

Appendix B

Estimation Methodologies

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Estimation Methodologies

Introduction

Statistics concerning vehicle miles traveled (VMT), vehicle fuel efficiency (given in terms of miles per gallon (MPG)), vehicle fuel consumption, and vehicle fuel expenditures are presented in this report. The methodology used to estimate these statistics relied on data from the 1990 Residential Energy Consumption Survey (RECS), the 1991 Residential Transportation Energy Consumption Survey (RTECS), the U.S. Environmental Protection Agency (EPA) fuel efficiency test results, the U.S. Bureau of Labor Statistics (BLS) retail pump price series, and the Lundberg Survey, Inc., price series for 1991.

The estimation of these four statistics (VMT, vehicle fuel efficiency, vehicle fuel consumption, and vehicle fuel expenditures) occurred in several steps (Figure B1). First, for each RTECS vehicle, the VMT were determined from two actual odometer readings or imputed using data from the 1990 RECS. Second, the annual on-road fuel efficiency, given in terms of MPG, was estimated using the questionnaire responses, decoded Vehicle Identification Number (VIN) data, EPA fuel efficiency test results, and the months that the vehicle was in use. The MPG were adjusted to account for the difference between EPA test values and on-road values. Third, estimated vehicle fuel consumption was derived by dividing the VMT by the estimated MPG. Finally, the estimated vehicle fuel expenditures were derived by multiplying the vehicle fuel consumption by the fuel price. The 1991 RTECS, like the 1988 RTECS, did not collect vehicle fuel prices via fuel purchase diaries. Instead each RTECS vehicle was assigned a price based on reported fuel type used in each vehicle. Gasoline prices were obtained from the BLS 1991 Retail Gasoline Pump Price Series. Diesel fuel prices were obtained from the Lundberg Survey, Inc. (See "Other Fuel Types" in this appendix for a discussion of the gasohol and propane prices.)

The following sections of this appendix describe the estimation procedures used for calculating the VMT, the MPG, the vehicle fuel consumption, the vehicle fuel prices, and the vehicle fuel expenditures. Also described in this appendix are the sources of data that were used in the estimation procedures.

The following terms are used throughout this appendix:

Terms	Definitions
EPA Composite MPG	The EPA dynamometer test procedure, performed on preproduction prototype vehicles, yields separate test values for EPA city and highway MPG. These city and highway MPG are often combined to form the "composite" MPG.
On-Road MPG	A composite MPG that was adjusted to account for the shortfall between the test value and the fuel efficiency actually obtained on the road. The adjustment did not take into account the driving patterns of individual drivers and seasonal differences.
In-Use MPG	MPG that were adjusted for seasonal differences and annual miles driven. Vehicles that are driven relatively few miles during the year are assumed to be driven mostly on short trips that involve frequent stops. Vehicles that are driven relatively many miles are assumed to be driven mostly on long trips where few stops are needed.

MPG Shortfall A measure of the difference between actual on-road MPG and the EPA laboratory test MPG. Expressed as the ratio of test MPG to on-road MPG.

Figure B1. Estimation Schematic

Note: RTECS--Residential Transportation Energy Consumption Survey, EPA--Environmental Protection Agency, BLS--Bureau of Labor Statistics; and Lundberg--Lundberg Survey, Inc.

Source: Energy Information Administration, Office of Energy Markets and End Use, 1991 Residential Transportation Energy Consumption Survey.

Vehicle Miles Traveled

When possible, VMT were determined for a sample vehicle by taking the difference between two odometer readings, which spanned a period of time. This method was used to determine VMT for 3,352 (55 percent) of the 6,084 RTECS sample vehicles. Attempts were made to obtain odometer readings during the RECS interviews, the Beginning-of-Year (B-O-Y) RTECS interview, the End-of-Year (E-O-Y) RTECS interview, and any time a vehicle was acquired or disposed. A "span" of odometer readings was the difference between two odometer readings. In most cases, this span was a B-O-Y to E-O-Y span, although due to an occasional nonresponse, only shorter spans were obtained, such as RECS to B-O-Y. Odometer spans of less than a full year were also obtained for vehicles that were either acquired or disposed of during the survey year.

In addition, the onset of the Persian Gulf War caused the start of the 1991 RTECS data collection to be delayed by 7 weeks. However, the E-O-Y data collection was carried out according to the original schedule. Thus, the B-O-Y to E-O-Y span of odometer readings was slightly less than a full year for all vehicles. Response Analysis Corporation (RAC) studied the impact of this delay on annualized VMT. Preliminary data studied by RAC for the first 3 months of 1991 suggest no radical or even moderate departure in relative proportions of travel by month from 1990. Moreover, comparison of the 1984 NPD fractions (See Table B1) with Federal Highway Administration (FHA) monthly fractions for 1984 and 1990 suggests there is no significant bias in continuing to use the 1984 NPD monthly fractions to inflate the odometer spans to a full year. This process is described as step 1 of the 2-step adjustment procedure in the following paragraph.

The VMT that were assigned to each RTECS vehicle corresponded to the period of time that the vehicle was in possession by the sample household. In most cases, however, this period of possession did not correspond exactly with the beginning and ending dates for the odometer span. This was true even for vehicles with a complete B-O-Y to E-O-Y odometer span; because odometer cards were mailed to respondents in several distinct waves at the beginning and end of the RTECS survey; and because the exact dates of odometer readings were often left to the convenience of the respondents. Therefore, all VMT obtained from odometer spans were adjusted to correspond to the period of time that the vehicle was in possession by the sample household. A 2-step adjustment procedure was used. STEP 1 adjusted the odometer-span VMT to a standard annualized mileage covering 365 days, and STEP 2 readjusted the annualized VMT to correspond to the exact period of time that the vehicle was in possession by the household. These adjustments took into account a typical distribution of VMT fractions among the different months of the year. Step 2 was performed only for vehicles that were not in the possession of the household for the entire calendar year 1991.

STEP 1:

This step adjusted the odometer-span VMT to a standard annualized VMT covering a full year, regardless of whether the span of odometer readings covered approximately 1 year or only a short span of time. Annualized VMT for vehicle i were computed as:

$$Annualized\ VMT_i = \frac{[Odometer - Span\ VMT_i]}{\sum_{j=SO_i}^{EO_i} F_j} \quad (1)$$

Where:

F_j = Monthly VMT fractions from the standard distribution in Table B1

so_i = Month of starting odometer readings for vehicle i
 eo_i = Month of ending odometer readings for vehicle i.

The starting and ending F_j were prorated according to the exact day of the month for the odometer readings. For example, if a final odometer reading was taken on September 15, then $(14/30) \times F_{SEP}$ was used.

Table B1. Distribution of Average Monthly Vehicle Miles Traveled Fractions

Month j	Average VMT per Vehicle	F_j
January	688	0.0728
February	697	0.0738
March	771	0.0816
April	783	0.0829
May	832	0.0880
June	847	0.0896
July	868	0.0919
August	872	0.0923
September	800	0.0847
October	802	0.0849
November	756	0.0800
December	734	0.0777
Total	9,450	1.0000

Source: 1984 Petroleum Marketing Index (PMI) Survey, NPD Research Inc. The survey is a demographically and geographically balanced-quota sample of 4,100 households. Respondents maintained fuel purchase diaries for an average of 10 months. As part of the survey, information was collected on the characteristics of trips taken in vehicles during a designated day. Trip lengths were recorded as respondent perception rather than from odometer readings. The distribution of monthly mileage fractions has been obtained from this survey.

STEP 2:

Once an annualized VMT was obtained from STEP 1 as described earlier, it was adjusted to correspond to the time period that vehicle i was in possession by the sample household as:

$$VMT \text{ During Possession}_i = [Annualized VMT_i] \times \sum_{j=sp_i}^{ep_i} F_j \quad (2)$$

Where:

- F_j = Monthly VMT fractions from the standard distribution in Table B1
- sp_i = Month starting possession of vehicle i by the household, or January 1991, whichever is later
- ep_i = Month ending possession of vehicle i by the household, or December 1991, whichever is earlier.

If vehicle i was in the household for the entire year then $sp_i = JAN$ and $ep_i = DEC$. If a vehicle was acquired or

disposed of during the survey, the starting or ending F_j was prorated according to the appropriate day of the month.

To ensure that the distribution of average monthly vehicle miles traveled fractions given in Table B1 reflected 1991 driving patterns, a study of Federal Highway Administration (FHWA) Traffic Volume data for 1991 was conducted. This study resulted in FHWA VMT fractions being constructed for 1984 and 1990. FHWA 1990 data were used since the 1991 data for the entire year was unavailable. Annual VMT calculations were completed using both the NPD and FHWA fractions. The differences in average annual VMT per vehicle between using the NPD and FHWA VMT fractions ranged between 1 and 18 miles and were less than the standard errors of the average annual VMT. Therefore, in 1991 the NPD VMT fractions given in Table B1 will be used to compute annualized VMT since the differences in annual VMT between using the NPD and FHWA fractions were minor (RTECS Technote 5[3]).

Incomplete Odometer or VMT Data

For 1,576 sample vehicles (26 percent), no odometer span was available, although an estimate of annual VMT had been obtained from the respondent during the RECS interview. VMT for these vehicles were imputed from a regression on the estimated VMT obtained from the RECS. For another 1,150 sample vehicles (19 percent), no odometer span was available and a VMT estimate was not obtained during the RECS interview. VMT for these vehicles were imputed using a multiple linear regression model, where the independent variables were number of drivers, household income, age of household head, type of vehicle, and use of vehicle on the job. This regression was also used for imputing VMT for vehicles that were imputed as being acquired or disposed. Both of the regression models described above yielded estimates of annualized VMT. The STEP 2 adjustment described previously was then used to adjust this VMT to correspond with the time the vehicle was in the possession of the household.

Vehicle Fuel Efficiency

Fuel efficiency (MPG) must be estimated for each RTECS sample vehicle in order to estimate each vehicle's fuel consumption for the survey year. (Fuel consumption is estimated by dividing the VMT for time of possession, by the MPG.) Prior to 1988, the RTECS obtained actual fuel consumption data and on-road MPG from fuel purchase diaries maintained by the respondents. However, no fuel purchase diaries were used in the 1988 or 1991 RTECS. Instead, the 1991 MPG were estimated using EPA laboratory test MPG that were adjusted to account for differences between actual on-road MPG and the EPA test MPG. This difference is known as MPG "shortfall." The feasibility of using shortfall-adjusted MPG in an RTECS survey was investigated by Lax, 1987[6]. That study verified that the method yielded unbiased MPG, when using a data base from a 1984 fuel purchase diary study performed by NPD Research, Inc. The adequacy of current shortfall adjustment methods is sufficient for late 1980 through early 1990's motor vehicle model years also (RTECS Technote 5[3]).

The RTECS sample vehicles were assigned EPA test MPG from the EPA Emissions Certification Files. Each record of the Certification Files contained EPA test MPG for each unique combination of vehicle attributes within a given make, model, and year. These attributes were (1) number of cylinders, (2) cubic inches of engine displacement (CID), (3) type of transmission (manual or automatic), (4) gasoline or diesel fuel, and (5) whether the vehicle's emissions control package met Federal or California standards. Each record of the Certification Files also contained the number of vehicles sold for each unique combination of attributes. The vehicle attributes needed to assign a test MPG for sample vehicles were obtained from the Vehicle Identification Number (VIN), and/or from the RTECS questionnaire responses when the VIN was unavailable. The VIN was decoded to yield the vehicle attributes, by use of the Highway Loss Data Institute's "Vindicator" software.

In addition to assigning test MPG, the EPA Certification Files were used to impute for missing vehicle attributes. Based on the nonmissing vehicle attributes obtained from the questionnaire and VIN, several records from the EPA Certification Files were usually found as potential "matches" to a given sample vehicle. A matching record was chosen from among the several applicable ones, with probability proportional to sales, using the sales figures on the EPA Certification Files. Once chosen, a record provided EPA test MPG (city and highway), as well as any vehicle attributes that were missing.

The 1991 RTECS used a sequential adjustment procedure where the EPA Composite MPG was adjusted first to an on-road MPG, and then to an in-use MPG. Figure B2 shows the MPG adjustments that were used to determine the final in-use MPG.

The EPA Composite MPG

Beginning in the early 1970's, EPA measured fuel efficiency from tests that were conducted on a dynamometer to simulate actual driving conditions. By 1975, EPA had incorporated separate "city" and "highway" driving cycles into the test. The city and highway MPG were combined to form a "composite" MPG, that was then weighted according to sales of the production vehicles in order to assess compliance with Corporate Average Fuel Economy (CAFE) standards. The EPA Composite MPG is based on the assumption of a "typical" vehicle-use pattern of 55 percent city driving and 45 percent highway driving, and has become a convenient single fuel efficiency measure for analytical and regulatory purposes.

The EPA Composite MPG is defined as:

$$MPG_{(EPA55/45)} = \frac{1}{0.55 \times \frac{1}{MPG_{(EPAcity)}} + 0.45 \times \frac{1}{MPG_{(EPAhighway)}}} \quad (3)$$

where:

$MPG_{(EPA55/45)}$ = the composite MPG

$MPG_{(EPAcity)}$ = the fuel efficiency when vehicle use pattern is city driving only

$MPG_{(EPAhighway)}$ = the fuel efficiency when vehicle use pattern is highway driving only.

Fuel Efficiency Shortfall

Fuel efficiency shortfall occurs when the fuel efficiency that is actually obtained while using the vehicle is lower than the EPA test results. Reasons for this shortfall are (1) a result of the differences between EPA test vehicles and the vehicles actually in use and (2) the differences between EPA procedures for simulated driving conditions and actual driving conditions. For example, EPA test vehicles are prototypes that do not contain the wide variety of power-consuming accessories often found on vehicles sold to consumers. The test procedures also do not simulate the actual driving conditions that affect fuel efficiency such as speed and acceleration of individual drivers, road conditions, weather, and traffic. In the 1991 RTECS, adjustments for this fuel efficiency shortfall were made to the composite MPG ($MPG_{(EPA55/45)}$) that were assigned to the sample vehicles.

Fuel efficiency shortfall was expressed in terms of the "Gallons per Mile Ratio" or GPMR:

$$GPMR_i = \frac{MPG_i(EPA55/45)}{MPG_i} \quad (4)$$

Where:

$GPMR_i$ = Gallons per Mile Ratio for vehicle i

MPG_i = On-road MPG or in-use MPG for vehicle i, depending on the analysis

$MPG_{(EPA\ 55/45)}$ = EPA Composite MPG applicable to vehicle i.

Figure B2. Miles per Gallon Adjustment Procedures

Source: Energy Information Administration, Office of Energy Markets and End Use, 1991 Residential Transportation Energy Consumption Survey.

If $GPMR_i = 1$ then there is no shortfall. If $GPMR_i > 1$ then there is a shortfall for vehicle i (That is, the on-road or in-use fuel efficiency is less than the fuel efficiency indicated by the EPA Composite MPG.) Note that $GPMR_i$ can represent shortfall with respect to either the on-road or in-use MPG_i , depending on the analysis being performed. $GPMR_i$ is commonly chosen as a measure of shortfall as opposed to MPG_i for the following reasons:

- A shortfall adjustment is most often thought of as a correction factor, or multiplicative constant, rather than as an additive correction. $GPMR_i$ satisfies this convention.
- Shortfall is usually dependent on a vehicle's fuel efficiency level. That is, shortfall is usually higher at high levels of $MPG_{(EPA\ 55/45)}$ than at low levels of $MPG_{(EPA\ 55/45)}$. Therefore, it is more informative to express the amount of shortfall relative to $MPG_{(EPA\ 55/45)}$ rather than as an absolute quantity.
- $GPMR_i$ is a linear function of $MPG_{(EPA\ 55/45)}$ and can be modeled using ordinary least squares linear regression.
- $GPMR_i$ is a transformation that stabilizes error variances for the purposes of least squares linear regression.

The On-Road MPG

On-road MPG is a composite MPG that was adjusted to account for the shortfall between the EPA fuel efficiency and the actual fuel efficiency obtained on the road.

The EPA developed two general procedures for adjusting $MPG_{(EPA\ 55/45)}$ to an on-road value. One procedure bases the size of the adjustment on specific technology features of the vehicle. The other procedure uses just two MPG discount factors, one to adjust the EPA highway estimate, the other to adjust the city estimate. These two factors are used for all vehicles, regardless of technology class. Either of these procedures could be used to adjust $MPG_{(EPA\ 55/45)}$ to an on-road MPG value for use in the 1991 RTECS. Since both procedures were unbiased for trucks, the choice as to which to employ in the 1991 RTECS should be based on their performance with cars. The adjustment based on discount factors seemed to be less biased than the Technology-Specific Adjustment. The discount factors are also less expensive since they do not require collection or imputation of information on fuel delivery system and drive-train. Because of these reasons the Discount Factors Adjustment Method was selected.

Shortfall Adjustment Based on Discount Factors

EPA's discount factors have widespread appeal because of their simplicity (Hellman and Murrell, 1985[4]; Hellman and Murrell, 1984[5]). The factors are .10 percent for city MPG and .22 percent for highway MPG. That is, for any vehicle i ,

$$MPG_{i(on-road, city)} = 0.90 \times MPG_{i(EPA city)} \quad (5)$$

$$MPG_{i(on-road, highway)} = 0.78 \times MPG_{i(EPA highway)}$$

These discount factors are the ones used to produce the "sticker" MPG figures seen on vehicles on dealer lots, and are used to produce the DOE/EPA *Gas Mileage Guide*. The analysis behind the development of these factors was performed on a conglomerate data base with data from Ford Motor Company, General Motors, Chrysler Corporation, DOE, and EPA. The data base contained approximately 38,000 vehicle records with model years from 1979 through

1981 with some 1982 models included. The data base contained predominately American-made vehicles, but also included foreign vehicles as well. The technology mix was dominated by rear-wheel drive and carbureted vehicles, but contained some vehicles with front-wheel drive or fuel injection. Vehicle records contained make, model, year, vehicle characteristics, the MPG as measured on the road, $MPG_{(EPA\ city)}$, and $MPG_{(EPA\ highway)}$. The data base also

included the driver's perceptions of the proportion of their travel that was mostly urban (so called "city fraction"), and their average miles driven per day (AMPD).

Fuel economy shortfall is affected by the vehicle use pattern: city-driving pattern is characterized by frequent starts and short trip lengths, while highway-driving pattern is characterized by infrequent starts and long trips. AMPD is a good surrogate variable for representing these different driving patterns.

The city-driving pattern was characterized by AMPD from 5 to 22 miles per day, while the highway-driving pattern was characterized by AMPD's from 15 to 105 miles per day (Hellman and Murrell, 1984). City fraction and AMPD were used to split the data into two sets, one for development of the city discount factor, the other for development of the highway factor. The "city" and "highway" data sets were each stratified by vehicle technology classes. Linear regression was performed within each stratum. GPMR was regressed on city fraction, AMPD, $MPG_{(EPA\ 55/45)}$, odometer reading, and average temperature. The fitted models were then weighted and combined across vehicle technology strata, to produce a single "city" shortfall model and a single "highway" shortfall model. The weights were used to increase the influence of those models that represented technology mixes expected to become more prominent in the future (e.g., front-wheel drive and fuel-injected vehicles). The discount factors were derived from the two weighted models set at average or typical values of the independent variables.

For each RTECS vehicle, discounted city and highway on-road MPG were computed and then combined to form an on-road 55/45 composite as follows:

$$MPG_{i(on-road, 55/45)} = \frac{1}{0.55 \times \frac{1}{MPG_{i(on-road, city)}} + 0.45 \times \frac{1}{MPG_{i(on-road, highway)}}} \quad (6)$$

A shortfall ratio based on EPA discount factors was computed for each RTECS vehicle as follows:

$$GPMR_{i(on-road)} = \frac{MPG_{i(EPA\ 55/45)}}{MPG_{i(on-road, 55/45)}} \quad (7)$$

The In-Use MPG

In-use MPG are MPG that are adjusted for individual driving circumstances. The on-road adjustments to $MPG_{(EPA\ 55/45)}$ discussed in the previous sections were "general" in that they did not take into account any effects on fuel economy that are due to the driver's individual circumstances. They, instead, utilized general attributes such as the technology features of the vehicle and average driving conditions. Fuel economy shortfall estimates can be refined for an individual vehicle by taking into account the following "in-use" effects.

- Urban versus rural driving pattern. That is, frequent starts and short trips as opposed to infrequent starts and longer trips. As mentioned in the previous section, a useful single variable for representing this effect is AMPD. High AMPD's usually represent mileage accumulated on the highway.
- Traffic congestion, which increases with population density.
- Seasonal temperature variations, especially for gasoline-carbureted vehicles.
- Humidity, which together with temperature, affects air-conditioner use.

- Differences among geographic areas of the country.
- Altitude.

- Wind.
- Road gradient and road surface conditions.

In general, the first four items are considered the most significant in-use influences (Crawford, 1983[1]). In the cited study, shortfall variations as high as 25 percent or more occurred over the range of typical AMPD. Shortfall was 16 percent higher in urban areas than in completely uncongested areas, and was 12 percent higher in suburban areas. Shortfall varied seasonally (i.e., monthly) by 7 percent in the South and by 13 percent in the North.

Regression models were developed (Crawford, 1983) for use in adjusting $GPMR_{i(on-road)}$ to an in-use shortfall employing measurements of several in-use effects as the independent variables.

The regressions yielded a shortfall adjustment that was an additive one, as follows:

$$GPMR_{i(in-use)} = GPMR_{i(on-road)} + \delta_{ij} \quad (8)$$

where:

$GPMR_{ij(in-use)}$ = the in-use shortfall ratio estimated for vehicle i and month j ($j = 1...12$),
 $GPMR_{i(on-road)}$ = the on-road shortfall ratio estimated for vehicle i , from the above equations, and
 δ_{ij} = an adjustment calculated for vehicle i and month j , from a regression model.

One regression model from the Crawford reference which is appropriate for use in RTECS is as follows:

$$\delta_{ij} = 3.296 \left[\left(\frac{1}{AMPD_{ij}} \right) - \left(\frac{1}{35.6} \right) \right] + NORTH [0.050 \sin(j\pi/6)] + SOUTH [0.031 \cos(j\pi/6)] \quad (9)$$

Where:

$AMPD_{ij}$ = Average Miles per Day for vehicle i and month j , typically 35.6 (i.e., 13,000 miles per year).

$NORTH = 1$ if the household is in the North.

0 if the household is not in the North.

$SOUTH = 1$ if the household is in the South.

0 if the household is not in the South.

This regression model was chosen because the independent variables that are important in explaining shortfall were readily available from the 1991 RTECS data. The model had two components. One component involved $AMPD_{ij}$ and represented the influence of individual driving patterns for a given vehicle and month. The other component represented the change in shortfall that occurred throughout the seasons, due to the annual temperature cycle. The original regression equation also contained a minor term which accounted for the influence of air-conditioner use during hot, humid weather. This term was dropped in the 1991 RTECS estimations because it involved the rather complex computation of "Discomfort Index" from NOAA weather records, and the slight additional precision was judged insufficient to warrant the additional processing expense. Additional terms representing geographic regional effects, and the natural logarithm of population density (people per square mile, to represent the influence of traffic congestion) were not considered because of the computational cost.

Once a $GPMR_{ij(in-use)}$ was estimated it was used to estimate the final in-use fuel economy for vehicle i and month j as follows:

$$MPG_{ij(in-use)} = \frac{MPG_i(EPA55/45)}{GPMR_{ij(in-use)}} \quad (10)$$

The regression equation had separate seasonal components for the "North" and "South," because the difference between the winter shortfall and the summer shortfall was greater in the North than in the South. This difference can be seen in the model parameters. To define the North and South geographic areas the continental United States were divided into 97 two-digit ZIP Code regions. These regions were grouped to form two aggregate regions ("North" and "South") according to average winter and summer temperatures, and seasonal shortfall trends.

Annual Vehicle Fuel Consumption

In the 1991 RTECS, annual consumption was calculated by dividing the annual VMT by the annual MPG. The following is a derivation of the annual VMT and annual MPG.

The $MPG_{ij(in-use)}$ shown in the above section about fuel efficiency estimation procedures were final estimates of monthly in-use fuel economies for vehicle i , and could have been used for estimating monthly fuel consumptions and expenditures if monthly VMT were known. However, RTECS collected only annual VMT, as calculated from the B-O-Y and E-O-Y odometer readings. Nevertheless, the 1991 RTECS still made use of the $MPG_{ij(in-use)}$ by disaggregating the annual VMT of sample vehicles into monthly VMT.

The annual consumption for vehicle i can be thought of as the sum of the individual monthly consumptions:

$$C_i = \sum_{j=sp_i}^{ep_i} c_{ij} \quad (11)$$

Where:

- C_i = Annual consumption of vehicle fuel for vehicle i , in gallons
- sp_i = Month starting possession of vehicle i by the household, or January 1991, whichever is later
- ep_i = Month ending possession of vehicle i by the household, or December 1991, whichever is earlier
- c_{ij} = Consumption of vehicle fuel for vehicle i , during month j .

Consumption is calculated over only those months that vehicle i was reported to be owned or used by the household. In this sense, "annual" does not necessarily mean a full 12 months. This is an important point since fuel economy varies seasonally. If vehicle i was in the household for the entire year, then sp_i = JAN and ep_i = DEC.

Consumption for each month can be expressed in terms of monthly VMT and monthly fuel economy:

$$C_{ij} = \frac{m_{ij}}{mpg_{ij}} \quad (12)$$

Where:

m_{ij} = VMT for vehicle i , month j

mpg_{ij} = Fuel economy in miles per gallon for vehicle i , month j

so that:

$$C_i = \sum_{j=sp_i}^{ep_i} \frac{m_{ij}}{mpg_{ij}} \quad (13)$$

In the 1991 RTECS C_i was estimated by substituting the estimated $MPG_{ij(\text{in-use})}$ for mpg_{ij} . The m_{ij} was estimated in RTECS by disaggregating the annual VMT from odometer readings into monthly VMT. The disaggregation was performed as follows:

$$m_{ij} = M_i \times f_{(i,j)} \quad (14)$$

Where:

M_i = Annual VMT for vehicle i , calculated using odometer readings and the two-step adjustment procedure discussed in the section titled "Vehicle Miles Traveled"

$f_{(i,j)}$ = Average fraction of "annual" VMT that was driven during month j , estimated for vehicle i

There is no single distribution of average monthly VMT fractions $f_{(ij)}$. Rather, there was a family of distributions, the members of which were determined by the particular months a vehicle was owned or used by a household. According to this definition of monthly VMT fractions, no matter which months vehicle i was in a household, it was always true that:

$$\sum_{j=sp_i}^{ep_i} f_{(ij)} = 1 \quad (15)$$

The $f_{(ij)}$ were derived from the F_j in Table B1 as follows:

$$f_{(i,j)} = F_j, \quad f_{sp_i} = \text{JAN and } ep_i = \text{DEC}$$

Otherwise

$$f_{(i,j)} = \frac{F_j}{\sum_{j=sp_i}^{ep_i} F_j} \quad (16)$$

Substituting $mpg_{ij} = MPG_{ij(\text{in-use})}$ and $m_{ij} = M_i \times f_{(ij)}$ into Equation 13.

yields the following estimate of annual consumption for vehicle i :

$$C_i = \sum_{j=SP_i}^{EP_i} \frac{M_i \times f_{(i,j)}}{MPG_{ij(in-use)}} \quad (17)$$

The estimator of annual consumption in the above equation was constructed with 1991 RTECS data.

For vehicles that were acquired or disposed of during 1991, the estimator took into account seasonal differences in the overall fuel economy and the effects of these differences on the overall fuel consumption.

Substituting $MPG_{(EPA\ 55/45)}$ in the above equation, and slightly rearranging the terms, the estimator of consumption is:

$$C_i = \frac{M_i}{MPG_{(EPA55/45)}} \sum_{j=SP_i}^{EP_i} f_{(i,j)} \times GPMR_{ij(in-use)} \quad (18)$$

A single "annualized" fuel economy that is analogous to the "annualized" MPG_i from previous RTECS, was estimated as:

$$MPG_{i(annualized)} = \frac{MPG_{(EPA55/45)}}{\sum_{j=SP_i}^{EP_i} f_{(i,j)} \times GPMR_{ij(in-use)}} \quad (19)$$

Thus

$$C_i = \frac{M_i}{MPG_{i(annualized)}} \quad (20)$$

Annual Vehicle-Fuel Expenditures and Price

Vehicle Fuel Expenditures

In the 1991 RTECS, fuel expenditures were calculated by multiplying the vehicle-fuel consumption by the price of the vehicle fuel. The 1991 RTECS, like the 1988 RTECS, did not collect vehicle fuel prices via fuel purchase diaries. Instead, each RTECS vehicle was assigned a price based on reported fuel type used in the vehicle. Gasoline prices were obtained from the BLS 1991 Retail Gasoline Pump Price Series. Diesel fuel prices were obtained from the Lundberg Survey, Inc. (See "Other Fuel Types" in this appendix for a discussion of the gasohol and propane prices.)

Respondents were asked if they purchased leaded or unleaded gasoline, and if unleaded, they were asked the grade.

(See Appendix D, "Survey Forms.") The BLS prices are published by month, by Census region, and by type and grade of fuel. In 1988, the BLS monthly prices (for the Census region in which the household lived) were averaged across the months that the vehicle was in the possession of the household. This yielded for each RTECS vehicle a single fuel price, P_i , dependent on the Census region, type and grade of gasoline, and the months that the vehicle was in the possession of the household. In 1988, the annual fuel expenditures in dollars for each sample vehicle, E_i , was estimated by multiplying its assigned average fuel price, P_i , by its total consumption in gallons, C_i , as estimated in the previous section. However, in 1991, annual fuel expenditures, E_i , was estimated by multiplying monthly gasoline prices by monthly consumption to produce monthly expenditures and summing the monthly expenditures to produce annual expenditures.

Type of Fuel Used

Table B2 provides the percentage distribution of RTECS vehicles by fuel type categories. In 1991, 93.7 percent of the 151.2 million RTECS vehicles used unleaded gasoline. The remaining 6.3 percent of vehicles used leaded gasoline, diesel fuel or other fuel types.

Table B2. Distribution of Residential Transportation Energy Consumption Survey Vehicles by Type of Fuel Used, 1991

Type of Vehicle Fuel	Number of Vehicles (millions)	Percent of Vehicles
Total	151.2	100.0
Gasoline	147.7	97.7
Leaded	6.0	4.0
Unleaded	141.7	93.7
Regular	92.6	61.2
Premium	32.4	21.4
Intermediate	16.7	11.1
Diesel	1.8	1.2
Gasohol	1.6	1.1

Notes: •Because of rounding, data may not sum to totals. •For a discussion of underreporting of gasohol see Appendix C, "Quality of the Data."

Source: Energy Information Administration, Office of Energy Markets and End Use, 1991 Residential Transportation Energy Consumption Survey.

Gasoline Prices

Prices published by the BLS survey are retail prices for leaded regular, unleaded regular, and unleaded premium gasoline. These prices are published monthly by Census region. The BLS Pump Price Survey is conducted as input to the *Consumer Price Index (CPI)*. Prices are collected in 85 urban areas. The population covered excludes the institutional population and households located on military bases. The covered population includes approximately 85 percent of all U.S. households. The BLS uses a rotating sample of approximately 1,100 service stations.

Each vehicle in the 1991 RTECS that used one of the three gasoline types, was assigned a monthly BLS fuel price. The BLS "leaded regular" price was assigned to all vehicles that reported using leaded gasoline. Also since BLS

stopped publishing leaded prices in May (Lundberg, 1991[7]), leaded and unleaded gasoline prices were used to establish leaded prices from the BLS unleaded prices from May to December. Because the BLS survey did not publish a price for an intermediate grade of unleaded gasoline in 1991, an average of the BLS regular and premium unleaded prices was assigned to the 11.1 percent of RTECS vehicles that used an intermediate grade of unleaded fuel.

Diesel Fuel Prices

Diesel fuel prices were obtained from the "Lundberg Letter-PS" published by Lundberg Survey, Inc. The Lundberg Survey, Inc. collects pump prices at retail service stations in approximately 80 major metropolitan markets. The survey includes about 15,000 service stations divided into 2 bimonthly panels. At least one city from every State is included. Service stations on military bases and in rural areas are excluded. Sales-weighted price data for both full- and self-service stations are published bimonthly. Regional prices are not published. All RTECS vehicles that used diesel fuel were assigned the same diesel fuel prices regardless of Census region.

For the RTECS, the following two steps were used to create diesel prices. (1) Bimonthly diesel fuel full-service and self-service prices, obtained from the Lundberg Letter-PS, were averaged to create prices for each grade in the intermediate months. (2) The monthly full- and self-service prices were then weighted and averaged to obtain overall diesel fuel prices. The weights used to create an average diesel fuel price from the full- and self-service prices were based on RTECS data on "type of service" (full-service or self-/mini-service) used when purchasing diesel fuel. For each vehicle monthly prices were multiplied by monthly consumption to yield monthly expenditures. The monthly expenditures were summed to produce annual expenditures.

Other Fuel Type Prices

Approximately 1.6 million 1991 RTECS vehicles were reported using gasohol. In the absence of applicable national estimates of the average price paid for gasohol, the RTECS vehicles using gasohol were assigned fuel prices using the same methodology as the most common group of vehicles in the survey--vehicles using regular unleaded gasoline. (See above for methodology assigning unleaded regular gasoline prices and Appendix C, "Quality of the Data" for a discussion of RTECS underestimation of other fuels.)

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