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THE U.S. DEMAND FOR HIGHWAY TRAVEL
AND MOTOR FUEL

by

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1. Introduction

Virtually all analysts project that world dependence on OPEC will increase dramatically in the 1990's. One-third of world oil consumption is that of the US, of which two-thirds is for transportation. US *gasoline* consumption exceeds the *oil* consumption of every other country in the OECD; no other OECD country's total highway fuel consumption is as great as that of US large trucks alone. Hence it is important to examine the prospects for US highway travel and fuel demand, based on an analysis of the past two decades¹. Here we provide such projections and present some interesting conclusions, which include the following.

The rapid growth in fuel demand for passenger travel before 1978 was at least partly the result of rapid growth in the number of drivers, which was attributable to a combination of the baby-boomers reaching driving age and a substantial increase in the ratio of drivers to driving-age population. Such rapid growth will not continue into the 1990's, however, which will relieve some pressure on fuel demand growth.

There has been an increasing role played by trucks, which now account for 43% of highway fuel consumed. This has resulted from rapid growth in the number of small trucks, an increase in miles/vehicle for large trucks, and growth rates for large trucks' vehicle-miles and fuel consumption that are one-fourth higher than GNP growth.

Despite projections by the US Department of Energy (DOE/EIA) of a 6% decline in highway fuel use by the year 2000, we project a 13% increase. They assume extraordinarily rapid improvement in fuel efficiency and relatively slow growth in large trucks' vehicle miles. We project slower gains in fuel efficiency and faster growth for large trucks' vehicle miles, both of which are consistent with historical experience.

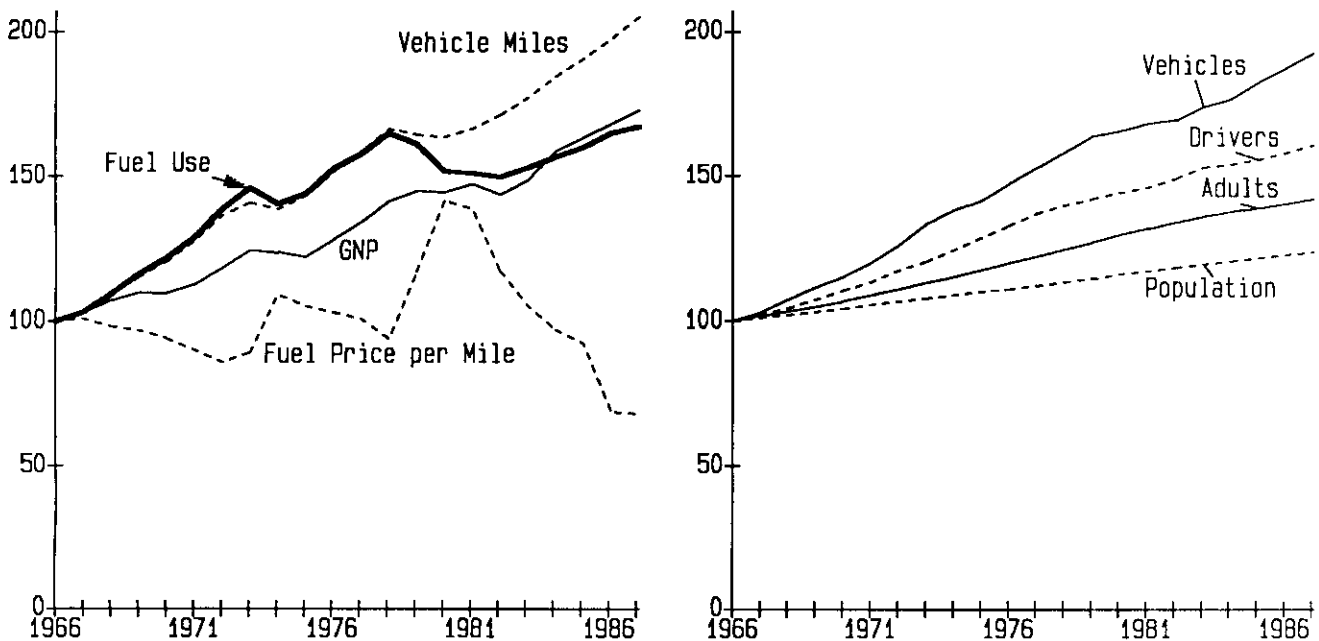
¹ In earlier papers we examined the prospects for jet fuel demand (Gately, 1988) and for oil demand in the aggregate (Gately and Rappoport, 1988).

2. Background

The aggregate data for 1966–87 are presented in Figure 1, as indices with 1966=100. Vehicle miles and fuel use increased together until 1978, at a faster rate than GNP. Between 1978 and 1982 fuel use declined, primarily because of fuel efficiency improvements. Since then it has increased, although at a slower rate than vehicle miles or GNP, to a 1987 level just above its previous 1978 peak. The fuel price per mile increased in 1973–74 and 1979–80 when oil prices increased, but it is now at its lowest level in the past two decades, because of price declines and improved fuel efficiency.

The right half of this figure describes the growth in some important demographic variables. The number of adults grew faster than the total population, especially in the 1970's as the baby-boomers reached adulthood. Growing faster than the number of adults was the number of drivers: the ratio of drivers to adults increased from 80% in 1966 to 89% by 1977. Growing most rapidly of all was the number of vehicles (cars, trucks, motorcycles, buses): in 1966 there were 93 vehicles for each 100 drivers, and by 1987 there were 112 vehicles per 100 drivers.

Figure 1
Indices of Vehicle Miles, Fuel Use and Other Variables for the U.S. (1966 = 100)

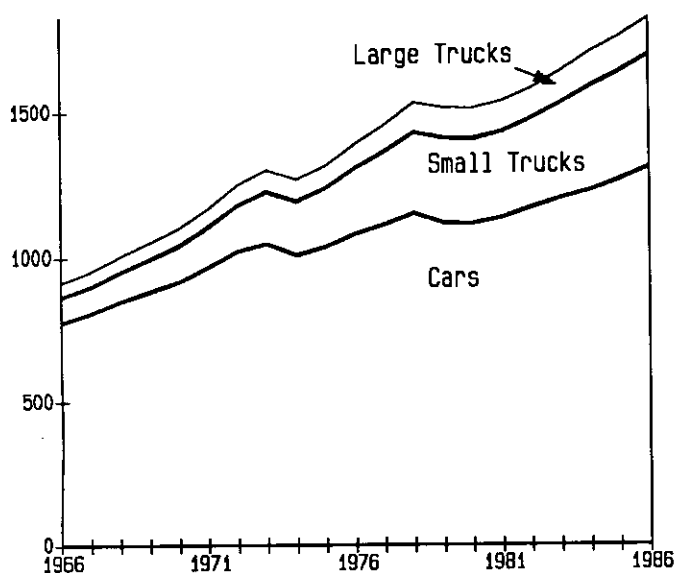


2.1 Disaggregating by Vehicle Type

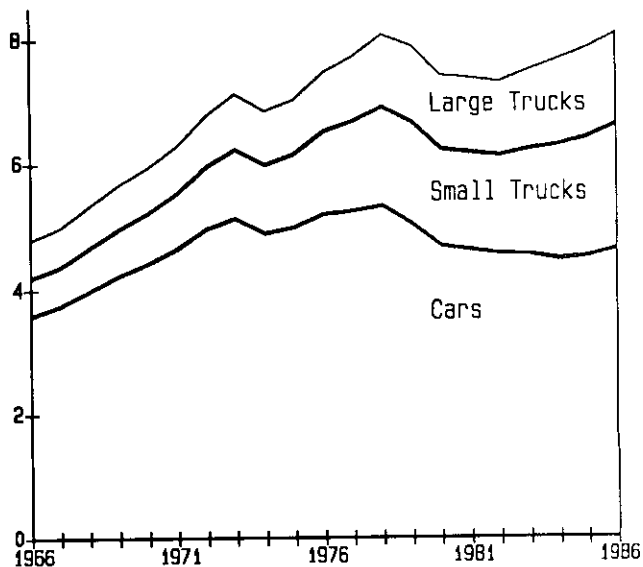
Although not often done when analyzing highway travel or motor fuel demand, it is important to disaggregate by vehicle type: cars, small trucks (pickups & vans), and large trucks². The reason for disaggregating is suggested in Figure 2, which shows their respective levels of vehicle miles and fuel consumption. Clearly, trucks have become increasingly important over the past two decades; their share has increased from 16% to 29% for total vehicle-miles and from 26% to 43% for total fuel used.

Figure 2

Vehicle Miles, by Vehicle Type: 1966-86
(billions)



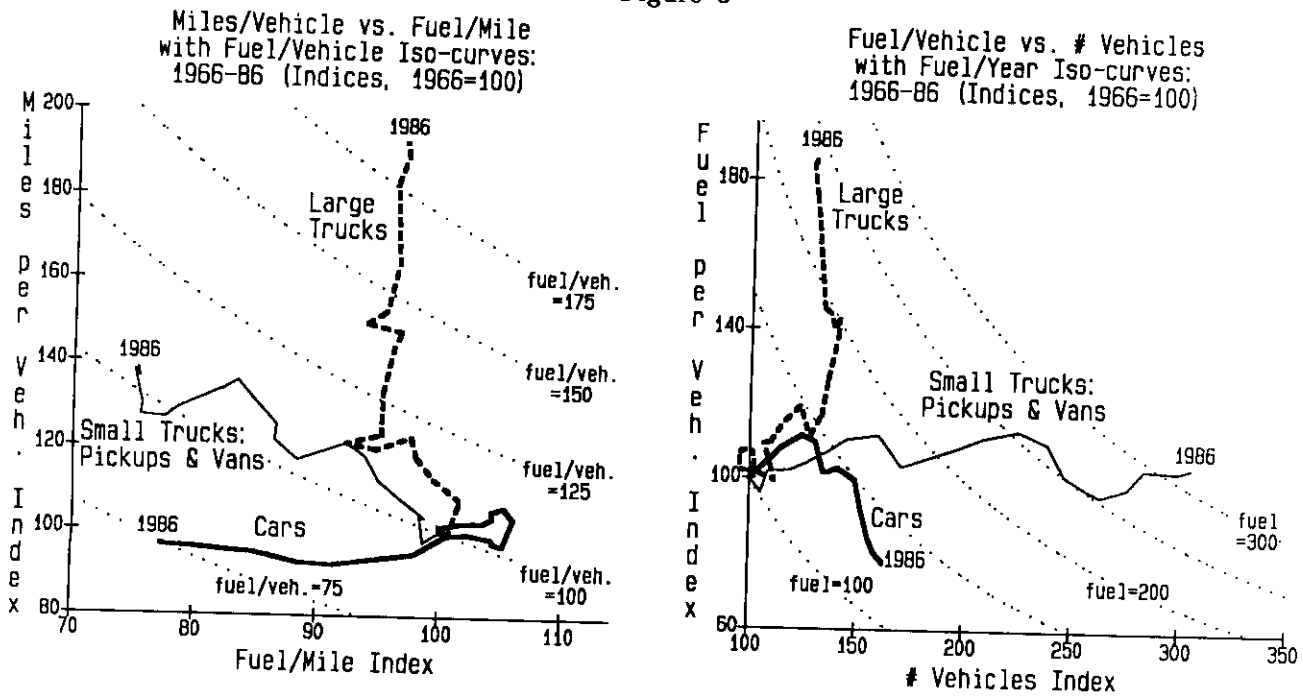
Fuel Consumption, by Vehicle Type: 1966-86
(million barrels/day)



² The data are taken from the Federal Highway Administration's *Highway Statistics*. Their disaggregation includes the following: cars; small trucks (2 axle, 4 wheel); other single-unit trucks; and trailer combination trucks. We combine the last two categories as "large trucks" and we consider cars and small trucks together in much of the analysis below. Other data sources are described at the end of the paper.

The increasing importance of trucks is the result of two main developments: (1) the increased utilization (miles/vehicle) of large trucks; and (2) the extraordinarily rapid growth in the number of small trucks. This can be seen when the data are disaggregated by vehicle type in Figure 3, which shows the different patterns over time of vehicle usage, fuel efficiency and numbers of vehicles. Using indices based on their respective 1966 values, the left graph shows the time-path of vehicle usage (miles/vehicle) vs. fuel per mile, with fuel-per-vehicle iso-curves. For each type of vehicle, the time-paths start in 1966 at 100 for the (horizontal) fuel/mile index, the (vertical) miles/vehicle index, and for the fuel/vehicle isoquant; the time-paths end in 1986. The right graph shows the 1966-86 time-paths, for each type of vehicle, of the (vertical) fuel/vehicle index vs. the (horizontal) number of vehicles index, with total-fuel-use-index iso-curves.

Figure 3



Cars have experienced reductions in fuel per mile (especially since 1976) which, when combined with slightly lower vehicle usage, yields a 25% reduction in fuel per vehicle below 1966. But this was offset by the increased number of cars, so that total fuel use increased through 1978, although it has declined since then.

For small trucks, the fuel-per-mile reductions have been comparable to those for cars, but they have just about been offset by increased miles per vehicle, so that fuel per vehicle has remained roughly constant. However, a threefold increase in the number of such vehicles since 1966 has resulted in a threefold increase in their total fuel consumption.

Large trucks, on the other hand, with little improvement in fuel efficiency but dramatic increases in miles per vehicle, have experienced nearly a doubling of fuel per vehicle since 1966. Combining this with a 50% increase in the number of such trucks, their total fuel usage is nearly two and a half times higher than in 1966.

In the analysis below, however, we examine only two clusters of vehicle types: (1) cars and small trucks, and (2) large trucks. We combine small trucks with cars because they are substitutes in many ways, and they have experienced similar fuel-efficiency improvements and similar usage patterns over time. Although some are used primarily for freight transport rather than personal transportation, nearly 60% of small trucks have personal transportation as their major use³.

³ See Motor Vehicle Manufacturers Association (MVMA), *Facts and Figures '88* (Detroit, 1988, page 47), which cites the *1982 Census of Transportation, Truck Inventory and Use Survey*, by the U.S. Department of Commerce, Bureau of the Census.

2.2 Passenger Travel: the Importance of Growth in Numbers of Drivers

As was already noted, in the decade prior to 1977 there was rapid growth in the number of drivers (2.9% annually). The baby-boomers reached driving age and the percentage of drivers in the driving-age population grew from 80% to 90%. But this growth has slowed in the past decade (to 1.6% annually) and will slow further in the 1990's. All the baby-boomers have now reached driving age, and the percentage of drivers in the driving-age population is close to its likely upper limit.

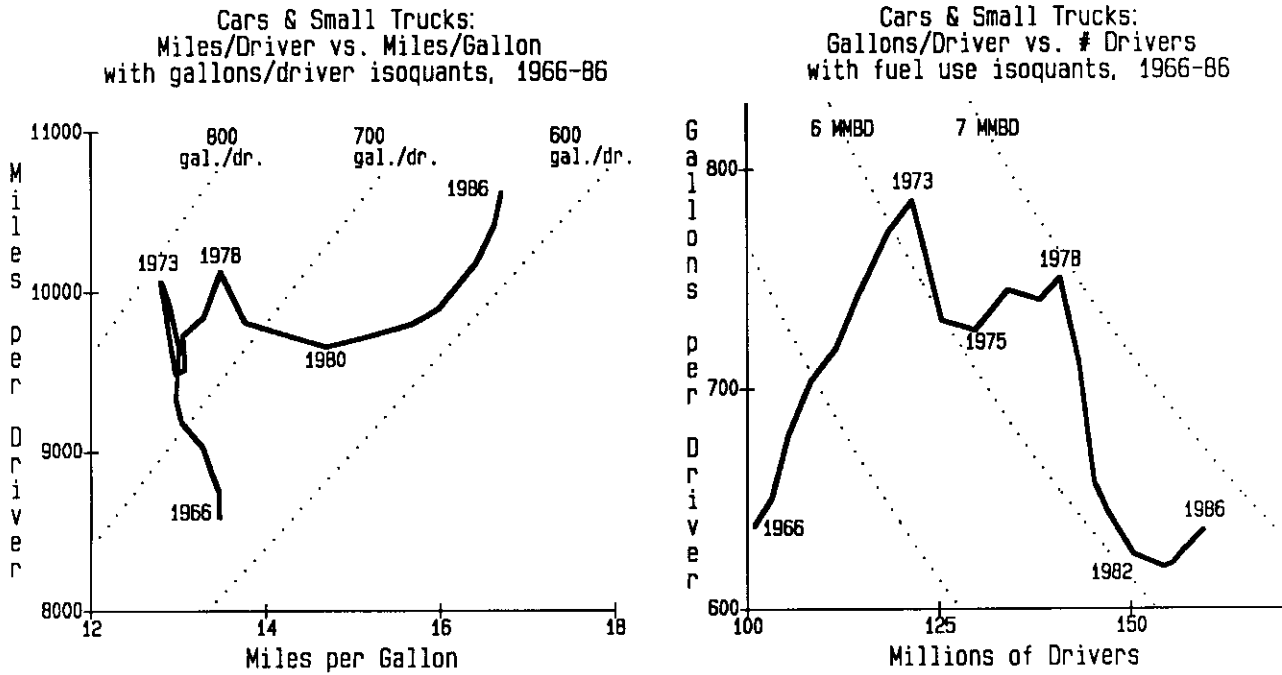
This is important for analyzing and projecting highway travel and fuel use, especially passenger travel in cars and small trucks. If the influence of drivers is ignored, and projections are based only upon fuel price and GNP, then projections of both travel and fuel use will be excessive. However, the importance of this factor has not been considered previously in the literature⁴.

To illustrate the importance of the number of drivers, Figure 4 presents 1966-86 data on a per-driver basis, for travel in cars and small trucks. The left graph shows miles per driver and miles per gallon, together with fuel per driver, measured by the isoquants. It shows the gradual increase in miles per driver, except for the periods 1973-75 and 1978-80. With miles per gallon being fairly constant from 1966 through 1976, fuel per driver increased regularly, reaching a peak in 1973 at nearly 800 gallons/year. But between 1976 and 1982 there was a significant drop in fuel per driver, to about 625 gallons/year, caused by a sharp increase in miles per gallon. Since 1982, however, increasing miles per driver have offset decelerating gains in miles per gallon, so that fuel per driver has increased by about 10%.

⁴ See, for example, the surveys by Dahl(1986) and Bohi(1981) or the demand studies by Baltagi and Griffin (1984), Dahl(1979), Drollas(1984), Dunkerley and Hoch(1987), Gallini(1983), Mannering and Winston(1985), and Wheaton(1982).

Yet despite substantial reductions in fuel per driver since 1973, especially during 1978-82, this has been offset by rapid increases in the number of drivers. This is shown in the right half of Figure 4, which shows fuel-per-driver vs. the number of drivers, with the isoquants showing total fuel use (in cars and small trucks). Due to the rapidly increasing number of drivers (nearly 50% during 1966-82), total fuel use has increased continually, except for 1973-74 and 1978-82.

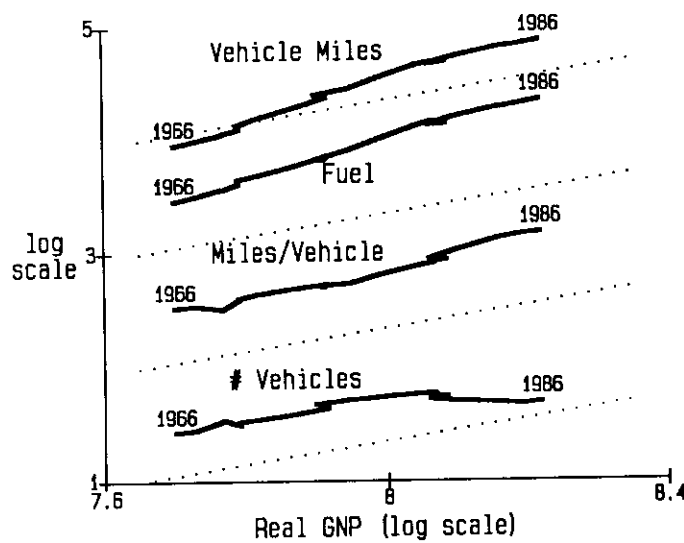
Figure 4



2.3 Large Trucks: the Importance of GNP Growth

In the last two decades, large trucks' vehicle miles and fuel use have more than doubled; both increased at a faster rate than GNP⁵. Figure 5 illustrates this, using logarithmic scales to compare GNP with the large trucks' vehicle miles, fuel use, miles-per-vehicle, and number of vehicles. Each of the background dotted lines is a curve of unit income-elasticity⁶. Vehicle miles show an income elasticity bigger than 1.0 (a steeper slope than the dotted lines); this resulted from growth in both the number of vehicles and, especially in the last decade, in miles per vehicle.

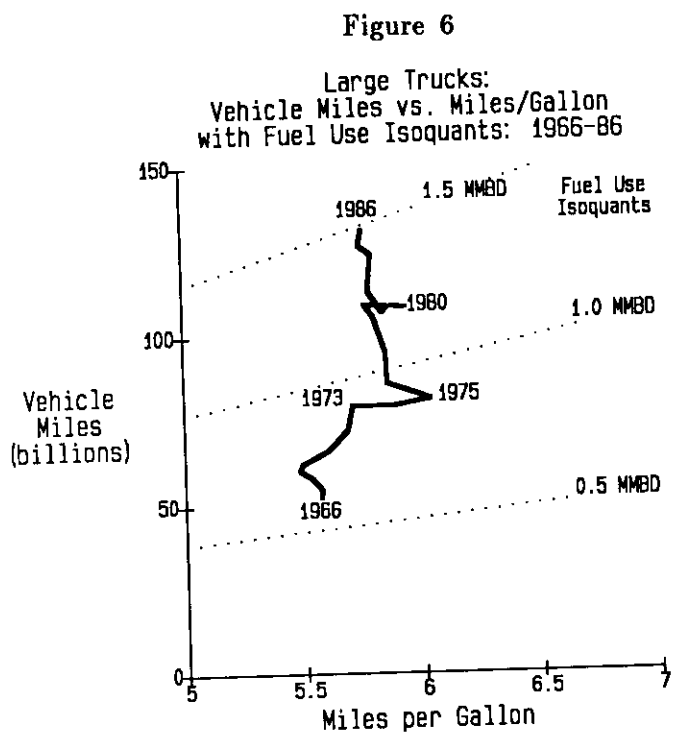
Figure 5
Large Trucks and Real GNP, 1966-86
with unit income-elasticity (dotted) lines;
logarithmic scales



⁵ Trucks' share of intercity freight movement has increased in the last two decades from 22% to 25% of total ton-miles, while railways' share has declined. The average annual growth rates in ton-miles have been 2.85% for trucks and 2.25% for the total, versus 2.78% for GNP. In comparison, large trucks' vehicle miles have increased at 4.29%, which suggests a shift toward smaller trucks. (Source: MVMA, *Motor Vehicle Facts & Figures '88*, page 57, which cites *Transportation in America*, by Transportation Policy Associates.)

⁶ With GNP on the horizontal axis and non-logarithmic scales, any ray from the origin would exhibit unit income-elasticity. When the scales are transformed logarithmically, this family of rays from the origin become the family of parallel dotted lines in Figure 5.

However, the increase in large trucks' vehicle miles has not been offset by any substantial improvement in miles per gallon, so that total fuel use has increased almost proportionately. Figure 6 shows this: large trucks' vehicle miles have more than doubled, to 130 billion; with little change in miles per gallon, their total fuel use has risen from 0.6 to 1.5 million barrels/day.



3. Econometric Results

3.1 Vehicle Miles: Cars and Small Trucks

In this section we estimate the relation expressing the growth of vehicle miles travelled, by cars and small trucks combined, as a function of GNP, fuel price, and the number of drivers. Table 1 shows the results of two log-linear regressions. Each regression includes the following explanatory variables: real GNP, the real fuel price per mile, and a dummy variable to reflect the gasoline shortages of 1974 and 1979. In addition, we use a constant term and an autoregressive term to correct for autocorrelation. The first equation also includes the number of drivers.

Table 1
Equation for Vehicle Miles: Cars & Small Trucks
 (t-statistics in parentheses)

equation number	Coefficients						Adjust. R ²	Durbin-Watson Stat.	Standard Error of Regr.
	Constant	Fuel Price /mile	Real GNP	Drivers	Dummy '74, '79	Autoregr. Correction			
#1-1	0.68 (0.8)	-.101 (-4.2)	.379 (3.8)	.75 (4.0)	-.015 (-2.5)	0.77 (5.5)	.9968	1.34	.0102
#1-2	0.62 (0.4)	-.080 (-2.2)	.85 (4.7)		-.021 (-2.2)	0.85 (11.)	.9921	1.60	.0162

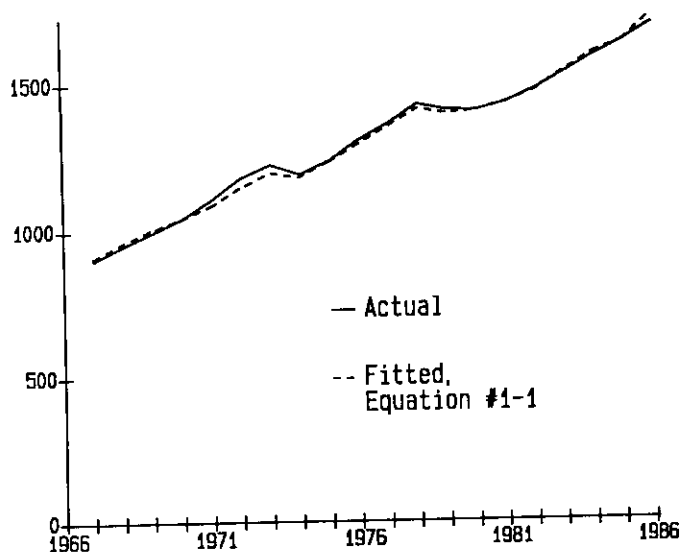
Sample Period: 1966-86
 All variables in logarithms

In both equations all coefficients have the expected signs and are significant, except for the constant term. When the number of drivers are not included as an explanatory variable (equation #1-2), the elasticity of vehicle miles with respect to GNP is relatively high, at 0.85. In contrast, when the number of drivers is also included (equation #1-1), we get a much lower income elasticity (0.379), and an elasticity with

respect to drivers of 0.75⁷. This equation also has a lower standard error and a higher adjusted R²; Figure 7 shows the very close correspondence of the actual and fitted values.

The omission of an important explanatory variable is a misspecification problem that is well documented in the literature⁸. As was noted above, because the number of drivers will not grow as rapidly in the 1990's, their omission will produce an upward bias in projections of vehicle miles that are based only on price and income. This will be discussed below.

Figure 7
 Vehicle Miles, Cars & Small Trucks: 1967-86
 Actual vs. Fitted Values (billions)



⁷ Comparisons with the range of results cited in the survey by Dahl(1986) are somewhat complicated. Our elasticity of vehicle miles with respect to price/mile (-.10) is at the low end of her range of estimates, but this range is apparently for price, not price per mile. With respect to income elasticity, she cites a range from .54 to .66; this is well above our estimate of .379 in equation #1-1, in which the number of drivers is included.

⁸ For conditions under which an omitted variable will produce bias, and the consequences, see Goldfeld(1972) and Lee(1982). There are several examples of the effects of demographic variables upon demand for agricultural products: see Andoh and Gately(1988) and its references.

3.2 Vehicle Miles: Large Trucks

In this section we examine the growth of vehicle miles travelled by large trucks. We use the same log-linear specification and explanatory variables as for cars and small trucks, except that here we do not consider the effect of the number of drivers. The regression results are presented in Table 2. In equation #2-1 all coefficients have the expected sign; all are significant except fuel price per mile. Introducing the dummy variable for 1974 and 1979 (equation #2-2) does not improve the results: it lowers the adjusted R^2 , increases the standard error, and the coefficient is not significant.

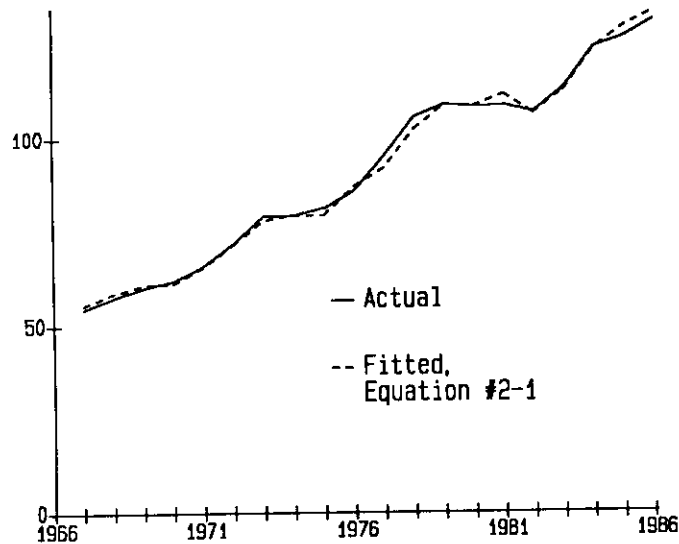
Hence, equation #2-1 is what we shall use for projections below; Figure 8 compares the actual and fitted values for 1967-86. The vehicle-mile elasticity with respect to GNP is 1.23; this is certainly consistent with what is indicated by Figure 5.

Table 2
Equation for Vehicle Miles: Large Trucks
(t-statistics in parentheses)

equation number	Coefficients					Adjust. R^2	Durbin-Watson Stat.	Standard Error of Regr.
	Constant	Fuel Price /mile	Real GNP	Dummy '74, '79	Autoregr. Correction			
#2-1	-5.00 (-3.1)	-.037 (-1.0)	1.23 (6.6)		0.93 (22.)	.9956	1.47	.0187
#2-2	-5.22 (-3.0)	-.030 (-0.7)	1.25 (6.4)	-.006 (-0.5)	0.93 (20.)	.9954	1.33	.0191

Sample Period: 1966-86
All variables in logarithms

Figure 8
 Vehicle Miles, Large Trucks: 1967-86
 Actual vs. Fitted Values (billions)



3.3 Fuel Efficiency

The fuel efficiency of the US car and truck fleet is the result of many influences: the utilization of the existing stock, the purchase of new vehicles, technological improvements made by the manufacturers, government-mandated standards, and demand-side decisions made by consumers. However, it is beyond the scope of this paper to undertake a complete analysis of these influences, examining both the supply and demand sides⁹. Instead we pursue a much simpler approach, as we did in our paper on jet fuel demand (Gately, 1988).

We assume that fuel efficiency, measured in miles per gallon (MPG), is determined by a time trend (reflecting ongoing technological improvement) and by the real

⁹ One approach would employ a hedonic pricing model, along the lines of Griliches and Ohta(1986). Another approach would be that of Gallini(1983).

price of fuel. We assume that actual fuel efficiency (MPG_t) adjusts slowly toward its desired level (MPG^*_t), in accord with a Koyck-adjustment process:

$$MPG_t - MPG_{t-1} = k (MPG^*_t - MPG_{t-1}).$$

Desired fuel efficiency is assumed to be a linear function¹⁰ of the real fuel price and time:

$$MPG^*_t = a + b (\text{fuel price})_t + c (\text{time}).$$

This yields the equation:

$$MPG_t = ka + kb(\text{fuel price})_t + kc(\text{time}) + (1-k)MPG_{t-1}$$

The results of estimation of this equation are presented in Table 3, disaggregated by vehicle type. For cars and small trucks (equation #3-1), all the coefficients except the constant term have the expected sign and are significant¹¹. Figure 9 compares the fitted values from this equation with the actual values. It tracks the data moderately well, for an admittedly simple equation. We shall use it below, for projections to the year 2000.

However, for large trucks the results of equation #3-2 are not very useful. This should not be surprising, given the time-path of fuel efficiency shown in Figure 6, which shows gallons-per-mile changing very little over the past two decades. Below, for projections to the year 2000, we shall assume a continuation of historical growth of the past two decades, 0.18% annual improvements in miles per gallon.

¹⁰ The survey of gasoline demand models by Dahl(1986, p. 76) suggests that linear models are preferable for miles-per-gallon, even though log-linear models are preferable for miles travelled and for gasoline demand.

¹¹ Alternative specifications for such an equation might include income rather than time; see Dahl(1979) and Wheaton(1982). But this yields a positive coefficient for income, the opposite of what would be expected. This is not surprising, since income has increased in most years, moving together with time.

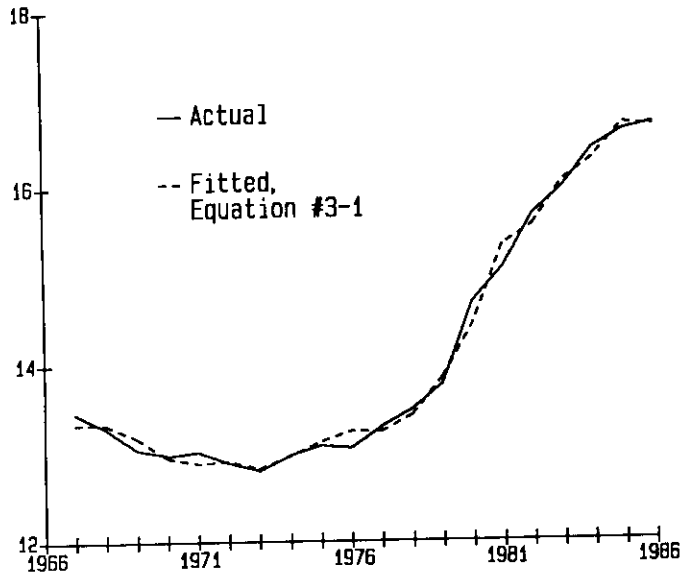
Table 3
Equation for Fuel Efficiency (Miles per gallon)
(t-statistics in parentheses)

equation number	Coefficients				Adjusted R ²	Durbin- Watson Statistic	Standard Error of Regr.
	Constant	Price Fuel	Time	Fuel Eff. _{t-1}			
Cars and Small Trucks:							
#3-1	-.29 (-5)	0.0097 (5.3)	0.027 (3.0)	0.94 (23.)	.9916	3.04	.1298
Large Trucks:							
#3-2	1.59 (1.6)	0.0010 (.76)	0.0013 (.27)	0.71 (3.8)	.6379	1.69	.0900

Sample Period: 1966-86

Figure 9

Miles per Gallon, Cars & Small Trucks: 1967-86
Actual vs. Fitted Values



4. Projections

We generate projections of vehicle miles from equations #1-1 and #2-1 respectively: for cars and small trucks together, and for large trucks. We project fuel efficiency using equation #3-1 for cars and small trucks; we assume a continuation of historical growth rates for large trucks' fuel efficiency (0.18% annually).

We assume that GNP grows at 2.5% annually and that motor fuel prices increase at 2% annually. For the number of drivers, we take driving-age-population projections from the Census Bureau and assume that the percentage of drivers continues to increase slowly (as it has since 1981), from its 1987 level of 90.23% to 93% by 2000¹².

Our projections for vehicle miles, fuel efficiency, and total fuel use to the year 2000 are contained in Figure 10 for cars and small trucks, and in Figure 11 for large trucks. Also contained in these figures are historical data for 1966-86, and projections by DOE/EIA, as of 1986¹³.

For cars and small trucks (Figure 10), our projections for the year 2000 show vehicle miles rising to 2214 billion, fuel efficiency rising to 20.7 miles per gallon (improvements of 1.55% annually), and fuel use rising to about 7 MMBD¹⁴. In contrast, DOE/EIA projects much more rapid improvements in fuel efficiency, 2.76% annually, to

¹² This is similar to the assumption in the "most likely" projections in a paper by the U.S. Federal Highway Administration (1987).

¹³ We use DOE/EIA's 1986 projections rather than the subsequent 1987 projections because only the 1986 projections provide enough detail about the underlying assumptions, contained in the "TPL Tables" (DOE/EIA, 1986). Because of slight differences in DOE/EIA's 1985 data and the 1985 *Highway Statistics* data, we scaled DOE/EIA's data and projections up or down by the difference.

¹⁴ With slower improvements in fuel efficiency, fuel use will grow more rapidly. With 1% annual improvement, fuel use would rise to 7.5 MMBD by year 2000; with only 0.5% annual improvement in fuel efficiency, fuel use would rise to 8.06 MMBD.

25.3 miles/gallon by year 2000; these would more than offset their higher projection of vehicle miles (2345 billion), such that fuel use would decline to about 6 MMBD. Such a rapid rate of fuel efficiency improvement would exceed the 2.06% annual growth of the 1973-86 period, and be exceeded only by the 3.09% annual growth during the 1976-82 period.¹⁵ With respect to projections of vehicle miles, the difference may be attributable to the fact that we take account of the slower growth in the number of drivers, using equation #1-1. Had we not done this, and used only price and income in our projections (equation #1-2), we would have projected a figure similar to that of DOE/EIA.

For large trucks (Figure 11), the differences in projections are greater. For fuel efficiency, DOE/EIA assumes 0.91% annual growth; this is considerably higher than the 0.18% annual growth of the past two decades, which we assume to continue. For vehicle miles, we use an income elasticity of 1.23 (from equation #2-1), while DOE/EIA uses an elasticity of 0.87. Hence, our projections of fuel use show continuing growth, to about 2.4 MMBD by the year 2000. DOE/EIA, in contrast, shows little growth in fuel use, to only about 1.7 MMBD.

Figure 10.

Cars & Small Trucks:
Vehicle Miles vs. Miles/Gallon,
1966-86, and Projections to year 2000

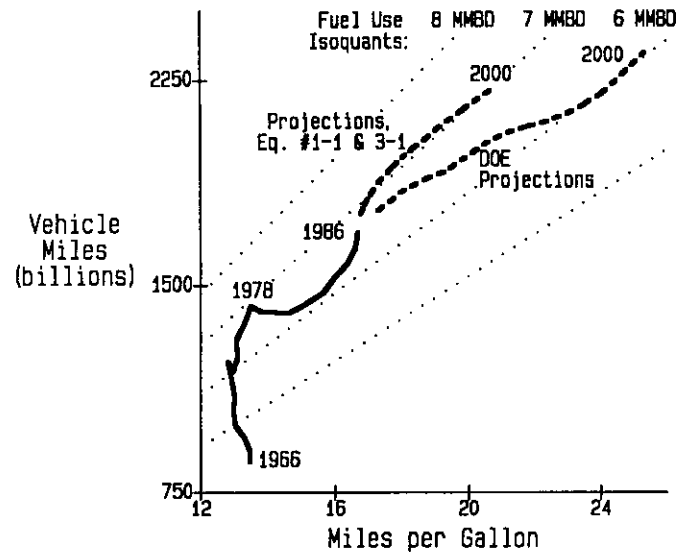
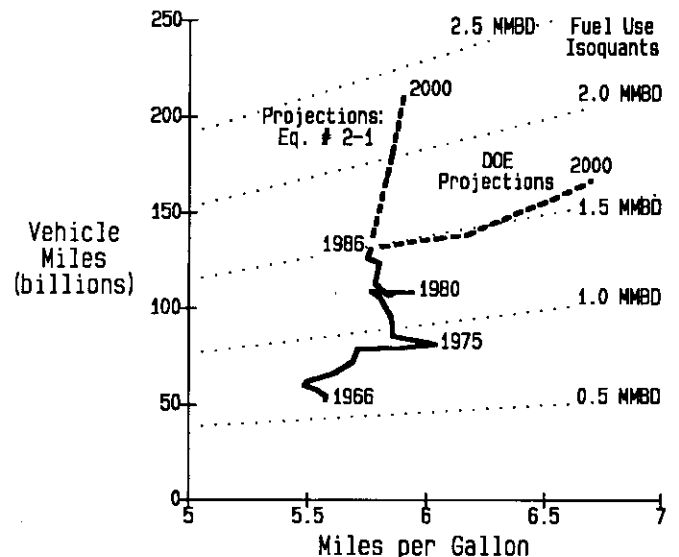


Figure 11.

Large Trucks:
Vehicle Miles vs. Miles/Gallon 1966-86
and Projections to year 2000



¹⁵ Surprisingly, their fuel efficiency projections are invariant to different oil price-paths: plus or minus 20% around their base-case price-path assumptions.

5. Summary

In analyzing US highway travel and fuel use, it is important to distinguish between large trucks' freight transport and passenger travel in cars and small trucks. Although fuel use by cars and small trucks is about the same level as in 1978, large trucks' fuel use is one-fourth higher. Large trucks' vehicle miles have grown more rapidly in the past two decades than has passenger travel: 4.7% vs. 3.4% annually. There has been little change in the fuel efficiency of large trucks, so that their fuel use has more than doubled. We expect these trends to continue: large trucks' fuel use will increase from 1.5 to 2.4 MMBD by the year 2000.

In contrast, fuel efficiency growth for cars and small trucks, especially since 1976, has offset increases in vehicle miles. Hence their fuel use has not grown very much in the past decade. Moreover, the rapid growth in the number of drivers (2.9% annually from 1966-77) slowed down substantially in the last decade (1.6% annually from 1977-87), and will slow down even more during the 1990's (1.1% annually from 1987-2000). This could keep the growth in vehicle miles low enough to be almost offset by continuing improvements in fuel efficiency, so that fuel use by cars and small trucks need not rise very much. However, if the historically low fuel-price-per-mile deters such efficiency gains, then fuel use will rise more rapidly.

The net projected effect on total highway fuel use is that it will rise slowly, to about 13% above its 1986 level by the year 2000. DOE/EIA, in contrast, projects a 6% decline. Although this 13% increase itself is not dramatic, when combined with rapidly increasing use of jet fuel and substantial declines in domestic production, US import dependence will rise much more rapidly than is forecast by DOE/EIA. This increased vulnerability to supply disruption is especially alarming, because of the substantial increase in the share of total oil used by the transportation sector, where there is no competitive substitute for oil.

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 Trucks, 2-axle 4-wheel
 Trucks, other single-unit
 Trucks, trailer combination
 on the following:
 Motor fuel consumption; Vehicle Registrations; Vehicle Miles Travelled