Demographic Influences on Household Travel and Fuel Purchase Behavior

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Monthly fuel purchase logs from the Residential Energy Consumption Survey's Household Transportation Panel (TP) were analyzed to determine the relationship between various household characteristics and purchase frequency, tank inventories, vehicle miles traveled, and fuel expenditures. Multiple classification analysis (MCA) was used to relate observed differences in dependent variables to such index-type household characteristics as income and residence location, as well as sex, race, and age of household head. Because it isolates the net effect of each parameter, after accounting for the effects of all other parameters, MCA is particularly appropriate for this type of analysis. Results reveal clear differences in travel and fuel purchase behavior for four distinct groups of vehicle-owning households. Black households tend to (a) own far fewer vehicles with less fuel economy, (b) use them more intensively, (c) purchase fuel more frequently, and (d) maintain smaller fuel inventories than do white households. Similarly, poor households own fewer vehicles with less fuel economy, but drive them less intensively, purchase fuel more frequently, and maintain smaller fuel inventories than do nonpoor households. Elderly households also own fewer vehicles with less fuel economy. But because they drive them much less intensively, their fuel purchases are much less frequent, and their fuel inventories are larger than those of nonelderly households. Female-headed households also own fewer vehicles but with somewhat larger fuel economy. They drive them less intensively, maintain larger fuel inventories, and purchase fuel less frequently than do male-headed households.

In this paper, differences in travel and fuel purchase patterns by demographically distinct groups of households are discussed. The analysis was conducted as part of an ongoing effort at Argonne National Laboratory (ANL) to analyze the relationship between various household attributes (primarily race and income) and transportation fuel use and expenditures. A number of racial differences in vehicle ownership and use have been found previously *(1, 2)*, particularly among low-income households living in central cities of metropolitan areas. Minority and poor households may respond differently to changes in fuel price and availability, either because of earlier investments in energy-intensive capital equipment or reduced flexibility to adjust household expenditure patterns [*1, 2*, and as described by S. J. LaBelle et al. (unpublished)].

DATA

The Residential Energy Consumption Survey (RECS) Household Transportation Panel (TP) (Energy Information Administration public use tape, U.S. Department of Energy) *(3)* was the principal data source used in this effort. The TP data set contains detailed fuel purchase, demographic, and socioeconomic information for a monthly sample of approximately 1,000 households that used vehicles for personal transportation, along with weighting factors for expanding the estimates to national monthly totals (e.g., gallons purchased, fuel expenditures, and miles traveled). Each month's panel was a representative national sample selected from the 48 contiguous states and the District of Columbia. Obtained by monthly logs, purchase data included total cost and quantity of each fuel purchase, price per gallon, the vehicle's fuel gauge reading before and after purchase, the odometer reading, and type of fuel. Demographic and socioeconomic data included income, size, and residence location of household, and race or Spanish origin, age, and sex of the household head. (Because Spanish origin was coded on only about one-third of the records, it was not used in the analysis reported in this paper.) The weights accounted for sampling, household nonresponse, and, in some cases, partial purchase data, as determined by an edit check. The data were collected over the 28-month period from June 1979 through September 1981.

DATA STRUCTURE

The TP public use tape has a four-level hierarchy: (a) all records for a given survey month, (b) household records (all records pertaining to a given household participating in the panel during that month), (c) vehicle records (all records pertaining to a vehicle used in that month), and (d) purchase records (all records pertaining to each fuel purchase). The household record is particularly rich. In addition to variables describing the household's demographic, social, and economic attributes, it includes responses to several qualitative questions on the 1979 fuel shortage.

Because the SAS software does not support hierarchical data structures, data restructuring was necessary. Restructuring involved four operations:

1. Creating classifying variables. On the basis of data in the household record, a set of binary classifying variables was created. The full list of classifying variables follows. It includes Shortage (identifying the most acute portion of the 1979 shortage), Short (marking those households claiming some problem in obtaining fuel), and numerous demographic variables.

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Classifying Variable	*Definition*
Black	Household head is black.
Other race	Household head is neither white nor black.
Poor	Household income <125 percent of poverty level.
Elderly	Household head >64 years old.
Female head	Household is headed by a female.
Suburbs	Household resides in standard metropolitan statistical area (SMSA) outside the central city.
Rural	Household resides outside an SMSA.
Short	Household reported that obtaining fuel was a problem.
Shortage	Reporting month is June or July 1979, the period when most purchase difficulties occurred.
RegNE	Household resides in Northeast census region.
RegS	Household resides in South census region.
RegW	Household resides in West census region.
PXYZZ	Reporting month is between *x* and *y* (inclusive) in the year *zz*. P101280 is 1 if reporting month is October, November, or December 1980.
Winter	Reporting month is December, January, or February.
Summer	Reporting month is June, July, or August.
First	Vehicle is the first listed for the household.

2. Data merging. The classifying variables were posted on the corresponding vehicle and purchase records.

3. Stage 1 aggregation. Vehicle and purchase records were aggregated one level upward (i.e., vehicle record data were summarized to create one household record describing all household vehicles; purchase record data were aggregated to create one vehicle record describing all fuel purchased for that vehicle).

4. Stage 2 aggregation. All data describing one stratum (i.e., one month, or one group of households defined by the classifying variables) were aggregated into a single, representative record.

Depending on which level of aggregation is used to summarize a particular variable, degrees of freedom (*df*) and R^2 can vary substantially. When the analysis is performed on Stage 1 data (with much inherent sampling variability), it is not surprising that the model tends to yield a relatively low R^2, that is, it explains only that part of the variability attributable to the independent variables. Because identification of the effects of specific factors is of primary concern, the model's R^2 is far less relevant than the F statistics associated with each of the factors. These tend to be highly significant.

Much of the analysis was performed on the fully aggregated data. Because of its relatively small size, the aggregated data set is convenient to work with and can be downloaded to a personal computer. At the same time, it contains all the information relevant for analysis and produces the same results as the disaggregated data set.

METHODOLOGY

Multiple classification analysis (MCA) was the major analytical tool used in this project. MCA quantifies the effect of class or index-type independent variables on a particular dependent variable by estimating the mean deviation of any particular class from a base or standard case.

Mechanically, MCA can be implemented with either multiple linear regression (with binary or dummy independent variables) or analysis of variance (ANOVA) procedures. (MCA is described in some detail by Nie et al. *(4)* under ANOVA.) In this application, MCA permitted testing of various hypotheses on the effect of such factors as race, sex, and age of household head, poverty status, residence location, and the fuel shortage on driving and fuel purchase behavior. Although standard behavior was defined somewhat differently for each dependent variable, it generally corresponded to the mean value observed for a vehicle in a household headed by a nonpoor, nonelderly, white male who lived in the central city of an SMSA and reported no fuel purchase problems. For variables strongly influenced by (a) weather, (b) time, or (c) the availability of more than one household vehicle, the standard was further constrained. These constraints were (a) spring or autumn months, (b) the last quarter year in the data set (i.e., July through September 1981), or (c) multivehicle households, respectively.

MCA is especially powerful in finding the pure effects of individual factors, after discounting the effects of other factors in the model. For example, because the percentage of poor black households is greater than the percentage of poor white households, one might ask whether poverty is responsible for many observed differences between black and white households. The magnitude of the F statistic for the variable Black (after accounting for all other variables, including poor) shows whether this is the case.

DATA ANALYSIS

Fuel Purchases

Purchase Frequency

The effect of significant independent variables on monthly fuel purchases per vehicle is given in Table 1. In the standard case, 4.97 purchases are made per month. Elderly households have about 1.5 fewer purchases per month, whereas black households have 0.58 more purchases per month. Other factors that significantly affect purchase frequency are rural (non-SMSA residence), other race, and female head.

Variations in the percentage of fuel purchases when the vehicle tank is filled to capacity are given in Table 2. In the standard case, the tank is filled in 66 percent of all purchases. Blacks tend to fill their vehicles' tanks about 20 percent less often. Members of other races, as well as elderly, poor, and rural residents, tend to fill their tanks more often by 11, 14, 9, and 8 percent, respectively. During June and July 1979 (shortage), an additional 12 percent of purchases ended in full tanks.

Recall that MCA gives the net effect of each variable after accounting for the effects of all other variables. Thus differences between any two population groups could vary substantially from the coefficient obtained by MCA. For example, because blacks have a higher proportion of poor and single-vehicle households and a lower proportion of elderly households, the total difference between whites and blacks is greater than the value given in Table 2. In MCA, the high F statistic associated with the variable Black indicates that race explains more of the variability in the data than other variables such as poverty, residence location, vehicle ownership, and so forth. If it is assumed that most of the significant variables have been

TABLE 1 EFFECT OF INDEPENDENT VARIABLES ON MONTHLY FUEL PURCHASES PER VEHICLE, COMPARED WITH STANDARD CASE

Variable	B (fuel purchases per mo)	Std. Error	F	Prob>F
Intercept	4.97	-	-	-
Black	0.58	0.14	16.86	0.0001
Other Race	-0.54	0.23	5.66	0.0175
Poor	0.20	0.13	2.36	0.1250
Elderly	-1.50	0.13	139.91	0.0001
Rural	-0.42	0.13	10.25	0.0014
Winter	-0.25	0.16	2.54	0.1108
Summer	0.24	0.14	2.84	0.0918
Female Head	-0.29	0.13	5.27	0.0218
Short	0.68	0.34	3.97	0.0466

Standard case (4.97 purchases per month) = monthly purchases per vehicle in a household headed by a nonelderly, nonpoor white male who lives in the central city of an SMSA and does not report fuel purchase problems.

Note: R^2 = 0.10 (df = 1916); F_{tot} = 23.29 (<0.0001).

TABLE 2 EFFECT OF INDEPENDENT VARIABLES ON PERCENTAGE OF PURCHASES WITH COMPLETE FILL-UP, COMPARED WITH STANDARD CASE

Variable	B (% of fill-ups)	Std. Error	F	Prob>F
Intercept	65.66	-	-	-
Black	-19.63	1.70	132.17	0.0001
Other Race	10.73	2.54	17.79	0.0001
Poor	-8.42	1.50	31.39	0.0001
Elderly	14.15	1.45	94.04	0.0001
Rural	-7.82	1.49	27.37	0.0001
Shortage	11.74	2.60	20.42	0.0001
Short	4.02	3.85	1.09	0.2966
First	-5.42	1.39	15.14	0.0001

Standard case (65.66% of purchases) - percentage of purchases with complete fill-up in a multivehicle household headed by a nonelderly, nonpoor white male who lives in the central city of an SMSA and does not report fuel purchase problems.

Note: R^2 = 0.10 (df = 1916); F_{tot} = 23.29 (<0.0001).

included, the data suggest that blacks, because of their special attributes and circumstances (e.g., social effects, access to wealth and capital, fixed investments, and expenditure patterns), behave differently from nonblacks.

The data also suggest interesting differences between actual versus perceived effects of the shortage. In the model, short identifies households that report some fuel supply problem, and shortage identifies purchases made during the most acute shortage period. The analysis shows that shortage is a much more powerful predictor of tank topping (i.e., it has a much higher *F* statistic), suggesting that fuel purchase behavior was affected more by news reports and rumors about the shortage than by individual households' actually experiencing purchase difficulties.

Stability of Fuel-Type Purchases

It can be hypothesized that in a free market without supply problems, drivers purchase a single grade (i.e., premium or regular octane) and type (leaded or unleaded) of fuel, the selection of which is based primarily on the manufacturer's recommendation and price, possibly slightly modified by individual preferences. Hence variability in the type or grade of fuel purchased could indicate supply interruptions that limited motorists' choices.

To test this hypothesis, purchase records were sorted into single versus multiple types or grades purchased for the same vehicle during the survey month. The types that were bought and the extent of type or grade switches were not of concern. The frequency with which more than one fuel type or grade was used during the same month was examined. Results showed that a single grade was used in more than 99 percent of the vehicles surveyed; a single type was used in more than 99.5 percent. Fuel shortages had no effect on misfueling or any other variability in fuel type and grade purchases.

Fuel Inventory

Fuel inventories provide additional insight into fuel purchase behavior, as well as important indicators of the relative ability of particular population groups to deal with a sudden shortage. Four measures of fuel inventory were examined in this study: average inventory (the weighted average volume of fuel in the vehicle tank at any moment, expressed as a percentage of tank capacity), minimum inventory (the average volume just before refueling, also expressed as a percentage of capacity), average range (the number of miles that can be driven on the average inventory), and minimum range (the number of miles that can be driven on the minimum inventory).

Average and Minimum Inventories

In the standard case, the vehicle tank is filled to 58.5 percent of capacity on average, declining to 30.3 percent of capacity at minimum. During the TP survey, the data show a slight trend for inventories to decline with time. This decrease can be attributed to the end of the 1979 shortage, which reduced public apprehension about fuel supplies and hence should have prompted a return to normal fuel purchase habits. At least a portion of the decline can be attributed to the recession and rising fuel prices that reduced both ready cash for fuel purchases and the amount of fuel obtained for a given outlay.

Table 3 shows that the variable Elderly—followed by Other Race and the Shortage period itself—increases both average and minimum inventories. Black—followed by Poor, Rural, and First—significantly decreases inventories. Again, Black and Elderly have the highest coefficients in the model.

Fuel Inventory Expressed as Available Range

Available range (i.e., percentage of tank filled × tank capacity × mpg) represents both a safety factor against sudden fuel supply interruptions and the extent of required changes in behavior (i.e., having to build up large inventories) that might accompany the expectation of a shortage. Figure 1 shows the average range calculated from average inventory and minimum range calculated from minimum inventory of vehicles in black and white households. Several trends are clear. First, whites have much longer ranges than blacks—about 125 mi on average with a minimum of about 45 mi, versus 75 mi on average with a minimum of only about 20 mi. Because blacks and whites purchase about the same average quantity of fuel (~11 gal) the difference is attributable to both the inventory variation and racial differences in the fuel economy and tank capacity of household vehicles (Figure 2). Fuel economy is also responsible for the clear seasonality shown in Figure 1. Average inventories exhibit virtually no monthly variability.

Fuel Economy

As presented in Table 4, fuel economy for the standard case is 14.5 mpg. Winter (−0.91), Black (−1.25), Elderly (−0.75), and Poor (−0.95) all affect fuel economy negatively. Only female head (+0.70) and those variables associated with relatively less traffic congestion (i.e., rural and suburbs) increase fuel economy (by 0.49 and 0.65 mpg, respectively).

A likely explanation for the lower fuel economy of vehicles owned by black, poor, and elderly households lies in average vehicle age. As was shown by Millar et al. *(1)*, these groups tend to own vehicles that predate the fuel economy improvements achieved since the late 1970s. Figure 2 shows a comparison of the average fuel economy of vehicles in black versus

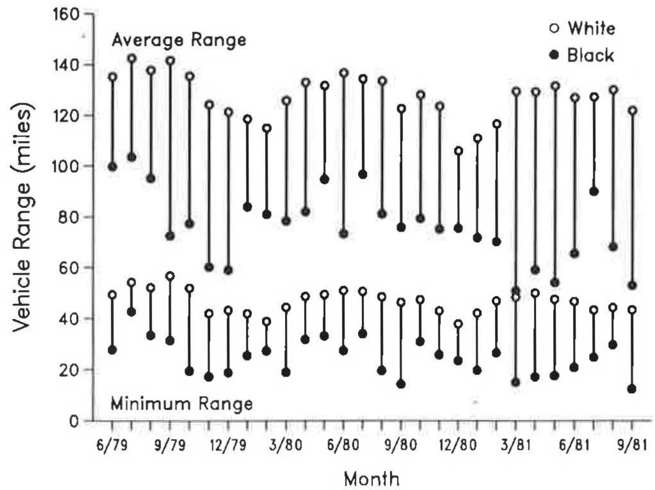

FIGURE 1 Available vehicle range on average and minimum volumes of fuel in vehicle tank, by Black and White households.

TABLE 3 EFFECT OF INDEPENDENT VARIABLES ON FUEL INVENTORY, EXPRESSED IN PERCENTAGE OF TANK CAPACITY, COMPARED WITH STANDARD CASE

	Average Inventory				Minimum Inventory			
Variable	B (% tank capacity)	Std. Error	F	Prob>F	B (% tank capacity)	Std. Error	F	Prob>F
Intercept	58.53	-	-	-	-	30.26	-	-
Black	-6.77	0.75	80.59	0.0001	-2.84	0.63	20.11	0.0001
Other Race	5.35	1.12	22.70	0.0001	2.69	0.93	8.34	0.0039
Poor	-3.47	0.65	28.45	0.0001	-2.07	0.54	14.60	0.0001
Elderly	8.51	0.63	181.82	0.0001	8.89	0.52	285.10	0.0001
Rural	-3.15	0.64	23.81	0.0001	-1.07	0.60	3.10	0.0785
Winter	-0.60	0.77	·0.61	0.4339	1.99	0.62	10.24	0.0014
Summer	-0.71	0.73	0.95	0.3295	0.69	0.58	1.43	0.2318
Shortage	4.37	1.23	12.64	0.0004	4.98	1.01	24.31	0.0001
Female Head	1.89	0.62	9.18	0.0025	1.50	0.52	8.25	0.0041
Short	2.29	1.68	1.85	0.1740	-	-	-	-
First	-2.90	0.60	23.31	0.0001	-2.33	0.50	21.10	0.0001

Standard case (58.53% of tank capacity filled on average; 30.26% at minimum) = percentage of vehicle tank filled during spring and autumn months in a multivehicle household headed by a nonelderly, nonpoor white male who lives in the central city of an SMSA and does not report fuel purchase problems.

Note: For average inventory, R^2 = 0.20 (df = 1655); F_{tot} = 38.63 (<0.0001).
For minimum inventory, R^2 = 0.20 (df = 1712); F_{tot} = 42.8 (<0.0001).

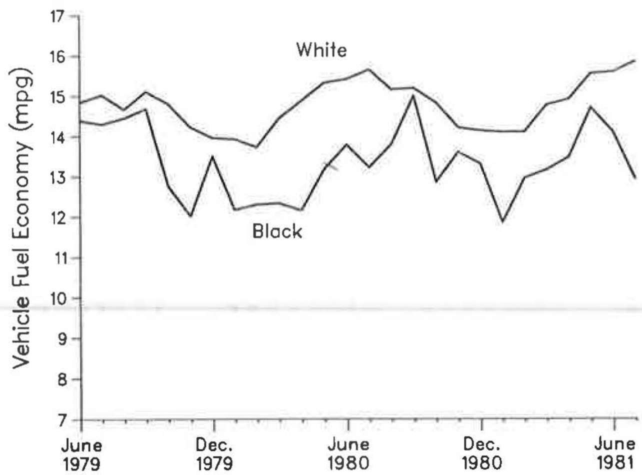

FIGURE 2 Fuel economy of vehicles in Black and White households.

TABLE 4 EFFECT OF INDEPENDENT VARIABLES ON AVERAGE FUEL ECONOMY, COMPARED WITH STANDARD CASE

Variable	B (mpg)	Std. Error	F	Prob>F
Intercept	14.53	-	-	-
Black	-1.25	0.14	75.25	0.0001
Other Race	0.83	0.31	7.15	0.0075
Poor	-0.95	0.13	52.73	0.0001
Elderly	-0.75	0.09	68.82	0.0001
Suburbs	0.65	0.09	52.48	0.0001
Rural	0.49	0.09	27.89	0.0001
Winter	-0.91	0.09	107.28	0.0001
Summer	0.56	0.08	47.30	0.0001
Shortage	-0.46	0.14	10.71	0.0011
Female Head	0.71	0.11	43.11	0.0001

Standard case (14.53 mpg) = average fuel economy (in mpg) during spring and autumn for vehicles in a household headed by a nonpoor, nonelderly white male who lives in the central city of an SMSA.

Note: R^2 = 0.032 (df = 16841);
F_{tot} = 62.25 (<0.0001).

white households. The consistently lower fuel economy of blacks is the cumulative result of all variables contained in Table 4 (as well as other unmeasured variables).

Vehicle Ownership and Use

Tables 5–7 present MCA results that relate rates of vehicle ownership and use to household characteristics. The standard vehicle-owning household owns 1.76 vehicles. The most significant variables that reduce this rate are female head (–0.45), elderly (–0.30), and poor (–0.23). Race has a lower (though significant) effect, decreasing vehicle ownership by 0.18 in

TABLE 5 EFFECT OF INDEPENDENT VARIABLES ON OWNERSHIP RATES OF VEHICLE-OWNING HOUSEHOLDS, COMPARED WITH STANDARD CASE

Variable	B (vehicles per household)	Std. Error	F	Prob>F
Intercept	1.76	-	-	-
Black	-0.18	0.02	56.28	0.0001
Other Race	-0.04	0.05	0.55	0.4578
Poor	-0.23	0.02	130.52	0.0001
Elderly	-0.30	0.01	496.15	0.0001
Suburbs	0.20	0.02	174.45	0.0001
Rural	0.24	0.02	246.18	0.0001
Winter	-0.04	0.02	5.89	0.0154
Summer	-0.02	0.01	1.96	0.1615
Shortage	0.15	0.08	3.87	0.0495
Female Head	-0.45	0.02	843.47	0.0001
P6979	-0.06	0.02	12.29	0.0005
P101279	-0.04	0.02	4.56	0.0330
P1380	-0.05	0.02	6.23	0.0127
P4680	-0.03	0.02	1.63	0.2027

Standard case (1.76 vehicles per household) = vehicle ownership rate during summer 1981 in a household headed by a nonpoor, nonelderly white male who lives in the central city of an SMSA.

The number of vehicles is computed using weights in the vehicle data file (after removing vehicles not used during the survey month), while the number of households is computed from the household file. If vehicles had been computed from the household file, average ownership would be higher by about 0.1, although relationships would remain the same.

Note: R^2 = 0.685 (df = 1144);
F_{tot} = 177.4 (<0.0001).

black households. Rural and suburban residences increase ownership by 0.24 and 0.195, respectively. A slightly increasing temporal trend in vehicle ownership is given in Table 5. Over the TP data collection period, average ownership increased by 0.06 vehicles per household (about 1.7 percent annual growth).

According to the MCA results, monthly mileage per vehicle (768 mi in the standard case) and per household (1,400 mi in the standard case) is higher for households residing outside a central city and sharply lower for poor, elderly, or female-headed households (Tables 6 and 7). Mileage also exhibits a regular seasonal pattern, as well as a clear sensitivity to fuel price changes. That sensitivity may be seen in the sign and magnitude of the coefficients for those months (variables in the form PXYZZ) in which prices increased most sharply.

Note that each of the variables has a somewhat different effect on vehicle ownership and travel. Elderly or female-headed households and poverty reduce both ownership and travel, while non–central-city residence increases both ownership and travel. The variable black has a smaller, mixed effect:

TABLE 6 EFFECT OF INDEPENDENT VARIABLES ON MONTHLY MILES PER VEHICLE, COMPARED WITH STANDARD CASE

Variable	B (miles per month)	Std. Error	F	Prob>F
Intercept	768.2	-	-	-
Black	57.3	15.7	13.28	0.0003
Poor	-44.9	13.3	11.37	0.0007
Elderly	-261.7	8.4	953.18	0.0001
Suburbs	77.6	9.1	72.36	0.0001
Rural	86.6	9.4	84.66	0.0001
Winter	-47.0	9.0	26.98	0.0001
Summer	70.5	7.9	79.40	0.0001
Female Head	-51.1	10.5	23.52	0.0001

Standard case (768.2 miles per vehicle = average monthly miles during spring and autumn by a vehicle in a household headed by a nonpoor, nonelderly white male who lives in the central city of an SMSA.

Note: R^2 = 0.076 (df = 16871); F_{tot} = 172.89 (<0.0001).

slightly fewer vehicles and miles per household, but slightly more miles per vehicle.

Fuel Expenditures

The data in Table 8 describe monthly household fuel expenditures. In the standard case, a household spent $124.19/month on transportation fuel, discounting the effects of all other variables. Temporal effects, primarily inflation and price increases (see variables of the form PXYZZ), increased expenditures by $39.42/month compared with summer 1979. In addition to price, the major variables associated with expenditure differences are elderly (–$44.65) or female head (–$36.28), and rural (+$21.78) or suburbs (+$18.03). For each of these household groups, expenditure differences represent the net result of differences in vehicle ownership, fuel economy, vehicle utilization, and fuel price.

DISCUSSION

Vehicle Fuel Economy

Lower fuel economy is the major factor responsible for observed differences in fuel consumption and tank-filling behavior between the standard case and either black or poor

TABLE 7 EFFECT OF INDEPENDENT VARIABLES ON MONTHLY VEHICLE MILES PER HOUSEHOLD, COMPARED WITH STANDARD CASE

Variable	B (vehicle-miles per household)	Std. Error	F	Prob>F
Intercept	1399.9			
Black	-61.1	31.3	3.81	0.0513
Poor	-219.9	25.9	71.81	0.0001
Elderly	-627.1	17.4	1290.86	0.0001
Suburbs	276.6	19.3	205.83	0.0001
Rural	327.2	20.0	268.64	0.0001
Winter	-91.7	23.6	15.09	0.0001
Summer	107.6	19.3	31.05	0.0001
Short	309.1	102.3	9.14	0.0026
Female Head	-414.4	20.3	417.13	0.0001
P6979	-98.2	26.5	13.73	0.0002
P1380	-104.9	28.8	13.28	0.0003
P4680	-106.9	27.1	15.54	0.0001
P7980	-56.7	28.1	4.05	0.0443
P1381	-113.4	28.6	15.75	0.0001
P4681	-54.9	26.9	4.16	0.0417

Standard case (1399.9 vehicle-miles monthly per household) = average monthly vehicle-miles during summer 1981 in a vehicle-owning household headed by a nonpoor, nonelderly white male who lives in the central city of an SMSA.

Note: R^2 = 0.708 (df = 1650); F_{tot} = 184.92 (<0.0001).

TABLE 8 EFFECT OF INDEPENDENT VARIABLES ON MONTHLY HOUSEHOLD FUEL EXPENDITURES, COMPARED WITH STANDARD CASE

Variable	B (fuel expenditures, $ per month)	Std. Error	F	Prob>F
Intercept	124.19	-	-	-
Black	4.84	2.54	3.62	0.0572
Other Race	-6.96	5.59	1.55	0.2137
Poor	-12.23	2.10	33.78	0.0001
Elderly	-44.64	1.41	993.54	0.0001
Suburbs	18.03	1.56	132.88	0.0001
Rural	21.78	1.62	180.56	0.0001
Winter	-4.24	1.97	4.61	0.0321
Summer	5.53	1.74	10.05	0.0016
Short	21.52	8.29	6.73	0.0096
Female Head	-36.28	1.64	486.69	0.0001
P6979	-39.42	2.47	253.22	0.0001
P101279	-24.16	2.95	66.91	0.0001
P1380	-17.19	2.16	29.55	0.0001
P4680	-17.52	2.68	42.46	0.0001
P7980	-13.93	2.62	28.23	0.0001
P101280	-7.69	2.94	6.84	0.0090
P1381	-7.41	3.15	5.53	0.0188
P4681	-4.51	2.67	2.85	0.0918

Standard case ($124.19 per month = average monthly expenditures during summer 1981 in a household headed by a nonpoor, nonelderly white male who lives in the central city of an SMSA.

Note: R^2 = 0.69 (df = 1139);
F_{tot} = 138.83 (<0.0001).

households. Clearly, lower fuel economy increases fuel expenditures for a given volume of travel, reduces vehicle range on a given volume of fuel, and—unless additional inventories are used to compensate for these effects—increases vulnerability to price runups and supply shortages.

Presumably, the tendency of poor households to own vehicles with lower fuel economy is a direct reflection of (a) the dynamics of the secondary market and (b) the lead time needed for vehicles with improved fuel economy to pass into the low-cost segment of that market:

1. Until fairly recently, fuel prices were either increasing or expected to increase, and older—generally less fuel-efficient—vehicles retained less of their value in the secondary market. In terms of first cost, these vehicles became increasingly affordable to households with limited means; in terms of variable cost, they became increasingly expensive to operate.
2. Between 1976 and 1984, as newer and more fuel-efficient vehicles came to account for a larger share of the automotive fleet, average fuel economy increased by nearly 25 percent *(5, 6)*. However, because buyers of new and late-model used cars tend to be concentrated in the more affluent population, most fuel economy improvements were confined to those segments, and little, if any, improvement occurred in the fleet operated by lower-income households. By September 1981, the last month of TP data collection, more fuel-efficient vehicles had not yet trickled down to lower income households. Not until quite recently (Millar, 1986, unpublished data) could the fuel economy gains achieved in late-model vehicles be discerned in the gasoline expenditure patterns of lower-income households.

Elderly and black groups also tend to own vehicles with substantially lower fuel economy. Among the elderly, low fuel economy is probably a function of preference and usage patterns. Market research has repeatedly shown that elderly households prefer larger, more comfortable vehicles and are more likely to own domestic makes *(7–9)*. Further, given their shorter daily travel distances, a substantial portion of their travel is likely to be under cold-start conditions, with a consequent loss in fuel economy. Low fuel economy among black households is less readily explained but is probably attributable to income. Because the only income variable is poor or nonpoor, Black may be picking up an income effect. Further, because of racial differences in the yearly fluctuation or dynamics of income *(1, 2)* among poor households, Black may be explaining some of the variability within Poor.

Risk-Taking and Fuel Purchase Behavior

It can be hypothesized that under normal (i.e., nonshortage) conditions, motorists' fill-up rates, fuel inventories, and refueling frequencies reflect their general attitude toward risk, perhaps modified by such external factors as available cash (or credit) and their amount and type of driving. Thus the much higher fill-up percentages and fuel inventories, in combination with much less frequent fuel purchases, suggest that elderly households tend to be risk-averse, perhaps because of physical limitations that increase the difficulty associated with running out of fuel. Conversely, the much lower fill-up percentages and fuel inventories, in combination with more frequent fuel purchases, suggest that black households tend to be risk-prone.

To test this hypothesis, the average volume of fuel per purchase for black and elderly households was calculated and compared with the average volume for the standard case. If elderly households are indeed risk-averse and black households are risk-prone, the elderly should purchase fuel in equal or larger quantities than the standard case, whereas blacks should purchase it in equal or smaller quantities. The results showed virtually no difference in average purchase quantity for elderly and standard households (10.5 versus 10.6 gal), and somewhat higher volumes (11.2 gal) for black households. Thus the hypothesis that fuel inventories and purchase frequency reflect fundamental differences in risk-taking is not supported for black households, and it is neither confirmed nor denied for elderly households.

Among black households, observed differences in fuel inventories, purchase frequencies, and fill-up rates are more likely related to household expenditure patterns, tank capacity, and fuel economy. The purchase quantities noted translate into an average outlay of approximately $14 to $15 per purchase. Many of those transactions are 10-gal or $10 purchases, either reflecting long-standing habits or household budget constraints. At the same time, differences in average vehicle age and size (hence, tank capacity) reported by Millar et al. *(1, 2)* suggest that black households would have to purchase larger quantities of fuel to maintain standard inventories measured as a percentage of tank capacity. Conceivably, the combination of larger tanks and habit- or budget-constrained purchase quantities accounts for the lower inventories and fill-up rates, as well as the more frequent purchases by black households. Along with lower fuel economy, these differences in turn produce lower available range and fewer inventory days (i.e., 2.7 driving days for the average inventory versus approximately 5 for the standard case).

Among elderly households, differences in fuel inventories, purchase frequencies, and fill-up rates are complicated by vehicle utilization rates only two-thirds those of the standard case. Purchase frequencies 30 percent below the standard are consistent with these extremely low utilization rates. Although purchase habits (e.g., weekly, fixed-dollar, or fixed-quantity) probably account for some of the difference in fuel inventories and fill-up rates, extremely high minimum inventories (tank is nearly 40 percent full just before refueling) suggest that risk aversion is also a factor.

SUMMARY AND CONCLUSIONS

Results of the MCA models may be synthesized into a general description of the vehicle ownership, travel, and fuel purchase tendencies of population groups defined by the independent variables (i.e., household attributes) that enter the models. Recall that MCA isolates the contribution of each attribute in explaining the difference between all households with that attribute and a standard case. The resulting, single-attribute-defined population group is more homogeneous than the actual population of such households, and because the influence of covariant attributes has been removed, it highlights attribute-linked tendencies. For example, low vehicle ownership in female-headed households is usually attributed to a combination of gender, poverty, and race [because 47 percent of the families below the poverty line in 1983 were headed by women, 43 percent of whom were black *(10)*]. By breaking out the influence of each of those factors, MCA shows that having a female head has a greater impact on ownership rates among vehicle-owning households—almost twice that of poverty alone and approximately 2.5 times that of race alone. Quite likely, Female head is a surrogate for a combination of low income and few licensed drivers.

The MCA results displayed in Tables 1–8 may be summarized in the following general descriptions of vehicle ownership, travel, and fuel purchase tendencies by vehicle-owning households with the following attributes:

1. Black households tend to own fewer vehicles with much lower fuel economy, to use them somewhat more intensively, and to purchase fuel more frequently than do standard households. Although they purchase fuel in approximately equal quantities, they maintain much lower fuel inventories than do standard households.
2. Poor households also tend to (a) own far fewer vehicles with much lower fuel economy, (b) purchase fuel more frequently, and (c) maintain lower fuel inventories than do standard households. However, unlike black households, members of poor households use their vehicles less intensively.
3. Elderly households are unique among the attribute-defined groups. Although they, too, tend to own far fewer vehicles with much lower fuel economy, they drive them much less intensively. Thus they refuel much less frequently and maintain much higher fuel inventories than do standard households.
4. Female-headed households also own far fewer vehicles but with higher fuel economy. They drive them less intensively, maintain higher fuel inventories, and purchase fuel somewhat less frequently than do standard households.

These attribute-linked tendencies may be plotted for various pairs of dependent variables for which an expected behavior pattern can be hypothesized. Figures 3–5 show three such scatter diagrams in which the origin represents the standard case. Single-attribute-defined groups are represented by their deviation from the standard along each of the two dimensions.

As shown in Figure 3, fuel economy tends to be inversely associated with purchase frequency. Although all of the groups diverge substantially from the standard, most do so in the expected direction. The key exception, the elderly, drive their vehicles much less than the standard. If corrected for vehicle utilization, the Elderly data point would shift to the vertical axis, close to the Poor data point.

Figure 4 shows the positive relationship between average inventories and fill-up rate. All groups diverge substantially

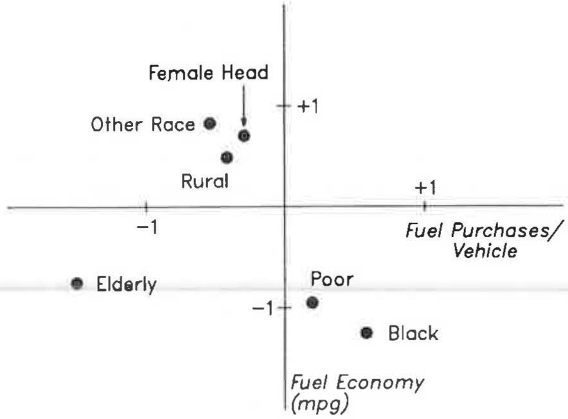

FIGURE 3 Relationship between variations in fuel purchase frequency and fuel economy, by population group.

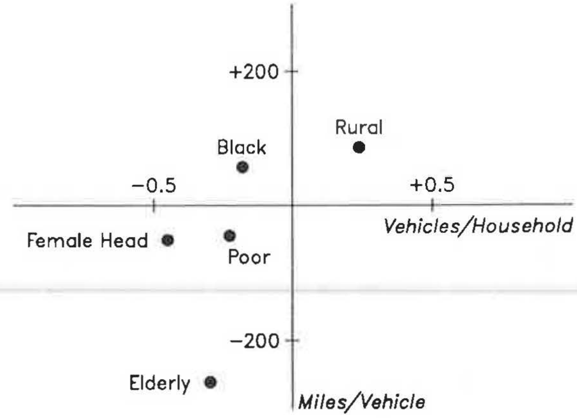

FIGURE 5 Relationship between variations in ownership rate and vehicle utilization, by population group.

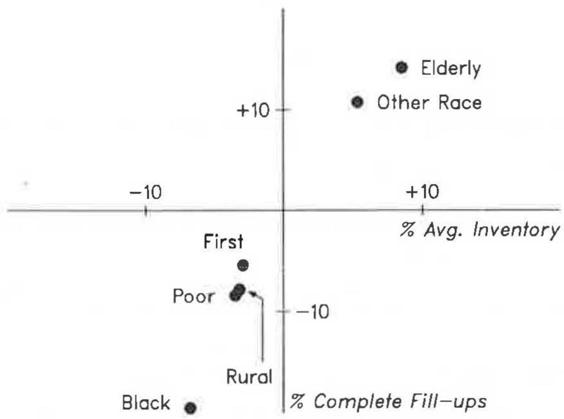

FIGURE 4 Relationship between variations in inventory level and fill-up rate, by population group.

from the standard case, but in the expected direction. Black and elderly groups diverge the most. Because there is no true income variable, Black may be capturing part of the income effect.

Figure 5 shows no clear association between vehicle ownership and utilization, primarily because of intervening factors such as household size (or number of drivers), life-style, and income. Black households are the only group whose position is as expected, but this may be the result of countervailing factors (e.g., income, household size, and life-style). Rural households drive more—because of longer distances, larger household sizes, and more dispersed travel opportunities—whereas elderly households drive less, primarily because of smaller household sizes and fewer travel needs. Poor and female-headed households also tend to drive less than the standard case, a finding that may be interpreted as fewer drivers per household, less income, life-style, and fewer travel needs (if there are fewer workers per household).

Some of the unexplained divergence apparent in Figures 3–5 may arise from limitations of the analysis, particularly from the omission of significant dependent variables. Although predictive ability has not been a focus of this effort, improvements in that regard are a logical direction for further research. As shown, overall rates of household vehicle ownership, travel, and fuel expenditures are fairly well predicted by household demographic characteristics that reflect underlying travel needs. However, variables that are more vehicle-dependent (e.g., fuel economy, vehicle utilization, fuel purchase rates, and fuel inventories) are not so well predicted by demographic factors. These variables are either dependent on vehicle attributes not considered in this effort or have so much internal variance (even within the same household) that a host of additional household- and location-specific variables would be needed to improve the predictive ability of the models.

As a next step to this research, such vehicle characteristics as model year and some measure of engine size could be entered into the models. This should improve predictive ability, but vehicle condition—the basic variable that influences utilization and refueling—would remain unmeasured and thus would continue to account for substantial variance. Likewise, such factors as local weather and road conditions, unanticipated vehicle breakdowns, amount of travel in nonhousehold vehicles (e.g., vacation travel in rental cars), and household illness are not readily modeled. Hence, future research will find it difficult to increase the amount of variance explained by the models.

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