BEHAVIORAL DISTINCTIONS:

THE USE OF LIGHT-DUTY TRUCKS AND PASSENGER CARS

by

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ABSTRACT

In the United Stated, pickup trucks, sport utility vehicles (SUVs), and minivans are classified as light-duty trucks (LDTs), resulting in a variety of regulatory protections. Production and purchase trends suggest that Americans have shifted toward significantly higher use of such vehicles for personal travel. Using the 1995 NPTS data set, this research explores the subtle differences in ownership and use patterns between LDTs and passenger cars. Based on a variety of model specifications and response variables, the results suggest that the average LDT is used over longer distances with more people aboard and is purchased by wealthier households living in less dense neighborhoods. Pickups tend to be driven by males, be owned by smaller households, and carry fewer persons. There is no indication that SUVs or minivans serve additional work purposes for American households; however, their occupancies and total annual mileages are higher than those of passenger cars, and SUVs are relatively popular for weekend travel.

KEY WORDS

light-duty trucks, personal travel, vehicle use, car ownership, sport utility vehicles

INTRODUCTION AND MOTIVATION

Before purchasing a vehicle today, many American households seriously consider pickups, minivans, sport utility vehicles (SUVs), and passenger cars. These first three vehicle types are classified as light-duty trucks (LDTs), and they currently capture 51% of new U.S. passenger vehicle sales[1] – much more than their 9.8% share in 1972 (Federal Register 64 [82]). Due to differences in federal regulation of passenger cars and LDTs, this shift in ownership and use is marked by reductions in fleetwide fuel economy, relative increases in pollutant emissions, and changes in crash frequency and severity. Ideally, regulatory differences across vehicle manufacturers and vehicle types should counterbalance differences in consumption externalities (both positive and negative). If regulations favor goods that do not provide external benefits, markets are likely to be inefficient (see, e.g., Varian [1992]). To shed some light on differences in household use of various vehicle types, this paper analyzes the 1995 National Personal Travel Survey data.

When the Corporate Average Fuel Economy legislation was introduced in the early 1970s, the argument for distinct classification was that light-duty[2] pickups and cargo vans were almost exclusively used as work vehicles, hauling cargo, rather than for personal travel. At that time, Economic Censuses suggested about 50% of U.S. trucks under 10,000 lbs. of gross vehicle weight were used primarily for personal transportation; this figure is 75% today. (USDOC 1999) Also at that time, manufacturers specializing in light trucks and vans argued they would not be able to meet the standards being set for passenger cars (which required an average fuel economy of 27.5 mpg in 1985 and beyond), due to differences in body and engine types. These arguments prevailed, and LDTs were subjected to a significantly lower standard (20.7 mpg).[3] For reasons also largely related to body and engine differences, LDTs enjoy higher emissions caps[4] and do not endure luxury-goods or gas-guzzler taxes; pickups also enjoy substantial import-tax protection.

On the basis of structural similarities (particularly in early models), minivans and sport utility vehicles (SUVs) also were classified as LDTs, rather than as passenger cars. As these vehicles become more prevalent for personal travel, policy makers should question whether they also deserve regulatory protections. Analysis of household purchase and use patterns can suggest whether certain differences exist. By employing the 1995 National Personal Travel Survey data, this research estimates a variety of models which illuminate these behaviors and identify any behavioral distinctions. And, in identifying such distinctions, this research aims to educate policy makers and others on American travel habits across vehicle types so that related policies can be tailored most appropriately. Towards this end, models, data, and results are presented in the following sections.

DATA SET, MODELS USED, AND RESULTS

The data come from the 1995 National Personal Transportation Survey (NPTS), which offer travel-behavior information for a broad cross-section of roughly 42,000 American households, with members of at least five years of age recording all trips on a single day. The specific NPTS data incorporated here as explanatory and response variables are shown in Table 1. Unfortunately, due to non-reporting of variables like annual income and VMT, many records were not complete. However, comparisons of variable distributions before and after record removal suggests that there are no significant distinctions in the full and culled samples. Thus, only complete records were used in the analysis of the various models presented here. These models estimate VMT per vehicle, number of person trips per vehicle, vehicle occupancy, vehicle choice for trip-making, and vehicle ownership. Several statistical specifications are used, in order to most appropriately model the different response variables. All model specifications are described here now, followed by their numeric results.

Models of Vehicle Miles Traveled

Using household estimates of annual vehicle miles traveled (VMT) for each vehicle owned, two weighted least squares (WLS) models of VMT were developed; one groups all LDTs together, in a single class, while the second permits distinct VMT effects for each of the LDT vehicle types. Everything else constant, additional household members add driving distance to individual vehicles, so the variance associated with VMT is expected to rise with household size. Thus, the weights used in these models are the inverse of household size. Finally, only complete vehicle records were used, requiring removal of 42 percent of the records on the basis of no VMT information.

The results are shown in Table 2, which suggests that all parameter estimates differ from zero in a highly statistically significant way (evidenced by negligible p-values). As expected, newer vehicles driven by wealthier households residing in less population-dense neighborhoods appear to be driven longer distances. And, as the number of household members per vehicle owned by the household increases, a vehicle's annual mileage increases. What is surprising is that after controlling for all these factors, LDTs are found to be driven substantially more than passenger cars; this is particularly true for minivans and SUVs. The additional mileage driven in an SUV, pickup, and minivan, *ceteris paribus,* is estimated to represent 9.3%, 6.5%, and 20% of a passenger car's VMT, respectively. Such figures suggest that these vehicles are more popular and/or more useful to households. Their larger carrying capacity (*e.g.*, eight passengers in many minivans and towing options for virtually all pickups) and off-road capability (in the case of many SUVs and pickups) make these vehicles more versatile. Such qualities are a large part of the reason these vehicles generally cost significantly more than passenger cars: in 1997, the average SUV, pickup, and minivan cost about 58%, 39%, and 21% more than the average passenger car sold[5]. Applying Table 2's numeric results, it appears that a doubling of population density, from its mean value of 3858 persons per square mile (6 persons per acre, or 4.9 persons per hectare) to 7716 would provoke, on average, a per-vehicle VMT drop of 590 miles. This suggests a very significant density shift, but its effect pales in comparison to the extra VMT associated with SUVs (1027 miles) and minivans (2150). Of course, one's vehicle choice is – to some extent – a function of environmental qualities like density (since, *e.g.*, it may be harder to park a larger vehicle in a denser environment), and persons seeking denser living environments may prefer to drive less (so density may be proxying for some effects of unobserved personal preferences). Thus, if LDT sales declined or densities increased, VMT is not guaranteed to fall. But a comparison of mileages – across distinct densities and vehicle types – illustrates a rather remarkable magnitude of difference. This also is apparent in the effects of the income variable: If one were to double mean incomes per household member, the effect on VMT is expected to be a rather negligible 76 miles per year per vehicle. Thus, it seems clear that LDTs are being driven substantially further, on average – even after controlling for their age (as done here).

Models of Person Trips per Vehicle

Given its non-negative integer nature, the number of person trips per vehicle in the data set was estimated using negative binomial regression models. (See, e.g., Cameron and Trivedi's [1986] discussion of such models.) This variable's mean was specified as an exponential function, so that the expected number of trips is equal to $exp(\beta' x)$. Unlike a Poisson distribution (which implies that the variance equal the mean), a negative binomial specification permits over-dispersion in observed values; its variance equals its mean times the quantity one plus a non-negative over-dispersion parameter. Log-likelihood results are shown for the assumption of a Poisson model, alongside the results for the negative binomial specification.

The results of person-trip-per-vehicle models suggest whether one vehicle type is used more than another and whether this differs by trip type. Since SUVs are heavily marketed for their off-road abilities and cargo space for long trips, one may expect to find evidence of this in the nature of their use; for example, they may be used more, particularly for trips of a recreational nature. In contrast, pickups have been portrayed as providing non-recreational, heavy-work uses, and they generally safely seat no more than three occupants (though this is changing via new four-door "car-plus-truck" models); thus, one may expect pickups to exhibit less recreational trip-making.

Originally, three person-trip models were estimated: one counts trips of all purpose types, another counts only those trips of a recreational nature, and a third counts those trips with a work purpose. The almost all parameters are estimated to differ significantly from zero in a statistical sense, the empirical results of the third, work-purpose model are not provided, because their overall predictive value is almost zero (pseudo-R^2's < 0.01). Their low predictive value is probably due to the fact that most work trips are made solo, since two U.S. workers rarely share the same (or a similar) workplace location.

Table 3 provides the estimates resulting from application of the all-purposes and recreational-purposes person-trip models. These data are based on a single-day's trip-making, which introduces a lot of random variation; and this variation is evident in a low goodness of fit (as measured by the pseduo-R^2s). While a Poisson stochastic specification superficially suggests better fit, the negative binomial specifications are statistically superior (the addition of a single parameter, the over-dispersion coefficient, increases the log-likelihood significantly).

Looking at Table 3's results, it is not surprising that newer vehicles belonging to households residing in lower-density environments and having higher incomes and more household members per vehicle owned are found to carry more person trips per day. However, recognizing that these models' mean values are characterized by exponential functions and halving density from its average value reduces person trips by just one percent; doubling incomes (per household member) from their current mean produces only a 6% change. Considering all trip types, 10% more person trips are estimated to occur on weekends (versus weekdays); this difference becomes a very significant 80% when trips are of a recreational nature.

Table 3's general distinctions among different vehicle types are not surprising: minivans carry the most person trips per day, followed by SUVs, passenger cars, and finally pickups. SUVs are estimated to carry, on average, 4.6% more person trips per day than passenger cars, while pickups average 15% fewer, and minivans average an impressive 35% more. For recreational purposes, the figures are less than one percent more for SUVs, a remarkable 25% fewer for pickups, and 36% more for minivans. When person-trip models bundling all LDTs into a single category are run, the average differences translate to 6% more person trips across all trip purposes being carried by LDTs and only 1% more for recreational purposes[6].

In summary, these results suggest that SUV and "average" LDT person-trip counts are very close to those of passenger cars. However, minivans are estimated to carry significantly more person-trips – and pickups significantly fewer. It is surprising that SUVs are not carrying more recreational person-trips, on average, than passenger cars. The 58% higher purchase price and performance distinctions of the average new SUV – relative to the average new car – are not evident in this form of use intensity.

Models of Vehicle Occupancy

Vehicle occupancy during trip-making was also studied here, using ordered probit models. (See, e.g., Greene's [1993] discussion of this model specification.) Relative to the negative binomial specifications used above (for estimation of person-trip counts), an ordered probit specification can provide some important flexibility by removing implications of cardinality. For example, it can distinguish two-person vehicle occupancy from two times single-person occupancy. Additional occupants frequently are non-driving children or others who may have very distinct motivations prompting their trip participation than the vehicle's driver; thus, we hypothesize the existence of underlying, latent variables whose thresholds (*i.e.*, cut-off points for integer occupancy values) differ only ordinally. This set-up contrasts with underlying, cardinal rates fundamental to Poisson and negative binomial specifications.

Table 4 provides the results of the trip-occupancy estimations for trips of all types and for only those trips with a recreational purpose at the destination. Without cardinality, the magnitudes of ordered probit parameters are not as easily interpreted as those of the WLS and negative binomial models; however, it is clear that trips made by lower-income households for shopping, eating-out, or other, recreational purposes tend to exhibit higher occupancies. The same is true of weekend trips made by households having more members per vehicle. In general, minivans draw the largest occupancies, followed by SUVs, cars, and, lastly, pickups.

In the all-trip-purposes model of occupancies, the minivan, eating-out, and weekend indicator variables have coefficients high enough to almost raise expected occupancy by one, while few of the other variables exert comparable effects. For example, occupancy appears to be negligibly influenced by income levels and population density: the parameter estimates suggest it would take more than a $47,000 reduction in the average income per household member or almost 90 more persons per acre (36 more per hectare) to find people occupying passenger cars to the degree they occupy minivans!

In the recreational-trip-purposes model of occupancies, the minivan indicator variable has a coefficient estimate that almost raises expected occupancy by one; weekend day and members-per-vehicle variables also exert strong effects. In contrast, recreational-trip occupancy appears to be only very slightly influenced by income levels and population density: the parameter estimates suggest it would require more than a $53,000 reduction in average income per household member to find people occupying passenger cars to the degree they occupy minivans.

It may be noted that the parameter sign on the variable of population density changes between the two trip-occupancy models: neighborhood density is associated with reduced occupancies in general (*i.e.*, across all trip types) but higher occupancies for recreational trips. In practical terms, density's effect on recreational-trips occupancy is estimated to be effectively zero, so it would appear that density does not affect that decision.

In general, these occupancy results across vehicle types are consistent with expectations and the person-trips-per-vehicle results. Minivans carry significantly more occupants per trip than do passenger cars, while pickups carry fewer. In regards to the other variables, density and income do not exert very strong effects, but day of the week, trip purpose, and number of household members per vehicle owned certainly do.

Model of Mode Choice

Another model of vehicle use emphasizes a driver's vehicle choice. When multiple vehicle types are available for trip-making, of great interest are the driver's probabilities of electing each type. Here the choices are clearly discrete; thus, a multinomial logit (MNL) specification was selected for estimation. (See, e.g., Greene's [1993] discussion of this model.) To avoid issues of correlation in unobserved components of similar vehicle types, only trip records by drivers residing in households with no more than one vehicle of each type are examined.[7] Since all explanatory variables – except that of vehicle age – are constant across driver trip records, they are interacted with indicator variables of vehicle type. In addition, a reference alternative is needed for parameter identifiability; thus, all parameter estimates are relative to choice of a passenger-car (whose parameter estimates effectively are forced to equal zero here). As a consequence, three parameters are estimated for all but the vehicle-age variable; these correspond to the three non-car vehicle types.

The results of this model's estimation are shown in Table 5, and these suggest that cars are more likely to be chosen (or assigned, depending on intra-household vehicle-use constraints) in general. Driver age plays a role for SUV use, with drivers in their late 40's most likely to be using an SUV, when other alternatives exist. The role of driver age is not practically significant, however, for minivan or pickup choice/assignment. Males are far more likely to use pickups and somewhat more likely to use SUVs, while women have a tendency to drive minivans. Employed persons have a slight tendency to favor pickups and SUVs but a stronger tendency to avoid minivans. If the trip's purpose is work-related, pickups are more likely; and, if the purpose is recreational in nature, the converse is true. In contrast, trip-purpose effects for minivans and SUVs are not statistically significant. Population density does not enjoy statistical significance, for any of the these vehicle choices, relative to passenger cars.

On weekend days, the model results suggest that an SUV is a more likely choice and a pickup somewhat less likely (though its effect is not quite significant, in neither a statistical nor a practical sense). Vehicle trips made with more occupants lead to a higher probablity of SUV and minivan choice, but lower likelihood of pickup; this result echoes the results of the occupancy models. Perhaps unexpectedly, trip length (as measured in time units reported by drivers) does not impact SUV and pickup choices but negatively impacts the likelihood of minivan choice.

Models of Vehicle Ownership

The final pair of models estimated here center on vehicle ownership. Similar to the above analysis of vehicle types chosen for specific trips, a multinomial logit model was used first. This specification was employed to predict the type of "newest vehicle owned" (as measured by model year) in a household's fleet. In addition, a set of simultaneous Poisson regression equations (for the various numbers of different vehicle types owned) was estimated. The simultaneity in this second form of ownership model results from restricting the vehicle price-over-income variable's parameter to be the same for all of the exponential equations.[8] The results of these models are shown in Tables 6 and 7.

As evident in the negative constant terms for various LDT vehicle types in both these tables, passenger cars are relatively favored, on average. However, current total sales figures indicate that LDTs as a class are catching up and starting to surpass passenger car sales. Moreover, some LDTs are held longer by households than are passenger cars, suggesting that household vehicle holdings may differ substantially in the coming years.[9] And, as results reported above suggest, LDTs are driven significantly more miles each year and minivans serve substantially more person-trips than passenger cars. Therefore, LDTs contribute significantly more toward congestion, pollution, and crashes than ownership information alone suggests.

Tables 6 and 7 results also suggest that as household sizes increase, SUVs and minivans are more popular choices than are passenger cars, while pickups become a slightly less likely choice. And, as incomes (per household member) increase, SUVs are more common – and pickups less common. Minivan-ownership response to higher incomes is not as significant – statistically or practically.

Table 6 suggests that when a household owns multiple cars, addition of minivans and pickups are favored; yet, an SUV's addition is not affected in a statistically significant way. And ownership of a relatively new minivan becomes a less likely event as a household's overall fleet size increases. Finally, considering results of both Tables 6 and 7, LDTs are more popular in lower-density environments; this result may be reflective of longer travel distances in such locations and fewer parking issues for these larger vehicles.[10]

These ownership models are based on a single, 1995 cross-section of data. In reality, preferences, products, and markets are changing over time. With a panel data set, temporal ownership patterns could be analyzed, illuminating any consumer trends and providing more insights for policymakers. However, the 1995 NPTS data are useful in that they validate many commonly held perceptions or beliefs about present consumption of light-duty trucks versus passenger cars. For example, larger household sizes favor minivans the most, SUVs next, and pickups least. Higher incomes favor SUVs but not pickups. And lower population densities favor pickups the most, passenger cars the least.

CONCLUSIONS

The U.S. government has taken an active regulatory stance in the area of emissions, as well as the safety, fuel economy, and size of different vehicle types. In many ways, cars and light-duty trucks, which include minivans, SUVs, and pickups, are regulated very differently, though households may use them for very similar purposes. This paper presented an investigation of the 1995 National Personal Travel Survey data set for evidence of household use differences across light-duty trucks (LDTs) and passenger cars in the U.S.

Total vehicle miles traveled, daily person trips served, vehicle occupancies, drivers' vehicle-type choices, and household ownership choices were analyzed to illuminate any significant differences in vehicle use. Weighted least squares (for VMT), negative binomials (for person trips), ordered probit (for occupancy), multinomial logits (for vehicles chosen by drivers [for trip-making] and for newest vehicle owned), and an MNL conditioned on a Poisson (for fleet combinations) were the stochastic specifications employed.

While the NPTS questionnaires do not target special uses of LDTs by households specifically, analysis of these data offers insights and does suggest use differences. In general, it appears that households drive LDTs for significantly more miles (up to 25 percent more, on average). And minivans are found to be carrying more occupants (on any given trip) and serving 35% more person-trips (over the course of a day) than passenger cars, while pickups are associated with significantly fewer occupants (per trip) and 15% fewer person-trips. SUVs, on the other hand, are used for the same number of person trips as passenger cars, and their occupancies are quite similar, except in the case of (vehicle) trips made for recreational purposes.

Light-duty-truck ownership decisions are strongly associated with household size, incomes, population density, and vehicles already owned. For example, SUVs are more likely to be found in higher-income, larger-size households living in low-density environments and owning multiple vehicles. In terms of within-fleet vehicle choice for trip-making, several driver and trip characteristics are very relevant. For example, males are far more likely to drive a pickup, and employed persons are unlikely to drive the household minivan. Pickups are more common for work-related trips, and SUVs are a more likely choice for weekend trips.

Taken together, the various models' results suggest that, when available, LDTs are used more regularly than cars for trip making of a personal nature. However, the NPTS data offer no strong indications that minivans and SUVs are used as "work" vehicles, which was the original basis for separate classification of LDTs (versus passenger cars). And pickups are more popular among households than they were 20 years ago, when American life was less urban; so it is not clear that pickups are performing unusual services either.

Even if LDTs perform special services for their owners (such as towing boats, hauling home furniture, or carrying many occupants), these benefits largely accrue only to their owners; in fact, such vehicles impose many negative externalities (Kockelman 2000a, Kockelman and Shabih 2000). Thus, it may be argued that their owners should be paying for these impacts, rather than facing more lenient regulation. Data sets like the NPTS provide much data for analysis to assist federal and more local policymaking. The topic of vehicle regulation is ripe for consideration.

Table 1. Definitions of Variables Used

Dependent Variables:			
		Mean*	**SD***
Annual VMT	Annual vehicle miles traveled in vehicle, as estimated by household respondent	11,040	8,230
#Person Trips	Number of person trips in the vehicle on the survey day	7.11	6.20
#Rec Person Trips	Number of person trips in the vehicle on the survey day for trips of recreational purpose (including social, shopping, and eating-out purposes)	2.20	3.06
Trip Occupancy: All Purposes	Number of vehicle occupants during trip	1.84	1.10
Trip Occupancy: Recr. Purposes	Number of vehicle occupants during recreational trip (including social, shopping, and eating-out purposes)	1.71	0.99
Vehicle Type Chosen for Trip	Type of vehicle chosen by driver for trip (all purposes included)	NA	NA
Newest Vehicle Owned	Type of newest-vehicle owned (identified by latest model year); includes passenger car, SUV, pickup, & minivan	NA	NA
Explanatory Variables:			
Population Density	Population density of Census tract (persons per square mile)	3858	5306
Income per HH Member	Annual household income (1995 US$) divided by household size (where income is taken to be middle of class range)	$ 19,075	$ 13,561
Vehicle Age	1996 minus model year of vehicle	6.02	4.96
HH Members per Vehicle Owned	Household size divided by vehicles owned by household	1.48	0.80
LDT Indicator	Equals one for SUVs, pickups, & minivans (zero otherwise)	0.26	0.44
SUV Indicator	Equals one for SUVs (zero otherwise)	0.08	0.27
Pickup Indicator	Equals one for pickups (zero otherwise)	0.11	0.31
Minivan Indicator	Equals one for minivans (zero otherwise)	0.08	0.27
Vehicle Price/Income	Average purchase price of new vehicle (based on 1997 sales data) divided by annual household income	0.74	0.14
Household size	Number of household members	2.83	1.31
#Vehicles Already Owned	Number of vehicles already owned by household, of that vehicle type	0.92	0.87
#Cars Already Owned	Number of passenger cars already owned by household	0.56	0.69
Weekend Day	Equals one for Saturday and Sunday trips (zero otherwise)	0.22	0.42
Vehicle Occupancy	Number of vehicle occupants (for model of vehicle-type choice)	1.58	0.99
Trip Length	Self-reported trip travel time (minutes)	14.21	13.0

*Note: Means and standard deviations (SDs) vary slightly in some cases, according to sample used/model applied.

Table 2. WLS Models of VMT

Dependent Variable: Annual VMT

Variable	Beta	SE	T-Stat	P-Value
Constant	9979	174.7	57.12	0.000
Population Density	-0.151	0.009	-16.21	0.000
Income per Household Member	4.010E-02	0.003	12.72	0.000
Vehicle Age	-408.0	8.753	-46.62	0.000
HH Members per Vehicle Owned	1883	84.55	22.27	0.000
LDT Indicator	1162	111.0	10.47	0.000

Adjusted R^2: 0.123
#Observations: 26398 vehicles
Weighted by: 1/Household Size
Model form: $VMT(X) = \beta X + \varepsilon$, where $\varepsilon \sim N(0, \sigma \times \text{Household Size})$

Dependent Variable: Annual VMT

Variable	Beta	SE	T-Stat	P-Value
Constant	10043	175.0	57.4	0.000
Population Density	-0.153	0.009	-16.3	0.000
Income per Household Member	4.00E-02	0.003	12.6	0.000
Vehicle Age	-405.4	8.76	-46.2	0.000
HH Members per Vehicle Owned	1821	85.2	21.4	0.000
SUV Indicator	1027	189	5.44	0.000
Pickup Indicator	721.7	152	4.74	0.000
Minivan Indicator	2150	202	10.6	0.000

Adjusted R^2: 0.125
#Observations: 26398 vehicles
Weighted by: 1/Household Size
Model form: $VMT = \beta' x + \varepsilon$, where $\varepsilon \sim N(0, \sigma^2 \times \text{Household Size})$

Table 3. Negative Binomial Regressions for Number of Person Trips: All Purposes and Recreational Purposes

Dependent Variable: #Person Trips for All Purposes

Variable	Beta	SE	T-Stat	P-Value
Constant	1.672	0.012	138	0.000
HH Members per Vehicle Owned	0.255	0.004	59.2	0.000
Income per Household Member	-3.16E-06	2.77E-07	-11.4	0.000
Population Density	-4.42E-06	6.10E-07	-7.25	0.000
Vehicle Age	-0.014	0.001	-20.8	0.000
Weekend Day Indicator	0.100	0.007	13.5	0.000
SUV Indicator	0.045	0.012	3.85	0.000
Pickup Indicator	-0.164	0.011	-14.9	0.000
Minivan Indicator	0.302	0.011	28.5	0.000
Over-dispersion Parameter	0.351	0.004	97.1	0.000

Log Likelihood Function	Negative Binomial Regression	Poisson Regression
Constant only	-121113.3	-160951.3
Convergence	-117983.1	-148642.7
Pseudo R^2	0.026	0.076

#Observations: 41,538 vehicles

Model form: #Person Trips ~ Neg.Bin., with expected value exp($\beta' x$) & non-negative over-dispersion parameter

Dependent Variable: #Person Trips for Recreational Purposes

Variable	Beta	SE	T-Stat	P-Value
Constant	0.485	0.021	22.8	0.000
HH Members per Vehicle Owned	0.204	0.008	25.9	0.000
Income per Household Member	-3.14E-06	4.73E-07	-6.6	0.000
Population Density	-6.12E-06	1.09E-06	-5.6	0.000
Vehicle Age	-0.018	0.001	-15.6	0.000
Weekend Day Indicator	0.590	0.014	41.4	0.000
SUV Indicator	0.005	0.021	0.2	0.814
Pickup Indicator	-0.292	0.019	-15.2	0.000
Minivan Indicator	0.308	0.020	15.7	0.000
Over-dispersion Parameter	1.009	0.011	93.4	0.000

Log Likelihood Function	Negative Binomial Regression	Poisson Regression
Constant only	-82460.37	-106536.4
Convergence	-80612.10	-99753.51
Pseudo R^2	0.022	0.064

#Observations: 41,538 vehicles

Model form: #Person Trips ~ Neg.Bin., with expected value exp($\beta' x$) & non-negative over-dispersion parameter

Table 4. Ordered Probit Model for Trip Occupancy: All Trip Purposes & Recreational Purposes

Dependent Variable: Trip Occupancy (all purposes)

Variable	Beta	SE	T-Stat	P-Value
Constant	-0.565	0.007	-79.9	0.000
HH Members per Vehicle Owned	0.340	0.002	153	0.000
Income per Household Member	-1.06E-05	2.05E-07	-51.5	0.000
Population Density	-8.79E-06	4.27E-07	-20.6	0.000
Weekend Day Indicator	0.474	0.005	91.2	0.000
SUV Indicator	0.174	0.008	20.9	0.000
Pickup Indicator	-0.229	0.008	-30.4	0.000
Minivan Indicator	0.500	0.006	78.8	0.000
Shopping Indicator	0.021	0.006	3.21	0.001
Eat-out Indicator	0.544	0.011	49.2	0.000
μ_o	0.000	na	na	na
μ_1	0.875	0.003	302	0.000
μ_2	1.431	0.004	365	0.000
μ_3	2.039	0.006	368	0.000

Note: Trip occupancy is grouped into 1, 2, 3, 4, and 5+ person levels.

Log Likelihood Function	
Constant only	-324471.0
Convergence	-298694.3
Pseudo R^2	0.079

#Observations: 263,031 trips

Model form: Pr(Occupancy=1) = Pr($\mu^*<\mu_o$), Pr(Occupancy=2) = Pr($\mu_o < \mu^* < \mu_1$), Pr(Occupancy = 3) = Pr($\mu_1 < \mu^* < \mu_2$), Pr(Occupancy = 4) = Pr($\mu_2 < \mu^* < \mu_3$), & Pr(Occupancy $\geq$ 5) = Pr($\mu_3 < \mu^*$), where $\mu^* = \beta X + \varepsilon$, and $\varepsilon \sim$ Normal(0, 1).

Dependent Variable: Trip Occupancy (all recreational purposes)

Variable	Beta	SE	T-Stat	P-Value
Constant	0.043	0.020	2.136	0.033
HH Members per Vehicle Owned	0.349	0.006	57.435	0.000
Income per Household Member	-9.77E-06	5.55E-07	-17.622	0.000
Population Density	1.95E-07	8.11E-08	2.404	0.016
Weekend Day Indicator	0.341	0.014	24.810	0.000
SUV Indicator	0.316	0.027	11.925	0.000
Pickup Indicator	-0.196	0.025	-7.802	0.000
Minivan Indicator	0.524	0.019	27.929	0.000
μ_o	0.000	na	na	na
μ_1	1.055	0.009	113.721	0.000
μ_2	1.612	0.011	146.304	0.000
μ_3	2.247	0.014	160.105	0.000

Note: Trip occupancy is grouped into 1, 2, 3, 4, and 5+-person levels.

Log Likelihood Function	
Constant only	-38686.52
Convergence	-35948.44
Pseudo R^2	0.071

#Observations: 26,190 trips

Model form: Pr(Occupancy=1) = Pr($\mu^* < \mu_o$), Pr(Occupancy=2) = Pr($\mu_o < \mu^* < \mu_1$), Pr(Occupancy = 3) = Pr($\mu_1 < \mu^* < \mu_2$), Pr(Occupancy = 4) = Pr($\mu_2 < \mu^* < \mu_3$), & Pr(Occupancy $\geq$ 5) = Pr($\mu_3 < \mu^*$), where $\mu^* = \beta X + \varepsilon$, and $\varepsilon \sim$ Normal(0, 1).

Table 5. Multinomial Logit Model for Vehicle Type Chosen for Trip by Driver

Dependent Variable: Vehicle Type Choice

Variable		Beta	SE	T-Stat	P-Value
Constant	SUV	-2.464	0.244	-10.108	0.000
	Pickup	-2.322	0.145	-16.046	0.000
	Minivan	-2.687	0.183	-14.653	0.000
Vehicle Age		-0.056	0.002	-31.158	0.000
Age of Traveler	SUV	0.077	0.012	6.550	0.000
	Pickup	0.047	0.006	7.239	0.000
	Minivan	0.112	0.008	13.575	0.000
Age^2 of Traveler	SUV	-8.34E-04	1.36E-04	-6.119	0.000
	Pickup	-5.71E-04	7.04E-05	-8.111	0.000
	Minivan	-1.09E-03	9.09E-05	-11.977	0.000
Male Driver	SUV	0.550	0.048	11.401	0.000
	Pickup	3.172	0.035	91.060	0.000
	Minivan	-0.411	0.035	-11.806	0.000
Employed Driver	SUV	0.119	0.071	1.685	0.092
	Pickup	0.089	0.046	1.927	0.054
	Minivan	-0.330	0.048	-6.824	0.000
Work Trip	SUV	0.058	0.063	0.919	0.358
	Pickup	0.359	0.042	8.549	0.000
	Minivan	-0.034	0.048	-0.713	0.476
Recreational Trip	SUV	0.056	0.059	0.947	0.344
	Pickup	-0.170	0.037	-4.579	0.000
	Minivan	-0.032	0.041	-0.773	0.440
Population Density	SUV	8.37E-06	5.34E-06	1.567	0.117
	Pickup	-1.54E-06	4.15E-06	-0.370	0.711
	Minivan	1.66E-06	3.75E-06	0.443	0.658
Income per Person	SUV	6.21E-07	1.67E-06	0.371	0.710
	Pickup	-6.29E-06	1.40E-06	-4.509	0.000
	Minivan	4.76E-06	1.64E-06	2.896	0.004
Weekend Indictor	SUV	0.169	0.053	3.199	0.001
	Pickup	-0.046	0.033	-1.387	0.166
	Minivan	-0.042	0.037	-1.138	0.255
Vehicle Occupancy	SUV	0.229	0.029	7.970	0.000
	Pickup	-0.449	0.020	-22.796	0.000
	Minivan	0.385	0.017	22.138	0.000
Trip Length (min.)	SUV	-0.40E-03	0.17E-02	0.228	0.820
	Pickup	-1.00E-03	0.11E-02	-0.882	0.378
	Minivan	-0.51E-02	0.13E-02	-3.866	0.001

Log Likelihood Function	
Constant only	-36009.5
Convergence	-27703.3
Pseudo R2	0.231

#Observations: 50,865 vehicle trips
Model Form:

$$\Pr(veh\ i\ chosen) = \Pr(u_i \geq u_j)\ \forall i \neq j = \Pr(\beta_i' x_i + \varepsilon_i \geq \beta_j' x_j + \varepsilon_j)\ \forall i \neq j$$

$$= \frac{\exp(\beta_i' x_i)}{\sum_j \exp(\beta_j' x_j)},\ where\ \varepsilon_i \sim iid\ Gumbel.$$

Table 6. MNL Model for Newest Vehicle Owned

Dependent Variable: Newest Vehicle Owned

Variable		Beta	SE	T-Stat	P-Value
Constant	SUV	-3.137	0.096	-32.6	0.000
	Pickup	-1.258	0.067	-18.9	0.000
	Minivan	-3.515	0.093	-38.0	0.000
Vehicle Price/Household Income		-0.660	0.074	-9.0	0.000
Household Size	SUV	0.242	0.020	11.9	0.000
	Pickup	-0.058	0.016	-3.5	0.000
	Minivan	0.542	0.018	30.6	0.000
Population Density	SUV	-2.81E-05	4.19E-06	-6.7	0.000
	Pickup	-6.91E-05	4.21E-06	-16.4	0.000
	Minivan	-3.93E-05	4.25E-06	-9.3	0.000
Income per Household Member	SUV	1.78E-05	1.58E-06	11.2	0.000
	Pickup	-1.55E-05	1.58E-06	-9.8	0.000
	Minivan	1.15E-06	2.08E-06	0.6	0.580
# of Vehicles Already Owned	SUV	0.206	0.04	5.9	0.000
	Pickup	0.193	0.03	6.9	0.000
	Minivan	-0.046	0.04	-1.3	0.209
# of Cars Already Owned	SUV	0.016	0.04	0.4	0.696
	Pickup	0.362	0.03	10.8	0.000
	Minivan	0.135	0.04	3.2	0.001

Log Likelihood Function	
Constant only	-28725.37
Convergence	-27080.58
Pseudo R^2	0.057

#Observations: 30,949 households

Model Form:

$$\Pr(veh\ i\ chosen) = \Pr(u_i \geq u_j)\ \forall i \neq j = \Pr(\beta_i' x_i + \varepsilon_i \geq \beta_j' x_j + \varepsilon_j)\ \forall i \neq j$$

$$= \frac{\exp(\beta_i' x_i)}{\sum_j \exp(\beta_j' x_j)},\ where\ \varepsilon_i \sim iid\ Gumbel.$$

Table 7. Simultaneous-Poissons Model for Vehicle Fleet Ownership

Dependent Variable: Total Vehicles Owned and Distribution among Cars, SUVs, Pickups, and Vans

Variable	Beta	SE	T-Stat	P-Value
Vehicle Price/Income	-0.2213	0.0075	-29.4	0.000
Car:				
Constant	0.148	0.021	7.03	0.000
Household Size	0.0699	0.0043	16.3	0.000
Population Density	-0.1519	0.0081	-18.7	0.000
Income per HH Member	0.02	0.0042	4.77	0.000
SUV:				
Constant	-2.8437	0.0553	-51.4	0.000
Household Size	0.273	0.0118	23.1	0.000
Population Density	-0.4526	0.0311	-14.6	0.000
Income per HH Member	0.1899	0.0095	20.0	0.000
Pickup:				
Constant	-0.6725	0.0383	-17.6	0.000
Household Size	0.0715	0.008	8.92	0.000
Population Density	-0.9598	0.0281	-34.2	0.000
Income per HH Member	-0.1102	0.0093	-11.8	0.000
Minivan:				
Constant	-3.1526	0.058	-54.3	0.000
Household Size	0.4446	0.0103	43.0	0.000
Population Density	-0.3993	0.0303	-13.2	0.000
Income per HH Member	0.0262	0.0141	1.86	0.031

Log Likelihood Function	
Constant only	-89026.8
Convergence	-84399.8
Pseudo R^2	0.0520

#Observations: 32,596 households

Model Form: #Vehicles of type *i* owned ~ Poisson($\lambda_i = \exp(\beta_i' x_i + \beta_{price/income} \times$Price/Income$)$)

ENDNOTES

[1] The source of these 1999 data is the Polk Company (without Hummer, Winnebago, and Workhorse truck makes). While these data are the most recently available, they are unpublished, and Polk restricts their use.

[2] The Code of Federal Regulations (CFR) defines a light-duty truck to be any motor vehicle having a gross vehicle weight rating (curb weight plus payload) of no more than 8,500 pounds which is "(1) Designed primarily for purposes of transportation of property or is a derivation of such a vehicle, or (2) Designed primarily for transportation of persons and has a capacity of more than 12 persons, or (3) Available with special features enabling off-street or off-highway operation and use." (40CFR86.082-2) The "special features" enabling off-road use are four-wheel drive and at least four of the following five clearance characteristics: an approach angle of not less than 28 degrees, a breakover angle of not less than 14 degrees; a departure angle of not less than 20 degrees, a running clearance of not less than 8 inches, and front and rear axle clearances of not less than 7 inches each. (CFR 40CFR86.084-2)

[3] It also is of interest to note that the LDT fuel-economy standard is set by Department of Transportation rule-making; it is not incorporated into formal statute, as in the case of passenger-car fuel economy.

[4] The EPA's Tier II plans for 2009 call for averaging emissions across a manufacturer's entire fleet of vehicles. Under this plan, LDTs are likely to continue emitting more than cars, on average; but low-emitting vehicles will have to be sold to meet the average, forcing individual manufacturers to balance emissions impacts of their LDT fleets against emissions benefits of their car sales. Ideally, manufacturers should be able to trade credits with one another, but the rule-making does not allow this.

[5] These numbers come from Ward's Automotive Yearbook (1997) prices and Automotive News (1998) sales data. They are based on sales-weighted values.

[6] In the interest of space, these models are not shown.

[7] A nested-logit specification would avoid the record removal used here. In such a framework, all passenger cars available to a household form one nest of choices, all minivans form a different nest, and so on. Our interest lies in distinctions across vehicle types, rather than among vehicles of a single type (i.e., within a nest), so the removal of households with more than one vehicle of any type was adopted here and simplified the estimation.

[8] A series of independent Poissons or simultaneous-in-unknown-parameters Poissons (as specified here) is equivalent to a multinomial distribution, for the combinations of vehicles owned, conditioned on a Poisson, for the total number of vehicles owned. The price-over-income variable was restricted to a single coefficient because the prices were constant for each vehicle type here (using 1997 average sales prices); thus, this variable would have simply reflected the inverse of income had its parameters been allowed to vary. A multiariate negative binomial also was attempted here, to allow heterogeneity across the vehicle ownership levels (see Kockelman [2000b] for an example application of this specification); however, this model's maximum-likelihood estimation would not converge, due to the dispersion parameter's tendency for near-zero values. Finally, a series of independent, non-simultaneous Poissons was run, without the price-over-income variable, and the pseudo-R^2 of this model was 4.93%.

[9] For example, the average household pickup age in the 1995 NPTS data set was 8.22 years, versus 6.83 for passenger cars. The average age of minivans and SUVs in the sample was just 4.72 and 5.16 years, which may be due to the fact that these body types have not been available in the market for nearly as long as pickups and passenger cars.

[10] The average van and pickup sold in 1997 were 8.2 and 16.2 percent longer and 9.2 and 12.2 percent wider, respectively, than the average car.

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