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Welfare Effects of Marginal Cost Taxation of Motor Freight Transportation: A Study of Infrastructure Pricing

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I. INTRODUCTION

Recent physical failures in the United States highway system, producing vehicle damage and even catastrophic accidents, have lent urgency to a growing perception that our highway infrastructure is seriously degraded. Repair estimates run in the hundreds of billions of dollars.

While this problem is nationwide in extent, much of the financial burden rests squarely on state and local governments. In 1982, state and local tax revenues financed about three-fourths of all U.S. highway expenditures, consuming over 8 percent of all state and local own-source revenues.[1] Virtually every state has a list of defective bridges for which repairs await funding, and several have raised fuel taxes and license fees. Individual cities such as New York responded to fiscal pressure for many years by deferring highway maintenance; now they face a seemingly impossible catch-up task, made more difficult by recent Congressional delays in appropriating interstate highway funds.

The most dramatic response has been the Surface Transportation Assistance Act of 1982, which increased federal fuel and truck-weight taxes in order to finance more federal highway assistance. Yet neither of these taxes bears a close relationship to the highway wear caused by various motor vehicles. Only the state weight-distance or ton-mile taxes vary with both weight and mileage, and only ten states have them.[2]

Furthermore, gross weight is a poor proxy for the damage done to a highway. Highway wear depends critically on weight per axle, hence it is not necessarily the heaviest vehicles that are most responsible for current conditions.

Thus, neither federal nor state policy seriously attempts to align motor vehicle taxes with the damage the vehicles inflict on highways, as would be required under a policy of marginal cost pricing. The state weight-distance taxes come closest. They also use administrative mechanisms that could be adapted to a such a policy, leading for example to a proposal along these lines by staff members of the Oregon Department of Transportation.[3] At present, however, little is known about what inpact such a policy would have.

The purpose of this paper is to estimate the welfare effects of instituting nationwide marginal cost pricing for heavy highway vehicles, with marginal cost defined as the incremental contribution of a vehicle to repaving costs. We first describe such a tax, using existing evidence on the marginal costs of various vehicle movements. Next, we outline a procedure for estimating the tax's impact on the distribution of vehicle-miles traveled by different types of heavy trucks, and on shippers' modal choice between truck and other forms of freight transportation. We then show how to calculate net benefits and the distribution of costs and benefits among shippers, carriers, and the public treasury. These calculations are carried out using 1982 data. Despite an attempt to be conservative throughout, we find that such a tax could go a long way toward solving the physical and financial problems of maintaining a sound infrastructure.

II. THE SIZE AND STRUCTURE OF MARGINAL COST HIGHWAY TAXES

Conventional highway engineering practice defines a unit of road wear called the equivalent single axle load (ESAL), which refers to the amount of wear caused by a single axle bearing 18,000 pounds. A highway is designed to withstand a given number of ESAL applications, after which major repairs such as resurfacing become necessary.[4] This implicitly assumes that the passing of a given vehicle does the same pavement damage as the passing of a particular number of single axles each bearing 18,000 pounds. That number is called the load equivalent factor or ESAL number of the vehicle, and it is a very sensitive function of the weights on each of its axles. As a rough approximation, the load equivalent factor of a truck (or tractor-trailer combination) is the sum for each of its axles of (w/18) to the fourth power, where w is the weight on that axle in thousands of pounds. This relationship is based on a test-track experiment performed in the early 1960s,[5] and is further supported by mechanical models of pavement stress.[6] Corroborating evidence from actual highways is weaker but not entirely absent.[7]

Besides hastening major repairs, pavement deterioration adversely affects user costs of all vehicles using the highway because of lower average speeds and greater vehicle wear. These are at present only very imprecisely known, and are not included here.

In an appendix to the recent Federal Highway Cost Allocation Study, the Federal Highway Administration (FHWA) has included estimates of the properly discounted highway repair costs caused by an ESAL under various conditions (U.S. FHWA, 1982a, p. E-28). These range from \$.05 to \$.50 per ESAL-mile. As a fairly conservative estimate, we use the average of rural interstate and rural arterial roads, which is \$.09.

To avoid double-counting, we do not include any allocation of the extra construction costs required to build the original highway to heavy-duty specification. In future work, we intend to refine these estimates and possibly the ESAL unit itself as a measure of highway damage. There seems no doubt, however, about the basic premise: highway damage varies steeply with axle weight.

The Cost Allocation Study also provides estimates of the load equivalent factors for selected motor vehicle types and gross weights. We have adapted these to the vehicle types and weight classes chosen for our analysis,[8] then multiplied by the $.09 figure. Selected results are presented in Table 1. Each vehicle type is identified by a code giving the basic configuration (SU for single unit, CS for conventional tractor and semi-trailer, DS for tractor and double-trailer) followed by the number of axles. The vehicle types used in this study are displayed in Figure 1.

Of the thirteen vehicle types distinguished in our data set, we have selected five as the starting points for what we think will be the most significant shifts, because of either high usage (e.g. the 5-axle tractor-semitrailer combination designated CS5) or high load equivalent factor (e.g. the 2-axle vans designated SU2 and registered above 33 thousand pounds). In 1982 these five accounted for 90 percent of all vehicle-miles by vehicles larger than pickup trucks. Similarly, of all the possible vehicle types to which truckers initially using each of these five might shift, due to the new tax, our analysis is restricted to one that seems most likely to be important. The resulting shifts are: from 2-axle to 3-axle single-unit trucks (SU2 to SU3); from SU3 to 5-axle tractor-semitrailer combinations (CS5, also known as "eighteen-wheelers"); from 4-axle to 5-axle semitrailer combinations (CS4 to CS5); from CS5 to the relatively rare 6-axle semitrailer combination (CS6); and from 5-axle to 9-axle double-trailer combinations (DS5 to DS9).

Table 1. Marginal Costs ($/vehicle-mile)

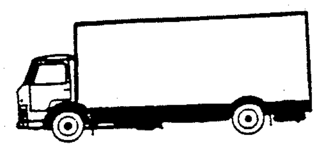
Vehicle Type	Gross Vehicle Weight (thousands of pounds) 26	33	55	80	105
SU2	.066	.171	1.319		
SU3	.012	.031	.236	1.058	
CS4		.012	.090	.404	
CS5		.006	.046	.207	.614
CS6			.027	.120	.356
DS5			.080	.360	1.068
DS9			.007	.030	.090

Key:
SU = single unit truck
CS = conventional tractor and semi-trailer
DS = tractor and double-trailer
The number following the letter code is the number of axles.

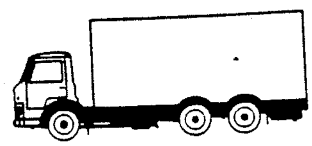
Figure 1.

TRUCK TYPES

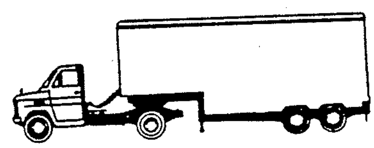
SU2 Single unit, 2 axle



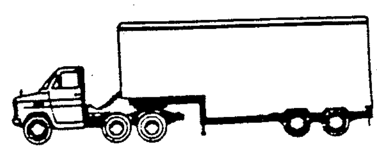
SU3 Single unit, 3 axle



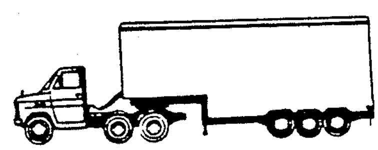
CS4 Conventional semi, 4 axle



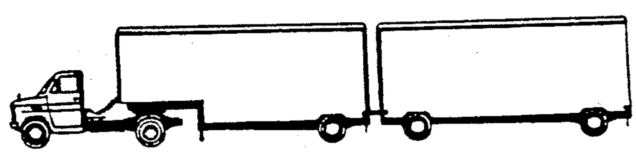
CS5 Conventional semi, 5 axle



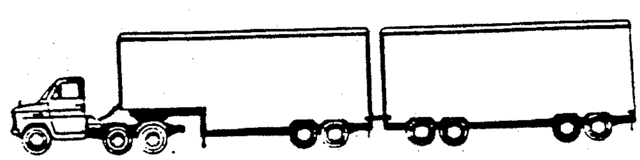
CS6 Conventional semi, 6 axle



DS5 Double, 5 axle



DS9 Double, 9 axle



The double-trailers are of greater interest than their small vehicle populations would suggest, because the 1982 federal legislation forced all states to legalize them. This raises a safety issue which is ignored here but which needs resolution before such a tax is adopted.

In order to translate the marginal costs into tax rates, we assume that each vehicle is taxed at 80 percent of its mileage. This is to account for the fact that between 10 and 25 percent of truck mileage is with no load, and that another 10 percent or so is with less than three-fourths of a load.[9] We also assume that each tax rate is an accurate reflection of the highway damage that vehicle produces. Finally, we assume that the tax replaces the existing (1982) federal and state mileage-related taxes, including fuel taxes, but not those taxes levied as an annual fee per vehicle. Our rationale is that annual fees are payments for services or externalities such as police, signaling, and congestion that are predominantly urban, and therefore not proportionally related to vehicle utilization.

A practical issue concerns implementation. As a first approximation, the tax could be collected on the basis of registered maximum gross weight, which is how we have modelled it and which accords with current taxing practice in those states that levy a weight-distance tax. A more fine-tuned tax could allow firms to document their actual load distributions and pay tax based on actual weight carried. A further refinement would be to vary the tax by road type, levying a higher rate for travel on non-interstates to reflect their greater vulnerability to wear from heavy loads. Each of these refinements requires greater record keeping, but if applied only to larger firms this does not seem an insurmountable burden. States with weight-distance taxes already require considerable record-keeping and have extensive auditing capabilities (New York State Legislative Commission, 1983).

III. WELFARE ANALYSIS METHODOLOGY

Instituting marginal cost pricing for motor vehicles will have a number of effects, not all of which we can model here. Truckers themselves would potentially respond in at least three ways. They might redistribute the loads on existing vehicles more evenly in order to reduce their highest gross weights (since the tax rises more than proportionally with weight). They might expand their fleets so as to operate at lower average loads. Finally, they might shift their fleet composition toward vehicles with more axles, either by selling and buying vehicles or, where possible, by retrofitting existing vehicles. Based on conversations with industry experts, we believe the last to be the most likely, and model it under the heading of vehicle-type shifts.

Since in most cases the new tax would be higher than the one it replaces, trucking rates would rise (though not by as much as would be predicted ignoring vehicle-type shifts). Shippers would respond by shifting some traffic to other transportation modes, particularly rail. We also model this modal shift.

For each of these two shifts, we calculate the change in tax revenues and in road maintenance and repair expenditures, the difference between which measures the effect on governments' budget balance. From that is subtracted the loss of producers' and shippers' surplus to obtain the net welfare gain.

Vehicle-Type Shifts

We analyze shifts within the five vehicle-type pairs described previously by assuming that exactly the same payloads will be carried in the new vehicles.[10] We originally planned to model vehicle-type choice as one of simply using the vehicle type with lowest cost including tax. In reality, however, firms have greatly varying needs that may make them favor some vehicles over others for reasons other than relative costs. We therefore assume that shifts between vehicle types are proportional to the change in their relative costs. We accomplish this by postulating a fixed elasticity of substitution. By doing this we implicitly assume that the shift is also proportional to the extent to which the new vehicle type is in use initially; this recognizes that it will take a long time to alter habits, vehicle stocks, and truck manufacturing capacity.

Each shift is measured as the change in vehicle-miles traveled by the new vehicle type. For the given vehicle-type pair and weight class under consideration, let $i=0,1$ denote the initial and new vehicle type, respectively, let q_i be the corresponding number of vehicle-miles, and let p_i be the average cost per vehicle-mile including taxes. Let tf_i be the fuel and weight-distance tax per mile, which we estimate from U.S.FHWA (1982b), and which is to be replaced by the new marginal-cost tax of t_i . Letting Δ denote a change, the changes in the two tax rates are $\Delta t_i \equiv t_i - tf_i$, $i=0,1$; and the vehicle-type shift as defined above is $\Delta q_1 = -\Delta q_0$.

The elasticity of subsitution σ between vehicle types 0 and 1 is defined (so as to be positive) by:

$$(1) \qquad d(\log q_1) - d(\log q_0) = \sigma[d(\log p_0) - d(\log p_1)] \quad ,$$

where d denotes a differential and $\log$ the natural logarithm. Since taxes are the only part of costs that change, we can write the approximation of this for discrete changes as:

(2) $(\Delta q_1/q_1) - (\Delta q_0/q_0) = \sigma[(\Delta t_0/p_0) - (\Delta t_1/p_1)]$.

The vehicle-type shifts will tend to come from firms that are nearly indifferent between the two vehicle types in the initial equilibrium. We represent this by the approximation $p_1=p_0$. Setting $\Delta q_1=-\Delta q_0$ and rearranging terms, we therefore have:

(3) $\Delta q_1 = -\Delta q_0 = \sigma[q_0q_1/(q_0+q_1)](\Delta t_0-\Delta t_1)/p_0$.

Since we have chosen our vehicle types so that type 0 has a larger tax rise than type 1, expression (3) is positive.

All welfare effects refer to those shipments originally using type 0 vehicles. These represent q_0 vehicle-miles of travel, both before and after the shift. To avoid double-counting, no welfare effects are measured for shipments originally using type 1 vehicles, since in most cases those vehicles are also treated as type 0 vehicles in another pair. Tax revenues from these shipments were originally $q_0t^f_0$ and become $(q_0-\Delta q_1)t_0 + (\Delta q_1)t_1$. Using the above definitions, this change in revenues can be written:

(4) $\Delta R = q_0\Delta t_0 - \Delta q_1(t_0-t_1)$.

Note that (t_0-t_1) is positive since the new tax rewards carrying a given load in a vehicle with more axles.

Because t_0 and t_1 reflect highway maintenance and rehabilitation expenditures caused by the respective shipments, the shift causes those expenditures to change by

(5) $\Delta M = -\Delta q_1(t_0-t_1)$.

This quantity will usually be negative, reflecting a cost saving. The change in the government budget balance is

(6) $\Delta B = \Delta R - \Delta M = q_0 \Delta t_0$.

Expression (6) is independent of the amount of shifting because the new tax is assumed exactly equal to the maintenance cost incurred by the vehicle paying it.

The marginal cost tax will generally lead to higher trucking costs, some or all of which will be passed on in higher shipping charges and, ultimately, in higher consumer prices. This will cause a loss in producers' and consumers' surplus that can be computed in the usual way using the simultaneous demand for services of the two vehicle types as a function of prices p_0 and p_1. Due to the absense of income effects in our model, it is independent of the particular path by which the prices are assumed to change. We use the path shown in Figure 2. First we simultaneously raise p_0 and p_1 by an amount Δt_1 ; since this does not change q_0 , it causes a change in surplus of $-q_0\Delta t_1$. Next, holding p_1 constant, we raise p_0 by an amount $(\Delta t_0-\Delta t_1)$, causing the shift Δq_0 and consequent change in surplus $-(q_0+\Delta q_0/2)(\Delta t_0-\Delta t_1)$. Thus we can write the total change in surplus as

(7) $\Delta S = -q_0\Delta t_0 + (1/2)\Delta q_1(\Delta t_0-\Delta t_1)$.

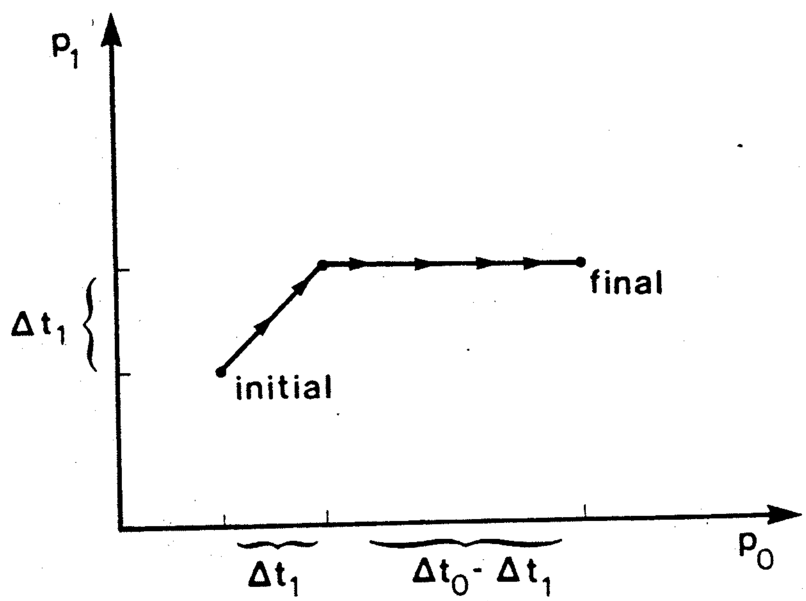


Figure 2. Price Path

The first term in (7) represents a naive calculation of the loss to truckers and shippers; the second term is an offset representing ability to reduce tax burden through vehicle-type shifting. Noting that ΔS is negative, it is useful to restate (7) as

$$(8) \qquad \Delta p \equiv -\Delta S/q_0 = \Delta t_0 - (1/2)(\Delta q_1/q_0)(\Delta t_0 - \Delta t_1) \quad .$$

If truckers earn no economic profits, this is the cost increase per vehicle-mile passed on to shippers through higher rates. It is used in the next subsection as the basis for computing shippers' response through modal shifts.

Combining equations (6) and (7), we obtain a net welfare gain from the vehicle-type shifts of

$$(9) \qquad \Delta W = \Delta B + \Delta S = (1/2)\Delta q_1(\Delta t_0 - \Delta t_1) \quad .$$

This equation should be recognized as an example of the "rule of a half" for measuring the welfare effects of simultaneous changes in tax rates on several goods (Harberger, 1964, p. 40).

Modal Shifts

With the higher trucking rates expressed in equation (8), some shippers will shift to other modes of freight transportation such as railroads. Use of trucks will therefore be reduced still further. Assuming an own-price elasticity of demand for trucking of $-e_m$ from this effect, the resulting change in vehicle-miles is $\Delta q_m = -q_0 e_m \Delta p/p_0$. Using (8), this can be written as:

$$(10) \qquad \Delta q_m = -e_m q_0 \Delta t_0 / p_0 + (1/2) e_m \Delta q_1 (\Delta t_0 - \Delta t_1)/p_0 \quad .$$

Note the loss in tax revenue from this shift, $t_0 \Delta q_m$, just cancels the reduction in highway maintenance and rehabilitation expenditures. Hence there is no net effect on the budget balance: $\Delta B_m = 0$. However, the existence of the rail option does offset the loss of producers' and consumers' surplus calculated above. Analytically, allowing for this shift is equivalent to adding a new transportation option at the old price, which is Δp below the new price. Shippers and consumers therefore realize an increase in surplus of one-half the demand for the option $(-\Delta q_m)$ times the price reduction (Δp) :

$$(11) \qquad \Delta S_m = -(1/2)\Delta q_m \Delta p = (1/2) e_m (q_0/p_0)(\Delta p)^2 \quad .$$

Finally, we note that net welfare gain from modal shifting is

$$(12) \qquad \Delta W_m = \Delta B_m + \Delta S_m = \Delta S_m \quad .$$

To summarize, equations (9) plus (12) capture the net welfare gain from instituting a marginal cost taxation policy for trucks, accounting for vehicle-type and modal shifts. In the next section, we calculate this welfare gain and the other quantities defined above using data on U.S. highway transportation for 1982.

IV. DATA

Our basic traffic and cost data were compiled by the U.S. Department of Transportation's Transportation Systems Center for use in a large computer model of highway operations.[11] The data are for 1982, reflecting the situation before implementation of the Surface Transportation Act of that year. Data on numbers and usage of vehicles were derived from the U.S. Census Bureau's 1977 Truck Inventory and Use Survey, and were updated using the Federal Highway Admistration's Revenue Forecasting Model. Since the weight classes used in that survey were too broad for our purposes, we allocated the totals for each class to finer categories within that class in proportion to that vehicle type's registrations as reported in the FHWA's Truck Weight Study of 1979-1982. The cost information is based on 1977 figures derived by the Transportation Systems Center as part of the Highway Cost Allocation Study and the Truck Size and Weight Study, updated using truck cost indices published by Data Resources, Inc. The initial fixed and variable taxes reflect the actual 1982 situation.

For reasons of data availability we use registered weights as proxies for actual weights. This raises the question of whether this procedure systematically over- or under-estimates the gains to be reaped from marginal cost taxation. While legally operated vehicles will often weigh less than they are registered for, there is also widespread overloading (U.S. General Accounting Office, 1979). On balance we suspect average highway damage from vehicles in a given registered gross weight class exceeds the damage that would be done if, as we assume, every vehicle travelled 80 percent of its mileage loaded to exactly its registered weight. Thus if anything this procedure probably underestimates benefits from the tax.

There is no direct empirical measurement of the elasticity of substitution among vehicle types, σ. However, Friedlaender and Spady (1981, p. 271) did estimate trucking firms' elasticity of substitution between capital and "purchased transportation," which means expenditures on rail, air, water, and hired-out trucking services. This elasticity, which they found to be roughly 1.25, provides an indication of the degree to which trucking firms respond to changing vehicle costs by substituting other carriers' services for their own vehicles. The substitutability among firms' own vehicles ought to be much higher than this, particularly if there are low-cost possibilities for retrofitting existing vehicles with more axles.[12] Hence we have assumed a value of 5.0. We discuss later the sensitivity of our results with respect to this parameter.

For the modal diversion elasticity, e_m, there is considerable empirical evidence (see Winston, 1985) suggesting a figure of about 1.0. Although it is known that this elasticity varies considerably with commodity shipped, we are not able to disaggregate our analysis by commodity.

V. RESULTS

The results of our calculations are summarized in Table 2. For each of the five initial vehicle types, the figures shown are the totals for between seven and fourteen distinct weight categories.

The welfare gain is substantial, roughly $1.2 billion per year. This represents real resources saved: the savings in highway maintenance and repair expenditures less the increase in real resources used in shipping. Keeping in mind that we have tried to make this estimate a conservative one, it seems large enough at least to arouse interest.

The policy contributes significantly to solving the "infrastructure problem". Not only does it raise $10 billion of additional tax revenues annually, it also reduces annual highway maintenance and repair expenditures by nearly $3 billion, or about 17% of total expenditures incurred because of these five truck types.

Accompanying these gains is a very sizable redistribution from truckers, shippers, and consumers to the public treasury. The nearly $12 billion reduction in producers' and consumers' surplus is, in effect, collected through the trucking industry, which can be relied upon to resist strenuously. However, the total rise in after-tax trucking costs is less than four percent, and much of this will be passed on to the public at large -- which is also the beneficiary of the redistribution. Furthermore, there seems to be a growing public awareness that the current excess of highway damage costs of heavy vehicles over the taxes they pay, which averages about $3000 per vehicle annually from our figures, can be regarded as an unjustified subsidy. Thus we do not think the policy should be ruled out immediately as politically infeasible, especially if the possibilities for reducing its initial impact through vehicle-type shifting are adequately publicized.

Table 2. Welfare Calculations

		VEHICLE TYPE					
		SU2	SU3	CS4	CS5	DS5	TOTAL
Initial values:							
Vehicles	v	4226.20	749.01	328.30	625.63	40.51	5969.65
Vehicle-miles traveled	q_0	56.40	14.70	10.97	36.39	2.58	121.03
Maint. & repair expend.	M	4.88	3.30	1.31	4.95	0.65	15.09
Total trucking costs	C	111.76	39.04	29.45	76.06	7.63	263.95
Changes from Vehicle Shifts:							
Vehicle-mile traveled	Δq	-1.60	-2.39	-0.50	-0.22	-0.09	-4.80
Revenue	ΔR	3.61	2.01	1.08	4.13	0.56	11.38
Maint. & repair expend.	ΔM	-0.43	-1.02	-0.04	-0.02	-0.03	-1.54
Budget balance	ΔB	4.03	3.03	1.11	4.15	0.59	12.92
Prod./Cons. Surplus	ΔS	-3.82	-2.52	-1.09	-4.14	-0.58	-12.14
Net welfare gain	ΔW	0.22	0.52	0.02	0.01	0.02	0.78
Changes from Modal Diversion:							
Vehicle-miles traveled	Δq	-1.78	-0.79	-0.43	-2.05	-0.24	-5.29
Revenue	ΔR	-0.23	-0.30	-0.08	-0.35	-0.08	-1.05
Maint. & repair expend.	ΔM	-0.23	-0.30	-0.08	-0.35	-0.08	-1.05
Budget balance	ΔB	0.00	0.00	0.00	0.00	0.00	0.00
Prod./cons. surplus	ΔS	0.10	0.11	0.04	0.15	0.04	0.44
Net welfare gain	ΔW	0.10	0.11	0.04	0.15	0.04	0.44
Total Changes:							
Vehicle-miles traveled	Δq	-3.38	-3.18	-0.93	-2.27	-0.32	-10.09
Revenue	ΔR	3.37	1.71	0.99	3.78	0.48	10.33
Maint. & repair expend.	ΔM	-0.66	-1.32	-0.12	-0.37	-0.11	-2.59
Budget balance	ΔB	4.03	3.03	1.11	4.15	0.59	12.92
Prod./cons. surplus	ΔS	-3.72	-2.41	-1.06	-3.99	-0.54	-11.71
Net welfare gain	ΔW	0.31	0.63	0.06	0.16	0.05	1.22

Note: All figures are in billions of vehicle-miles or billions of dollars, except v which is in thousands of vehicles. Notation is explained in text.

Another possible distributional effect is a one-time capital loss on trucking firms' vehicle stock. Marginal cost taxation might render certain vehicles economically obsolete and thereby lower their resale value, so that their owners would incur a disproportionate share of the tax burden. In other words, some of the loss of surplus could be capitalized into lower asset values for certain vehicles. (This represents a redistribution of costs we have already accounted for, not an additional cost). Given the possibilities of retrofitting and an international resale market, we doubt that capital losses would be very important. But if they are, one way to mitigate them is for the government to purchase obsolete vehicles for domestic use (but with smaller loads!) or for resale abroad. To ensure that government vehicles themselves not obstruct the policy, the tax should also apply to them.

Table 2 shows a $15 billion estimate of total highway expenditures caused by these five truck types. This is based on our marginal cost estimates and on the assumed linear relationahip between total ESAL applications and highway expenditures.[13] One check on our assumptions would be to compare this estimate with actual highway expenditures in 1982, which were $41 billion.[14] The latter figure includes new construction as well as maintenance and repair. Furthermore, our estimate is of the annual expenditures needed over a period of many years to maintain the infrastructure at constant level of service, whereas current expenditures may be either lower (allowing the level of service to deteriorate) or higher (compensating for past neglect). Nevertheless, it is reassuring that our numbers are of the right order of magnitude.

Two other interesting points emerge from a close look at Table 2. First, more than one-third of the net benefits are attributable to modal diversion. This suggests that if highways were priced as we recommend, any private or public actions that were to improve railroad pricing and service quality would generate additional benefits heretofore overlooked.

Second, in contrast to conventional thought,[15] we find that the smaller vehicles, the single-unit trucks, are the largest potential source of welfare improvement. Perhaps too much attention has been focussed on the heaviest trucks as the cause of our infrastructure problem. Indeed, highway maintainance officials often cite cement mixers and garbage trucks as the worst culprits. The latter are often municipally owned: again, it is better that the tax apply to the public as well as the private sector.

The most uncertain of our numerical assumptions is the elasticity of substitution between vehicle types, σ. If there is more substitutability than our figure of 5.0 suggests, overall benefits would be larger and the loss to truckers and shippers smaller. Table 3 shows that the main results change by at most 25 percent from their baseline values as the elasticity of substitution varies between 2.5 and 10.0.

Table 3. Sensitivity of Selected Results

	Elasticity of Substitution		
	2.5	5.0	10.0
Modal shift:			
Δq_m	-5.54	-5.29	-4.87
Total changes:			
ΔM	-2.04	-2.59	-3.01
ΔS	-11.99	-11.71	-11.47
ΔW	0.94	1.22	1.45

Note: All figures are in billions of vehicle-miles or billions of dollars, and are totals for the five vehicle types shown in Table 2. Except for Δq_m, they include the effects of both vehicle-type and modal shifts.

VI. QUALIFICATIONS AND SUGGESTIONS FOR FUTURE WORK

There are several factors omitted from our analysis that may be important. We discuss three below. The first two would cause us to underestimate the benefits of marginal cost taxation, while the third would cause an overestimate.

First, there is reason to believe that prices exceed marginal costs in many rail markets (Keeler, 1983). If so, there are additional benefits from modal diversion in the form of producers' surplus to railroad firms. We note in passing that, from a second-best perspective, uncorrectable distortions in rail prices would call for compensating distortions in motor carrier markets; however the latter should be done through shipping rates, not infrastructure taxes.

Second, we would expect some net improvement in highway safety to result from these taxes. The major reason is simply the reduction in number of trucks and perhaps, though we have not modelled it, a reduction in average payloads. In addition, improved pavement quality should have some positive effect on safety. Offsetting these somewhat is the relative increase in larger vehicles including double-trailer combinations.

Third, our calculation assumes that truckers' earnings reflect their opportunity costs in other occupations. This is not the case if displaced drivers or other trucking employees are unable to secure comparable employment elsewhere.

Regardless of how precise our numerical results prove to be, one point stands out: the current basis for taxing trucks is the wrong one. Neither gross weight, fuel consumed, nor number of axles (the sole basis for Ohio's distance-related tax and for many turnpike tolls) is a suitable proxy for contribution to highway costs. Although we have argued for a tax that is higher and more complex than current taxes, even a less thoroughgoing reform might be worthwhile. Switching to any distance-related tax based on a schedule increasing sharply with weight per axle would very likely bring substantial benefits, even if it were no more complex than current taxes and brought in the same revenues. In this respect, the recent Congressional directive to study the feasibility of a nationwide weight-distance tax threatens to lock us into an unsatisfactory solution for many years. Attention should instead be focussed on an axle-weight-distance tax.

We have not discussed the related question of choosing axle weight limits. Given that most states already have such limits, adjusting them is an alternative to the tax policy analyzed here. Indeed, Weitzman (1974) identifies certain conditions when such quantity controls are superior to corrective taxes. However it is doubtful that the trucking industry, with its large number of firms with independently varying marginal costs, would meet those conditions.

Methodologically, at least three extensions to our work are worth pursuing. First, the assumption that the distribution of payload weights carried would be unchanged should be replaced by an optimization model of vehicle loading. Second, our knowledge of the kinds and magnitudes of vehicle subsitutions that would take place could be greatly improved by developing and estimating an empirical model of motor vehicle type choice.

Finally, it would be worthwhile to analyze the welfare effects of an optimal highway maintenance policy that corresponds to our optimal pricing policy. It seems likely that some of the enormously expensive one-time highway rehabilitation being considered would be done differently, or not at all, if marginal cost pricing were in effect. Furthermore, on-going maintenance policies, often based on long-standing rules of thumb developed in an era of more or less unrestricted truck traffic, probably would need revision. Indeed, this might reduce the magnitude of the marginal cost taxes through the adoption of maintenance procedures better suited to the altered vehicle mix. This in turn would soften the impacts of the tax change on the trucking industry, while adding to the net welfare gains.

Despite these qualifications, our results suggest that significant benefits can be realized through a realistic and operationally feasible policy of marginal cost taxation of truck transportation. Such a policy has the appealing feature of providing significant new public revenues while correcting, rather than aggravating, economic distortions. Over a longer period, it promises to help solve the problem of how to maintain the very large and important portion of the nation's capital stock represented by its highway system.

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