for Highway Construction", American Economic Review, May 1958, pp. 224, 233.

** We would like to voice one dissent to Ferguson's method. He apportions each incremental road cost over all the vehicles contained in the classes which require that increment. The basis for this distribution is vehicle miles (p. 228). We would prefer the gross ton-mile as an indicator of use since the weight is the main factor in determining the need for the incremental investment and using vehicle-miles could easily force a shift to the use of heavier vehicles, raising costs further through faster deterioration and higher maintenance needs.

large iron ore exports from interior deposits even while an efficient line now moving large tonnages through a different port already exists.* Large investments would have to be made and present pricing plans call for favorable treatment to the one largest supplier, planning to ship in the largest trains, while setting higher rates to other shippers of ore and agricultural products. Peak-load theory, instead, would call for charging the largest shipper, the one who forces the government to undertake the high cost construction, the highest rates and, if these are not enough to cover the total expansion costs related to his activity,** setting rates for other users so as to collect the balance from them. The project, incidentally, is justified by frequent appeal to marginal cost pricing, which as used in the study more closely resembles short-run marginal-cost pricing, rather than long-run marginal cost, and neglects most of the new construction cost in determining the cost basis for the investment and pricing decisions.

Proponents of the project just discussed often argue that it is necessary to earn foreign exchange, the ore in question being very rich with an excellent market. In this case, however, it would be better to set a tariff policy giving producers an export bounty while pricing its shipment correctly. This way the government would be fully aware of the costs of shipping through one port or another, and off-peak shippers, i.e., small trains, could increase their use of the facility, with an increase in net social surplus.

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* See Alan Abouchar, "On the Transport Cost of Iron Ore Export via the Central do Brasil Railway", IPEA, Rio de Janeiro, June 1968.

** Part of the expansion costs are due to the higher volume rather than the larger train size. This part should be used as an input into the determination of the floor for the price to all users.

III. Review of Recent Examples

The last ten years have witnessed many empirical presentations urging adoption of marginal cost as a pricing criterion. The very frequency with which the term is used leads planners into thinking that marginal cost is easy to define and determine in actual situations. Defects in the presentation of cost concepts or in planners' understanding of the concepts then lead them to use something like short-run variable cost as an approximation to the long-run marginal cost which is required for efficient utilization of new investments. This was the case in the railroad project just discussed. Sometimes even more wayward notions are indulged; the Brazilian federal railroad network, for example, makes no charge for rolling stock in its annual operating result, presumably on the dubious grounds that being already in the network's possession it has zero marginal cost. Many of the presentations themselves are really examples of pricing at average cost, or relate to rising-cost industries, as we will now show, and so avoid the issue of where the funds are to come from to undertake expansion. This causes planners to think either that this issue is automatically resolved or that it is trivial. All these factors, then, encourage the view that marginal cost pricing is easy and that there is no difficulty in specifying marginal cost. But far from being the case, the determination of marginal cost is usually empirically difficult; and, what is even more vexatious, simply to define it is full of conceptual problems. How define, for example, marginal cost for the highway sector in which an existing large network is being expanded each year. For reasons such as these the following review will serve a useful purpose by disabusing planners in underdeveloped countries of the notion that their colleagues in developed economies have succeeded in implementing marginal cost pricing.

a. Highway Pricing and Locational Efficiency. In his recent study, of transport pricing, Alan Walters contends that highway users should pay only the marginal costs associated with their use of the road. He writes:

> "It is sometimes alleged that, if road users are not required to pay the fixed costs associated with the provision of the highway, industry and agriculture will make inefficient decisions about the location of plant and farm. If the government bears a substantial fraction of the fixed costs of location, it may be thought that the plant or farm will be located so that it requires too much of the (allegedly) subsidized road transport - and (perhaps?) the government will be induced to overbuild the highway system."
>
> "All these conclusions are, however, wrong, as argued in Chapter IV. If the road authority levies the EUC [economic user charge] for the use of the road and if it employs the consumer surplus criterion for investment, there will be no inefficient location decisions and the authority will not "overbuild" the highways. And this will be true whether or not the government collects the "fixed" charges by a levy on the rents generated by the building or improvement of the road."*

We have not far to look for the error in the proposal just put forth. Suppose that on the net consumer surplus criterion, as normally defined (the difference between total utility and total cost calculated at the point of intersection of the demand and long-run marginal cost curves), a highway investment project is justified. Well and good! But the "economic user charge" recommended by Walters reflects only the variable portion of annual maintenance costs and congestion cost. This cost curve would lie below the LRMC curve of Figure 1 and, therefore, would cut the demand curve to the right of the demand-marginal cost intersection, introducing a negative surplus and reducing the net social benefit. In the geometry of Figure 1 it would lead to production at a point like Q_3 rather than Q_2, yielding a smaller net surplus.

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* Alan A. Walters, The Economics of Road User Charges, International Bank for Reconstruction and Development, Washington, D.C., Jan. 1968, pp. 17-18. The economic user charge is defined earlier to reflect only a variable maintenance cost and a congestion cost (pp. 11-12).

Although we have appealed to Figure 1 to help in selection of the appropriate cost criterion for highways, the problem is really much more complex. Figure 1 illuminates the question of investment and pricing of individual projects, whereas highway investment is usually a supplement to existing networks, and, moreover, a supplement whose user charge collection would be difficult -- it would require limited access for one thing. We return to this problem in Section IV.

It is also worth noting here that the maintenance cost is in any event much higher than is usually supposed so that if a user charge relying only on maintenance and congestion is used, the charge will not be slight. Thus, a recent study of Brazilian highway costs shows that the amount spent on the maintenance function, broadly defined to include all costs of the "operating" rather than initial investment type and which, therefore, include heavy expenditures on premature reconstruction, was very much higher than what is normally assumed. This was due to the terrible abuse of the roads by heavy trucks. To discourage this, a tax was proposed which would impose disproportionately high user costs on new vehicles and encourage the observance of nameplate loading specifications, and also the use of smaller vehicles.*

b. <u>MCP in Electric Power Supply</u>. James R. Nelson's recent volume on French pricing** contains contributions by French engineers which attempt to justify marginal cost pricing intuitively. However, in reality these

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* Alan Abouchar, "Brazilian Highway Expenditures and the Construction-Maintenance Mix", paper presented at the Fourth Highway Research Symposium of the Brazilian Institute of Road Research, Rio de Janeiro, 1968. The tax is of the form X^aN^{-b}, with X the rated capacity and N the age in years. The coefficients would have to be calculated experimentally to encourage vehicle husbandry.

** James R. Nelson, <u>Marginal Cost Pricing in Practice</u>, Prentice Hall, 1964.

contributions either are examples of average cost pricing or reflect increasing cost activities and as such do not fall within the purview of the marginal cost concept which has stirred up all the controversy. The following three examples show this very clearly:

i. In a paper entitled "Marginal Cost Pricing", which forms Chapter III of the book, Marcel Boiteux describes a situation in which the needs of a potential new customer will require new generating capacity in a region. The cost of new capacity is 75 percent higher than the cost at existing plants owing to devaluation of the franc. Therefore, all power supplied from existing plants to already established users as well as that supplied to potential new users should be sold at the new higher price of 3.5 centimes, according to Boiteux, who reasons that "energy prices ought to be such that the head of the firm is constantly confronted with the cost which the entire society will have to bear if he increases his consumption" (p. 53).

Agreement with the quoted statement does not depend on acceptance of the marginal cost pricing principle which was espoused for decreasing cost industries. For competitive, rising-cost industries, even those whose higher costs are generated somewhat artificially through devaluation, there was never any question but that price would equal marginal cost through the workings of competition and profit maximization. And even in the example where we are dealing with a government controlled industry rather than competition, we could justify by other means the use of the higher price (3.5 centimes) for all facilities and to all users. For example, a price near 3.5 centimes would probably emerge as the shadow price for electric power in a regional final-output linear maximization problem, a Ricardian rent thereby accruing to all previously existing producing units.

ii. Boiteux's second example (p. 55) is the transmission of power over existing lines. Here he advises that all units should be sold at the same price, which should be set equal to the transmission loss encountered at any load. But since the loss rises with increased transmission load, we again have a problem of rising marginal cost and again nothing is gained by allusion to the doctrine whose controversial aspect appears only when it is concerned with decreasing cost activities.

Actually, the problem of electricity pricing is a good deal more complicated. As already noted, it has been more sharply defined as a peak-load problem and solved in varying degrees of generality by several writers, including Boiteux himself in the same volume containing the essay just discussed.

iii. In "The General Principles of Rate-Fixing in Public Utilities", another essay in the volume, to justify MCP Gabriel Dessus makes recourse to a short parable of a village surrounded by timber stands and coal deposits. He defines marginal cost as the cost of logging higher up the hill. When the price reaches the cost of coal mining, coal will begin to be used as a substitute. But, he suggests, if average logging cost is used to price firewood, an inefficient solution will result since some of the wood -- that logged higher up the hill -- will be purchased at cost higher than coal costs. If marginal cost is used, however, the signal for the consumption of coal will be given at the right time.

Two problems vitiate the use of this example to justify MCP in decreasing cost industries. First, marginal cost as defined by Dessus will rise rather than fall as timber is sawn higher up the hill, so that again we have the kind of situation for which MCP is not controversial. Moreover, the situation would not even arise, at least not if any kind of rationality prevails in the community. Logging would not take place simultaneously down below and up above. Instead, each year would see operations move a little higher, with the average cost each year rising somewhat. If this average cost is used as the pricing criterion the signal to start using coal will be unmistakable and will appear when an altitude is reached at which logging cost surpasses the cost of mining coal.

c. A Cost Function for the Highway Sector. In an already cited empirical study of highway cost, Allen Ferguson defines as a "marginal cost function" a cost apportionment in which the incremental highway expenditure -- the expenditure for incremental pavement depth, for example -- is distributed over the traffic for which the increment is required. To charge highway users according to the resulting costs means that each traffic class pays all the costs associated with its use of the highways, each unit of the class paying the average cost incurred in its behalf. Marginal cost, on the other hand, when correctly defined, refers to the extra cost required to produce an additional unit of a homogeneous product or service. In the case in question, to construct a marginal cost function might be to represent the increase in the total cost required to build and operate a highway for different volumes of traffic, with the technology of construction, of course, varying for different output levels, and the unit of output being e.g. vehicle miles per year or axle- or ton-miles, with the relative composition of the traffic being constant. Under MCP the marginal cost, so determined, would then be charged to all users and, as long as the curve is falling, the financial result would be a budgetary deficit rather than the solvency which the incremental cost function really would produce. As we indicated in Section II, however, the pricing and cost calculation schedules actually advocated by Ferguson, with the reservations noted earlier, do represent a sensible approach to the problem. But his cost allocation is not a marginal analysis.

IV. The Correct Cost Bases for Transportation Price-Setting

In many industries -- most notably transport industries such as railroading, coastal shipping, and automotive transport -- different capital components have very disparate lives. Typically, the life of moving equipment, which may account for 40-70 percent of the industry's capital costs, runs from eight to 20-25 years, while the bulk of the investment in fixed capital facilities has a life of upwards of 25-30 years. For example, locomotives may have a 25-year service life, ships 15-25 years, and trucks and buses up to 10-12 years. In contrast the associated permanent facilities have lives about twice as long; 40-50 years may pass in the life of railroad permanent way, tunnels, and harbor works before substantial improvements become necessary, and 20-25 years in the life of roads.

In conditions of extreme variability of important capital components, the economist's traditional short-run/long-run point of departure presents some disconcerting problems. For example, to hold constant the permanent facility and define the short run as the period -- perhaps as long as 30-40 years -- in which all other inputs, including moving equipment, are variable, is contrary to everyday concepts of time. A more important objection from the economist's viewpoint is that we may be interested in the behavior of costs after all of the major investments of the firm or industry have already been undertaken, i.e., in what happens when other inputs such as labor and materials are varied as operating intensity and maintenance schedules are altered to meet changes in business conditions. If we start by defining the short run as the period in which all inputs other than the basic permanent facility are variable we cannot isolate the effect of variations in equipment from that of changes in labor and fuel inputs. But such a distinction is necessary if we are to attempt more rational pricing.

The argument just presented against the consideration of equipment investment as a short run variable suggests the alternative of considering the short run as the period in which both the fixed facility and the moving equipment are given. This would be inconvenient for pricing policy, however. For example, while we might want to treat the basic facility as an irrecoverable sunk cost, the equipment itself has a definite value in alternative use -- ships or railway moving stock could be sold abroad, for one thing, and their lives could be extended by less intensive use. More generally, to consider both capital components together obscures the potentials inherent in different blends of the two kinds of capital. For example, a more fixed-facility-intensive railroad technology utilizing costlier-to-build flatter grades and gentler curves would require a smaller investment in rolling stock for a given traffic, since the equipment would travel faster and give a higher annual output, and these possibilities would be clouded by considering the two different capital components as a single input.

We now present two cost concepts: the first is appropriate for pricing of already existing facilities and the second for facilities undergoing expansion. The first, then, is relevant primarily to railroads while the chief application of the second will be the highway sector. Both cases represent simplifications, with a homogeneous good being assumed in each.

IV.1. Already Existing Facilities

A contribution to the resolution of the question of meaningful time periods in transportation cost analysis was recently made by Richard Heflebower who introduced the concepts of intermediate-run average cost and basic average cost.* Associated with a permanent facility of given technological standard there is a family of intermediate-run average cost curves each of which corresponds to a different equipment capital stock and shows the average cost per unit of output of all the inputs -- permanent facility, equipment, labor and material -- when the equipment is operated at different levels.** Then the basic average cost curve is the envelope of the family of intermediate-run average cost curves corresponding to a basic facility. It is important to note that the basic average cost curve does not refer to the average unit cost of the basic permanent facility itself

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* Heflebower, Richard B., "Characteristics of Transport Modes", in Gary Fromm, editor, Transport Investment and Economic Development, 1965, The Brookings Institution, Washington, D.C.

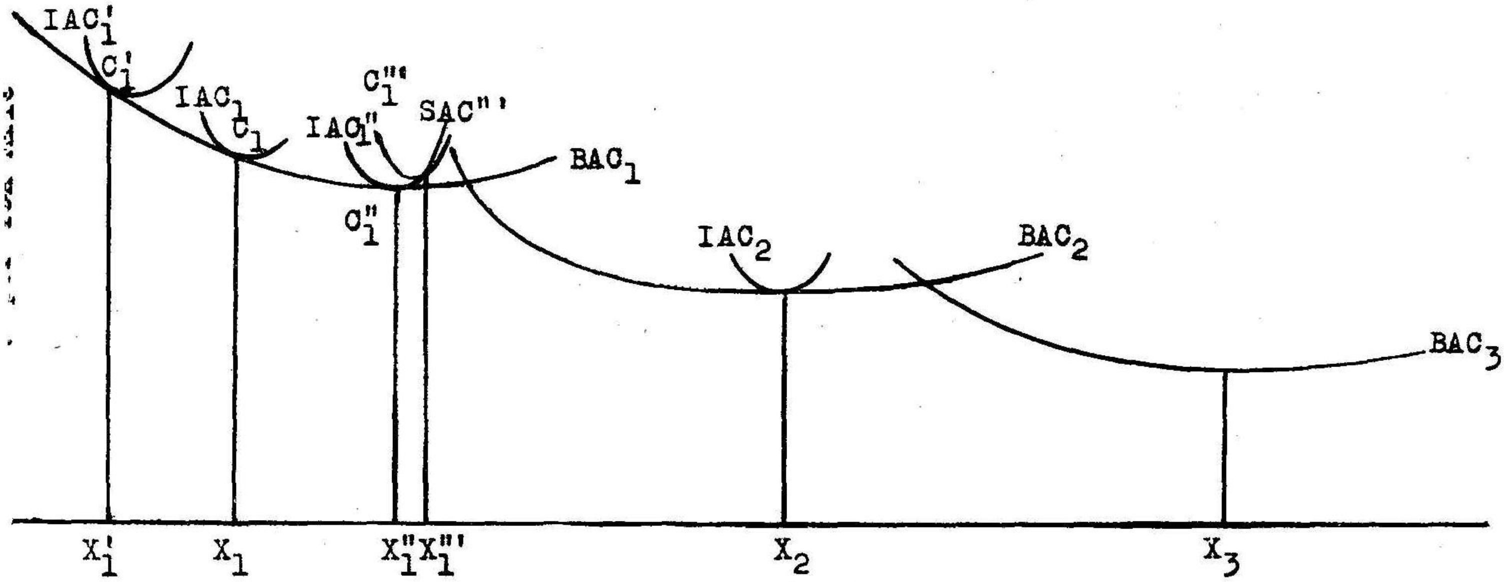
** Throughout this section we are assuming a homogeneous output in all respects, e.g. in respect to commodity composition, seasonal peak patterns, average length of haul -- or, indeed, distribution of lengths of haul, and so on. In any attempt at empirical verification we would have to keep this in mind in order to separate the effects of differences arising in different output composition from those ascribable purely to size of output. The problem, of course, is a serious and difficult one which has not been resolved to general satisfaction. Its magnitude may be perceived from a study by George Wilson which shows that the cost for a given ton-mileage of truck traffic fluctuates violently with the ratio of weight to miles. In general, a given ton-mileage composed of greater distances and smaller weights costs less than the same volume composed of shorter distances and greater weights. For example, 30 ton-miles could be the product of 600 pounds by 100 miles or 100 miles by 600 pounds. The truck operating costs required in the former combination are nearly twice as high as those required by the latter. See George Wilson, "On the Output Unit in Transportation", Land Economics, August 1959, p. 000.

and that no prominence is given to the average cost of all inputs except basic permanent facility. Thus, after recognizing the intermediate run as a crucial time period in transport economics, Heflebower clips its wings by failing to isolate those costs which may be varied while holding constant the permanent capital facility, although it is precisely this cost which is, or should be, the main criterion for traffic allocation and pricing in existing transport systems.

The difficulty in Helflbower's presentation can best be seen by reference to the original. Figure 2 is a copy of the diagram accompanying his article. The intermediate-run average cost curve shows the behavior of average total cost of a given amount of equipment operated with a particular permanent facility for different levels of output. Heflebower's basic average cost

FIGURE 2

Transport Costs for Different Periods and Capacities (Heflebower)



Ton-Miles of Traffic

curve is tangent to a family of such curves and shows the average total cost of the given technological mix when it is operated optimally. That is, each point on the basic average cost curve represents the unit operating cost of the combination of equipment and permanent way which is optimal for the traffic level indicated by a perpendicular from the point to the X axis. Now, while the basic average cost curve is the appropriate approach for the design of transport facilities and for investment choice among alternative transport modes, the intermediate-run average cost is not relevant for most analytical and decision-making purposes, either of the firm or of a central planning agency, when the basic transport facilities already exist. This is precisely the condition in most developed countries and is characteristic also of the important arcs even in a good many underdeveloped economies. In such conditions the following situations are likely to be encountered.
1) The central planning agency is interested in allocating total traffic so as to minimize costs "from now on". 2) Industry planners must consider the transport cost which their location decisions will impose on the economy in the future after a new plant is in operation and begins to generate regular traffic; a proper element in such a cost is, of course, the cost of the equipment to carry the new traffic. 3) Profit maximization would require that the individual railroad or trucker continue to accept traffic until the point where no more profit could be attained. The quasi-monopolistic nature of such enterprises enables them to discriminate among customers, i.e., among kinds of traffic, and can price different traffic components differently. What cost represents the floor below which such a firm could accept no more business?

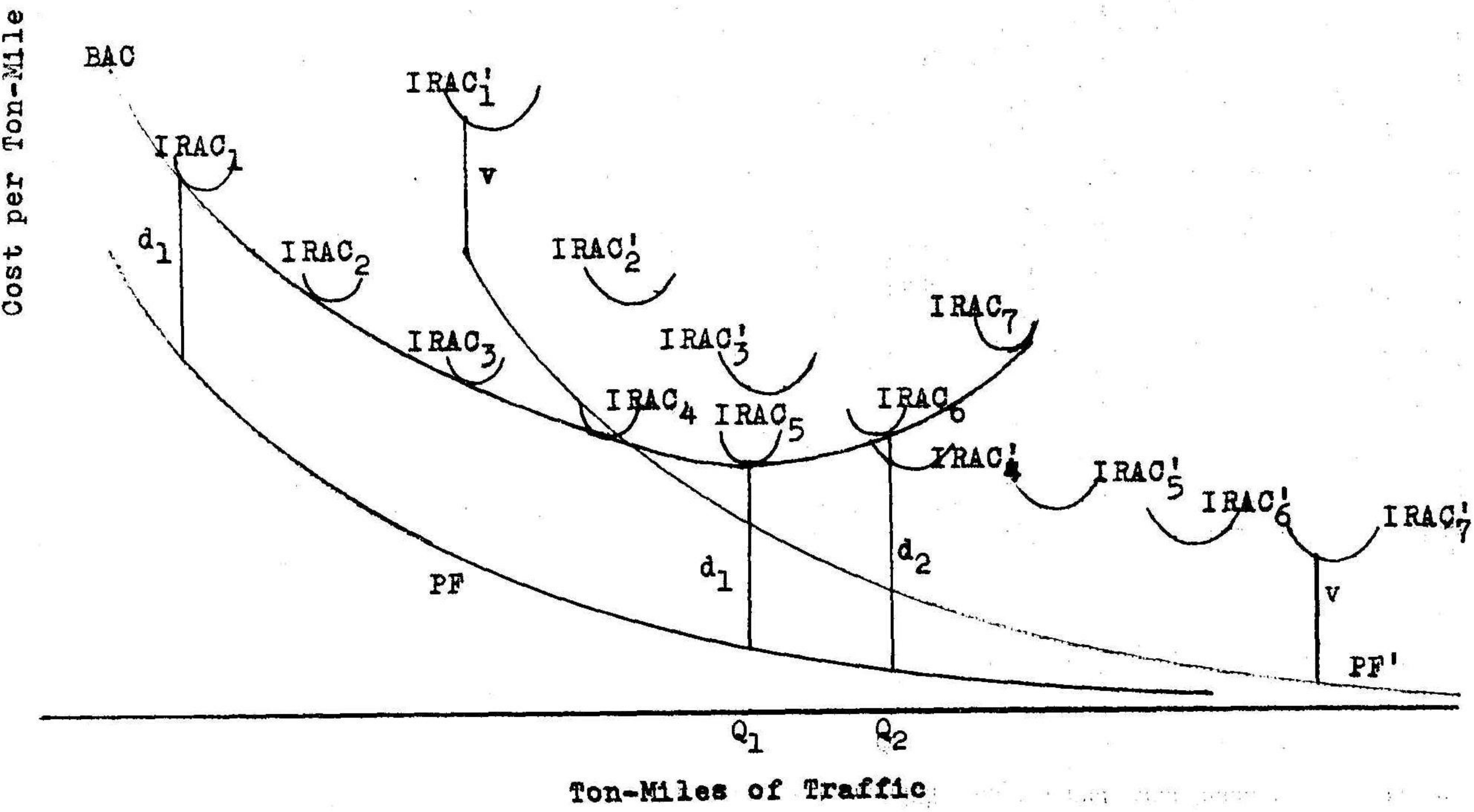
As we have just described the cost we are seeking, a kinship is suggested between it and the traditional short-run marginal cost. Obviously, however, it is not the latter cost since short-run marginal cost accepts as given the equipment stock while, as noted in the foregoing paragraph, the cost of the equipment required for new traffic must be included in e.g. plant location decisions. Nor would the cost we are seeking derive from any single intermediate-run average cost curve since the latter relates to a given equipment stock, and its first derivative, the intermediate-run marginal cost, would reflect only the cost of the inputs such as labor and fuel which are variable after the equipment investment is already made.

We will now derive the Permanent Facility Variable Cost, or PFVC, which we propose as the cost most relevant for transport analysis and policy when the permanent fixed facilities are already present. Even if a country does not have fully ramified networks of all transport modes, the cost which we propose here, calculated for each mode of transport, should nonetheless serve as a major input to traffic pricing and allocation decisions on arcs which are served by several modes; this cost is also extremely important even when just a single mode services an arc and should constitute the transport cost element used in location decisions, for example.

Starting with a permanent facility, such as the railroad permanent way, of a certain technical standard, the average fixed cost per unit of traffic is represented by an asymptotically falling curve; another basic facility built to higher standards regarding turning radius, grades, passing tracks, and so on will have a different permanent facility unit cost curve. Two such curves, PF and PF', are shown in Figure 3. These curves show the average fixed cost of the permanent facilities when operated at different levels. PF' is higher than PF since it represents a costlier facility. Each of these permanent facilities may be operated with varying amounts of equipment such

FIGURE 3

Intermediate-Run Average Cost, Basic Average Cost, and Average Fixed Cost for Two Permanent Capital Facilities



as locomotives and rolling stock. To each amount there corresponds an intermediate-run average cost curve whose minimum point is the point of minimum cost for that particular combination of intermediate-run capital and basic permanent capital; elsewhere on the curve costs are higher because of under- or over-utilization of equipment.

For each permanent facility we have drawn a family of seven intermediate-run average cost curves. However, with the usual divisibility assumption, each of the intermediate-run cost families would contain a great many more curves which would intersect. The line tangent to each curve in a family, i.e. the envelope of the family of curves, is Heflebower's BAC curve.* Such a curve is drawn for the lower cost permanent facility (for simplicity the line is drawn as continuous, indicating infinitessimally divisible variable capital stock increments, but this need not be the case). The perpendicular line segment drawn between the tangency points of BAC and PF shows the average cost, under efficient operation at the volume of output indicated by extension of the perpendicular to the X axis, of all the inputs except the investment cost of the basic permanent facility itself (maintenance of the permanent facility is included, however).

As in Heflebower's presentation, if we were to draw a long-run average cost curve it would be the scalloped envelope of the successive basic average cost curves. The more divisible were investment in progressively more advanced permanent facility complexes, the shorter would be the scallops in the long-run average cost curve.

The intermediate-run average cost curves for the lower cost permanent facility (IRAC) are a greater distance from their permanent facility cost curve than the intermediate-run average cost curves of the more expensive facility (IRAC') are from theirs. The reason is that the more expensive facility has smoother grades, better passing tracks, less severe curves, and other superior technical specifications all of which reduce the fuel input

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* The BAC curve is drawn tangent to the intermediate-run cost curves rather than as the locus of their minima in a manner analogous to the construction of the long-run average cost curve in standard theory. This is because at the output corresponding to the minimum of any given intermediate-run curve (except the lowest one), a lower average cost can be realized by operating with the technology represented by a later curve (or, after the lowest curve is reached, by an earlier one).

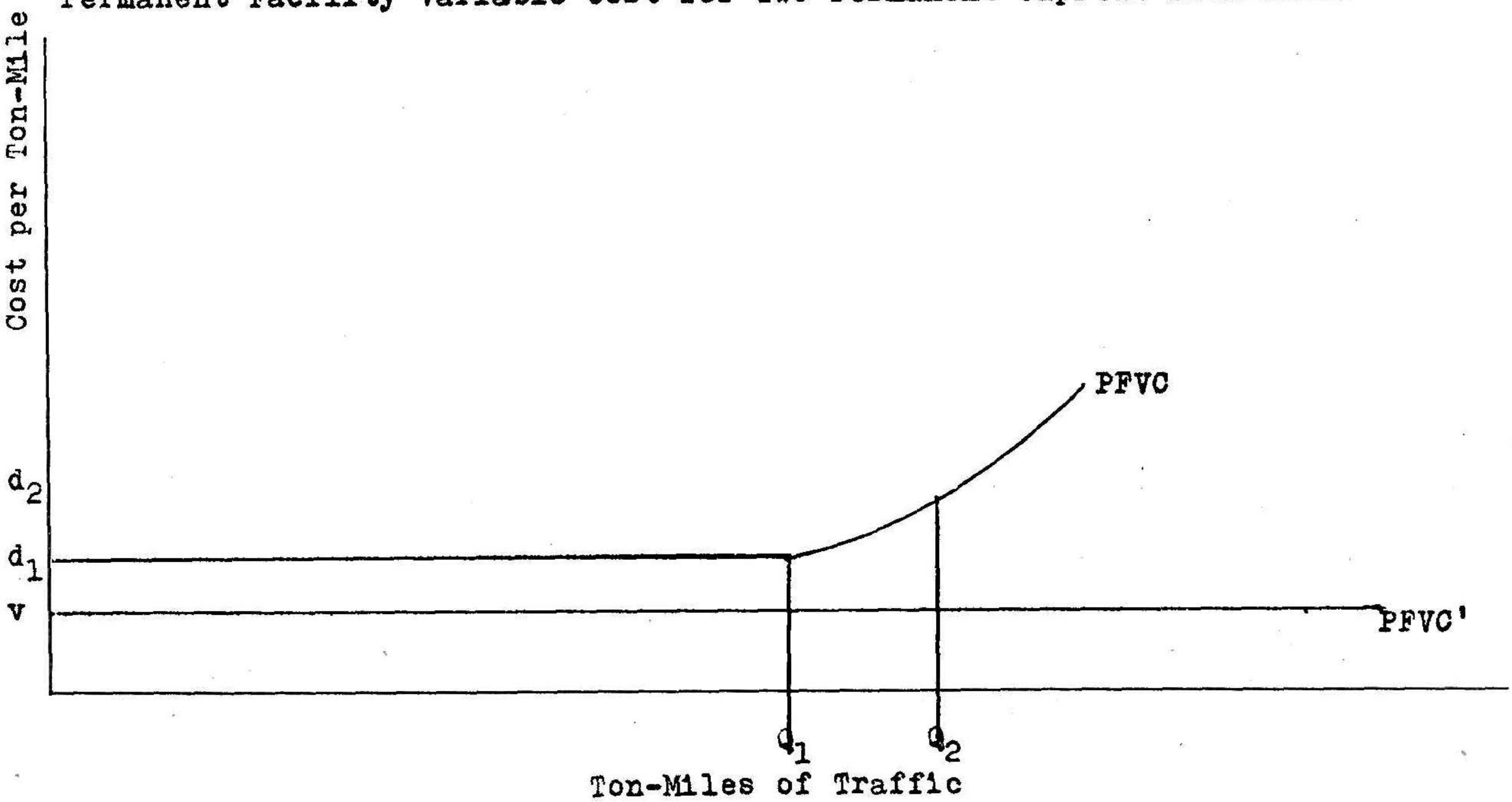
and also reduce the amount of equipment necessary for a given traffic by shortening trip time. Another point to note is that the IRAC curves rise and fall more sharply than the IRAC' curves; since the former reflect a greater amount of variable capital than the latter, there is a greater cost to distribute over traffic levels which are less than optimal for the given variable capital stock.

The envelope of the intermediate-run average cost curves falls following closely the slope of the permanent facility cost curve down to a point. For example, the BAC curve for the lower cost permanent facility follows the PF curve until the point Q_1 at which the direction is reversed, even though the average fixed cost shown by PF continues to fall. This happens because overcrowding of the facility necessitates more investment in variable capital equipment (signaling and communications devices, for example) and maintenance costs rise. At this point the distance between the BAC curve, which had been a constant d_1 up to point Q_1, begins to rise and becomes d_2 at point Q_2. Starting somewhere between Q_1 and Q_2 lower total facility costs, i.e. lower long-run average costs, would be attained with the more advanced set of basic equipment whose fixed cost curve is shown by PF'. The distance between PF' and the relevant points of the IRAC' curves over the range of observation is a constant, v.

In Figure 4 are traced the distances from the fixed-facility cost curve to the tangency points of the family of intermediate-run average cost curves for each of these two basic permanent facilities. (The lines are drawn as continuous because of our assumption of continuously divisible stocks of intermediate-run capital.)

FIGURE 4

Permanent Facility Variable Cost for Two Permanent Capital Facilities



The resulting curves are termed "permanent facility variable unit cost" and are designated PFVC and PFVC' and show, for each permanent facility, the average variable cost (fuel, labor, equipment charges, and so on) for each composition of variable equipment, when that set of equipment is operating as efficiently as possible. As Figure 4 shows, the variable cost for the technically superior and costlier permanent capital facility is lower than that of the less costly facility.

The expression "permanent-facility variable cost" which we have chosen for the important cost concept described here, although cumbersome, has been selected to avoid confusion with other costs. Thus, the expression "intermediate-run average cost" which might seem applicable has already been used to refer to a quite different concept. Other expressions, such as James Nelson's "out-of-pocket costs" or "long-term variable costs" include a return to capital invested in the fixed permanent facility which we exclude.* Finally, we might think of next year's traffic as an increment to the total output of the facility over its life and of its cost as a marginal cost of some kind, but this would introduce some confusion into a well defined static concept.

Finally, although the representation given here is believed to be new, novelty is not claimed for the cost concept itself. On the other hand while the desirability of such a cost standard for pricing, traffic allocation, and location analyses has sometimes been recognized, this concept has often been violated seriously, with the investment in moving equipment, such as rolling stock, being considered a sunk cost for which no charge need be made. Typically, this is the outlook of the Brazilian federal railroad network whose annual deficit calculation invariably excludes a proper equipment consumption charge, as we noted earlier. If the railroads were indeed prepared to close up their operations such a procedure might be acceptable; however far from anticipating such an eventuality, the railroads continue to purchase new locomotives and solicit new business although absolutely no effort is made to reflect such costs in the rate schedule.** A similar

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* Nelson, James C., Railroad Transportation and Public Policy, The Brookings Institution, Washington, D.C., 1959, pp. 36-7.

** This is discussed in my essay "Inflation and Transport Policy in Brazil", Economic Development and Cultural Change, Spring 1969.

situation is observed in the government coastal shipping sector where a regular liner passenger service has been recently introduced with very low rates, the argument being made that the ships represent a sunk investment whose costs need not be recovered. The ships are in fact relatively young and could be put to use in more lucrative international service or sold.

IV.2. Increments to Existing Permanent Facilities

When additions are being made to the part of the capital stock represented by the permanent facility the problem has a neat solution in theory although it is less satisfactory in application. The correct ideal solution would be to charge the users of the new increment at long-run marginal cost and charge PFVC to everybody on the old system. Because of its technological characteristics, this could be done without too great difficulty on the railroads, but typically the railroads are not expanding. Rather, it is the highway sector which is growing. Since highways are usually interconnected it is difficult to institute a system of charges specific to the particular artery or area in which the new addition is made. This approach would be preferable, however, as it would force users and regional planners to confront the real economic costs of their decisions. A second problem relates to the intertemporal distribution of cost. Since the road is built to last for several years its cost should be spread out over its life. Or should it?

While the letter of traditional marginal analysis cannot be applied here, considerations in the marginalist spirit do suggest a solution as follows.

First, as long as it is intended to maintain the road properly (we include large-scale maintenance or reconstruction as a maintenance item), no depreciation need be charged. However, an opportunity cost should be considered. As the system grew, this would lead rapidly to a stage at which annual interest was exceeding annual investment, causing highway users to object strenuously to their contribution, and the policy-maker would have to face an annual battle for reaffirmation, warding off the pleas that last year's construction is a sunk investment and should not enter this year's rate-making cost base. And, indeed, such objections are not trivial. It is very difficult to justify an opportunity cost for a highway built a few years back -- the investment did represent a forgone opportunity when it was built but what today are the alternative uses of "that stretch of road up there"?

The solution to the dilemma just posed is to incorporate the annual capital expansion cost into the cost base for establishing user charges. For an economy like Brazil this would appear to be a much more radical departure from the traditional and more widely accepted procedures than it really is. That is to say, many observers would be willing to accept the notion that maintenance is properly part of the rate base, but not so investment. However, it turns out that a good deal of what is commonly called investment really constitutes costs of the operating type, i.e. reconstruction due to heavy use of the road. Indeed, in an already cited paper it was shown that operating costs on this broader definition in Brazil are closer to 40-45 percent of total expenditures than to the 15-20 percent implied in the accounts of the highway authorities themselves.* Thus, to include total annual highway expenditures in the cost base would only represent an increase of 150 percent rather than a quint- or sextupling of the amount that more lenient observers prepared to accept maintenance in the basis for ratesetting would acknowledge as appropriate.

Finally, how should the amounts in question be distributed over users, if not on a specific road or regional basis? Again, the most obvious

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* Abouchar, Highway Expenditures.

solution is probably most efficient -- distribute the total over all users in proportion to their use. For the truth is that while the dramatic setting of some individual roads tends to invite our focus on the large expenditures being made in remote and unpopulated regions, these investments in sum are only a minor portion of the total annual undertaking. The traditional regions do get the lion's share. True, there is no guarantee that a particular user will take advantage of a new road being built in his region, and to this extent his activity will be penalized to encourage that of another, whose related social cost is higher. However, these imperfections are slight when compared with those existing in highway costing and pricing today. And to proceed thus probably would compare favorably with the procedures applied in education -- one of the other major targets of public expenditure. To charge every vehicle owner for a portion of the road investment, on the presumption that he constitutes a potential user of the new road, is probably less inequitable or inefficient than to levy property taxes on homeowners to pay for education on the presumption that it is the property owners who will use the schools, an area in which there certainly are many injustices.*

V. Conclusion

In this paper we have been concerned with the meaning and characteristics of marginal cost pricing in transportation. We first saw that in the simplified situation in which a single type service characterized a transport mode, discrimination and welfare maximization would lead to the same welfare and output levels as pricing at marginal cost. Later in reviewing many recent arguments for marginal cost pricing, however, we saw that these really

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* As noted in Section II.2, the highway charge would be best related to size and age to try to minimize road abuse, which is encouraged by the "scale-economy" taxes which are most widespread today.

depended on spurious examples or misconceptions of what constitutes marginal cost, and that marginal cost in reality is very difficult to define; simple situations in which it can be isolated require product homogeneity, for one thing, and this is seldom the case in transportation. The more realistic setting, in which several different kinds of service should be considered as the output, is analogous to the kind of situation for which peak-load pricing solutions have been put forth in recent years, and in Section II.2 we suggested that peak-load pricing principles be applied here as well. Doing this in an economy like Brazil would lead to charging heavy traffic such as iron ore for most of the cost of the railroad permanent way amelioration and extracting from other users the difference plus their own PFVC, a concept which we developed in Section IV to reflect the cost of variable capital equipment and normal operating expenditures. Section IV then concluded by presenting arguments for considering the annual highway investment as a cost component for determination of the user charge structure.