An Analysis of Trends in Automotive Fuel Economy from 1978 to 1984

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ABSTRACT

Between 1978 and 1984, the fuel economy of new automobiles increased by an estimated 6.7 miles per gallon. Previous analyses have shown that fuel economy improvements have been primarily achieved by lowering the average weight of the automobile and reducing the size of the engine. Detailed sales data were used to analyze the contributions of consumer sales shifts and engineering and design improvements to the 1978 to 1984 gain in fuel economy. Most of the gain (70 percent) was found to have resulted from changes in vehicle offerings by manufacturers, whereas only 30 percent of the gain was attributed to sales shifts. The lack of improvement in fuel economy of new automobiles since 1982 is attributed to both consumer selections and manufacturer decisions.

Between 1978, when new automobile fuel economy standards became effective, and 1982, the fuel economy of new automobiles increased by one-third, from 19.7 to 26.4 miles per gallon (mpg) (1). The 1982 fuel economy increased nearly 90 percent from the 1974 estimate of 14.2 mpg. However, the fuel economy of new automobiles has not increased since 1982. The estimated fuel economy of new automobiles for the first 6 months of model year 1984 stands at 26.3 mpg, just slightly below the 1982 value (2). If this estimate holds true for the remainder of 1984, it would be the first year the efficiency of all new automobiles fell below the standard mandated for individual manufacturers (27 mpg in 1984). The recent change in fuel economy trends creates doubt about whether the 27.5 mpg standard for 1985 and beyond can be achieved.

Substantial information is available to explain how fuel economy improvements since 1978 have been achieved (3,4,5). Studies of vehicle engineering and design changes indicate that automobile weight reduction and associated reductions in engine size have been primarily responsible for improved mpg. The actions of consumers responding to new vehicle offerings and fuel prices, and producers changing vehicle designs and offerings, are examined to determine new automobile fuel efficiencies. Detailed vehicle sales and fuel economy data from 1978 to 1984 are also analyzed. By means of a decomposition technique, each year's change in fuel economy is broken into eight components that quantify the effects of sales shifts and changing manufacturer offerings. The results indicate that although sales shifts were only a secondary contributor to improved automobile efficiency through 1982, they are a primary contributor to the lack of fuel economy improvements over the past 2 years.

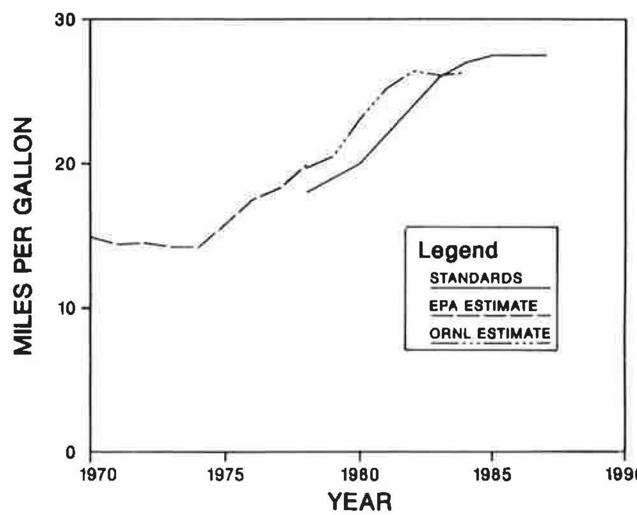

FIGURE 1 Estimated new automobile fuel economy and federal fuel economy standards.

HOW FUEL ECONOMY GAINS WERE ACHIEVED

In 1974 the fuel efficiency of new automobiles was at its lowest point (14.2 mpg) after years of gradual decline (see Figure 1). In the same year, gasoline prices jumped from 39 to 53 cents per gallon (current dollars) as a result of the worldwide increase in petroleum prices. The realization that cheap petroleum fuels in a stable market were a thing of the past stimulated Congress to pass the Energy Policy and Conservation Act of 1975 (P.L. 94-163), which established corporate average fuel economy (CAFE) standards. Consumers began to demand more efficient vehicles, and manufacturers responded with significant engineering improvements and design changes that combined to nearly double the fuel efficiency of new automobiles. Some of the improvement in the average fuel economy of new automobiles is the result of consumers' decisions to buy smaller automobiles and trucks or more efficient models and configurations. Some of the improvement can also be attributed to the fact that manufacturers made vehicle design and engineering changes to meet the demands of both consumers and CAFE standards. In the following section the changes that have been made, the types of technology used to improve fuel economy, and their relative contributions are examined.

ENGINEERING AND DESIGN CHANGES THAT IMPROVED FUEL ECONOMY

In 1973, 46 percent of all vehicles sold were large automobiles, according to the U.S. Environmental Protection Agency's (EPA's) vehicle classification system. Today, large automobiles compose only 13 percent of total sales. Difiglio and McNutt (6) calculated that the market shift to smaller cars improved new car fuel economy by 1.2 mpg from 1973 to 1975. From 1975 to 1979, although fuel prices were stable or slightly declining, there was essentially no increase in new automobile fuel economy (in fact, there was a decrease) from a shift in sales among size classes. In the 1980 model year, following the 25 percent real gasoline price increases in the summer of 1979 and during an equal increase in 1980, there was another gain of about 1.3 mpg because consumers chose to buy smaller automobiles. Overall, from 1973 to 1981 Difiglio and McNutt calculated a 1.6 mpg improvement because of size class sales shifts out of an overall 10.9 mpg improvement above the average in new automobile fleets.

Manufacturers have mostly improved automobile efficiency by decreasing the exterior vehicle dimensions of all size classes and using lighter materials to reduce vehicle weight. A statistical analysis of new automobile fuel economy from 1976 to 1981 (7) found that changes in vehicle curb weight explained almost all of the change in fuel economy. Statistically significant effects of changes in performance (measured by the horsepower-to-weight ratio) and transmission types were not found. It was also found that, as a control for these variables, imported automobiles were not significantly more efficient than those of domestic manufacture.

As part of its monitoring and analysis of automobile fuel economy pursuant to the Department of Energy Act of 1978 (P.L. 95-238), the U.S. Department of Transportation (DOT) conducted a detailed analysis of improvements to fuel economy of new automobiles from model year 1978 to 1981 (8). The greatest improvements in fuel economy over that time period were found to have resulted from a reduction in vehicle weight. The average inertial weight (equal to the curb weight plus 200 lb) for new passenger automobiles was reduced from 3,627 lb in model year 1978 to 3,155 lb in 1981, which is a loss of 472 lb, or 13 percent. Decreased vehicle weight within size classes, as opposed to sales shifts from large to small automobiles, accounted for almost 75 percent of the total weight loss.

Many other changes resulted in smaller improvements to fuel economy. DOT's analysis of the effects of these changes is summarized in Table 1 (8). Of the total improvement that could be attributed, 54 percent was due to weight reduction. Reduced vehicle performance, measured by the horsepower-to-weight ratio, was the next largest single factor. A 9 percent reduction in average horsepower per pound accounted for 18 percent of the attributable gain in fuel economy. All types of transmission modifications, including an increased market share for manual transmissions (16 to 30 percent), greater use of lock-up torque converters in automatic transmissions, (7.7 to 34.5 percent), and an increased number of gears in both manual and automatic transmissions constituted 13 percent of the attributable improvement. Improved aerodynamics followed at 9 percent and increased use of diesel engines contributed only 6 percent of the estimated 4.35-mpg gain. One mpg of improvement could not be attributed because of the inherent limitations of the analysis. Some of this improvement is surely due to sales mix shift effects unrelated to weight reduction. The rest of the improvement was due to factors not explicitly accounted for (e.g., radial tires and improved lubricants).

The same DOT report contains a similar but less detailed analysis of the gains in fuel efficiency of domestic light trucks from 1978 to 1981. The DOT analysis calculated the weight loss of average domestic light trucks from 1978 to 1981 at 440 lb, or about 10 percent (4,600 to 4,160 lb). At the same time engine sizes were also reduced from an average of 340 to 290 in^3. Installation of automatic transmissions declined slightly from 76 to 64 percent, but, more important, use of lock-up torque converters grew from nil to about half of all automatic transmission installations. Use of four-speed manual overdrive transmissions increased from negligible to 10 percent.

It is evident from the various analyses of the factors responsible for the improved fuel efficiency of automobiles and light trucks that very little of the improvement was actually due to technological advances. Downsizing, improved aerodynamics, an increase in the number of gears and the use of manual transmissions, and reductions in vehicle performance are primarily vehicle design changes. To the extent that these are more expensive than historical designs, or are perceived by consumers as less desirable, the improvements made thus far could be reversible. The extent to which a period of declining fuel prices could lead consumers to once again demand larger, heavier, more powerful, and less fuel-efficient vehicles is an interesting subject for research.

METHOD FOR DECOMPOSING FUEL ECONOMY TRENDS

New automobile fuel economy has improved little since 1981. Average vehicle weight, engine size, and combined EPA mpg are about the same in 1984 as they were in 1981 (see Table 2) (2).

TABLE 1 Summary of Engineering and Design Contributions to New Automobile Fuel Economy Improvement *(8)*

	1978	1981	Mpg Change
Average new automobile fuel economy (mpg)	19.9	25.2	+5.3
Inertial weight (lb)	3,627	3,155	+2.35
Diesel engine (%)	1.1	5.9	+0.25
Vehicle performance (horsepower to inertial weight)	0.339	0.310	+0.80
Aerodynamic drag (dynamometer power absorption, hp)	10.4	9.4	+0.37
Total transmission changes	–	–	+0.58
Increased manual (%)	16.0	29.6	+0.14
Lock-up torque converter (%)	7.7	34.5	+0.27
Four-speed automatic (%)	0.4	8.7	+0.08
Five-speed manual (%)	5.1	14.4	+0.09
Total change attributable (mpg)			4.35

TABLE 2 Light Vehicle Weight, Engine Size, and Fuel Economy *(2)*

	Automobiles				
Year	Weight (lb)	Interior Volume (ft^3)	Engine Size ($in.^3$)	Fuel Economy (mpg)	Light-Truck Fuel Economy (mpg)
1979	3,003	107	232	20.5	17.2
1980	2,799	105	198	23.1	17.9
1981	2,742	106	182	25.2	19.8
1982	2,727	106	176	26.4	20.4
1983	2,787	107	182	26.1	20.6
1984[a]	2,791	108	182	26.3	19.3

[a]Based on sales for the first 6 months of the model year (October to March).

The factors accounting for this recent trend can be determined by analyzing detailed data on vehicle sales and fuel efficiencies. A data system for tracking new automobile and light truck sales and fuel economy trends has been developed at Oak Ridge National Laboratory [refer to the "Decomposition Formulas" section of this paper; the report by Hu et al. (2); and the report by Patterson et al. (4)]. The system uses nameplate (e.g., Ford Tempo) sales data published by Wards' Automotive Reports (9) together with EPA fuel economy estimates, which are grouped by engine and transmission combination. The unadjusted, combined city-highway estimate is used. The nameplate sales data are distributed among engine-transmission categories using the percentage distribution of vehicle production by engine type and transmission type. The details of data manipulation are described by Hu and Roberts (1). This data system has been maintained on a monthly basis, with data going back to model year 1978. For the sake of consistency, model years are defined as the 12 calendar months from October to September. This detailed data system provides a rich resource for analyzing how manufacturer and consumer actions have contributed to fuel economy changes over a period of time.

The total change in fuel economy from one model year to the next can be thought of as comprising (a) shifts in sales from one type of vehicle to another, (b) introductions or discontinuations of vehicle types, and (c) improvements in the fuel economy of continued vehicle types. For example, an increase in sales of larger, less efficient automobiles, or of configurations with less efficient, larger engines and automatic transmissions, will tend to depress new automobile fuel economy. At the same time, however, manufacturers may introduce new, more efficient models and discontinue older, less efficient ones or they may employ engineering and design changes, such as lock-up automatic transmissions or the use of lighter materials, which all tend to improve fuel economy. With appropriate data on vehicle sales and fuel economies, each component can be identified and measured.

The first step is to define vehicle types. Three hierarchical levels of vehicle types, in descending order, will be used:

1. Size class, as defined by EPA interior volume;
2. Nameplate (e.g., Chevette, Escort, and Reliant); and
3. Configuration, which is the engine-transmission combination of a nameplate.

The smallest unit in the analysis is therefore a configuration of a nameplate, for instance, a four-cylinder diesel Rabbit with a four-speed manual transmission. Because this approximates the level at which the EPA certifies vehicle fuel economies, it is a logical choice for the basic unit.

Sales shifts effects are always computed by holding fuel efficiency constant at last year's level (for each configuration) and contrasting that year's sales distribution with that of the year before. All changes in efficiency within a continued configuration are thus attributed to an improvement in efficiency. The decomposition of efficiency changes is summarized in Figure 2. The mathematical formulas that correspond to the elements in Figure 2 are provided in the following section.

DECOMPOSITION FORMULAS

The formulas used to calculate each of the eight fuel economy change components (see Figure 2) are presented in the following paragraphs. A complete derivation can be found elsewhere (2).

The analysis of fuel economy changes is carried out in terms of gallons per mile rather than miles per gallon to simplify the arithmetic. The mean of different gallons per mile is the arithmetic mean, whereas the mean of miles per gallon is the harmonic mean.

Because neither all nameplates nor all configurations will be the same from one year to the next, the following three sets of vehicles are defined for the analysis.

V: the set of all (nameplate) configurations existing in either year t or t-1 (this is the universe of configurations);

C: the subset of V containing all configurations of nameplates that continue from year t-1 to year t;

C': the subset of C containing all configurations that continue from one year to the next.

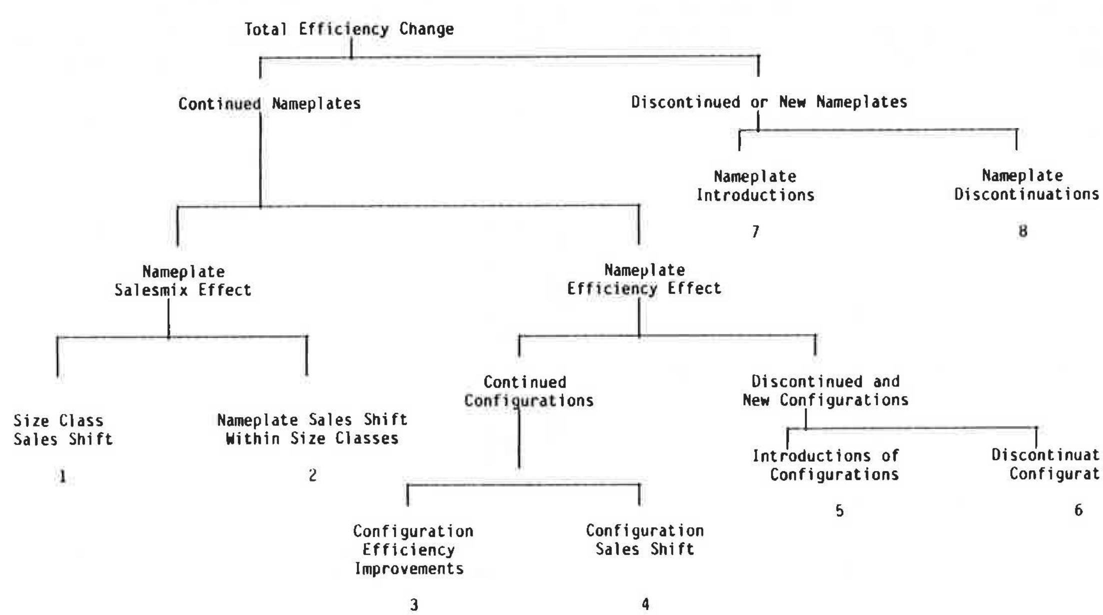

FIGURE 2 Decomposition of efficiency changes.

Total fuel economy change must be calculated on the set V, including all vehicle configurations. It makes sense to compute nameplate and configuration sales shifts only over the sets C (continued nameplates) and C' (continued configurations), respectively. Size class sales shifts could be computed over V or C. It was decided to compute the effect of size class shifts over C only. As a result, size class shifts associated with the introduction or discontinuation of nameplates will be attributed to nameplate changes in order to make a clearer distinction between the effects of consumer choice and those caused by changes in the range of options offered to consumers.

The following definitions are required:

E = vehicle efficiency (gal per mile),
ΔE = change in efficiency from year t-1 to t,
S_{Kt} = nameplate K's share of total sales in year t,
f_{iKt} = configuration i's share of nameplate K's sales in year t,
i = configuration,
K = nameplate (note that $\sum_i f_{iKt} = 1$ and $\sum_K S_{Kt} = 1$),
ℓ = size class, and
t = year.

Also,

$$S_{\ell t} = \sum_{K\in\ell} S_{Kt}$$

$$\bar{E}_{\ell t-1} = \sum_{K\in\ell}\left(S_{Kt-1}/\sum_{K\in\ell} S_{Kt-1}\right)\bar{E}_{Kt-1}$$

and

$$\bar{E}_{\substack{t-1\\ \text{in C}}} = \sum_{\substack{K\\ \text{in C}}}\left(S_{Kt-1}/\sum_{\substack{K\\ \text{in C}}} S_{Kt-1}\right)\bar{E}_{Kt-1}$$

$S_{\ell t}$ is the sales share of size class ℓ in year t (for continued nameplates only if summed over the set C). $\bar{E}_{\ell t}$ is the average efficiency of size class ℓ (in gallons per mile) and $\bar{E}_{\substack{t-1\\ \text{in C}}}$ is the average efficiency in year t-1 of all continued nameplates.

The eight components of efficiency change are summarized as follows (also see Figure 2). Summing all components will return the total change in efficiency, ΔE.

1. Size class sales shift:

$$\Delta EB_C = \left[\sum_{\substack{\ell\\ \text{in C}}} S_{\ell t}\bar{E}_{\ell t-1} + \left(\sum_{\substack{K\\ \text{not C}}} S_{Kt}\right)\bar{E}_{\substack{t-1\\ \text{in C}}}\right] - \left[\sum_{\substack{\ell\\ \text{in C}}} S_{\ell t-1}\bar{E}_{\ell t-1} + \left(\sum_{\substack{K\\ \text{not C}}} S_{Kt-1}\right)\bar{E}_{\substack{t-1\\ \text{in C}}}\right]$$

2. Nameplate sales shift within size classes:

$$\Delta EW_C = \sum_{\ell}\left(\sum_{K\in\ell} S_{Kt}\right)\sum_{K\in\ell}\left(S_{Kt}/\sum_{K\in\ell} S_{Kt}\right)\bar{E}_{Kt-1} - \sum_{\ell}\left(\sum_{K\in\ell} S_{Kt}\right)\sum_{K\in\ell}\left(S_{Kt-1}/\sum_{K\in\ell} S_{Kt-1}\right)\bar{E}_{Kt-1}$$

3. Configuration efficiency improvements:

$$\Delta EE_{C'} = \sum_{iK}\sum S_{Kt}f_{iKt}E_{iKt} - \sum_{iK}\sum S_{Kt}f_{iKt}E_{iKt-1}$$

4. Configuration sales shift:

$$\Delta ES_{C'} = \left(\sum_{iK}\sum S_{Kt}f_{iKt}E_{iKt-1} + \sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt}\bar{E}_{Kt-1}\right) - \left(\sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt-1}\bar{E}_{Kt-1} + \sum_{iK}\sum S_{Kt}f_{iKt-1}E_{iKt-1}\right)$$

5. Introductions of configurations:

$$\Delta ECI_{\text{C not C}'} = \sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt}E_{iKt} - \sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt}\bar{E}_{Kt-1}$$

6. Discontinuations of configurations:

$$\Delta ECD_{\text{C not C}'} = \sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt-1}\bar{E}_{Kt-1} - \sum_{\substack{iK\\ \text{C not C}'}}\sum S_{Kt}f_{iKt-1}E_{iKt-1}$$

7. Nameplate introductions:

$$\Delta ENI_{\text{not C}} = \sum_{\substack{K\\ \text{not C}}} S_{Kt}\bar{E}_{Kt} - \left(\sum_{\substack{K\\ \text{not C}}} S_{Kt}\right)\bar{E}_{\substack{t-1\\ \text{in C}}}$$

8. Nameplate discontinuations:

$$\Delta END_{\text{not C}} = \left(\sum_{\substack{K\\ \text{not C}}} S_{Kt-1}\right)\bar{E}_{\substack{t-1\\ \text{in C}}} - \sum_{\text{not C}} S_{Kt-1}\bar{E}_{Kt-1}$$

These components are expressed in units of gallons per mile. They can be converted back to units of mpg by multiplying each by the term $-(MPG_t MPG_{t-1})$.

COMPONENTS OF THE NEW AUTOMOBILE FUEL ECONOMY CHANGE FROM 1978 TO 1984

Improvements in automobile fuel efficiency since 1978 have been achieved by a combination of consumer sales shifts in response to higher fuel prices and changes in the products offered by manufacturers. Between 1978 and 1984, new automobile efficiency increased from 19.7 to 26.4 mpg in 1982 and remained nearly constant through 1984. During the same time period, the price of unleaded gasoline rose from $1.02 to $1.51 per gallon (1983 dollars) but has since declined to $1.21 per gallon (see Figure 3). By means of a simple model, a crude estimate of the relative impacts of fuel price (in the short run) and other factors can be calculated from these data.

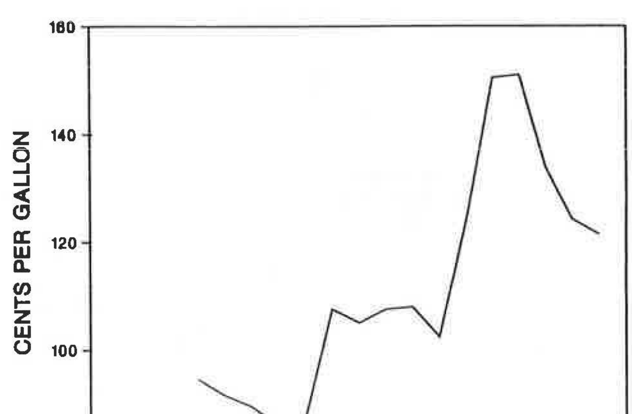

FIGURE 3 Gasoline prices, 1969-1984, in constant 1983 dollars.

TABLE 3 Fuel Economy and Gasoline Price Changes, 1978 to 1984

Year	Fuel Economy Mpg[a]	Δ Mpg	Gasoline Price[b] (1983 cents)	Δ Price[c]
1978	19.7		102.3	
1979	20.5	0.8	123.9	21.6
1980	23.2	2.7	150.5	26.6
1981	25.3	2.1	151.0	0.5
1982	26.4	1.1	133.8	-17.2
1983	26.1	-0.2	124.1	-9.7
1984	26.3	0.2	121.3	-2.8

[a]Report by Hu et al (2).
[b]U.S. Department of Energy (11).
[c]U.S. Department of Commerce (12, 13).

Let mpg in year t be expressed by a linear function of gasoline price and a linear time trend:

$$(\mathrm{MPG})_t = a + b(\mathrm{PRICE})_t + c(\mathrm{TREND})_t \quad (1)$$

The time trend is intended to capture efficiency improvements caused by factors other than immediate consumer response to gasoline price changes. This would include engineering and design improvements by manufacturers as a long-term response to current or anticipated higher fuel prices as well as technical advances. The differences of Equation 1 create a simple formula that can be computed on a programmable hand calculator using the data in Table 3.

$$\Delta(\mathrm{MPG})_t = b\,\Delta(\mathrm{PRICE})_t + c$$

The results of this formulation by using a programmable hand calculator are

$$\Delta(\mathrm{MPG})_t = 0.0340\,\Delta(\mathrm{PRICE})_{t-1} + 1.009 \qquad n = 6, \; r^2 = 0.28 \quad (2)$$

The low r^2 is not surprising for a differenced equation.

This result implies that between 1978 and 1984, a 6.0-mpg improvement could have been expected without any short-term consumer response to price increases. This is about 90 percent of the actual 6.6-mpg improvement. A short-term (mid-point) price elasticity [e(p)] can be computed from Equation 2:

$$e(p) = 0.0340\,(126.65/23.05) = 0.19$$

This result suggests that consumers would respond to a 10-percent price increase by shifting their purchases to more efficient cars in the following year, resulting in about a 2-percent improvement in efficiency. These rather crude calculations indicate that most of the improvement in fuel economy from 1978 to 1984 was due to long-term decisions by manufacturers, motivated by fuel economy standards or expectations of higher fuel prices, to offer more efficient vehicles to the public.

The manner in which changes in fuel economy have actually been made can be better understood by using the decomposition method to analyze annual sales and fuel economy data. For each year from 1979 to 1984, the change in mpg was broken down by using the data and method described earlier. The calculations that resulted are presented in Table 4. These calculations indicate that the single largest contributor to fuel efficiency over the 1979 to 1984 time period was an improvement in the efficiency of continued configurations. This component alone accounted for almost one-third of the total gain in fuel economy. New introductions of configurations and nameplates together accounted for another 29 percent of the total gain in fuel efficiency. Discontinuations of less efficient models were responsible for about 12 percent of the total gain.

Sales shifts of all types improved fuel efficiency a total of 1.8 mpg, or 27 percent. This is broadly consistent with the 10-percent improvement predicted by the simple model presented earlier. Sales shifts among nameplates within a size class composed the single largest component, accounting for half of the sales shifts improvements. The method of calculation, however, may overstate the importance of this factor. Because the model year was arbitrarily defined as being from October to September, new nameplates introduced in August or September, for example, would be counted as having been introduced in the previous model year and continued in the current year. Most of the contribution to fuel efficiency would, therefore, be attributed to nameplate sales shifts from the previous to the current model year. The importance of this effect has yet to be quantified.

Size class shifts have proven to be a relatively minor factor. Consumers' primary strategy for buying a more efficient automobile is not to buy a smaller one, at least not in terms of interior space, but to shop around for a more efficient nameplate or configuration. The combined contributions of nameplate and configuration sales shifts within size classes are nearly 2.5 times the size of sales shifts among size classes. This fact has some interesting implications. First, it underscores the importance of providing accurate fuel economy information to new automobile buyers to enable them to distinguish more efficient from less efficient models in the same size class. Second, it aids in understanding why consumers did not strongly resist downsizing, as had been predicted before the fuel economy standard had fully gone into effect (10). Consumers appear to be reluctant to accept downsizing in terms of interior volume, but are willing to accept downsizing in terms

TABLE 4 Components of New Automobile Fuel Economy Change, 1978 to 1984

	Fuel Economy		Size Class Sales Shift		Configurations				Nameplate	
	Mpg	Mpg Change	Between (17.7%)	Within (14.0%)	Improvement (33.3%)	Sales Shift (6.0%)	Introduction (10.7%)	Discontinuation (3.6%)	Introduction (18.1%)	Discontinuation (6.3%)
1978	19.72									
1979	20.52	0.80	0.29	0.17	-0.13	0.14	-0.03	-0.01	0.30	0.07
1980	23.24	2.72	0.43	0.59	0.89	0.25	0.30	0.03	0.12	0.11
1981	25.30	2.06	-0.18	0.37	1.05	0.04	0.08	0.01	0.61	0.08
1982	26.36	1.06	0.15	-0.20	0.62	-0.04	0.38	0.02	0.07	0.06
1983	26.12	-0.24	-0.06	-0.12	-0.08	-0.12	0.00	0.08	0.12	-0.05
1984[a]	26.34	0.23	-0.12	0.12	-0.14	0.13	-0.02	0.11	-0.02	0.15
1978-1984		6.63	0.51	0.93	2.21	0.40	0.71	0.24	1.20	0.42

Note: Total sales shifts = 1.84 mpg; total manufacturer changes = 4.78 mpg.
[a]Based on a comparison between the first 6 months of model year 1984 and the first 6 months of model year 1983.

TABLE 5 Sales Shift and Manufacturer Improvement Components of New Automobile Fuel Economy Changes, 1978 to 1984

	Sales Shifts (Δ mpg)	Manufacturer Improvements (Δ mpg)	Gasoline Price Change (1983 cents/gal)
1978-1979	0.60	0.20	21.6
1979-1980	1.27	1.45	26.6
1980-1981	0.23	1.83	0.5
1981-1982	-0.09	1.15	-17.2
1982-1983	-0.30	0.06	-9.7
1983-1984[a]	0.13	0.10	-2.8

[a]Based on first 6 months of each year.

of vehicle weight or exterior dimensions. This explains why consumers have been able to make the transition from the large American cars of the early 1970s to the more European-sized fleet of today.

A more precise calculation of the sensitivity of fuel efficiencyto fuel prices in the short term can be made by using the results of the decomposition of fuel economy changes. Table 5 summarizes the year-to-year changes in fuel economy from 1978 to 1984 in terms of sales shifts versus manufacturer improvements. The same simple model estimated earlier by using total changes can be used to estimate the effect of price changes through sales shifts only. The results of estimation on a programmable hand calculator are

$$\Delta MPG_t (\text{sales shift}) = 0.212 + 0.030\ \Delta PRICE_t \qquad n = 6 \quad r^2 = 0.85$$

The mid-point elasticity implied by these results is small:

$$\epsilon_p = (126.65/23.05)\ 0.030 = 0.16$$

This elasticity estimate indicates that a 10-percent price increase would cause a 1.6 percent improvement in fuel efficiency through consumer sales shifts in the same year. It is interesting that the trend of a 0.21-mpg per year improvement is still not accounted for by price changes; this could be evidence of a long-term sales shift price response.

The summarized results shown in Table 5 suggest that manufacturers have also responded to short-term price changes, but with a time lag. Since 1982, it appears that manufacturers have also relaxed their efforts to improve fuel economy by introducing new, more efficient models and retiring older, less efficient models. Over the past 2 years, the contribution to fuel economy from these actions has been virtually nonexistent. This undoubtedly reflects a response to a change in consumer demand for fuel economy. Yet it is clear that over the last 3 years manufacturers did not initiate improvements in fuel economy but simply followed market trends.

SUMMARY

New automobile fuel economy has improved from 19.7 mpg in 1978 to 26.3 mpg for the first 6 months of model year 1984. Detailed sales data have been used to break annual changes down into eight separate components associated with sales shifts or manufacturer decisions to improve or discontinue models, or introduce new, more efficient models. Overall, manufacturer engineering changes have dominated sales shifts, accounting for 70 percent of the total improvement in fuel efficiency. Sales shift improvements in fuel economy have been shown to be insensitive to gasoline price changes in the short term although the presence of a long-term effect is indicated.

New automobile fuel economy has not improved since 1982. Sales shifts have tended to decrease mpg slightly, whereas manufacturers' design changes have only improved enough to offset the small effects of sales shifts. In the absence of fuel price increases, the full burden of meeting the 1985 standard of 27.5 mpg will fall on the manufacturers.

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