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The Impacts of an Auto Weight Limitation on Energy, Resources, and the Economy

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ABSTRACT

The impacts of a hypothetical auto weight limitation on energy conservation, resources usage, pollutant emission and the economy are quantitatively estimated by a linear input–output model and a linear estimation method. These estimations are the first step toward a multiple criteria formulation for understanding and solving complex energy problems.

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1. Introduction

There is general awareness in the United States of the existence of the energy crisis and the need for an effective national energy policy. This study focuses on the feasibility of a hypothetical auto weight limitation plan as a means of conserving energy. Any evaluation of this hypothetical plan must consider a variety of criteria in addition to energy conservation. For instance, what are the impacts of such a plan on public safety, the economy, natural resource consumption and pollution emissions? To effectively evaluate these impacts is not a simple task, since industrial activity and personal economic activity are interrelated in a complex system. Therefore, one of the goals of this study is to estimate some quantifiable impacts of this hypothetical plan on the criteria mentioned.

The main tool used to estimate these impacts is input–output analysis, using the available 1967 interindustry input–output tables adjusted for certain formulas that are derived in this paper. In order to achieve our quantitative predictions, a number of assumptions have been imposed. These are discussed in the appropriate places. Note that the techniques used here to estimate the impacts of this plan could be extended to other alternative energy savings plans.

Specifically, the impacts of two limitation plans are measured. The first assumes the imposition of a new auto weight restriction to a maximum of 2500 lbs beginning January 1, 1978. The second plan is identical to the first except that the weight limit is a more lenient 3000 lbs. The estimated impact on the criteria of energy savings,

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materials usage, pollution and the economy which result from these two limitations are summarized in Table 0.

The section which follows is devoted to a discussion of the mathematical model used in obtaining the results depicted in Table 0. Section 3 discusses the energy savings from the two auto weight restriction plans in terms of energy saved through both the manufacturing and operation of automobiles (rows denoted by (3) in Table 0). Section 4 discusses the effects of each auto weight restriction plan in terms of the reduction in natural resources consumption and pollution emissions which would result from the plans (rows denoted by (4) in Table 0). Section 5 discusses the effects of each auto weight restriction plan in terms of the economic effects of each as measured by employment level and income paid to households (rows denoted by (5) in Table 0).

TABLE 0

Summary of the Impacts of Two Auto Weight Limitation Plans on Certain Criteria

Criterion	Impacts of weight restriction plan initiated in 1978 Weight restricted to 2500 lbs	 Weight restricted to 3000 lbs
Energy savings (crude pet.) (3)		
operational (transportation)	1.1×10^6 bbl/day (1981) 3.0×10^6 bbl/day (1987)	0.9×10^6 bbl/day (1981) 2.4×10^6 bbl/day (1987)
manufacturing (industrial)[a]	0.51×10^6 bbl/day	0.47×10^6 bbl/day
Natural resource savings (4)		
steel (per year)[a]	18.2×10^9 lbs (12.3%)	16.8×10^9 lbs (11.4%)
aluminum (per year)[a]	632×10^6 lbs (7.9%)	585×10^6 lbs (7.3%)
Pollution reduction (4)		
waste water (per year)[a]	695×10^9 gal (5.3%)	643×10^9 gal (4.9%)
air particulate (per year)[a]	784×10^6 lbs (1.8%)	726×10^6 lbs (1.7%)
Economic impacts (5)		
employment[a]	1.4% less employment	1.3% less employment
income to households[a]	\$12.1 $\times 10^9$ less (2.5%)	\$11.2 $\times 10^9$ less (2.4%)

[a] This is an estimated saving in the final equilibrium state. The details are given in later sections.

The available literature on energy conservation policy is abundant. The National Petroleum Council study [17] recognizes an auto weight limitation as a possible long-range energy conservation policy alternative, but does not estimate the impacts of such a policy on nonenergy criteria. Wildhom et al. [25] consider the effect on employment of reducing auto weight and estimate this through a regression equation. Hannon et al. [8] use an input–output approach to estimate the energy saving potential, dollar costs and employment impacts of transportation mode switches, but do not consider technical change alternatives such as an auto weight restriction.

2. A Basic Predictive Model

In this section two basic models for predicting the impacts of a weight restriction plan on energy consumption, natural resource usage, pollution emission and the economy are described. The first model is the standard input–output model introduced by Leontief. The second model is a resource intensity formula which is derived from input–output analysis. This formula which has been used by Bullard and Herendeen [3, 4, 10] and Alterman [1] allows us to quantify how much of various resources are consumed in the production process. For more detailed treatments of the concepts of input–output analysis, see for instance [5, 7, 11, 12, 15 and 19].

Let $x = (x_1, x_2, \ldots, x_n)$ be the output vector of the producing sector of the economy, with the understanding that x_i denotes the annual dollar output of industry i in some year. Let $y = (y_1, y_2, \ldots, y_n)$ be the final demand vector of the economy, where y_i denotes the annual dollar final demand for the output of industry i in some year. Let the matrix $A = A_{nxn} = \{A_{ij}\}$ denote the input–output coefficients for the producing sector, where its element A_{ij} can be interpreted as the ratio of the dollar input to industry j from industry i to the total dollar output of industry j. We obtain the following important equation:

$$x = Ax+y \tag{1}$$

Roughly speaking, (1) is a distribution equation. The right hand side of (1) indicates how the output of each industry is distributed among the industries in the producing sector and final demand. From (1) it can be verified that:

$$x = (I-A)^{-1}y \tag{2}$$

where I is the identity matrix of order n. The elements of $(I-A)^{-1}$ will be denoted by d_{ij} which gives the dollar increase in the ith industry for each dollar increase in final demand of the jth industry. The matrix $(I-A)^{-1}$ is called the "Leontief Matrix" or the "total requirements matrix." A national $(I-A)^{-1}$ matrix is available for 1967 which partitions the producing sector into 370 industries [22].

Using the input–output relationship of (2), it is possible to develop a formula for quantifying the resource usage which occurs in the production of certain goods. In order to measure the total energy resource which is consumed in the production of an automobile, it is necessary to measure the energy consumed in mining iron ore, transporting it to a steel mill, processing it into steel sheets and bars, transporting it to the auto manufacturer, shaping it into an auto body and assembling the automobile. A similar framework applies to resources other than energy and to more complex industrial interdependencies.

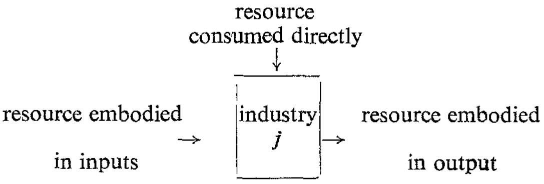

Fig. 1.

Fig. 1. The resource flows through an industry j.

Let us examine one industry j, and the resource flows through it, as depicted in Fig. 1. Figure 1 illustrates the concept that the total resource "embodied" in the output of industry j is the sum of the resource embodied in all of the industry's inputs and the resource consumed directly by the industry.

Let $\varepsilon = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_j, \ldots, \varepsilon_n)$ be the *resource intensity to output vector*, where ε_j is the quantity of some resource (energy, steel, aluminum, pollutant [a negative resource], labor, etc.) embodied in one dollar's worth of output of industry j, that is, ε_j is expressed in terms of units of resource per dollar of output. The following input–output equation can be obtained:

$$\varepsilon X = \varepsilon AX + E \tag{3}$$

where:

$$X = \begin{bmatrix} x_1 & & 0 \\ & \ddots & \\ 0 & & x_n \end{bmatrix}$$

is a diagonal matrix, and E is a vector whose jth element, E_j, represents the amount of resource directly consumed annually by industry j. In order to further motivate (3) (see Fig. 2), note that εX is a vector whose jth element $(\varepsilon X)_j = \varepsilon_j x_j$ is the total amount of resource embodied in the output of industry j. Also note that the ith column of matrix AX represents the dollar distribution of the inputs into industry j from all industries in the producing sector. Thus, it can be seen that εAX is a vector whose jth element represents the total amount of resource embodied in the inputs to industry j.

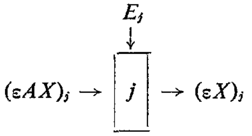

Fig. 2.

Fig. 2. Resource flow through industry j.

The resource intensity vector ε can now be found by solving (3). This is,

$$\begin{aligned} \varepsilon &= E(X-AX)^{-1} \\ &= EX^{-1}(I-A)^{-1} \quad \text{or} \\ \varepsilon &= e(I-A)^{-1} \end{aligned} \tag{4}$$

where e is a vector whose jth element $e_j = E_j/x_j$ is the amount of the resource consumed directly by industry j per dollar value of its output. Hence, the resource intensity[1] to output for a particular industry j is given by

$$\varepsilon_j = \sum_{i=1}^{n} e_i d_{ij} \tag{4a}$$

Once the vector ε is obtained, the impact of change in final demand for the output of different industries on the usage of a particular resource can be determined as follows:

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[1] Note that ε is defined with respect to output. According to (5) and (6) ε also serves as a multiplier with respect to final demand ΔY in computing the change in resources consumption throughout all industries. Since we are primarily interested in changes in final demand, ε will also be referred to as the resource intensity to final demand vector.

Let ΔY be a vector with the jth element, ΔY_j, being the change in final demand for the output of industry j due to some exogenous factor. Then the change in the amount of resource consumed throughout the entire producing sector denoted by ΔE, is given by:

$$\Delta E = \varepsilon \cdot \Delta Y = \sum_j \varepsilon_j \Delta Y_j \tag{5}$$

Equation (5) follows from previous equations, since from (4) we know that:

$$\varepsilon \cdot \Delta Y = e(I-A)^{-1}\Delta Y \tag{5a}$$

Let ΔX be a vector whose ith element, ΔX_i, represents the total change in output of industry i resulting from a change in final demand of ΔY. Equation (2) yields:

$$\Delta X = (I-A)^{-1}\Delta Y$$

Equation (5a) reduces to:

$$\begin{aligned} \varepsilon \cdot \Delta Y &= e \cdot \Delta X \\ &= \sum_{i=1}^{n} e_i \Delta X_i = \sum_{i=1}^{n} E_i \frac{\Delta X_i}{X_i} \end{aligned}$$

Note that $E_i \Delta X_i / X_i$ is the resource savings realized through decreased output of industry i. Thus, $\varepsilon \cdot \Delta Y$ represents the resource savings for all industries in the producing sector.

In the case where a change in final demand occurs in only one industry j, (5) simplifies to:

$$\Delta E = \varepsilon_j \Delta Y_j \tag{6}$$

We will be interested, in particular, in the case where industry j is the automobile industry and ΔY_j is the anticipated decrease in final demand for automobiles resulting from the imposition of an auto weight restriction plan in the beginning of 1978. We refer to this change in final demand for automobiles as ΔY_a. Once ΔY_a is determined and the resource intensity to final demand for automobiles, ε_a, is calculated for each resource, (6) allows us to estimate the reduction in energy, steel and aluminum consumption, labor requirements, income paid to households, industrial pollution emissions, etc.

Observe that the above described estimation formulas have the virtue of simplicity in studying complex economic systems. However they suffer all the shortcomings of linear input and output analysis. For instance, the linearity assumption and equilibrium state are not always warranted in our complex economic system. Such shortcomings have been discussed, for instance in [5], [7], [11], [12], [15], and [19]. In interpreting the results of this report, one should not overlook such inherent shortcomings.

3. Energy Savings

In this section the energy savings through directly operating private automobiles and through the automobile manufacturing process will be discussed. Quite a few simplifying assumptions are made in order to make the computations feasible. The weaknesses of such assumptions are discussed at the end of the section.

3.1 Energy Savings through Operating Automobiles

Suppose that a new car weight limitation will be imposed so that no new cars can exceed 2500 lbs or, alternatively, 3000 lbs after January 1, 1978. It is desirable to know what the impact will be on the consumption of energy.

There are several factors which will affect the energy savings. The first is the rate at which existing cars are replaced with new ones. It has been reported in [18] that each year about 10% of the auto population in use is replaced. It will be assumed that such a rate is reasonably applicable to each weight class of car. Thus no relationship between the weight of a car and its replacement rate will be assumed.

The second factor is the gasoline consumption rate of a newly produced car. It will be assumed that a newly produced car under the weight limitation has the same gasoline efficiency[2] as an older car of the same weight. Thus, a savings is being considered which reflects no new technological breakthroughs in gasoline efficiency. The third factor is the automobile population growth rate. According to Harvey and Menchen [9], it seems reasonable to assume that the population growth rate of automobiles is slightly more than two million cars per year. The miles traveled per year by an automobile is another important factor in computing energy consumption. According to [13], the average automobile traveled 9633 miles in 1969. It will be assumed that this average mileage will remain unchanged.

In order to facilitate the presentation, the energy savings is computed in two steps. In step 1, which is shown in Table 1, the average annual gasoline consumption of a typical car in each weight class is computed. Column 1 of Table 1 is the auto registra-

TABLE 1

Average Yearly Fuel Consumption of Automobiles by Weight Class (1973)

(0) i	Weight class	(1) q_i Distribution % of total	(2) Fuel consumption (miles/gallon)	(3) g_i 9633 mi/mpg (gallons per year)
0	under 2500	10.47	19.6	491.5
1	2500–3000	10.57	15.7	613.6
2	3000–3500	17.02	14.7	655.3
3	3500–4000	29.11	10.9	883.8
4	4000–4500	24.15	10.0	963.3
5	4500–5000	6.98	9.0	1070.3
6	5000–5500	1.43	8.9	1082.4
7	5500–6000	0.04	8.6	1120.1
		99.77%		

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[2] Clearly this is an oversimplification. According to EPA tests, newer models have increased fuel efficiency over older models. Nevertheless, that auto weight and fuel efficiency have an "inverse proportional" relationship still holds, and the analysis can be applied to the new data. (Because of data inconsistency, computation based on this new EPA data is not carried out in this article.)

tion weight distribution for the State of Texas in 1973.[3] Here, because of lacking national data, it is assumed that the national auto weight distribution is similar to that of Texas in 1973.

Note that the registered automobiles represent those currently in operation. A weighted average method is used to derive the m.p.g. (miles per gallon) in Column 2 for each weight class. The weights used correspond to the 1973 production quantity for each model within the weight class, as classified according to [14, 16]. More precisely, let q_i^k and $(\text{mpg})_i^k$ be the number of cars produced and the fuel efficiency in m.p.g. respectively for model k within weight class i. Then, $(\text{mpg})_i$, as given in Column 2, is derived by

$$(\text{mpg})_i = \sum_k (q_i^k(\text{mpg})_i^k)/\sum_k q_i^k.$$

Note that $\{q_i^k\}$ and $\{(\text{mpg})_i^k\}$ come from [16] and [24] respectively. Also note that while the 1973 registration distribution is used in Column 1, the 1973 production distribution is used to derive Column 2. This is due to the lack of relevant gasoline mileage figures for older cars in the distribution. In interpreting the results, it is important to keep this discrepancy in mind. Column 3 shows the estimated annual gasoline consumption of a "typical" car in each weight class, which is derived using the formulas given at the top of Column 3.

From Table 1 we obtain g_L, the average annual gasoline consumption rate for "overweight" cars, that is, those cars in weight classes 1 through 7. Note that:

$$g_L = \left(\sum_{i=1}^{7} g_i q_i\right) \Big/ \sum_{i=1}^{7} q_i = 845 \text{ gallons/yr.} \tag{7}$$

where g_i comes from Column 3 of Table 1 and q_i is the relative percentage of automobiles in class i.

In Table 2a, the estimated energy savings from automobile operations in each future year is given. Column 1 of Table 2a is the total projected number of cars to be registered nationally in future years, $Q(t)$, which is obtained from the following formula from [9]:

$$Q(t) = 90{,}000{,}000 + 2{,}030{,}000\, t$$

where 90,000,000 cars was the estimated car registration at the beginning of 1970, and t is the number of years past the beginning of 1970. In Column 2, $R(t)$ is the number of overweight registered cars at time t if there is no weight limitation plan. Here it is assumed that if no restrictions are imposed, the proportion of "overweight" cars in the population will be constant. That is, $R(t) = 0.895\ Q(t)$ where 0.895 is the estimated proportion of "overweight" cars in the population under a weight limitation of 2500 lbs. Note that from Column 1 of Table 1, the proportion of cars which comply with the restriction is 0.105. Subtracting it from 1.000 yields 0.895. In Column 3 of Table 2a, $R'(t)$ contains the projected number of overweight automobiles still remaining in the population t years past the beginning of 1970, assuming that a weight restriction had been imposed at the beginning of 1978.[4]

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[3] This information was supplied by the Texas Department of Highways and Public Transportation from auto registration data.

[4] The computation is based on an annual replacement rate of 10% as discussed on a preceding page.

TABLE 2a

Gasoline Saved Each Year Through Weight Restriction Plan Limiting Weight to 2500 lbs

0	1	2	3	4	5	6
Year	$Q(t)$ Projected registration (millions of cars)	$R(t)$ Overweight cars (no restriction) (millions of cars)	$R'(t)$ Overweight cars (under restriction) (millions of cars)	$S(t)$ Cars realizing savings (millions of cars)	$S_g(t)$ Gasoline saved $(g_L-g_s) . S(t)$ (million gals/ year)	$S_g(t)$ In energy equiv. million bbls crude oil per day
1976	102.18	91.48	91.48	0	0	0
1977	104.21	93.30	93.30	0	0	0
1978	106.24	95.12	95.12	5.66	2,001	0.2
1979	108.27	96.93	85.61	16.99	6,006	0.5
1980	110.30	98.75	76.10	28.32	10,011	0.8
1981	112.33	100.57	66.58	39.66	14,020	1.1
1982	114.36	102.39	57.07	50.98	18,021	1.4
1983	116.39	104.20	47.56	62.31	22,027	1.7
1984	118.42	106.02	38.05	73.64	26,032	2.1
1985	120.45	107.84	28.54	84.97	30,037	2.4
1986	122.48	109.66	19.02	96.30	34,042	2.7
1987	124.51	111.47	9.51	107.63	38,047	3.0
1988	126.54	113.29	0	114.20	40,370	3.2
1989	128.57	115.11	0	116.02	41,013	3.2
1990	130.60	116.93	0	117.80	—	—

At any point in time, $R(t)-R'(t)$ gives the number of overweight cars which have been replaced by smaller ones in order to comply with the weight restriction. It is because of these cars that a fuel savings is realized, and the fuel savings is directly proportional to the level of operation of these cars. In Appendix A we show that under a linear replacement pattern, the number of cars realizing a gasoline consumption savings in the year beginning at t, $S(t)$, is given by:

$$S(t) = \tfrac{1}{2}[(R(t)-R'(t))+(R(t+1)-R'(t+1))] \tag{8}$$

and is found in Column 4 of Table 2a.

Since $S(t)$ is the number of cars realizing a fuel consumption savings in year t, and (g_L-g_0) is the amount of fuel saved by a lightweight class 0 car which replaces an overweight car, the total fuel savings from operations in year t which can be attributed to the weight restriction plan is $(g_L-g_0)S(t) = S_g(t)$, the values of which are given in Columns 5 and 6 of Table 2a. Column 6 is a measure of the gasoline savings in Column 5 expressed in energy equivalent barrels of crude oil. To obtain this measure, first, gallons of gasoline are converted into the equivalent number of BTU's contained by them, and then are expressed in terms of the number of barrels of crude oil which contain the same BTU content as the gasoline.[5]

Table 2b is identical to Table 2a except that the weight restriction is more lenient. That is, new car weight is limited to a maximum of 3000 lbs and it is assumed that all

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[5] Conversion factors: 1 bbl gasoline = 5.248×10^9 BTU, from [27]; 1 bbl crude oil = 5.8×10^6 BTU, from [28].

overweight cars are replaced by Class 1 cars. The computations in Table 2b are identical to those in 2a, hence, the details are omitted.

It is interesting to observe that the savings from a 2500 lbs weight limitation are about 2, 15 and 30%[6] of the total operating gasoline consumption when no limitation is imposed in the years 1978, 1981 and 1985 respectively. In other words, if no weight limitation is imposed and if annual driving mileage is the only course for saving gasoline, in order to achieve the same amount of energy savings the public must be persuaded to reduce their annual driving by 2, 15 and 30% in the years 1978, 1981 and 1985 respectively. These tradeoffs between weight limitation and annual driving mileage are important for policy formulation. Also observe that if crude oil is imported at a price of $12/bbl, the annual decrease in imported oil from auto operations will amount to $876 million, $4.8 billion and $10.5 billion per year in 1978, 1981 and 1985 respectively.

TABLE 2b

Gasoline Saved Each Year Through Weight Restriction Plan Limiting Weight to 3000 lbs

0 Year	1 $Q(t)$ Projected registration (millions of cars)	2 $R(t)$ Overweight cars (no restriction) (millions of cars)	3 $R'(t)$ Overweight cars (under restriction) (millions of cars)	4 $S(t)$ Cars realizing savings (millions of cars)	5 $S_g(t)$ Gasoline saved $(g_L - g_s) . S(t)$ (million gals/ year)	6 $S_g(t)$ In energy equiv. million bbls crude oil per day
1976	102.18	80.68	80.68	0	0	0
1977	104.21	82.28	82.28	0	0	0
1978	106.24	83.89	83.89	5.00	1,630	0.1
1979	108.27	85.49	75.50	14.99	4,887	0.4
1980	110.30	87.09	67.11	24.98	8,143	0.6
1981	112.33	88.70	58.72	34.98	11,403	0.9
1982	114.36	90.30	50.33	44.96	14,657	1.2
1983	116.39	91.90	41.95	54.95	17,914	1.4
1984	118.42	93.50	33.56	64.94	21,170	1.7
1985	120.45	95.11	25.17	74.94	24,430	1.9
1986	122.48	96.71	16.78	84.92	27,684	2.2
1987	124.51	98.31	8.39	94.92	30,944	2.4
1988	126.54	99.92	0	100.72	32,835	2.6
1989	128.57	101.52	0	102.32	33,356	2.6
1990	130.60	103.12	0	—	—	—

3.2 Energy Savings through the Manufacturing of Automobiles

In order to use (6) to estimate the energy savings through auto manufacturing which can be realized through an automobile weight limitation plan, we must first

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[6] These percentages were derived by the formula:

$$\%\text{ savings in year } i = \frac{100\% \cdot \text{gallons of gasoline saved in year } i}{\begin{pmatrix}\text{Avg. yearly per car}\\ \text{gasoline consumption}\end{pmatrix}\begin{pmatrix}\text{Number of cars regis-}\\ \text{tered in year } i\end{pmatrix}}$$

obtain the energy intensity to final demand for automobiles, ε_a, as well as the estimated decrease in final demand for automobiles, ΔY_a, under both weight restriction plans.

The value of ε_a has been computed by Bullard and Herendeen [4] and is summarized in Table 3. Column 2 of Table 3 is the energy intensity to final demand for motor vehicles for each energy source listed in Column 1.

TABLE 3

Projected Manufacturing Energy Savings Under Auto Weight Restriction Plans

1	2	3	4	5	6
		Manufacturing energy savings			
		Limit to 2500 lbs		Limit to 3000 lbs	
			crude oil		crude oil
Energy source	ε_a[a] (btu/1973$)	10^{12} btu/yr	10^{6} bbl/day	10^{12} btu/yr	10^{6} bbl/day
Coal	26,182	528.88	0.250	489.60	0.231
Crude oil and gas	25,011	505.22	0.239	467.71	0.221
Refined petroleum	11,553	233.37	0.110	216.04	0.102
Electricity	3,773	76.21	0.036	70.56	0.033
Natural gas	14,447	291.83	0.138	270.16	0.128
Primary energy	53,437	1,079.43	0.510	999.27	0.472

[a] The energy intensities given in [4] have been converted to 1973 dollars by considering a 31 % rise in the wholesale price index between 1963 and 1973.

The energy source "primary energy" is defined by Bullard and Herendeen as the weighted sum of coal, crude oil, natural gas, hydro and nuclear electricity such that the double counting of energy sources is eliminated.

Note that Columns 3, 4, 5 and 6 of Table 3 list the energy savings in BTU per year and energy equivalent barrels of crude oil per day which could be saved under the two limitation plans.

As is summarized in Table 5, the decrease in final demand for motor vehicles, ΔY_a, is estimated at \$20.2 billion and \$18.7 billion for weight restriction plans limiting auto weight to 2500 lbs and 3000 lbs respectively. The derivation of these values of ΔY_a follows subsequently.

3.2.1 Calculation of the Decrease in Final Demand for Domestic Automobiles Under Auto Weight Limitations

In order to compute ΔY_a, Table 4 is constructed. Column 3 of Table 4 lists q_i, the 1973 model year domestic automobile production quantity for each weight class i, which is obtained from [16] and classified using [14]. Column 4 lists the weighted average price $\bar{p}_i$ for a car in each weight class i. Each value of $\bar{p}_i$ is weighted with respect to the quantity of each model of car in weight class i. That is,

$$\bar{p}_i = \Big(\sum_k q_{ik} p_{ik}\Big) \Big/ \sum_k q_{ik}$$

where q_{ik} and p_{ik} are the 1973 quantity produced and the manufacturers list price of the kth model of weight class i domestic car. The data of q_{ik} and p_{ik} are obtained from [16] and [2] respectively.

TABLE 4

Predicted Total Sales Value of Domestic Auto Output Under Weight Restriction Plans

(1) i Weight class	(2) Weight range (lbs)	(3) q_i Units of 1973 domestic production	(4) $\bar{p}_i$ 1973 average price (\$)	(5) $P_i = \bar{p}_i \cdot q_i$ (millions of \$)	
0	2000–2500	728,982	2165	1578.2	$P_1^0 = 21414.5$
1	2501–3000	411,474	2287	941.0	$P_1^1 = 22532.3$
2	3001–3500	1,609,300	2641	4250.2	
3	3501–4000	1,979,232	3243	6418.6	
4	4001–4500	2,901,092	3821	11085.1	
5	4501–5000	1,806,135	4582	8275.7	
6	5001–5500	195,846	7901	1547.4	
7	5501–6000	252,226	7381	1861.7	
		$Q = 9{,}891{,}212$		$P_0 = 35957.9$	

Column 5 yields the total value of cars produced for each weight class, as obtained from the formula given at the top of the column. Now, suppose that a weight limitation has been imposed at 2500 lbs. That is, only new cars in class 0 will be available subsequent to January 1978. All the owners of cars in weight class 1–7 will be compelled to replace them with cars in class 0. If we assume that these buyers replace their cars with an "average" class 0 car, then the new cars will have an average price of $\bar{p}_0$. If we assume that new automobile production in those years will be at the 1973 level, then the total value of all cars produced will be $P_1^0 = \bar{p}_0 Q$, where Q is the total number of automobiles produced in 1973. Letting P_0 be the total estimated sales value of all cars produced if there is no weight limitation, then the fractional reduction in total value of new automobiles can be given by

$$1-(P_1^0/P_0) = 0.40 \qquad \text{where } P_0 = \sum_{i=0}^{7} q_i\bar{p}_i \tag{9}$$

Similarly, suppose the auto weight restriction is imposed at 3000 lbs. This means that all newly produced cars will be either in class 0 or in class 1 subsequent to 1978. Suppose that previous owners of overweight cars replace them with the largest car available, that is, a car in class 1. The total value of new automobiles, if produced at 1973 levels is given by P_1^1 where $P_1^1 = \bar{p}_0 q_0 + \bar{p}_1 \sum_{i=1}^{7} q_i$. The fraction reduction in total value of new automobiles can be given by:

$$1-(P_1^1/P_0) = 0.37. \tag{10}$$

Since P_0 includes only the theoretical value of new cars sold and does not measure the decrease in consumption of other automobile-related goods and services, it is more accurate to apply the fractional reductions given in equations (9) and (10) to the gross auto product, which amounted to $50 billion in 1973 [21]. Table 5 includes the values of equations (9) and (10) as well as the projected reduction in final demand for automobiles resulting from the two weight restriction plans.

TABLE 5

Reduction in Final Demand for Automobiles Under Weight Restriction Plan

Restrict weight to:			
2500 lbs		3000 lbs	
% reduction in output $1-P_1^0/P_0$	reduction in final demand $(1-P_1^0/P_0)\times$ gross auto product	% reduction in output $1-P_1^1/P_0$	reduction in final demand $(1-P_1^1/P_0)\times$ gross auto product
0.40	$20.2 billion	0.37	$18.7 billion

Before applying Table 5, two points must be noted. First, it is assumed that auto production in the future (i.e., at the beginning of 1978) is maintained at the 1973 level. This is an oversimplified assumption, since in response to the growing demand for automobiles which may be 2 to 3% annually (as indicated in Sec. 3.1) and the current economic situation, the number of automobiles produced may vary substantially from year to year. To simplify our presentation, we have not considered such long-term trends and fluctuations in our calculations of annual resource savings through manufacturing. Secondly, it is assumed that any overweight car which is replaced with one complying with the weight restriction is replaced with one in the maximum allowable weight class, and that this new car has a value equal to the average value, $\bar{p}_i$, of a car in that weight class. It is conceivable that the owner of an overweight car might prefer a more expensive model in the lower weight class. Exactly what such a preference might be is unknown, but if the preference is known, the projected reduction in final demand can be adjusted accordingly. It must also be considered that if a weight restriction is imposed, new lightweight models aimed at the prestige or quality oriented buyer will emerge. Finally, it needs to be pointed out that a change in final demand for automobiles is part of a change in final demand for motor vehicles. Since the input–output tables used do not separate the automobile industry from the motor vehicles industry in any satisfactory way, the input–output coefficients of the motor vehicles industry are used for the automobile production sector.

4. Resources and Pollution

In this section the models developed in Section 2 are used to predict the effects of an auto weight limitation plan on certain environmental factors. The environmental effect of auto manufacturing is two-fold. First, manufacturing automobiles consumes precious and exhaustible natural resources. Second, manufacturing automobiles creates harmful side products in the form of various kinds of environmental pollution. The decrease in final demand for automobiles predicted in Section 3.2.1 will have the effect of reducing both material consumption and pollution emissions.

Because of emission control, there is no evidence that large cars will emit more pollutants than small cars per mile driven. This conclusion is based on emission data found in [24]. Thus, in discussing pollution aspects of the auto weight limitation it suffices to discuss the pollution through manufacturing process only.

Table 6 summarizes the predictions of resource savings for steel and aluminum, and pollution reductions in wastewater and particulate emissions which result from the two auto weight limitation plans. Column 2 of Table 6 shows the intensities to final demand for automobiles, ε_a for the resources and pollutants in Column 1. Each element of Column 2 is obtained using equation (4a) and data obtained in [20], [6], [23], and [11]. The interested reader is referred to Appendix B which contains detailed tables for calculation of ε_a for steel, aluminum, wastewater and particulates. For the weight restriction plan which limits auto weight to 2500 lbs, Column 3 gives the total predicted reduction in consumption or emission for each resource or pollutant listed in Column 1. Column 4 is the corresponding entry in Column 3 given as a percentage of yearly national consumption or emission. Data for steel and aluminum consumption are for 1967, and the figure in Column 4 is a percentage of 1967 consumption. Data for wastewater emissions is for 1964 while data for particulate emissions is a projection for 1978. The figures in Column 4 are a percentage of 1964 and estimated 1978 total emissions for wastewater and particulates, respectively. For the weight limitation plan

TABLE 6

Projected Reduction in Raw Materials Usage and Pollution Emissions Under Auto Weight Restriction Plans

1	2	3	4	5	6	7
	ε_a	Weight limited to 2500 lbs		Weight limited to 3000 lbs		
Resource or pollutant	Intensity to final demand for automobiles	Reduction in consumption (emission)	%[a]	Reduction in consumption (emission)	%[a]	ε_j/e_j
Steel[b]	899 lbs/\$1000	$18{,}160\times10^6$ lbs	12.3	$16{,}811\times10^6$ lbs	11.4	2.1
Aluminum[b]	31.3 lbs/\$1000	632×10^6 lbs	7.9	585×10^6 lbs	7.3	2.3
Waste water[c]	34,400 gals/\$1000	694.9×10^9 gal	5.3	643.3×10^9 gal	4.9	10.6
Particulates[d]	38.8 lbs/\$1000	784×10^6 lbs	1.8	726×10^6 lbs	1.7	—

[a] Percentage of the total national annual consumption or emission. For steel and aluminum, 1967 total consumption is the denominator; for waste water, 1964 total emission; for particulates, the estimated 1978 emissions.

[b] 1967 data from [20].

[c] 1964 data from [6].

[d] 1978 estimations from [23].

which limits maximum auto weight to 3000 lbs, Columns 5 and 6 correspond to Columns 3 and 4.[7]

Not only does input–output analysis allow us to predict aggregate amounts of reductions in the use of resources and the emission of pollutants, but it also allows us to discover what part of the total resource consumption or pollutant emission reductions can be attributed to reductions by the auto industry itself, and what part can be attributed to reductions by other industries in the producing sector. This ratio, ε_a/e_a is the ratio of total consumption (or emission) reductions throughout the producing sector to the reduction in consumption (or emission) attributable directly to the auto industry. Column 7 of Table 6 gives the ε_a/e_a ratio for the corresponding resource or pollutant in Column 1.

5. Economic Impacts

In this section we extend the models introduced in Section 2 to predict some economic impacts of an auto weight limitation plan. Our analysis will concentrate on two key economic measurements, income to households (also called employee compensation) and employment. Both of these measurements reflect the level of utilization of the resource of labor.

It is important to realize that the measurement of the impacts of an auto weight restriction plan on income to households and employment does not yield a complete representation of the economic impacts of such a plan. For instance, the effects of such a plan on the balance of international trade will also be substantial, since a reduction of oil imports of 1.6 million bbls per day[8] by 1981 would mean a reduction in imports of about $7 billion in that year (based on $12 per bbl). The impacts of such a reduction would have far-reaching political and economic impacts.

5.1 Effects on Income to Households

Income to households is a measurement of the degree of utilization of labor. "Households" as a whole can be viewed as an industry in itself, since "households" distributes its "product," that is, labor inputs, to all industries, while each industry provides inputs to households in the form of employee compensation. But, "households" is a very special industry since the employee compensation which is its input is used to create final demand for the output of all other industries. That is, a large part of GNP is precisely the aggregate of this employee compensation. Consequently, not only will a decrease in income to households result from a decrease in final demand for automobiles, but an "induced" decrease in final demand for all industries will eventually result as consumers "slide down" their consumption curves because of decreases in their disposable income. We will not attempt to measure this induced decrease in final demand, since it requires behavioral assumptions which are beyond the scope of this article. It will suffice to say, however, that a decrease in income to households is especially significant.

Equation (4a) can be used to determine the value of ε_a, the total income paid to households by all industries in the industrial sector for each dollar of the auto industry's

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[7] The time inconsistency of data is due to scarcity of relevant yearly data.

[8] Includes 1.1 million bbls from operations of automobiles and 0.5 million bbls manufacturing.

final demand. In (4a), e_i is the total compensation paid to employees of industry i for each dollar of industry i's output. The value of e_i is available in [11] for each industry.

Row 1 of Table 7 summarizes the results of our calculations of the effect on income to households of both auto weight restriction plans discussed. The entry in Column 2 is the 1967 value of ε_a mentioned above. The entry in Column 3 is the total predicted decrease in income to households for all industries in the producing sector which results from an auto weight limitation to 2500 lbs. The entry in Column 4 is the corresponding entry in Column 3 given as a percentage of total national income paid to households in 1973, as given in [21]. The entries in Columns 5 and 6 correspond to the entries in Columns 3 and 4 for the weight restriction plan which limits auto weight to 3000 lbs.

TABLE 7

Projected Reduction in Income to Households and Employment Under Auto Weight Restriction Plans

		Weight limited to:				
	(2)	2500 lbs		3000 lbs		
	ε_a	(3)	(4)	(5)	(6)	(7)
(1)	intensity to final demand	total decrease[a] $\varepsilon_a \Delta Y_a$	%[b]	total decrease[a] $\varepsilon_a \Delta Y_a$	%[b]	ε_a / e_a
Income to households	\$0.597 per \$	\$12.1 × 10^9	2.5	\$11.2 × 10^9	2.4	3.09
Employees	57,015 jobs/ \$billion	1.151 × 10^6 jobs	1.4	1.066 × 10^6 jobs	1.3	3.22

[a] For ΔY_a see Table 5.

[b] For income to households, the denominator is total 1973 employee compensation. For employees, the denominator is total 1973 civilian employment.

Row 1 of Table 7 gives us some idea of the aggregate decreases in income to households which might be expected under a weight restriction plan. The decreases can be attributed largely to those industries which most heavily supply the auto industry either directly or indirectly. Column 2 of Table 8 lists those industries which suffer the greatest dollar decreases in income to households. Column 3 shows the decrease in income to households which would result from a one dollar decrease in final demand for automobiles for each industry listed in Column 2, as computed by the formula given at the top of Column 3. For a weight restriction plan limiting new auto weight to 2500 lbs, Column 4 gives the total dollar decrease in income to households for each industry in Column 2, as computed by the formula at the top of Column 4. Column 5 shows the total annual payroll for each industry in 1967, as obtained from [11]. Note that the payroll is smaller than the total employee compensation since fringe benefits are not included. As discussed in Section 4, it is useful to know what part of the total decrease in income to households given in Columns 3 and 5 of Table 7 can be attributed directly to decreases in compensation paid to employees of the auto industry. In Column 7 of Table 7, the ratio ε_a / e_a is the ratio of the decrease in employee compensation throughout all industries to the decrease in compensation paid directly to employees of the automobile industry.

5.2 Effect on Employment

As demand for industrial output declines, businesses are sure to respond by decreasing the variable costs associated with direct labor. If output continues to decline past some limit, layoffs are sure to follow. Equation (4a) can be used to derive ε_a, the total number of employed persons in all industries required for each dollar of the auto industry's final demand. In (4a) e_i is the total number of persons employed by industry i per dollar of industry i's output, and is based on 1972 data obtained from [21]. The details of the calculation of ε_a can be found in Appendix C. Row 2 of Table 7 gives the results of our calculation of the effects of both auto weight limitation plans on employment. Column 2 gives ε_a, the labor intensity to final demand for automobiles expressed in number of jobs per billion 1973 dollars of final demand. The entry in Column 3 is the prediction of the total decrease in jobs which would result from an auto weight limitation plan limiting auto weight to 2500 lbs, as computed by the

TABLE 8

Projected Decrease in Income to Households of Supplying Industries Under Auto Weight Limitation to 2500 lbs

SIC code	Industry	Decrease in income to households per dollar of auto final demand $e_i d_{ia}$[a]	Decrease in income to households from auto weight limitation of 2500 lbs $e_i d_{ia} \Delta Y_a$[b]	Total payroll for each industry, 1972[c]
(1)	(2)	(3)	(4)	(5)
		$	billions of $	billions of $
59	Motor vehicles and equipment	0.271	5.47	9.46
87	Primary iron and steel manufacturing	0.054	1.09	8.54
41	Stampings, screw machine products and bolts	0.030	0.61	3.70
69	Wholesale and retail trade	0.026	0.53	69.6[d]
65	Transport and warehousing	0.021	0.42	20.6[d]
42	Other fabricated metal products	0.015	0.30	3.56
73	Business services	0.014	0.28	16.0
38	Primary nonferrous manufacturing	0.011	0.22	3.59
32	Rubber and miscellaneous plastics	0.011	0.22	5.16

[a] e_i and d_{ia} are from 1967 input–output tables [11].

[b] ΔY_a is 1973 dollars (see Table 5).

[c] Data is total payroll for each industry which is smaller than income to households since fringe benefits etc. are not included. Source: [21].

[d] 1972 data unavailable, 1967 data used from [11].

formula at the top of the column. The entry in Column 4 is the corresponding entry in Column 3 given as a percentage of total national civilian employment in 1973 [21]. The entries in Columns 5 and 6 correspond to the entries in Columns 3 and 4 for the weight limitation plan limiting auto weight to 3000 lbs. As before, the entry in Column 7 of Row 2 gives the ratio of the number of jobs lost throughout the producing sector to the number of jobs directly lost in the automobile industry.

When using the input–output model to predict the loss of jobs which might result from an auto weight limitation plan, the assumptions which underlie the model become particularly restrictive. The assumptions of the model seem to indicate that businesses within some industry j are constantly adjusting the number of employees so as to maintain a constant ratio e_j, the number of employees per dollar of output. This is clearly not the case, since businesses must maintain some fixed level of administrative employment for all levels of output, as well as comply with the moral obligation and the constraints of organized labor to attempt to stabilize the level of employment over ranges of output. The labor intensity vector ε_a does, however, provide some information as to the total direct and indirect industrial labor requirements which result from final demand for each industry.

6. Conclusion

In the preceding sections, two feasible energy conservation policies have been evaluated in terms of certain energy, natural resources, pollution and economic criteria. These two feasible energy conservation policies are only two out of numerous alternatives. In order to compare an auto weight limitation plan with other alternatives on the basis of the criteria examined here, it is necessary that similar analysis be done for the other alternatives. Note that an optimal energy policy may consist of combining a number of feasible alternatives. For instance, the development of a lightweight higher priced automobile in conjunction with an auto weight limitation plan may help to stave off some of the negative economic effects of such a plan.

As stated before, the set of criteria examined here are not represented as being exhaustive. Indeed, all of the criteria examined apply only to our national condition without regard to the interaction with the rest of the world. Opting for an auto weight limitation plan will have its effects on the balance of trade, since such a plan would reduce oil imports and, perhaps, the import of small foreign cars. In the long run, as imports decline so may the level of exports, a situation which may have additional impacts on the domestic economy as well as international relations. Clearly, such an "international" criterion is also needed.

In closing, the reader is reminded again of the linear assumptions which underlie the models discussed. Although the models are far from perfect, in a complex economic system the estimations could serve as a preliminary step in a systematic evaluation of energy policies.

Appendix A

We have shown in Section 3.1 that the number of cars which are realizing savings at any point in time t is given by $R(t)-R'(t)$. We want to determine $S(i)$ the number of cars realizing a savings during some year i.

Note that,

$$S(i) = \int_{i}^{i+i} [R(t)-R'(t)]\,dt$$

Assume that $R(t)$ and $R'(t)$ are linear functions. Then we can write $R(t) = at+b$ and $R'(t) = a't+b'$. It follows that:

$$\begin{aligned} S(i) &= \int_{i}^{i+i} (at+b)\,dt - \int_{i}^{i+i} (a't+b')\,dt \\ &= [\tfrac{1}{2}a(2i+1)+b]-[\tfrac{1}{2}a'(2i+1)+b'] \\ &= \tfrac{1}{2}[(ai+b)+(a(i+1)+b)-(a'i+b')-(a'(i+1)+b')] \\ &= \tfrac{1}{2}[R(i)-R'(i)+R(i+1)-R'(i+1)] \end{aligned}$$

Appendix B

Tables B1 through B4 present in tabular form the calculations of ε_a, the intensities of steel, aluminum, wastewater and particulates to final demand for automobiles,

TABLE B1

Table for Calculating Steel Intensity to Final Demand for Automobiles

i Industry	E_i[a] Quantity consumed (1967) (1000 short tons)	$e_i = E_i/X_i$ (1000 short tons per million $)	d_{ia}	$e_i d_{ia}$
22, 23	1773.8	0.2233	0.00212	0.00047
32	96.7	0.0070	0.03785	0.00026
35, 36	119.5	0.0081	0.02162	0.00018
37, 38	2106.9	0.0401	0.24783	0.00994
39	6302.0	1.8784	0.00157	0.00295
40	13785.3	1.1019	0.00405	0.00446
41	11112.4	1.1958	0.09070	0.10846
42	4088.2	0.3266	0.05168	0.01688
43	333.7	0.0872	0.00994	0.00087
44	2033.9	0.4214	0.00139	0.00059
45	1996.8	0.3342	0.00399	0.00133
46	767.8	0.3025	0.00160	0.00048
47–52	4635.1	0.1218	0.01627	0.00198
53–58	5739.0	0.1194	0.05618	0.00671
59 (= a)	9154.2	0.2093 = e_a	1.40019	0.29306
60	271.4	0.0123	0.00428	0.00005
61	3357.2	0.4298	0.00111	0.00048
62, 63	139.6	0.0127	0.00865	0.00011
64	332.4	0.0345	0.00298	0.00010
13	1052.2	0.0980	0.00122	0.00012
Steel intensity to final demand for automobiles $\varepsilon_a = \sum_i e_i d_{ia} = 0.44948$				

[a] E_i from [20] based on 1967 data.

TABLE B2

Table for Calculating Aluminum Intensity to Final Demand for Automobiles (ε_a)

i Industry	E_i[a] Quantity (1000 short tons)	$e_i = E_i/X_i$ (1000 short tons) per million $	d_{ia}	$e_i d_{ia}$
22, 23	111.5	0.0140	0.00212	0.00003
24, 25	23.4	0.0010	0.01224	0.00001
37	4.5	0.0001	0.18138	0.00002
38	183.8	0.0088	0.06645	0.00058
39	460.6	0.1373	0.00157	0.00022
40	909.6	0.0727	0.00405	0.00029
41	355.0	0.0382	0.09070	0.00340
42	240.8	0.0192	0.05168	0.00099
43–52	372.5	0.0067	0.03319	0.00022
53–58	371.8	0.0077	0.05618	0.00043
$59 = a$	286.8	$0.0066 = e_a$	1.40019	0.00924
60, 61	484.2	0.0162	0.00539	0.00009
62	13.4	0.0022	0.00757	0.00002
63	8.2	0.0017	0.00108	0.00000
64	48.6	0.0052	0.00298	0.00002
13	108.1	0.0101	0.00122	0.00001

Aluminum intensity to final demand for automobiles $\varepsilon_a = \sum_i e_i d_{ia} = 0.01563$

[a] E_i from [20], based on 1967 data.

TABLE B3

Table for Calculating Particulate Intensity to Final Demand for Automobiles

i Industry	E_i[a] Quantity emitted (1000 tons/year)	$e_i = E_i/X_i$	d_{ia}	$e_i d_{ia}$
3	84	0.0317	0.00064	0.00002
4	1539	0.5764	0.00034	0.00020
7	71	0.0171	0.00609	0.00010
8	0	0.0000	0.00705	0.00000
9	3303	0.8237	0.00160	0.00132
19	707	0.1308	0.02009	0.00263
20	960	0.0522	0.00662	0.00035
27	348	0.0084	0.02202	0.00018
31	225	0.0063	0.01163	0.00007
37	862	0.0211	0.18138	0.00383
38	220	0.0057	0.06645	0.00038
68	7076	0.0982	0.02628	0.00258
All industries	6867	0.0030	2.57854	0.00774

Particulate intensity to final demand for automobiles $\varepsilon_a = \sum_i e_i d_{ia} = 0.01940$

[a] E_i from [6], based on projected 1978 data.

according to equation (4a). Column 1 of Table B1 lists the SIC codes of each industry which was a significant consumer of steel. Column 2 lists the quantity of steel, E_i, consumed directly in 1967 by each industry i as given in [20]. Column 3 gives the quantity of steel consumed per dollar of output of each industry i, yielding e_i. Column 4 contains the relevant elements of the ath (motor vehicles) column of the matrix $(I-A)^{-1}$ which correspond to the industries in Column 1. Column 5 gives the amount of steel consumed by each industry i per dollar of final demand for automobiles. The sum of all the elements in Column 5 corresponds to ε_a, the steel intensity to final demand for automobiles as given in (4a). In this case, $\varepsilon_a = 0.44948$ thousand short tons of steel per million dollars of final demand for automobiles.

Table B2 is identical to Table B1 except that it computes ε_a for aluminum. Tables B3 and B4 are also identical to Table B1 except that E_i in Column 2 of both tables represents the quantity of pollutant emitted by industry i in Column 1, rather than a resource consumed by it. For wastewater and particulates, E_i was obtained from [6] and [23] respectively.

TABLE B4

Table for Calculating the Wastewater Intensity to Final Demand for Automobiles ε_a

i Industry	E_i[a] Quantity emitted (billion gals/year)	$e_i = E_i/X_i$	d_{ia}	$e_i d_{ia}$
14	690	0.0077	0.00542	0.00004
16–19	140	0.0029	0.04968	0.00014
24, 25	1900	0.0835	0.01843	0.00154
27, 29, 30	3700	0.0957	0.03033	0.00290
7, 8, 31	1300	0.0288	0.02477	0.00071
28, 32	100	0.0045	0.05135	0.00023
37	3600	0.1135	0.18138	0.02059
38	740	0.0355	0.06645	0.00236
43–52	150	0.0027	0.09432	0.00025
53–55, 58	91	0.0040	0.04535	0.00018
59–61	240	0.0033	1.40558	0.00464
22, 23, 35, 36 39–42, 56, 57 62–64, 13	450	0.0043	0.19542	0.00084

Wastewater intensity to final demand for automobiles $\varepsilon_a = \sum_i e_i d_{ia} = 0.03442$

[a] E_i from [23] based on 1964 data.

Appendix C

Table C1 presents in tabular form the calculation of ε_a, the labor intensity to final demand for automobiles, according to (4a). The calculation follows a similar calculation made in 1965 by Alterman in [1]. Column 1 of Table C1 contains the SIC codes for the 80 industrial classifications used in [11] to segment the producing sector. Column 2 contains the average number of persons employed in 1972 by the industries in Column 1, corresponding to E_i for each industry i. Column 3 contains the dollar output, in 1972 dollars, of each industry i in Column 1. The values for Columns 2 and 3 were obtained from [21], and can be found mostly in Table No. 1234 of the 1973 edition and Table No. 370 of the 1974 edition. Column 4 contains the number of employees per dollar of output of each industry i. Column 5 is the ath column of the 80-sector Leontief matrix for the year 1967, as found in [11]. Column 6 contains the product of Columns 4 and 5, the sum of which corresponds to (4a).

TABLE C1

Table for Calculating Labor Intensity to Final Demand for Automobiles (ε_a) (1972)

	Employees	Dollar output	Employees/ million		
1	2	3	4	5	6
	(1000's)	(million $)			
i	E_i	X_i	$E_i/X_i = e_i$	d_{ia}	$(E_i/X_i)d_{ia}$
1 2 3 4	3,005	65,132[71]	46.137	0.00714	329.41
5 6	86	3,641	23.620	0.01370	323.59
7	147	4,647	31.633	0.00609	192.64
8	262	17,361	15.091	0.00705	106.39
9 10	112	6,566	17.058	0.00256	43.67
11 12	3,521	127,059[71]	27.712	0.01372	380.21
13	188	7,520	25.000	0.00122	30.50
14	17,559	114,322	13.637	0.00542	73.91
15	66	5,892	11.202	0.00024	2.69
16	737	19,272	38.242	0.01820	696.00
17	212	8,585	24.694	0.00912	225.21
18	1,172	22,132	52.955	0.00227	120.21
19	186	4,983	37.327	0.02009	749.90
20	645	22,671	28.450	0.00662	188.34
21	36	754	47.745	0.00055	26.26
22	322	7,636	42.169	0.00048	20.24
23	142	3,859	36.797	0.00164	60.35
24	411	20,144	20.403	0.01186	241.98
25	222	8,023	27.670	0.00657	181.79
26	1,046	29,892	34.993	0.01146	401.02
27	225	13,997	16.075	0.02202	353.97
28	164	9,888	16.586	0.01350	223.91
29	241	17,934	13.438	0.00131	17.60
30	67	3,876	17.286	0.00700	121.00
31	139	28,602	4.860	0.01163	56.52
32	617	21,269	29.009	0.03785	1097.99
33	26	1,042	24.952	0.00026	6.49
34	232	4,614	50.282	0.00025	12.57
35	140	4,336	32.288	0.01352	436.53

TABLE C1 continued

	Employees	Dollar output	Employees/ million		
1 i	2 (1000's) E_i	3 (million \$) X_i	4 $E_i/X_i = e_i$	5 d_{ia}	6 $(E_i/X_i)d_{ia}$
36	476	17,094	27.846	0.00810	225.55
37	784	34,759	22.555	0.18138	4091.03
38	355	23,521	15.093	0.06645	1002.93
39	78	4,965	15.710	0.00157	24.66
40	454	16,263	27.916	0.00405	113.06
41	361	12,900	27.984	0.09070	2538.15
42	404	12,934	31.236	0.05168	1614.28
43	116	5,502	21.083	0.00994	209.57
44	124	5,537	22.395	0.00139	31.13
45 46	273	11,010	24.796	0.00559	138.61
47	268	7,249	36.971	0.02193	810.77
48	186	6,088	30.552	0.00173	52.85
49 50	444	12,910	34.392	0.03686	1267.69
51	211	8,655	24.379	0.00061	14.87
52	197	8,656	22.759	0.06127	1394.44
53	301	8,944	33.654	0.01256	422.69
54	162	6,876	23.560	0.00275	64.79
55	177	5,621	31.489	0.01043	328.43
56	561	18,641	30.095	0.00660	198.63
57	331	8,705	38.024	0.00423	168.45
58	119	4,367	27.250	0.01961	534.37
59	808	63,872	12.650	1.40019	17712.40
60	438	15,445	28.359	0.00428	121.38
61	311	9,588	32.436	0.00111	36.00
62	218	5,974	36.491	0.00757	276.24
63	226	8,853	25.528	0.00108	27.57
64	444	12,041	36.874	0.00298	109.88
65	4,495	83,270[e]	53.980	0.05490	2963.50
66	987	35,000[e]	28.200	0.00878	247.60
67	138	4,586	30.092	0.00272	81.85
68	720	40,000[e]	18.000	0.02628	473.04
69	15,683	746,000	21.023	0.06182	1299.64
70 71	3,926	131,761	29.796	0.04162	1240.11
72	1,762	39,976	44.076	0.02796	1232.36
73	1,663	34,165	48.676	0.04883	2376.85
74					
75					
76	191	11,876	16.083	0.00148	23.80
77	3,442	61,800[e]	55.696	0.00149	82.99
78	2,650	8,124[e]	326.199	0.00434	1415.70
79	10,640	12,006[e]	886.244	0.00601	5326.33
80	—	—	—	0.05435	0.00
				Total =	57015.08

[e] Data not available. Values estimated from past data by extrapolation.

[71] Relevant 1972 data not available, 1971 data used instead.

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