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THE REGULATION OF SURFACE FREIGHT TRANSPORTATION:
THE WELFARE EFFECTS REVISITED

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ABSTRACT

This paper reexamines a topic that has been much studied by economists--estimating the effects on resource allocation of the economic regulation of surface freight transport. It demonstrates that in several studies the methods used to estimate the welfare costs of rate regulation are invalid, develops a correct procedure, and provides estimates of the welfare effects using data and estimates of modal market share relationships from a study by Boyer. The paper also analyzes some implications of an important assumption that is common among studies of the transportation sector. The assumption is that the total quantity of freight shipments by all modes is invariant with respect to tariff levels.

Numerous studies have addressed the problem of estimating the costs of resource misallocation due to the regulation of surface freight transportation.¹ Regulation creates inefficiency to the extent that it does not systematically relate prices to marginal costs. The theoretically correct method for estimating this inefficiency is to measure the loss in total surplus arising from the regulator's pricing policy.

Most of the early studies of the effects of regulation in this industry did not use this method, instead using the "comparative cost" approach. The latter assumes that modes are perfect substitutes. The cost of regulation is then estimated as the difference in shipping costs between the mode by which shipments are transported and the marginal cost of shipments by the lowest cost mode.

More recent studies have used estimates of cross elasticities of demand to take account of the fact that most shippers do not regard transportation modes as perfect substitutes. Unfortunately, each of these studies adopts an approach that is not in general theoretically

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correct and that is likely to produce a biased estimate. This paper examines the methods that have been used, and uses the data and econometric results in one paper, Boyer (1977), to calculate the magnitude of this bias. As is customary in these studies, we are ignoring other costs of regulation, such as on the costs of service (see, for example, Douglas and Miller (1974)) or of the process itself. Section I derives the theoretically correct method for estimating the welfare effects of surface freight regulation and shows how it differs from the methods actually used in other studies. It identifies two methodological problems in other studies: incorrect accounting for intermodal effects in calculating total surplus, and the assumption in most studies that the demand for total transportation shipments is perfectly inelastic with respect to all prices. Sections II and III estimate the empirical significance of these methodological problems. In both cases, these problems are found to cause serious underestimates of the cost of regulation using Boyer's data.

I. WELFARE MEASUREMENT IN INTERRELATED MARKETS

Let the tariffs for transporting a commodity be p_i for mode i , $i = 1, 2$. The demand schedules for the two modes are assumed to be interdependent, and are written as $x_i(p_1, p_2)$. Let the marginal cost of transport service by mode i be a constant c_i .² Assuming that deregulation will lead to prices equal to marginal costs, the problem is to estimate the welfare effects of moving prices from (p_1, p_2) to

(c_1, c_2) .³

If income effects are zero, a measure of the sum of consumer and producer surplus (e.g. total surplus) associated with the set of tariffs (p_1', p_2') can be written (suppressing the argument of the demand schedules in the integral) as:

$$T(p_1', p_2', p_1'', p_2'') = \int_{\mathbf{r}} (x_1 dp_1 + x_2 dp_2) + \sum_{i=1}^2 (p_i' - c_i) x_i(p_1', p_2') \quad (1)$$

over any path \mathbf{r} that connects (p_1', p_2') with (p_1'', p_2'') , where $x_1(p_1'', p_2'') = x_2(p_1'', p_2'') = 0$. In other words, the demands are zero at the tariffs (p_1'', p_2'') . The independence of $T(p_1', p_2')$ on the path of integration follows from the assumption of zero income effects.⁴

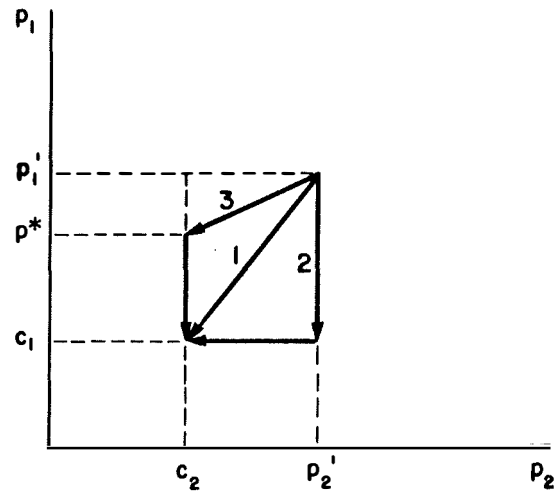
The change in total surplus that would result from a movement of tariffs from (p_1', p_2') to marginal costs (c_1, c_2) can be written as:

$$\Delta T = \int_{\mathbf{r}} (x_1 dp_1 + x_2 dp_2) - \sum_{i=1}^2 (p_i' - c_i) x_i(p_1', p_2'), \quad (2)$$

where \mathbf{r} is any path from (c_1, c_2) to (p_1', p_2') . Some possible paths of integration are shown in Figure 1. The ΔT obtained in this process is the gain in total surplus that would result if marginal cost pricing were used instead of the tariffs (p_1', p_2') .

Suppose we want to estimate the welfare effects associated with moving one of these tariffs (say, p_1) from its regulated level (p_1') to marginal cost (c_1) . Assume that under regulation in neither mode does price equal marginal cost (i.e., $p_i \neq c_i$, for $i = 1, 2$). One way to estimate these welfare effects is to evaluate the expression $T(c_1, p_2', p_1'', p_2'') - T(p_1', p_2', p_1'', p_2'')$, in which the first tariff is moved

FIGURE 1
PATHS OF INTEGRATION



Notation p_i - tariff on mode i
 p_i' - regulated tariff on mode i
 c_i - marginal cost on mode i

from p_1' to c_1 and the second tariff remains at $p_2' \neq c_2$. In this case the welfare effects of mode 1 regulation cannot be evaluated without information about the change in the demand for mode 2 service that would occur as a result of the change in the first tariff. The effect of a differential change in p_1 on T is estimated by:

$$\frac{\partial T}{\partial p_1} = (p_1 - c_1) \frac{\partial x_1(p_1, p_2')}{\partial p_1} + (p_2' - c_2) \frac{\partial x_2(p_1, p_2')}{\partial p_1}. \quad (3)$$

Using a linear approximation of demand, (3) is approximated

by:

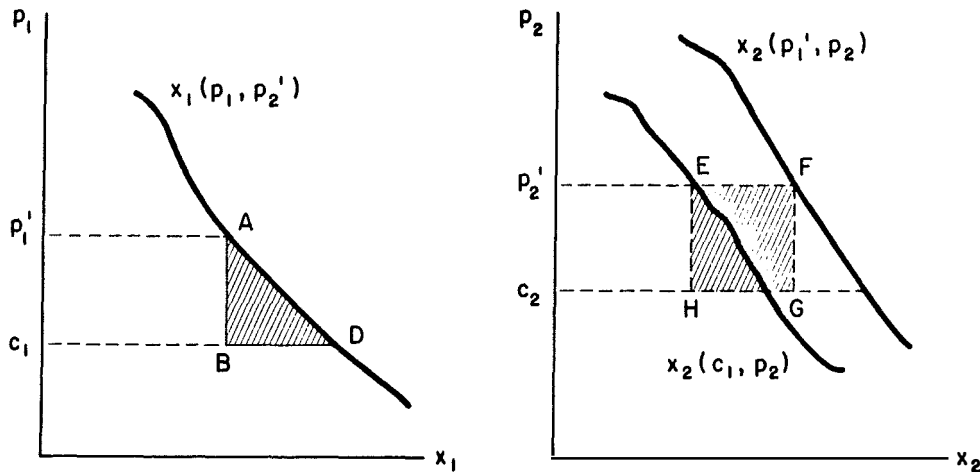
$$\Delta T_1 \approx \frac{1}{2}(p_1' - c_1)[x_1(c_1, p_2') - x_1(p_1', p_2')] + (p_2' - c_2)[x_2(p_1', p_2') - x_2(c_1, p_2')] \quad (4)$$

The first term on the right hand side of (4) is the dead weight loss triangle, computed using the Marshallian demand for x_1 , evaluated at p_2' . With constant marginal costs, the second term corresponds to the change in profits for mode 2 resulting from the change in that mode's traffic when the tariff in mode 1 is moved from p_1' to c_1 . The total surplus change is thus depicted in Figure 2. The change in total surplus is the shaded area ABD minus the shaded area EFGH, approximated by (4). This corresponds to the vertical part of Path 2 in Figure 1.

To estimate the change in total surplus associated with moving both tariffs to marginal cost, Path 2 (Figure 1) must be completed by integrating its horizontal portion. The welfare effect of a

FIGURE 2

CHANGE IN TOTAL SURPLUS IF MARGINAL COST PRICING IS ADOPTED IN MARKET 1



Notation: x_i - quantity shipped by mode i
 p_i - tariff on mode i
 $x_i(p_1, p_2)$ - demand curve for mode i
 p_i' - regulated tariff on mode i
 c_i - marginal cost on mode i

differential change in p_2 , holding p_1 constant, is:

$$\frac{\partial T}{\partial p_2} = (p_1 - c_1) \frac{\partial x_1(p_1, p_2)}{\partial p_2} + (p_2 - c_2) \frac{\partial x_2(p_1, p_2)}{\partial p_2} . \quad (5)$$

On the horizontal segment of Path 2, $p_1 = c_1$, so that the first term of (5) is zero. The second term is estimated as:

$$\Delta T_2 \approx \frac{1}{2}(p_2' - c_2)[x_2(c_1, c_2) - x_2(c_1, p_2')] . \quad (6)$$

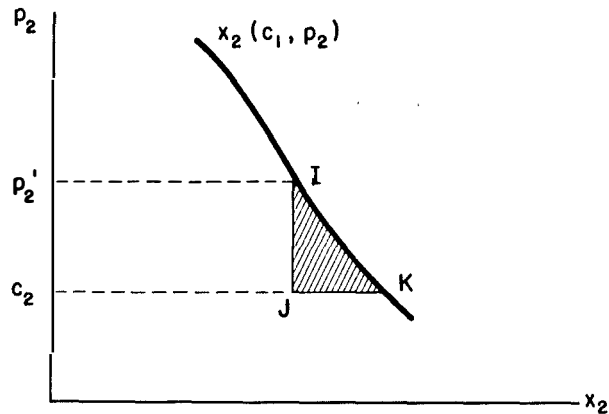
Equation (6) is the usual dead weight loss triangle, computed using the Marshallian demand schedule x_2 , evaluated at $p_1 = c_1$. This is depicted in Figure 3 as the shaded area IJK, which, when added to area ABD minus EFGH in Figure 2, approximates the total surplus gain that could be realized if marginal cost pricing were used instead of the regulated tariffs. Total surplus is maximized with marginal cost pricing, so that area ABD plus area IJK minus area EFGH must be nonnegative (area ABD minus area EFGH may be negative).

As an alternative to the use of Marshallian demand schedules, it is also possible to employ mutatis mutandis demand schedules (in which both prices vary simultaneously), shown by Path 1 in Figure 1. By integrating along Path 1, the welfare loss from regulation can be estimated as:

$$\Delta T = \frac{1}{2}[x_1(c_1, c_2) - x_1(p_1', p_2')] [p_1' - c_1] + \frac{1}{2}[x_2(c_1, c_2) - x_2(p_1', p_2')] (p_2' - c_2) \quad (7)$$

The method of (7) is an alternative to summing the estimates from (4) and (6). If the demand equations are correctly specified as linear,

FIGURE 3
 CHANGE IN TOTAL SURPLUS IF MARGINAL COST
 PRICING IS ADOPTED IN MARKET 2



Notation: x_i - quantity shipped by mode i
 p_i - tariff on mode i
 $x_i(p_1, p_2)$ - demand curve for mode i
 p_i' - regulated tariff on mode i
 c_i - marginal cost on mode i

both methods will produce the same estimate of the change in surplus. In practice, if nonlinear demand relationships are approximated by linear ones, the methods will produce different estimates. In Section II these methods are compared using Boyer's data.

A surprisingly common practice in transportation studies is to overlook some of the components of total surplus. Indeed, only Levin (1978) uses a theoretically correct path of integration; however he also assumes that truck prices are set at marginal cost, so that the effects of changes in rail tariffs can be calculated without considering secondary effects in trucking. He does correctly account for interaction effects between two other modes, rail and piggyback, by appropriate use of (7).

Boyer attempts to use the method depicted by Path 2, but ignores the effects of railroad deregulation on trucking profits in calculating the first step. Friedlaender (1969) and Keeler (1976) adopt an approach closer to Path 1; however they base their calculations solely on own price-elasticities, thereby implicitly calculating the quantity changes in mode i by using p_j' instead of c_j in the demand functions, $x_i(p_i, p_j)$, in equation (7).

Friedlaender and Spady (1980) recognize that the position of the demand curve for one mode is shifted by a change in price in the other mode. They make two estimates of the sum of the dead weight loss triangles associated with prices above marginal costs, one with the other mode price set at marginal cost. Neither method is correct, for neither defines a continuous path in Figure 1 from (p_1', p_2') to

(c_1, c_2) .

Spann and Erickson (1970), and Zerbe (1980) in commenting on their work, do the same thing in calculating the welfare effects of the combined short-haul and long-haul rate changes instituted when the ICC was organized, thereby implicitly assuming a zero long-run cross-elasticity of demand between long-haul and short-haul shipments. As Zerbe points out, Spann and Erickson also ignore part of the effect on profits from price and quantity changes in the same market.

Moore (1975) bases his estimates on constant-elasticity demand equations that have both direct- and cross-elasticity terms. He proceeds by calculating the effect on surplus from first lowering truck prices to marginal costs, then lowering rail rates so that total rail shipments are left at their initial amount, and then calculating the extra surplus in trucking that arises from an increase in truck shipments at lower prices. To this he then adds the estimates of excess costs due to shipping by the wrong mode, as estimated by Harbeson (1969) and Peck (1965), on the assumption that if rail rates were lowered further to marginal cost these shipments would switch modes. This is methodologically invalid as well. Let mode 1 be rails and mode 2 be trucks. After embarking on the first segment of Path 3 in Figure 1 from (p_1', p_2') to (p_1^*, c_2) , where (p_1^*, c_2) leaves total rail shipments unchanged, Moore should use the same demand equation to estimate the further surplus from (p_1^*, c_2) to (c_1, c_2) . His procedure is correct only if: (1) as he points out, no new traffic is created by the second reduction in rail prices; (2) only "old" truck traffic,

and no "new" traffic generated by the fall in truck prices switches modes when rail rates are lowered to marginal costs; and (3) the nature of the cross-elasticity of demand is such that all of the truck traffic that will switch to rails will do so at rail rates of $p_1^* - \epsilon$. All three of these conditions are inconsistent with the estimated demand functions used by Moore to calculate the welfare changes from moving along the first part of the path he uses.

Another common error is to try to determine how much of the total surplus change should be attributed to each mode if both tariffs are changed to marginal costs. For example, in one of his calculations, Boyer attempted to separate the welfare effects by mode (see his footnote 10). First, he calculates the welfare gain from railroad deregulation by holding truck prices fixed. Then, he calculates the gains from truck deregulation, given the new rail prices. This procedure is faulty because no such unique measure exists. For example, in Figure 1, a path of integration that changed p_2 first, moving from (p_1', p_2') to (p_1', c_2) to (c_1, c_2) , would normally produce a different "allocation" of the welfare gains between modes than an integration along Path 2 would yield, even though the totals would be the same in the absence of errors of approximation. In general, the line integral is a function of rate changes in both modes, and cannot be written separably to ascribe a unique and meaningful change in surplus to either mode individually.

A final source of error in other studies is the common assumption that total freight shipments are unaffected by tariffs.

The comparative cost studies estimate the costs of regulation by reallocating actual shipments in a given year according to marginal costs and multiplying the amounts of shipments reallocated by the differences in costs between the modes. Boyer and Levin employ a logit model to estimate the market share of each mode, given tariffs in all modes. The quantity of shipments by mode are then calculated by multiplying these shares by the actual quantity of shipments in a given year. This obviously ignores any business gained or lost by the transportation sector as a result of a change in prices to equal marginal costs; in (7), Δx_1 must be equal in magnitude and opposite in sign to Δx_2 . (For other problems with this use of logit, see Oum (1979).)

The assumption of perfectly inelastic total demand affects the estimated welfare effects of price changes. It does so by its effects on the estimate of the quantity effects of price changes.

The quantity to be shipped by mode 1 is defined to be the share of the market shipped by that mode times the total quantity shipped by both modes.

$$x_1 = S_1(x_1 + x_2) \quad (8)$$

Thus, a change in p_1 can be expected to affect x_1 as follows:

$$\frac{\partial x_1}{\partial p_1} = \frac{\partial S_1}{\partial p_1} (x_1 + x_2) + S_1 \left(\frac{\partial x_1}{\partial p_1} + \frac{\partial x_2}{\partial p_1} \right). \quad (9)$$

If the total ton miles of freight shipped by both modes is assumed to be constant, the second term of (9) will be zero by

assumption ($\frac{\partial x_1}{\partial p_1} + \frac{\partial x_2}{\partial p_1} = 0$). In reality, if p_1 drops while p_2 is unchanged, one would expect the sign of the second term to be negative, since shippers might demand more transportation when one tariff is lowered. Moreover, the data used to estimate the modal split equation will be from various markets with different tariffs. Hence the parameters estimated in the modal split equation will incorporate both market-elasticity and cross-elasticity effects into a model that explicitly accounts for only the latter. The predicted share of a mode after a price decrease will be a share of a quantity that reflects both elasticity effects; however the (smaller) initial quantity will be multiplied by this new estimated share to determine the new quantity shipped by the same mode.

Thus, the inelasticity assumption will lead to an understatement of the effects of a change in p_1 on x_1 and to an overestimate of the extent to which mode 2 will be affected by a change in p_1 . Further, in each case the magnitude of the effect will be most significant when the market share of the corresponding mode is large. This is apparent from (8), in which S_1 is the coefficient on the quantity effect that is assumed to be zero.

How does the inelasticity assumption affect the estimates of the change in welfare resulting from movements of tariffs in both markets to marginal costs? To answer this question, we analyze the effects of the inelasticity assumption using the method of calculation of (7). Consider an estimation of the change in x_1 that would result from a movement of both tariffs from their regulated levels to

marginal cost. An approximation of this change, $(\Delta x_i)^*$, without the inelasticity assumption can be written as:

$$(\Delta x_i)^* \approx \sum_{j=1}^2 \frac{\partial x_i}{\partial p_j} (c_j - p_j') ; \quad i = 1, 2. \quad (10)$$

For notational convenience, let $x_1 + x_2 = Q$ at (p_1', p_2') . Using (8), (10) can be rewritten:

$$(\Delta x_i)^* \approx \sum_{j=1}^2 \left[\frac{\partial S_i}{\partial p_i} Q + S_i \frac{\partial Q}{\partial p_j} \right] (c_j - p_j') ; \quad i = 1, 2 \quad (11)$$

From (7), the change in total surplus, ΔT^* , without the inelasticity assumption from moving both tariffs to marginal costs is approximately:

$$\Delta T^* \approx \sum_{i=1}^2 (p_i' - c_i) (\Delta x_i)^* \quad (12)$$

Finally, after some algebra, ΔT^* can be approximated as:

$$\Delta T^* \approx \frac{1}{2} \sum_{i=1}^2 \left[(p_i' - c_i) \sum_{j=1}^2 \frac{\partial S_i}{\partial p_j} Q (c_j - p_j') \right] + \frac{1}{2} \left[\sum_{i=1}^2 \frac{\partial Q}{\partial p_i} (c_i - p_i') \right] \left[\sum_{i=1}^2 (p_i' - c_i) S_i \right] \quad (13)$$

The first term on the right hand side of (13) would be the welfare change estimated if the inelasticity assumption were valid. Denote this term by ΔT^0 . The bias introduced if the inelasticity assumption is invalid is captured by the second term on the right hand side of (13), which is denoted by δ . Note that if the inelasticity assumption is valid, $\delta = 0$ because $\frac{\partial Q}{\partial p_i}$ is zero.

The sign of δ must be positive whenever both regulated tariffs depart from marginal costs in the same direction, because in either case both of the bracketed components of δ are of the same sign. Thus, a larger estimate of the welfare effects of regulation would be expected if the inelasticity assumption were not imposed. The sign of δ cannot be determined purely theoretically if the regulated tariff exceeds marginal cost in one market, but is less than marginal cost in the other, for then the two bracketed components of δ may or may not have the same sign.

II. THE EFFECTS OF INVALID PATHS OF INTEGRATION

In this section, the data and demand equations presented by Boyer are used to recalculate the welfare effects of regulation in 1963 along a valid path of integration. The approximations in both equation (7) and equations (4) and (6) are used. The results of these calculations are shown in Table 1.

The demand equation that Boyer used to calculate welfare effects was as follows:⁵

$$\Delta \ln \frac{S_1}{S_2} = -4.15 \left[\left(\frac{p_1}{p_2} \right)_a - \left(\frac{p_1}{p_2} \right)_b \right] \quad (14)$$

where

i = a modal index, 1 for rail, 2 for motor carriers

S_i = the share of traffic for mode i , where $S_1 + S_2 = 1$

p_i = the tariff for mode i

TABLE 1
WELFARE CALCULATIONS

Mileage Block	S_1 at (p_1^1, p_2^1)	c /Ton·Mile				1963 Ton·Miles of Traffic (billions)	S_1 at (c_1, p_2^1)	ΔW_4 from Eq(4), \$mil.	S_1 at (c_1, c_2)	ΔW_6 from Eq(6), \$mil.	$\Delta W_4 + \Delta W_6$ \$ mil.	ΔW_7 from Eq(7), \$mil.	Boyer's W rail \$ mil.
		p_1^1	p_2^1	c_1	c_2								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
25	0.35	6.14	19.84	6.64	18.56	2.63	0.33	1.0	0.31	0.3	1.3	0.9	n.c.
75	0.36	3.21	10.41	2.97	8.45	7.51	0.38	-3.0	0.32	4.6	1.6	2.6	n.c.
150	0.50	2.69	6.88	2.00	5.94	21.09	0.60	-12.9	0.56	4.3	-8.6	-1.6	4.4
250	0.55	2.23	4.97	1.61	5.17	26.92	0.68	17.8	0.69	0.3	18.1	14.3	10.8*
350	0.60	2.11	4.00	1.44	4.96	17.62	0.75	34.7	0.80	4.1	38.8	28.7	11.8
450	0.66	2.05	3.98	1.37	4.86	22.32	0.80	37.5	0.81	0.7	38.2	31.3	13.7
550	0.68	2.11	3.99	1.29	4.81	22.05	0.83	41.5	0.86	2.4	43.9	32.5	16.3
700	0.71	1.87	3.45	1.24	4.73	40.01	0.84	82.8	0.89	12.8	95.6	68.8	22.7
900	0.76	1.71	3.24	1.18	4.68	33.15	0.86	57.0	0.91	11.7	68.7	49.0	13.2
1100	0.79	1.74	3.23	1.16	4.65	18.93	0.89	31.6	0.93	5.6	37.2	34.2	7.7
1350	0.83	1.75	2.59	1.13	4.62	21.03	0.93	49.2	0.96	6.4	55.6	36.2	8.5
1750	0.86	1.68	2.47	1.11	4.59	39.30	0.94	76.2	0.97	12.1	88.3	58.1	12.3*
Total								413.4		65.3	478.7	355.0	121.4*

Sources: Col. 2 from Boyer (Table 4, column 9)
 Col. 3 from Boyer (Table 4, column 5)
 Col. 4 from Boyer (Table 4, column 6)
 Col. 5 from Boyer (Table 4, column 2)
 Col. 6 from Boyer (Table 4, column 3)
 Col. 7 from Boyer (Table 4, column 8)
 Cols. 8 - 13, calculated as described in text
 Col. 14 from Boyer (Table 4, column 11), where n.c. means not calculated and (*) means correction of Boyer's reported numbers using his methodology and data.

b denotes the situation before tariffs are changed
a denotes the situation after tariffs are changed.

The entries in Table 1 are calculated as follows. Column 2 shows the rail market share at regulated rates for each mileage block. If the rail rate is changed from p_1' to c_1 , holding p_2 equal to p_2' , a new rail share can be estimated from (14). The welfare change associated with the rail rate change (with no change in the motor carrier rate) is calculated from (4) and reported as ΔW_4 in column 9. Thus, ΔW_4 provides one estimate of the effects of rail rate regulation, given unchanged motor carrier regulation. The estimated welfare effect of railroad regulation is \$413.4 million, which is much larger than Boyer's estimate (column 14).

To complete the estimate of the welfare effects of regulation for both modes, we carry out the calculation of equation (6), reported as ΔW_6 in column 11 of Table 1. Once again we employ equation (16) to calculate the market shares when both modes are priced at marginal cost.⁶ Column 11 is the incremental gain from deregulating trucks, given that railroads have been deregulated, and is estimated by calculating the dead weight loss triangle from prices differing from marginal cost in trucking. The total welfare effect of regulation, the sum of column 9 and 11 (shown in column 12),⁷ is \$478.7 million.

In column 13 we use the *mutatis mutandis* demand schedules of equation (7) to calculate an alternative estimate of the welfare loss from regulation. This estimate is \$355 million.

Boyer's estimate of the total cost of regulation is much less than either of ours. The source of the difference is that he overlooks the effect of railroad deregulation on truck profits. This biases his result downward because, according to his data, truck prices are below marginal cost for long-distance shipping, so that truck profits increase if they lose market share in these mileage blocks. This we view as highly implausible, although we use his data in our calculations to compare our welfare estimates with his.

The difference in our two estimates arises from the error introduced by using a linear approximation to the nonlinear demand curve (14). The term $(p_1' - c_1)$ is as much as 35 percent of p_1' for rails and 80 percent for trucks in some mileage blocks. Thus, it is stretching matters to regard the change in tariffs as "small" for purposes of approximation.

III. THE EFFECTS OF THE INELASTIC DEMAND ASSUMPTION

This section explores the empirical significance of the assumption that the total market demand for surface freight transportation is perfectly inelastic with respect to all tariffs. Direct estimation of the effects of this assumption would require econometric estimates of properly specified modal demand equations that, among other things, included the tariffs for all modes in the demand equation of each. We have not attempted this. Instead, we have used Boyer's data to estimate the sensitivity of his estimates of welfare loss to alternative assumptions about the price elasticity of

market demand. Consider two effects on shipments in mode i due to a change in its price, p_i : the change in mode i 's share of total shipping, and the change in mode i 's shipments owing to a change in total shipping. Let s be the proportionality factor between these quantities:

$$\frac{\partial Q}{\partial p_i} = s \frac{\partial S_i}{\partial p_i} Q \quad (15)$$

The right-hand side of (15) can be substituted for the term $\frac{\partial Q}{\partial p_i}$ in (13), and the data in Table 1 can then be used to estimate the change in surplus as a function of s .

Of course, s is closely related to the elasticity of total shipments with respect to a change in modal prices. If both sides of (15) are divided by the ratio of Q to p_i , the result is:

$$e_i = s S_i e_{is} \quad (16)$$

where e_{is} is the elasticity of mode i 's share with respect to p_i and e_i is the elasticity of total demand with respect to p_i .

Values of $S_i e_{is}$ can be calculated from Table 1, and tend to lie in the range $-.2$ to $-.5$ for rails, and between $-.05$ and $-.3$ for trucks. Thus, if e_i were $-.1$ (e.g. a ten percent change in p_i causes a one percent net change in total shipments), s would fall in the range of $.2$ to $.4$ for rails and between $.3$ and 2.5 for trucks. Alternatively, a value of s of unity implies a value of e_i of about $-.35$. These values are roughly consistent with the elasticities reported by Moore.⁸

We have calculated the value of the last term in (13)—the magnitude of the bias from overlooking the net increments to shipping from a change in modal prices—using Boyer's data. The results are shown in Table 2. If for each mileage block one selects a value of s that makes e_i equal to $-.1$, the estimated welfare gain from marginal cost pricing increases by approximately \$15 million (column (3)). If instead a value of s equal to unity is applied for all calculations, the estimated welfare gain from marginal cost pricing is increased by \$55 million (column (4)). These calculations are substantially affected by the peculiar feature of Boyer's data that truck prices are below marginal costs for most blocks. If regulated truck prices are assumed to be equal to marginal cost, and if e_i is assumed to be $-.1$, then the additional welfare gain from prices equal to marginal costs in rails is \$36 million (column (5)). If s is assumed to be unity in all blocks, the additional gain is \$136 million (column (4)). As is apparent from Table 2, these magnitudes are nontrivial fractions of Boyer's estimates of the welfare effects of regulation.

IV. CONCLUSIONS

This paper has investigated methods for estimating the total welfare loss from the regulation of surface freight transportation. Numerous previous studies have been found to use invalid methods for calculating this loss. We have used methodologically correct procedures to estimate the welfare loss from regulation, using Boyer's data and market share estimation technique. Three principal findings

TABLE 2
 ADDITIONAL WELFARE EFFECTS IF DEMAND ELASTICITY NONZERO
 (Figure in \$millions)

Mileage Block (1)	Assumption A (2)	Assumption B (3)	Assumption C (4)	Assumption D (5)	Welfare Estimates at Zero Elasticity Path 1 (ΔW_7) (6)	Boyer Rail Only (7)
25	0	0	0	0	0.9	n.c
75	8.2	2.9	1.3	.5	2.6	n.c
150	24.3	6.7	7.3	2.0	-1.6	4.4
250	8.1	1.2	11.8	2.5	14.3	10.8*
350	.4	0	10.6	2.2	28.7	11.8
450	4.7	.4	14.3	3.3	31.3	13.7
550	7.9	1.3	18.5	4.8	32.5	16.3
700	-8.0	-.9	24.0	3.6	68.8	22.7
900	1.0	.2	13.3	3.7	49.0	13.2
1100	1.7	.6	8.7	2.9	34.2	7.7
1350	2.3	.7	10.7	3.9	36.2	8.5
1750	3.9	1.7	15.7	7.1	58.1	12.3*
TOTAL	54.5	14.8	136.2	36.5	355.0	121.4*

Assumption A: if mode i changes its price, the resulting change in shipments is equally divided into substitution from mode j and a net increment to total traffic ($s = 1$).

Assumption B: the elasticity of total traffic by all modes with respect to change in price in any one mode (e_i) is -1 .

Assumption C: only rail rates change (trucks now priced at marginal cost) and $s = 1$.

Assumption D: Same as Assumption C, except $e_r = .1$.

Columns (6) and (7) repeated from Table 1 for convenience.

emerge. First, the choice of a correct path of integration increased the estimated welfare loss by a factor of three or four. Second, the choice of a path of integration substantially affects the estimated welfare loss because of the errors introduced by linear approximations of nonlinear demand curves over relatively large changes in prices and quantities. Third, the assumption that the total quantity of freight shipped by all modes is perfectly inelastic caused an underestimate of the welfare costs of regulation that is substantial. When the first and last effects are accounted for, the estimate of the annual welfare loss of surface freight transportation is increased from \$121 million to upwards of \$500 million.

FOOTNOTES

1. See, for example, Peck (1965), Harbeson (1969), Friedlaender (1969), Woods and Domencich (1971), Moore (1975), Keeler (1976), Boyer (1977), Levin (1978), and Friedlaender and Spady (1980).
2. We are ignoring the problem of fixed costs, or scale economies and the possible necessity of a second-best price structure (see Braeutigam (1979)).
3. Whether railroads will behave as perfect competitors is a matter of some dispute (see Levin (1980)).
4. Consumer and producer surplus may still be useful concepts even if there are nonzero income effects (see Willig (1976)).
5. This difference equation follows from regression 1 of Boyer's paper, p. 501.
6. Column 10 in our paper differs from Boyer's predicted market shares in column 10, of Table 4, of his paper. We calculated the change in market shares in moving from (c_1, p_2) to (c_1, c_2) , in order to avoid the error made by Boyer that is discussed in footnote 10 of Levin's paper. In this case the error had little effect on the welfare calculations. For a more detailed discussion, see Levin, p. 25.
7. Each entry in column 12 should be positive, because total surplus

should increase when both tariffs are moved to marginal cost. An anomalous result (and one that cannot be correct) appears in the 150 mileage block. This could occur because for this block the welfare calculations in this paper may be poor approximations to equation (2) in the text, or because there are errors in the estimates of the demand structure not explored in this paper.

8. Moore reports estimates of demand functions for trucks and rails that have cross-elasticities of demand of about .9 for both modes, and own-price elasticities of -1.8 for trucks and -.9 for rails. With about sixty percent of shipments in ton-miles moving by rail, this suggests that one-third of the new business generated by a reduction in rail tariffs is a net increase in total shipment (e.g. $s = 0.5$), whereas about one-fourth of trucking gains from a price reduction would be net new shipments (e.g. $s = .33$). These estimates are, of course, extremely crude, being based on single-equation demand models that aggregate over all types of commodities and shipping distances.

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