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**Economics of Overloading and the
Effect of Weight Enforcement**

Research Note

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Economics of Overloading and the Effect of Weight Enforcement: Research Note

Abstract

This note describes the economic rationale for exceeding weight limits by motor carriers in the face of weight enforcement activities. Patterns of weight enforcement practices by states are identified reflecting differences in enforcement intensity and the severity of penalties imposed for exceeding weight limits. Statistical analysis of weight enforcement data shows that the marginal effects of enforcement intensity and penalties are similar in deterring overloading, with most of the enforcement-related deterrence attributable to the use of portable/semi-portable scales.

In principle, freight carriers are motivated to set load weight levels that will yield maximum profits. In this context they will exceed legal weight limits to the point where additional revenues obtained from overloading are just offset by additional costs, including the expected penalty from detection through weight enforcement activity. Focusing on operating revenues and costs, the net operating profit per mile to the overloading carrier can be represented as follows:

$$\pi = r * (W_{\text{limit}} + W_{\text{excess}}) - P_d * f(W_{\text{excess}}) - c * (W_{\text{limit}} + W_{\text{excess}}), \text{ where } \quad (1)$$

r = revenue per ton-mile;

W_{limit} = the legal load limit, in tons;

W_{excess} = the load in excess of the legal limit, in tons;

P_d = the probability per mile of detection by weight enforcement activity;

$f(W_{\text{excess}})$ = the penalty associated with overloading, which is defined to be a function of the level of overloading;

c = operating costs per ton-mile.

For the sake of simplicity, both the revenue and cost components of equation 1 are defined to be linear.

First order conditions for maximizing operating profits per mile from overloading are obtained by differentiating equation 1 with respect to excess load, or

$$\partial \pi / \partial W_{\text{excess}} = r - P_d f'(W_{\text{excess}}) - c = 0, \text{ or} \quad (2)$$

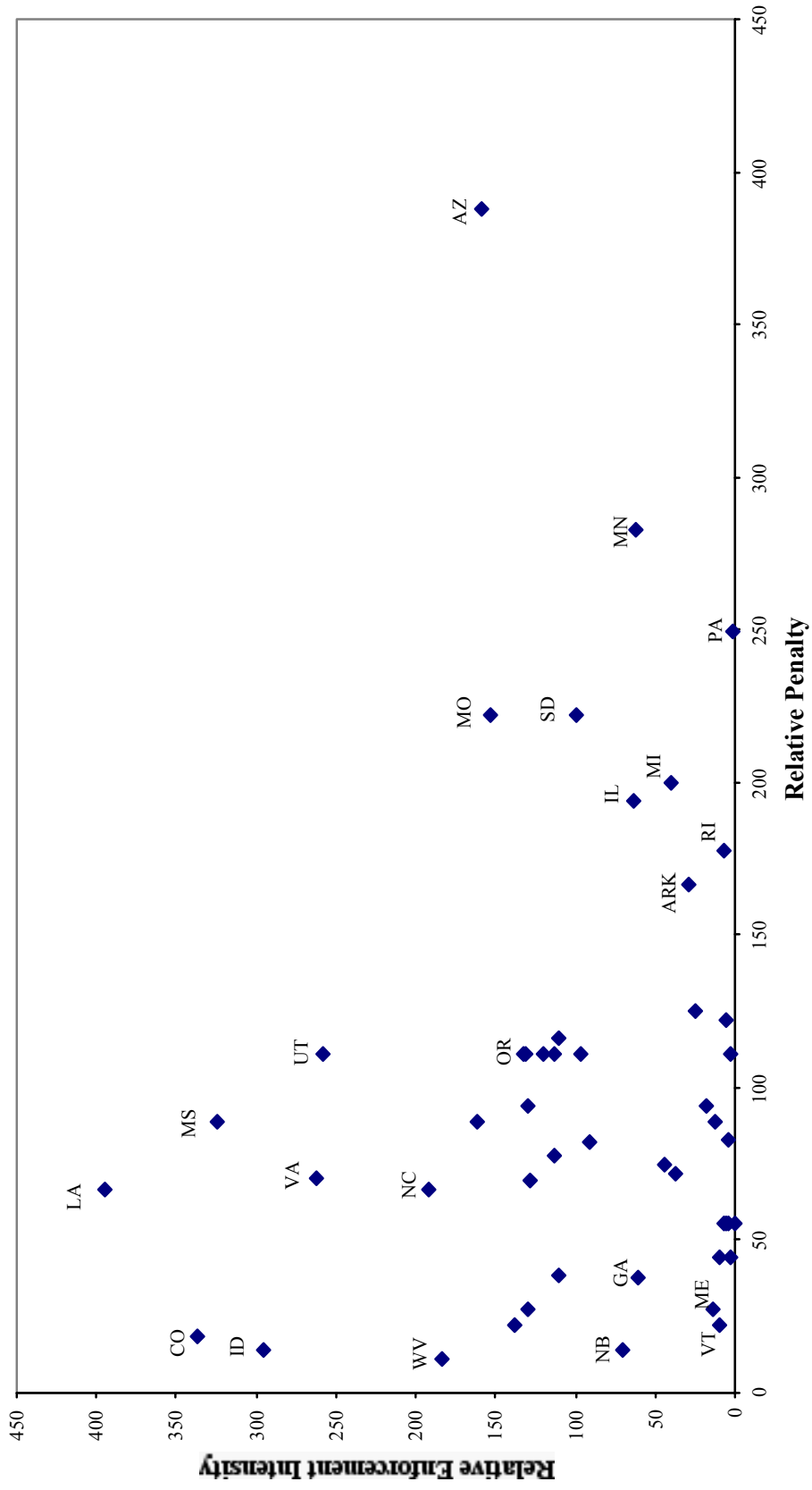
$$r = P_d f'(W_{\text{excess}}) + c, \text{ where} \quad (3)$$

$$f'(W_{\text{excess}}) = \partial f(W_{\text{excess}}) / \partial W_{\text{excess}}$$

Equation 3 indicates that operating profits per ton-mile are maximized when the marginal revenue from overloading is equal to the marginal additional operating cost plus the marginal expected penalty from detection through weight enforcement. As can be seen, the expected penalty is comprised of two elements. The first, P_d , is an indicator of the intensity of weight enforcement activity, while the second, $f'(W_{\text{excess}})$, reflects the severity of the marginal fine imposed on a detected overloader. Thus, state highway officials can seek to reduce overloading activity through increased enforcement, stiffer penalties, or both.

The relative emphasis on enforcement intensity and penalties among states varies considerably, as shown in Figure 1. Data represented in the figure are for 1999 and are derived from state weight enforcement reports to the Federal Highway Administration (FHWA), an FHWA-reported compendium of state penalties for a 4,000 lb. weight violation, and FHWA

Figure A1
Relative State Weight Enforcement Intensity and Penalties Charged for Weight Violation



estimates of truck vehicle miles traveled (VMT) on freeways and other principal arterials.¹ The horizontal axis in the figure represents the penalty for weight violation, while the vertical axis represents the number of weighings per million vehicle miles. The scales of both axes are indexed at mean values equaling 100.

Four weight enforcement regimes are apparent in Figure 1. The first includes states that combine relatively small penalties with relatively extensive enforcement (e.g., Louisiana, Colorado, Mississippi, Idaho, Virginia, North Carolina, and West Virginia). The second category includes states that combine relatively low levels of enforcement with relatively high penalties (e.g., Minnesota, Pennsylvania, Michigan, Illinois, Rhode Island, and Arkansas). The third category includes states that combine relatively high penalties with relatively intensive enforcement (e.g., Arizona, Missouri, Oregon, South Dakota, and Utah, with Oregon taking the most balanced approach). The final category includes states that combine relatively small penalties with relatively low levels of enforcement (e.g., Vermont, Maine, Nebraska, and Georgia).

Which enforcement regime, if any, is relatively more effective in deterring overloading is essentially an empirical question. Given the conceptual framework and the differential enforcement practices described above, a regression model was estimated relating overweight citations issued in the 48 covered states to enforcement intensity, overweight penalties and revenue potential from overloading. The general specification of the regression is as follows:

$$\text{Ln Citations} = f(\text{Ln Weighings}, \text{Ln Fine}, \text{Ln VMT}, \text{Ln Value per Ton}), \text{ where} \quad (4)$$

Ln Citations = the log of the number of overweight citations issued in 1999;

Ln Weighings = the log of the number of vehicles weighed in 1999;

Ln Fine = the log of the penalty for a 4,000 lb. overload in 2000.

Ln VMT = the log of truck VMT on freeways and principal arterials in 1999;

Ln Value per Ton = the log of the value of truck shipments per ton in 1997.

Data sources for all but the final variable are explained in footnote 1. Value per ton data by state were obtained from the 1997 Commodity Flow Survey conducted by the U.S. Census Bureau.² Variables in the regression are specified in log form to allow interpretation of the parameter estimates as elasticities and to avoid heteroskedasticity.

The expected effects of the independent variables on citations are as follows. Holding VMT and other factors constant, we expect citations to increase with the number of weighings, reflecting the increased likelihood of detection of overweight activity. Higher fines are expected to have a deterrent effect on overloading and should therefore be inversely related to the number of citations issued. Holding other factors constant, the number of citations should increase with VMT, given that such growth implies a reduction in the perceived probability of detection. Value per ton shipped is included to represent revenue potential, with the expectation that greater revenue should lead to more overloading activity and, consequently, more overweight citations.

Regression results are presented in Table 1. Two equations were estimated based on alternative treatment of the number of vehicles weighed. Model 1 specifies the total number of weighings while Model 2 distinguishes between weighings on fixed location and portable/semi-portable scales.³ Focusing first on Model 1, the results indicate that fines do act to deter overloading, although their effect is relatively inelastic. For example, a 10 percent fine increase is estimated to reduce the number of citations by 2.86 percent. A similar effect is found for weighings, where a 10 percent increase is estimated to reduce the number of citations by 2.59

percent. A more elastic relationship is found for VMT, where a 10 percent increase is estimated to result in an 8.85 percent increase in citations. A moderate elasticity effect is estimated for the value of shipments per ton, but it is not statistically significant.

Table 1
Enforcement Model Parameter Estimates*
 (Dependent Variable = Ln Overweight Citations)

Variable	Mean** (St. Dev.)	Model 1	Model 2
Ln Fine	\$182.1 (138.8)	-.286 (-2.00)	-.238 (-1.56)
Ln Weighings _{total}	2,081,400 (2,751,500)	.259 (3.62)	--
Ln Weighings _{fixed}	2,047,500 (2,753,000)	--	.041 (1.80)
Ln Weighings _{portable}	33,877 (57,926)	--	.251 (2.75)
Ln VMT (millions)	3,855.1 (3,755.2)	.885 (6.23)	1.033 (7.79)
Ln Value per Ton	\$603.0 (221.4)	.382 (1.11)	-.019 (-.05)
Constant	--	-2.747 (-1.23)	-1.018 (-.46)
R ²	--	.78	.76
n	48	48	48

* Coefficients in bold type are statistically significant at the .05 level.

** Means and standard deviations are reported in nominal values.

Turning to Model 2, the estimated fine elasticity is about 20 percent smaller than before and is no longer significant. The estimated elasticities for fixed location and portable scale weighings are interesting. Although the elasticity for portable weighings is about the same as the combined elasticity in Model 1, it is about six times greater than the elasticity estimated for fixed location weighings. This result is consistent with much of the previous work on enforcement deployment strategies, which concludes that weighing at fixed locations is much less effective

than at variable locations with portable scales (Fekpe and Clayton, 1994). This is because fixed weigh station operations are quickly communicated and easily evaded by motor carriers, either by pulling off the road or by diverting to alternate routes (Cunagin et al., 1997; Grundmanis, 1988).⁴ The estimated VMT elasticity in Model 2 is about 15 percent greater than its Model 1 counterpart, indicating that the growth of citations is nearly proportionate to the growth of truck VMT. Finally, as in Model 1, the estimated effect of value per ton is not significant.

Returning to the initial question of enforcement strategy, the regression results indicate that the relative consequences of emphasizing enforcement intensity or overweight penalties are about the same in terms of deterring overloading activity. The enforcement intensity effect, however, is found to be largely associated with the use of portable/semi-portable scales, which accounted for less than two percent of vehicle weighings reported by the subject states in 1999.⁵

There is substantial evidence that overweight fine structures are well below marginal revenues from overloading, as well as estimates of the marginal cost of road damage from overloading (Bisson and Gould, 1989; Casavant and Lenzi, 1993; Church and Mergel, 2000; Euritt, 1987). Thus there is a basis for states to either increase fines or intensify enforcement, with the former likely being more cost-effective given the findings of this note.

FOOTNOTES

1. Data on the number of vehicles weighed and weight violation penalties are posted on the FHWA web site at <http://www.ops.fhwa.gov/freight/regulate/sw/index.htm>. Two states (Alabama and Indiana) are excluded because their weight penalty schedules do not report a fixed value for a 4,000 lb. overload. Truck VMT data are taken from FHWA's Highway Statistics 1999, Section V, which is posted at <http://www.fhwa.dot.gov/ohim/hs99/roads.htm>. The enforcement intensity scale in the figure should be interpreted with caution because the highway classification used to construct the VMT base measure does not directly correspond to state highway systems.
2. The 1997 Commodity Flow Data by state are reported at <http://www.bts.gov/ntda/cfs/cfsstate.html>.
3. Five states (Maine, Massachusetts, New Hampshire, New York, and Rhode Island) reported zero weighings on fixed location scales. In order to take the logarithms, the values for these states were set at .1.
4. While it is not the purpose of this research note to address the overall effectiveness of state weight enforcement practices, it should be acknowledged that considerable evasion exists. For example, among the 48 states analyzed here, data used in the regressions show that only .7 percent of the vehicles weighed were issued overweight citations. Church and Mergel (2000) refer to analysis of data collected by weigh-in-motion scales for the Highway Performance Monitoring System that show between 10 and 20 percent of vehicles exceeding legal weight limits. While an unknown share of these overweight vehicles is legally operating with permits, it would probably not be an exaggeration to claim that evasion approaches 90%.

5. It would be wrong to conclude from these results that fixed location weighing is ineffectual in deterring overloading. Frequently, enforcement practice involves deployment of portable scales on by-pass routes to intercept vehicles attempting to evade operations at fixed weigh stations. Were the fixed weigh stations not operating, the effectiveness of portable scales would certainly be lessened. The more relevant enforcement question (which is beyond the scope of this note) is the determination of the most effective deployment strategy combining fixed location and portable weighings, recognizing that the cost per vehicle weighed is substantially greater for portable scales.

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