Determinants of Automobile Demand and Implications for Hybrid-Electric Market Penetration

Sruthi M. Thatchenkery*

Professor Arie Beresteanu, Faculty Advisor

Honors Thesis submitted in partial fulfillment of the requirements for Graduation with Distinction in Economics in Trinity College of Duke University

Duke University

Durham, North Carolina

2008

* I would like to thank my advisor, Dr. Arie Beresteanu, whose guidance was essential to the design and execution of this study. I would also like to thank Dr. Michelle Connolly, Dr. Edward Tower, and the students in the economics honors seminar, for their continuous advice and suggestions for improvement.

Abstract

This paper investigates market receptivity to hybrid-electric vehicles by using cross-sectional data on vehicle registrations to estimate demand functions for the overall market, the hybrid market, and specialized vehicle segments. Each specification features intrinsic product attributes such as fuel efficiency and horsepower, while the hybrid specification also includes external influences on demand, such as government incentives, demographics, and environmentalism. I find that a preference for greater fuel efficiency is fairly consistent across most markets, but is typically overshadowed by stronger affinities for horsepower and weight. Certain external influences, such as convenience-based incentives and environmentalism, boost explanatory power but do not outweigh the effects of vehicle attributes.

I. Introduction

Although the concept dates back to 1901, when Ferdinand Porsche designed the *Mixte* series-hybrid, automotive hybrid technology did not gain traction in the consumer market until the introduction of the Honda Insight and the Toyota Prius at the turn of the millennium. In the midst of escalating concerns about the dangers of greenhouse gas emissions, environmentalists hailed the superior fuel economy and wide range of the hybrid-electric engine as a critical breakthrough that could help save the environment without inconveniencing consumers. Other major automakers quickly followed Honda and Toyota's lead in an attempt to cash in on what many saw as the future of transportation, while US policymakers at the local, state, and federal level jumped on the bandwagon by offering varied incentives for residents that purchased a hybrid vehicle, ranging from free parking to tax rebates.

Eight years after the introduction of the first hybrid-electric vehicle to the United States, however, little scholarly work has been done on consumer demand for hybrids. Moreover, that which exists is based on first-generation hybrids and thus is already out of date. This study aims to fill the gap by using data on US vehicle registrations from 2006 to estimate demand functions for automobiles in the context of the overall market, the hybrid market, and specialized vehicle segments. I then use those results to analyze the extent to which hybrids might be able to gain market share in the future. To accomplish this, I use the Berry logit framework to regress the number of vehicle registrations for each model on an array of explanatory variables. In the case of the overall market and vehicle segment specifications, the explanatory variables are intrinsic product attributes such as fuel efficiency and horsepower. In the hybrid specification I also include external influences, such as local demographics, community environmentalism, and government incentives. Although investigation of external influences on demand for automobiles is relatively rare, it tends to add a great deal of insight into what attracts consumers to “specialty” vehicles such as hybrids. The inclusion of government incentives in particular creates the potential for interesting policy implications. Moreover, most existing studies do not separate vehicles by segment. Given that a consumer shopping for a minivan probably prefers a very different mix of product attributes than one shopping for a sports car, this division of the market results in a clearer picture of the relative viability of hybrids between segments.

The value added by such an analysis is clear, as the factors affecting the decision to purchase a hybrid over a conventional gas-powered vehicle, or one hybrid over another, are still a matter of controversy. Indeed, despite the obvious success of the compact Toyota Prius, General Motors’ Vice Chairman of Product Development Bob Lutz went on record as saying that compact hybrids were bad business, and that the greatest potential for hybrid success comes from higher-margin, less fuel-efficient vehicles such as SUVs and pickups (CNN Money, 2004). Honda and Toyota obviously disagree, as they have continued to push hybrid sedans and compacts through the market. By estimating separate demand functions for each vehicle segment I am able to extract more specialized estimates of consumer preference for fuel efficiency, thereby gaining insight into which segments might be most suited for hybrids. In contrast, the results for fuel efficiency and other relevant product attributes in the generalized demand estimation could offer some insight into the extent to which hybrids will be able to lure consumers away from conventional gas powered vehicles in the overall market.

Mass media outlets have been quick to chime in on possible determinants of demand for hybrids. Some point to the recent rise in gasoline prices as the primary driver behind a surge in hybrid sales (International Herald Tribune, 2007) while others claim that an increased level of environmental consciousness evidenced by the success of the burgeoning "Green" movement should be credited (BusinessWeek, 2005). News and magazine articles, however, offer little in the way of serious empirical analysis. There certainly may be a correlation between rising gas prices, stronger environmentalist sentiment, and an increase in hybrid sales, but that in and of itself does not answer the question of whether either of the former caused the latter. I therefore take care to include both local gas prices and a proxy for community environmentalism in my hybrid demand specification, so that I may test the veracity of these common claims.

I find that the primary determinants of demand are quite similar between the overall market and the hybrid market, but vary greatly between vehicle segments. In particular, my results suggest that a relatively strong preference for fuel efficiency exists in the markets for hybrids, certain vehicle segments, and automobiles in general. This affinity for fuel efficiency, however, is typically overshadowed by stronger preferences for horsepower and weight, two characteristics that are negatively related to a vehicle's fuel economy. Other consistent influences on demand include brand or model-based prestige, safety ratings, and brand nationality, although the competitive advantage gained by one nationality over another varies between segments. The external influences on demand included in the hybrid specification increase the model's explanatory power but do not outweigh the effects of vehicle attributes. Nevertheless, I find that environmentalism, convenience-based incentives, median income, average commute time, and age all have significant effects on hybrid demand, while cost- and tax-based incentives and other demographic factors do not appear to stimulate purchase of hybrids. Gas price only returns as significant if not controlling for environmentalism, which is likely a result of the cross-sectional nature of the data.

The rest of the paper is organized as follows. Section II surveys the existing economic literature on hybrid-electric vehicles and consumer preference for fuel-efficiency. Section III covers data sources and presents summary statistics for the explanatory variables used in various specifications. Section IV describes the empirical framework used to estimate the demand functions. Section V outlines the study's findings. Section VI explores marketing and policy implications, as well as suggestions for further research.

II. Literature Review

The existing economic literature on hybrid cars is quite limited in scope. This can be at least partially attributed to the fact that hybrid-electric vehicles have only been on the market for a relatively short period of time. Still, some papers have examined the dynamics of the production, distribution, and consumption of these vehicles. Calef and Goble studied the effectiveness of technology-forcing in California, in which the government mandated and stringently regulated the development and sale of low-emission vehicles (2007). Although the study focused primarily on the steps taken by producers to develop the necessary technology, Calef and Goble saw it as no coincidence that California came to be home to one of the largest concentrations of electric and hybrid-electric vehicles in the world, and deemed the state's aggressive promotion of alternative fuel vehicles in order to reduce air pollution a success. However, there was no discussion on why exactly California consumers might have responded so positively to the introduction of the hybrid. It is possible that California residents were already particularly inclined towards alternative fuel-powered vehicles, and thus would have chosen to purchase such cars regardless of whether the government had taken such a pointed interest in the matter.

Others seek to predict consumer behavior by evaluating the true value of hybrids; that is, whether the benefits of lower emissions and increased fuel economy offset the costs of raised sticker prices and increased technological complexity. Lave and MacLean address this by comparing the lifetime costs of a Toyota Prius, the earliest and most successful commercial hybrid, to its closest conventional counterpart, the compact Toyota Corolla (2002). Calculating the relative costs of owning a Prius versus a Corolla over 14 years and 250,000 miles, they estimate that gasoline prices would have to rise to $3.55 per gallon in order for the savings in gasoline expenditures to offset the purchase price premium of the Prius. Because the average price of gas was at the time $1.50, the authors conclude that hybrids would be unable to sell themselves on fuel efficiency alone. Although their calculations were sound, the authors fail to take into account any environmentalist sentiment that may make hybrids a desirable option for those who place a high value on environmental protection and derive a great amount of utility from believing that they are helping combat pollution. In addition, recent advancements in hybrid technology combined with the rapid rise of gas prices have narrowed the gap between the savings and purchase premium associated with hybrids.

Some studies pre-dating the diffusion of hybrids have looked at consumer preference for fuel-efficiency, especially in light of rising or falling gasoline prices. A survey conducted by Opinion Research in 1999 asked about the amount consumers would be willing to pay as a premium for a doubling of fuel economy, with the average consumer claiming they would pay only an extra $2563 in exchange for such a dramatic increase in fuel efficiency (cited in Kenworthy & Laube, 1999). Greene (1998) studied the relationship between vehicle size and fuel costs, with the assumption that consumers do take into account the inverse relationship between a vehicle's size and its fuel-efficiency, and showed that compact and subcompact market share is in fact a positive function of gasoline price. A more recent study by Greene et. al. (2005) modeled hypothetical increases in fuel efficiency among the US automotive fleet and found that increases in overall fuel efficiency would most likely be due to general technological improvement rather than consumer substitution towards more fuel-efficient vehicles. In studying the potency of government regulation of fuel economy, Dreyfus and Viscusi (1995) found that consumers do to some extent take a long-term perspective on fuel efficiency, and government interventions that affect the payoffs associated with fuel economy could affect consumer choice.

Santini, Patterson, and Vyas (1999) examined survey data from 1981 through 1998 and found that a higher proportion of consumers rated fuel-efficiency as the most important attribute considered in their purchase decision in years in which gas prices were greatly and frequently rising. Alternatively, as gas prices dropped, a much smaller percentage of consumers rated fuel-efficiency as a major consideration. Later in the same paper, they consider the imminent introduction of the Toyota Prius to the US market by estimating expected costs and benefits, quantified through variables such as fuel savings, lowered performance, purchase price premium, and expected battery life. Like Lave and

MacLean, they conclude that the US market for hybrids would be quite limited. It is important to keep in mind, however, that authors base their calculations on the first-generation Prius, which, compared to its descendents, suffers from lowered performance in terms of acceleration and fuel economy. In addition, the paper predates the rapid rise in gas prices experienced in the early 2000s. The authors acknowledge that such a rise would probably serve as a boost to hybrid sales, but warn that a subsequent downturn in gas prices would likely cool demand unless there was something else to attract consumers to the product.

Although it did not explicitly consider consumer demand for hybrid cars, Kayser's study of the determinants of demand for gasoline yielded an especially relevant and intriguing result. Using household-level data from 1981, which at the time was the most recent year in which gas prices rose sharply, the author found that in response to the sudden and rapid increase in gas prices, households lowered total gasoline consumption without lowering total miles traveled (Kayser, 2000). The implication was that they must be switching to more fuel-efficient cars. Because data was drawn from only a single year, the author assumed consumers were most likely switching between cars already in their household fleet. Kayser was interested in how households purchase behavior might have been influenced, but lacked sufficiently detailed information to draw any conclusions on the subject.

Certainly, the existing economic literature on fuel efficiency and hybrid vehicles offers valuable insights into possible challenges and opportunities for automakers hoping to penetrate the market or policymakers looking to encourage environmentally-friendly purchasing patterns among their constituents. The hybrid sector of the automobile industry, however, is moving forward at a blistering pace, with new models being introduced by major manufacturers on a yearly basis. Even the most recently published studies were not able to take into account the ongoing rise in gasoline prices, ever-expanding government incentives, or the rapid diversification of available hybrid makes and models. In addition, no empirical work has been done on the viability of hybrids between vehicle segments or the influence of external variables on consumer preference for hybrids. In light of all this, I believe there is much to be gained in using up-to-date data to investigate the determinants of demand and relative preference for fuel efficiency in hybrids, specific vehicle segments, and automobiles in general.

III. Data

3.1 Vehicle Registrations

Information on vehicle sales comes from a subset of the 2006 Polk New Vehicle Registration dataset, available free of charge through the Duke library. This cross-sectional dataset reports the raw number of new registrations for a particular make and model within a given year for 21 randomly selected Designated Market Areas (DMAs)[1]. Registration numbers for each DMA are further split up into individual counties. The DMAs included are listed below.

Table 3.1 - Selected Designated Market Areas

DMA	State	Ranking[2]
Albany-Schenectady-Troy	NY	17
Atlanta	GA	2
Cleveland-Akron-Canton	OH	7

[1] The 'DMA' grouping was coined by Nielsen Media Research and is defined as a group of counties covered by a specific set of television stations. The Polk dataset is likely organized in this way for the benefit of auto manufacturers hoping to optimize their advertising strategy.
[2] Refers to the DMA's population-based rank in the context of the subset

Denver	CO	8
Des Moines	IA	18
Harrisburg-Lancaster-York	PA	15
Hartford-New Haven	CT	11
Houston	TX	3
Las Vegas	NV	16
Madison	WI	20
Miami-Ft. Lauderdale	FL	6
Milwaukee	WI	13
Monterey-Salinas	CA	21
Nashville	TN	12
Phoenix	AZ	4
San Antonio	TX	14
San Diego	CA	10
San Francisco-San Jose-Oakland	CA	1
Seattle-Tacoma	WA	5
St. Louis	MO & IL	9
Syracuse	NY	19

The use of registrations as opposed to sales is a particular strength of the dataset. It is fairly common for consumers to purchase a vehicle in a different city or even state than the one in which they reside. Thus, a vehicle being sold in a particular DMA would not necessarily mean it was purchased by a resident of that DMA. Vehicle registrations, on the other hand, must be filed in the proper state of residency, regardless of where the owner purchased the vehicle. I can therefore be quite confident that the locus of a vehicle registration is a good indicator of the owner's true residency.

Unfortunately, the Polk dataset has some weaknesses as well. Most obvious is the fact that the reported registration numbers come from a single year. In a young, fast-growing market segment like hybrids, panel data would have been especially useful. The cross-sectional nature of the data mitigates this somewhat, as differences in demographics and environmental attitudes between locations also offer potential for interesting insights. While a higher number of DMAs would have been nice, these selected DMAs cover a solid cross-section of the country and should be adequate for the purposes of this study. Finally, it must be pointed out that the Polk dataset reports only aggregate registration numbers. Although household- or consumer-level data is always ideal when embarking on demand estimation, an extensive review of the existing literature indicates that such a dataset on purchasing decisions for automobiles simply does not exist.

Because I am only interested in vehicles purchased by households, I exclude models primarily purchased for commercial use, such as cargo vans or heavy trucks. In addition, the dataset occasionally lists separate registration numbers for different trims of the same model. For example, data for the GMC Yukon, Yukon XL, Yukon Denali, and Yukon Denali XL were all reported separately. In order to make sure registration numbers were aggregated at the same level across models, I combine the numbers for each trim into one base model data point.

After excluding non-household vehicles and aggregating separate trims, I am left with 338 distinct models, eleven of which are hybrids. The hybrid models included in the dataset are listed below:

Table 3.2 - Hybrid models included in Polk New Registration Dataset

Make/Model	Total Registrations
Honda Civic	7,216
Honda Insight	193
Honda Accord	1,191
Toyota Prius	26,448
Toyota Camry	6,941
Toyota Highlander	7,502
Lexus GS 450H	424
Lexus RX 400H	4,952
Ford Escape	3,794
Mercury Mariner	532
Saturn Vue	306

I then had to verify that the data is operational. Summary statistics on DMA-level registration numbers for models from a variety of vehicle segments are listed below to serve as an illustrative example. These are raw registration numbers and therefore have not been weighted by population.

Table 3.3 - Number of registrations for subset of models (DMA-level)

Make/Model	Mean	Std. Dev.	Min	Max
Toyota Prius	1259.42	2124.47	158	10,085
Honda Civic Hybrid	343.62	590.30	34	2411
Honda Accord	3293.14	3040.67	327	10,472
Toyota Camry	3382.43	2946.65	225	9501
Dodge Caravan	927.00	624.75	40	2583
Honda Odyssey	1759.14	1616.90	150	6437
Jeep Grand Cherokee	831.76	499.76	43	1624
Chevrolet Trailblazer	713.29	525.32	24	1881
Ford Mustang	1318.91	1030.20	131	3435
Ford F-Series	5115.95	4824.70	531	20,889
Dodge Ram	2597.91	2366.01	169	9480
Lexus LS	271.19	295.67	17	899
Mercedes-Benz E-Class	477.19	640.31	20	2432

As shown by the wide ranges and large standard deviations, registration numbers seem to be quite spread out among the 21 DMAs. The data therefore exhibits sufficient variation to be operational.

3.2 Product Attributes

After gathering the necessary data on vehicle registrations and the locations in which they occurred, I assembled information on relevant product attributes from internetautoguide.com, Edmunds.com, and consumerguideauto.com. Internetautoguide.com functioned as the default data source. If information on price was missing, I consulted consumerguideauto.com. If any other product attributes were missing, I used Edmunds.com. Unless the model ceased production before 2007, product specifications were recorded for 2007 base models. If a 2007 model did not exist, data from the last model year produced was used instead.

The following tables report descriptive statistics for relevant product attributes, first among hybrids only, and then for all 338 models.

Table 3.4 - Summary statistics for product attributes, hybrids only

Variable	Mean	Std. Dev.	Min	Max
Horsepower	184.27	86.78	73.00	339.00
MPG	37.55	12.70	26.35	62.70
Size (sq ft)	88.37	7.14	71.84	95.02
Weight (lbs)	3521.00	731.22	1850.00	4365.00
Cargo Room (cu ft)	18.65	10.47	7.50	38.30
MSRP ($)	29,794.55	10,262.92	19,330.00	54,900.00
Years Sold	3.36	2.73	1.00	9.00

Table 3.5: Summary statistics for product attributes, all models

Variable	Mean	Std. Dev.	Min	Max
Horsepower	254.55	108.89	73.00	1001.00
MPG	21.63	6.03	10.40	62.70
Size (sq ft)	95.77	12.73	65.95	137.48
Weight (lbs)	3850.70	855.77	1850.00	7189.00
Cargo Room (cu ft)	22.35	14.38	1.50	83.26
MSRP ($)	52,137.73	98,695.46	9430.00	1,440,800.00
Years Sold	11.35	12.12	1.00	59.00

MPG is the combined fuel-efficiency, based on official EPA measurements and calculated using the EPA's standard formula for combining city and highway mileage.[3] *Size* represents an approximate cross-sectional area of the vehicle and is defined as length multiplied by width. *Weight* is the vehicle's curb weight, i.e. the weight of the vehicle when completely empty, measured in pounds. *Cargo* is the amount of cargo space in a vehicle, measured in cubic feet when all seats are in their upright position. *MSRP* is the manufacturer's suggested retail price for the base model or trim. *Years* is the number of

[3] Combined MPG = (.45)(highway MPG) + (.55)(city MPG)

years a model has been sold in the US market. The only cause for concern comes from the oddly skewed variation in MSRP, due to the existence of extremely high-priced outliers.

The model also includes a set of product attributed-based dummy variables. *Prestige* indicates whether or not a specific model is associated with wealth-based prestige or exclusivity. A vehicle qualifies if it is produced by a designated “luxury” brand or if it retails for over $45,000. Designated luxury brands are listed below.

Table 3.6 – Prestige brands included in dataset

Acura	Aston Martin	Audi
Bentley	BMW	Bugatti
Cadillac	Ferrari	Infiniti
Jaguar	Lamborghini	Lexus
Lincoln	Lotus	Maserati
Maybach	Mercedes-Benz	Porsche
Rolls Royce	Saab	Volvo

The other set of dummies relates to safety. Data on official crash test and rollover safety ratings granted by the National Highway and Traffic Safety Administration were gathered from http://safercar.gov. Vehicles can undergo a maximum of six safety tests: two related to front-end collisions, two related to side collisions, and two rollover tests. The NHTSA then rates the vehicles on a scale of one to five stars for each test. There is no overall rating granted. Note that safety testing is not mandatory, so not all vehicles had such data available. In addition, vehicles do not necessarily have to undergo all six tests, so many vehicles only had partial data available. In light of this, I decided the best approach to including safety would be to create two dummy variables for the vehicles that had undergone testing – one to indicate exemplary performance on safety tests, another to reflect potential risk. These are labeled *FiveStar* and *ThreeStar*, respectively.

FiveStar means a vehicle earned a strict majority of five star ratings on the tests it underwent. *ThreeStar* indicates that a vehicle earned at least one rating of three stars or lower. Most vehicles earn a mix of four star and five star ratings, with about half or the majority being four stars. I did not take the number of tests a vehicle underwent into account.

3.3 External Influences

The question then turns to possible external influences on demand, which, with the exception of federal tax rebates, vary between DMAs. Summary statistics for three geographic influences are listed below:

Table 3.7 - Summary statistics for geographic influences

Variable	Mean	Std. Dev.	Min	Max
Average gas price ($)	2.33	.15	2.11	2.59
Average LCV score	54.26	23.78	21.67	98.50

Gas is the price of regular unleaded fuel at the end of 2006, taken from Triple A's Daily Fuel Gauge Report. If a DMA covered more than one of Triple A's "metropolitan areas," I averaged the values to arrive at an estimated DMA-wide price. Although data on premium fuel prices was also available, I had no way of knowing what proportion of consumers actually purchased higher grades of gasoline. Thus, I decided it would be safest to impute only the standard baseline price. *LCV* is the average League of Conservations Voters Score for all representatives in a particular DMA for the 109th Congress. Scores are based on voting patterns on key environmental legislation and range from 0 to 100, with 100 representing the most environmentally-conscious a congressperson can be. This is meant to serve as a proxy for community environmentalism, as a representative who votes in favor of the environment 80% of the time has probably been elected by a markedly different constituency than one who votes against it 80% of the time. Note that Congressional districts do not follow county lines, so certain districts were only partially contained within a DMA. For the purposes of this study, a Congressperson's scores were included in a DMA's average if they had any constituents at all within its geographic bounds.

Details regarding federal tax rebates for selected models can be found at http://fueleconomy.gov, a site run by the US Department of Energy. The level of a tax rebate varies by the type of model and the number of cars sold. Once a model has sold over 60,000 units, the rebate is cut down to 50% of the original value, and then to 25% of the initial value before being completely phased out. This complicates the inclusion of federal tax rebates in my model, as the Toyota hybrids were eligible for the full rebate until October 1st 2006, and then only half the rebate for the rest of the year. To address this, I calculated a weighted average based on the length of time the model was eligible for the full versus the half-rebate. No other manufacturers have been affected by the phase-out, so all other values are the original full rebate.

Information on state and local government incentives are also a matter of public record and are tracked by the Union of Concerned Scientists at HybridCenter.org. State or local incentives that were in effect at some point in 2006 are included in the model. This means that incentives that expired during or after 2006 are included, while incentives that did not become viable until 2007 are not. Although the details of these incentive structures vary, they are grouped into four basic categories and will be represented by four dummy variables in the model: *HOV, Park, SalesTax,* and *Emissions*.

HOV refers to incentives that allow single-driver hybrids to travel in high-occupancy vehicle lanes that normally require two or more passengers per car. *Park* includes any incentive that grants hybrids free parking in some section of the relevant DMA. *SalesTax* refers to exemption from state or local sales taxes when purchasing a hybrid. *Emissions* refers to exemption from emissions-based inspection. The distribution of these incentives among the 21 DMAs in the dataset is summarized below.

Table 3.8 - State and local incentives

DMA	HOV Access	Free Parking	Tax Exemption	Emissions Exemption
Albany	x			
Atlanta	x			
Cleveland-Akron				
Denver	x	x	x	
Des Moines				
Harrisburg-Lancaster			x	
Hartford-New Haven		x	x	
Houston				
Las Vegas				x
Madison				
Miami-Ft Lauderdale	x	x		
Milwaukee				
Monterey-Salinas	x			
Nashville	x		x	
Phoenix	x			
San Antonio		x		
San Diego	x			
San Francisco	x	x		
Seattle-Tacoma			x	x
St. Louis			x	
Syracuse	x			

Certain demographic factors, such as ethnicity, age, and level of education, have been shown to affect consumer preference for fuel-efficiency through previous studies, including the aforementioned paper by Kayser on the determinants of gasoline demand. In order to include these potential influences, I gathered county-level demographic data from the 2000 United States Census. The variables I will be using in my model are presented below:

Table 3.9 - Summary statistics for demographic variables

Variable	Mean	Std. Dev.	Min	Max
Med. household income ($)	48,918.720	5484.080	38,634.98	61,384.19
No HS diploma	.172	.043	.09	.26
Bachelor's degree	.271	.050	.17	.37
Avg. Commute Time (min)	25.130	3.240	19.64	31.27
Non-white	.327	.173	.12	.67
Over 65 years old	.116	.019	.08	.14
Under 18 years old	.247	.016	.22	.28

MedInc represents median household income. *No_HS* is the proportion of the population over 25 years of age that does not have at least a high school diploma, while *Bach* is the proportion of the population over 25 that has at least a bachelor's degree. *Comm* represents the average commute time to work. *Nonwhite* is the proportion of individuals who identify as ethnically Hispanic or racially non-white. While this is not directly reported in the Census, it is calculated by subtracting the proportion of white, non-Hispanics from 1. *Over65* reflects the proportion of the population that is at least 65 years old while *under18* represents the proportion that is under 18 years of age. As previously mentioned, this data was gathered at the county level, but aggregated at the DMA-level. Values for DMAs were calculated through a weighted average of the reported values for individual counties. Each variable was weighted by population, with the exception of median household income, which was weighted by number of households.

IV. Empirical Specification

4.1 Definition of Options and Market Shares

The question then turns to the best method of estimating such a demand function. The Berry logit (Berry, 1994), a logistic model often used to describe discrete consumer choice, should suit my purposes well. Consumers in a particular market are known to have J options. As previously explained, these J options will constitute all passenger vehicle models that are typically purchased for personal rather than commercial use. Consumers also have an “outside option,” known as option zero. In this case, the outside option refers to the portion of the market that did not purchase a passenger vehicle for personal use in 2006. In order to define this, I will make two assumptions. First, all households in the US have some need for transportation, and this need can be fulfilled by a personal vehicle. Second, I assume that households purchase at most one car per year. In doing this, I can define the outside option as the number of households in each DMA that did not purchase a vehicle. This is calculated by subtracting the number of vehicles sold in a particular market from the total number of households in that market.

The market share captured by a particular option, in this case a specific vehicle model, is labeled S_j, while the outside option is designated by S_0. Summary statistics for individual shares and the outside option are reported below. Individual shares vary across each model and DMA, while the share of the outside option is consistent across models within the same DMA.

Table 4.1 - Summary statistics for market shares

Variable	Mean	Std. Dev.	Min	Max
Individual Models	.0003906	.0007555	0.00	.0125
Outside Option	.8679550	.0288586	.799	.8963

The outside option’s market share falls within a 10% range across DMAs. This serves as a reassurance that the propensity to buy some kind of personal vehicle is relatively consistent across different geographic markets. The fact that the outside option constitutes such a large portion of the market is also to be expected, as only a small share of households purchase a vehicle in a given year.

4.2 Utility and Discrete Choice

We then turn our attention to how utility enters into this model of discrete choice, using the method developed by Berry and further explained by Beresteanu (2007). The market of J options contains N individual consumers. The utility consumer n gains from purchasing option j, labeled U_{nj}, is composed of two parts. The first, V_{nj}, is known and observable up to some parameters. We call this the average utility of option j for consumer n. There also exists, however, an unknown and unobservable part that we are forced to treat as random. This is labeled $\varepsilon_{nj,}$ and is referred to as consumer n's "shock taste" for option j. Thus:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \quad \text{(Eq. 1)}$$

Each consumer is known to have J+1 independent random taste shocks for each option. They are distributed Type I Extreme Value, with a mean of zero and variance of $\pi^2/6$. This gives rise to the following cumulative distribution function:

$$F(\varepsilon) = e^{-e^{-\varepsilon}} \quad \text{(Eq. 2)}$$

P_{nj} refers to the probability that consumer n will choose option j. It depends on both the known and unknown parts of utility found in Equation 1 and can be described as follows:

$$P_{nj} = \Pr(V_{nj} + \varepsilon_{nj} > V_{ni} + \varepsilon_{ni} \ \forall\, i \neq j) = \Pr(V_{nj} - V_{ni} > \varepsilon_{ni} - \varepsilon_{nj} \ \forall\, i \neq j) \quad \text{(Eq. 3)}$$

A special property of Type I Extreme Values is that the difference between two random values generated by this distribution is Logit distributed. Thus, the difference between the two error terms in Equation 3 has the following cumulative distribution function:

$$F(\varepsilon) = \frac{e^{\varepsilon}}{1+e^{\varepsilon}} \quad \text{(Eq. 4)}$$

Integration over the above distribution, combined with some algebra, yields a new expression for P_{nj}:

$$P_{nj} = \frac{e^{V_{nj}}}{\sum_{i=0}^{J} e^{V_{ni}}} \quad \text{(Eq. 5)}$$

We then normalize this by fixing $V_{n0} = 0$. Although assigning the utility of the outside good to zero may seem somewhat arbitrary, what we are actually concerned with is the difference between utilities. Thus, this normalization will not be a problem, as it simply means that everything is measured with respect to the outside good. As a result:

$$P_{nj} = \frac{e^{V_{nj}}}{1+\sum_{i=1}^{J} e^{V_{ni}}} \quad \text{(Eq. 6)}$$

$$P_{n0} = \frac{1}{1+\sum_{i=1}^{J} e^{V_{ni}}} \quad \text{(Eq. 7)}$$

Next, we assume that the N consumers in the market are essentially identical. This means that, although they differ in the taste shocks they draw, they do not differ in average utility gained from each option. This allows us to drop the n subscript. In addition, we define S_j as follows:

$$S_j = N^*P_j \quad \text{(Eq. 8)}$$

Dividing Equation 6 by Equation 7 and plugging into Equation 8, we find an expression for relative market share in terms of average utility:

$$\frac{S_j}{S_0} = e^{V_j} \quad \text{(Eq. 9)}$$

Taking the natural logarithm of Equation 9 yields:

$$\log\left(\frac{S_j}{S_0}\right) = V_j \quad \text{(Eq. 10)}$$

Finally, we assume that average utility is linear in characteristics and price. Thus, observed market shares for all j options plus the outside option can be used to construct the following regression:

$$\log(S_j/S_0) = \beta_0 + \beta_1 X_1 + ... + \beta_k X_k - \alpha P_j - \eta_j \quad \text{(Eq. 11)}$$

X_1 through X_k represent explanatory variables, i.e. the aforementioned product characteristics and external influences on consumer preferences, P_j represents the price of the option, and η_j encapsulates unobserved product characteristics.

4.3 Endogeneity of Prices

A simultaneity problem arises in that P_j is likely correlated with at least some of the unobserved product characteristics included in η_j. To remedy this, instrumental variables must be used to derive an expected value of P_j. A satisfactory instrument will affect the price of an option without being correlated with any unobserved product characteristics. In his 1995 paper on automobile prices, Berry included miles per dollar rather than miles per gallon into the demand equation, as the former represents the true cost of use to the consumer. Miles per gallon may then be used on the supply side, as increased fuel-efficiency is in fact expensive to produce. I can calculate miles per dollar for each model and geographic location based on reported fuel-efficiency and recorded average gas price. Therefore, neither *Gas* nor *MPG* will enter the demand-side equation; instead, they will be combined into a new variable, *MP$*. Raw fuel efficiency (*MPG)*, on the other hand, will be included in the equation for price. Summary statistics for MP$ are presented below.

Table 4.2 – Summary statistics for miles per dollar term, all models

Variable	Mean	Std. Dev.	Min	Max
MP$	9.33	2.67	4.02	29.66

A more general strategy for dealing with the endogeneity problem is detailed in Aviv Nevo's study of the ready-to-eat cereal industry (Nevo, 2001). Each option occupies a particular position in a broader spectrum of product attributes, with most options clustered around a central, average value. The further an option is from this average, the more differentiated it is. Greater differentiation implies less competition. This decreased competition in turn implies greater market power, meaning the producer has more freedom to increase its price. Consequently, distance from the average value for a particular characteristic has an influence on price. In addition, the fact that this instrument is based on rival characteristics means that it will not be correlated with the unobserved product characteristics in the demand function. Thus, distance from rivals satisfies both requirements for an acceptable instrument within a Berry logit framework. I will first regress P_j on these instruments and then include the estimated value of P_j into the demand-side regression. In other words, the Berry method ultimately boils down to a standard 2SLS regression.

V. Findings

5.1 Determinants of Demand for Passenger Vehicles

I first estimate a demand function for all models based solely on product attributes. To aid in interpreting the results, the independent variables are scaled down to similar magnitudes. In addition, in order to isolate a vehicle's power from its size, horsepower is divided by curb weight. Summary statistics for the scaled variables are available in the appendix. The scaled variables are then imputed into the previously described Berry logit model. Only observations that recorded at least one registration for a particular model were included, as dependent values of zero are dropped from the regression.[4] Results from three different specifications are as follows:

Table 5.1 – 2SLS estimation for all models

$Log(S_j/S_0)$	**(1)** β	p-value	**(2)** β	p-value	**(3)** β	p-value
MSRP	-0.810	.11	-2.229	.00	-1.542	.00
HP/Weight	-0.245	.77	5.833	.00	4.309	.00
Miles per dollar	1.245	.00	1.789	.00	1.384	.00
Size	0.003	.89	-0.317	.00	-0.234	.00
Cargo room	0.189	.00	-0.099	.00	-0.432	.15
Weight	0.161	.19	2.312	.00	1.384	.00
Years	0.011	.00	0.022	.00	0.019	.00
Prestige	-0.661	.00	1.543	.00	0.954	.00
Five star			1.093	.00	1.051	.00
Three star			-0.095	.15	-0.138	.02
Japanese			0.340	.00	0.310	.00
European			0.313	.01	0.074	.47
Korean			-0.395	.00	-0.292	.01
Weight subsidy					0.729	.00
Constant	-10.519	.00	-14.130	.00	-12.028	.00
N	6370		4921		4921	
R-Squared	.221		.446		.451	

[4] Recall that the Berry logit involves taking the natural log of a vehicle's relative market share. Given that the natural log of zero is undefined, observations of zero are automatically dropped from the regression.

The first specification is what can be called a “bare bones” regression, similar to the minimal product attribute-based regression run by Berry (1995). This minimalist approach tends to be favored in the literature on automobile demand, as researchers are often wary of overspecifying their demand functions (Arguea et al, 1994). The magnitude and significance of my results are similar to Berry’s. Both found that horsepower was insignificant, while fuel efficiency was significant, positive, and greatest in magnitude. The similarity of my results to some found in the existing literature is encouraging; however, the interpretation of these results is a bit perplexing. While it is not hard to understand why consumers would find fuel efficiency very important, especially given the recent and continuing rise in gas prices, horsepower being altogether insignificant is a bit hard to believe. It may not necessarily be a consumer’s primary concern in choosing one model over another, but I find it unlikely that it would not matter at all, especially given the preponderance of “power-based” vehicles like SUVs in the overall market. The insignificance of MSRP is also odd, as one would expect price to have a strong effect on a vehicle’s market share. Finally, the negative coefficient on prestige does not make much sense, as one would expect prestige associated with a specific brand or model to have a positive effect on demand, given that I have controlled for price.

The most likely explanation for these odd results is that they are being skewed by outliers. “Exotic” vehicles such as Ferraris and Rolls Royce tend to come attached to extremely high values for horsepower and MSRP, as well as very low individual market shares. The Berry logit framework combats this somewhat by automatically dropping observations in which no registrations for a particular model were recorded. A model that sells one unit, however, is given equal weight as a model that sells 10,000 units, leaving ample opportunity for low-selling exotic vehicles to skew the results. Dropping vehicles that do not pass a certain sales benchmark could be one option for minimizing this effect; however, that would also involve dropping models that were aimed at the mass market but for one reason or another sold poorly. Because an accurate demand function must include vehicles that failed in addition to those that succeeded, I am reluctant to drop models from my regressions simply because they do not sell well.

An alternate approach to minimizing the effect of outliers comes through the inclusion of safety ratings, as shown in specifications two and three. As previously mentioned, not all vehicles undergo federal crash and rollover testing. Those that avoid testing tend to be prestige sports cars, very high-end luxury cars, and heavy duty utility vehicles. Incidentally, these are also the segments that are most likely to contain outliers that could potentially skew my results. With few exceptions, vehicles aimed at the mass market underwent safety testing, unsurprising given that a vehicle without safety information would likely raise suspicion in the minds of mainstream consumers. “Specialty” vehicles such as high-performance sports cars or high-end luxury cars, however, are aimed at niche markets. These consumers may be less concerned with safety ratings as compared to the performance or other amenities of the vehicle, and as a result the manufacturer or testing agencies may not see testing as worthwhile. Thus, the existence of safety ratings seems to be an adequate tool for separating mass market vehicles from high-end niche models.

In addition to including safety ratings, the second specification also includes dummies for the nationality of the vehicle’s brand. An attempt to include dummies for each individual brand was made; however the resulting regression ran into numerous problems with multicollinearity and dropped terms. The inclusion of brand nationality seems to be a good way to acknowledge the potential effects of the producers' image on demand without making the model too complicated. Brands fell into one of four categories: domestic (i.e. American), Japanese, European, and Korean. Note that this is based entirely on the brand and not the parent company. For example, the United Kingdom-based Jaguar brand falls into the European category, despite being owned by Ford in 2006. The highest proportion of models belonged to the domestic category, so it was the term excluded from the overall regression.

In general, the second specification seems to be a great improvement on the first. Besides the greater explanatory power reflected by the jump in R-squared, the direction of most coefficients now make much more intuitive sense. MSRP becomes more strongly negative and is now significant. Horsepower switches from negative to positive and also becomes significant. In addition, its coefficient is greatest in magnitude. This is not surprising, given that consumers tend to have a preference for greater horsepower, evidenced by how powerful vehicles such as SUVs and trucks often dominate year-end "best seller" lists. Horsepower is also probably acting as a proxy for other performance-related specifications, such as acceleration. Fuel efficiency, on the other hand, remains positive and significant and only rises slightly in magnitude. This consistency is encouraging, as it is this study's primary variable of interest. Although it no longer has the strongest effect on demand, it remains a relatively important regardless of the specification used. Granted, this may also be influenced by the fact that the data is drawn from only 2006, creating a snapshot of automobile demand squarely in the midst of a historic rise in fuel prices. Nevertheless, Berry's longitudinal estimation also found that fuel efficiency had a large impact on demand, so I am not too concerned by the study's narrow time focus.

The contrasting coefficients on size and weight may be seen as counterintuitive, given that the terms are correlated with each other. Delving deeper, the apparent contradiction can likely be traced to the definition of size. Recall that in creating the term, I took a length by width cross section of the vehicle, thereby excluding height. Thus, a full size sedan and an SUV with the same lengths and widths would be considered the same size, despite the fact that the SUV is likely to be larger due to greater height and heavier build. In light of that, the positive coefficient on weight is probably picking up on a preference for taller, strongly built vehicles that cannot be adequately captured by an approximation of cross-sectional area. In addition, because I scaled horsepower by weight, the weight term may also be picking up on a preference for more horsepower overall, rather than simply a high level of horsepower given the size of the vehicle.

The coefficients on years and cargo room both come out quite small. Years is positive and significant, likely due to consumers being attracted to more established models. The relatively small influence of the years term is also to be expected, as once a model moves past the introductory and potential "debugging" stage, the added benefit of existing for forty years as opposed to ten is probably quite small. In contrast, the negative coefficient on cargo room stands out as the one counterintuitive result from the second specification. All else equal, I cannot think of a plausible reason as to why consumers would prefer less cargo room. In light of the apparent soundness of all the other results, however, the negative coefficient on cargo room is not enough to discount the entire specification.

Finally, results for the dummy variables fall in line with expectations. Controlling for MSRP, prestige comes out positive and significant. Similarly, being regarded as a five star vehicle in terms of safety has a positive, significant, and fairly strong effect on demand. Results for the nationality dummies are also quite intuitive; Japanese and European brands have similar positive and significant effects, while the also-significant effect of Korean brands is similar in magnitude but opposite in sign. These results seem to reflect the general market perception of each nation as an automobile manufacturer compared to the United States. Japanese cars are typically seen as being very high in quality, European cars tend to come attached to an added aura of desirability, and the much more recently established Korean brands are viewed as uncertain, “cheap” alternatives (Parameswaran & Pisharodi, 1994). With time the Korean brands may undergo a journey similar to the Japanese automakers and emerge as high-quality sources of production, but for now it seems they are still seen as relatively undesirable.

While the second specification’s results seem to be quite sound, the relatively large coefficient on weight could be related to an outside variable which I did not include in my product attribute-based specification. Section 179 of the United States Internal Revenue Code, often referred to as the “SUV subsidy,” allows small business owners to deduct up to $25,000 of the cost of a vehicle with a gross weight over 6,000 pounds from their reported income (26 U.S.C. § 179). Note that gross weight is not the same as the curb weight measure used in this study. Curb weight refers to the vehicle’s weight when empty while gross weight adds the maximum load the vehicle is capable of carrying. In contrast, small business owners can only deduct $10,610 of the cost of a regular automobile. This therefore provides an incentive for small business owners to purchase heavy vehicles such as trucks and SUVs instead of sedans or compacts.

Because this subsidy only applies to small businesses, however, it is not clear if it should be included in a demand function aimed at household demand. Nevertheless, I ran a third regression with a dummy variable indicating whether or not a vehicle qualified for the subsidy. Unsurprisingly, the weight subsidy had a small, positive, and significant effect on demand, with the relatively small magnitude likely the result of its being aimed at small business owners rather then the overall market. In addition, the coefficient on weight remained positive and significant, but decreased by over 40 percent. Thus, it seems the existence of this subsidy does in fact partially account for the relatively high coefficient on weight. Most other results remained consistent between the second and third specification. Notably, however, three star safety ratings now return as negative and significant, as was expected.

I can then use these results to make some inferences about the potential for greater hybrid penetration in the overall market. The consistently positive, significant, and relatively strong coefficient on fuel efficiency confirmed by both this study and the existing literature is encouraging. Consumers clearly have a taste for fuel efficiency which may grow even stronger if gas prices continue to rise. It is important to keep in mind, however, that there exist important trade-offs in automobile production. Barring breakthrough technology, increased fuel efficiency typically comes at the cost of features also shown to have a strong positive effect on demand, namely horsepower and weight. In addition, the magnitude of the coefficients on horsepower and weight are quite a bit larger than the magnitude of the coefficient on horsepower. Thus, the relative difficulty many hybrid models have encountered when attempting to penetrate the American market may be related to consumers having a stronger preference for large, powerful vehicles than they have for fuel-efficiency. Firms therefore need to be very careful to strike the right balance in terms of fuel efficiency, power, and size. Sacrificing too much for the sake of fuel efficiency, as was likely the case with the now-defunct 73 horsepower Honda Insight, would make it very difficult for a hybrid model to successfully penetrate the market. Consumer preferences, however, are not invariable across different locations, nor are they immune to external intervention. The next section therefore narrows the estimation's focus to only hybrid vehicles in order to investigate the possible effects of external influences on demand for hybrids.

5.2 Determinants of Demand for Hybrid Vehicles

In limiting the regression's scope to hybrid vehicles, non-hybrid vehicles were excluded, but market shares were not recalculated. Thus this specification still places hybrids in the context of the overall passenger vehicle market, but allows the factors that attract consumers specifically to hybrids to be brought to the surface, rather than be buried amongst determinants of demand for the much greater number of conventional vehicles. I also added the previously described "external influences," i.e. gas prices, environmentalism, government incentives, and demographics.

Before analyzing regression results, however, it is necessary to discuss the limitations of this approach. Compared to the 338 models in the overall market, there are only eleven hybrid models included in the dataset. This drops the number of observations down to 226. A second difficulty arises in the interpretation of the regression output. In previous specifications run on the entire market, coefficients could be used to determine the sign and magnitude of consumer preferences irrespective of any added context. In contrast, when running a regression on a subset of vehicles, coefficients must be interpreted in light of the segment's position in the overall market. By purchasing a vehicle within a specific segment, such as hybrids or SUVs, consumers have already demonstrated a preference for a certain mix of product attributes. Regression results would then reflect an additional level of preference. In order to aid in these interpretations, summary statistics of hybrids as compared to the overall market and various vehicle segments are included in the appendix.

Table 5.2 – 2SLS estimation for hybrids only

$Log(S_j/S_0)$	β	p-value
MSRP	-1.779	.00
HP/Weight	3.769	.00
Miles per dollar	2.403	.00
Size	1.169	.00
Cargo room	-0.025	.98
Weight	1.685	.00
Years	0.831	.00
Prestige	0.704	.14
Five star	0.813	.00
Three star	-1.538	.00
Japanese	3.193	.00
Average gas price	-0.952	.21
Average LCV score	0.148	.00
Federal rebate	-0.001	.11
HOV access	0.230	.04
Free parking	-0.215	.18
Sales tax exemption	-0.023	.87
Emissions exemption	0.613	.08
Median household income	0.422	.01
% without high school diploma	1.259	.67
% with at least bachelor's degree	3.415	.32
% non-white	0.458	.46
% under 18	2.534	.07
% over 65	2.049	.69
Average commute time	-0.859	.00
Constant	-16.351	.00
N	226	
R-Squared	.889	

The coefficient on MSRP is negative, significant, and fairly high in magnitude, as expected. The prestige dummy being insignificant is also understandable. There are only two qualifying models in the hybrid subset, both sold under the Lexus marquee. The GS 450 had only been sold for four months at the time the data was collected, so its sales numbers were understandably low. The more established RX400, on the other hand, sold quite well for a hybrid. The conflict between these opposing data points is probably the source of prestige's lost significance.

As was the case in the overall market, preference for both horsepower and fuel efficiency appears to be quite strong. The magnitude of these coefficients for hybrids, however, are much closer, with the effect of fuel efficiency being only slightly weaker than that of horsepower. Since hybrids already have, on average, significantly higher fuel economy than the overall market, this demonstrated preference can be seen as particularly strong. The high priority placed on both horsepower and fuel efficiency even in the hybrid market makes the previous suggestion to properly balance fuel efficiency with the existing consumer preference for size and power even more critical. As previously mentioned, too much fuel efficiency at the expense of performance can doom a hybrid to failure; however, it seems too little fuel efficiency would give consumers insufficient incentive to make the switch from a conventional vehicle, as well as make it difficult to successfully compete with other hybrids.

Like in the overall specification, the years term has a positive and significant effect on demand. In the hybrid regression, however, its magnitude greatly increases. This is probably related to the fact that hybrids are a much newer technology and consumers are therefore likely to be cautious when purchasing relatively unproven vehicles. The coefficients on safety can also be related to the newness of hybrid technology. The five star term is positive and significant, as expected, but what is particularly interesting is that the three star term is negative, significant, and greater in magnitude. Thus, while in the overall market consumers were primarily concerned with seeking out five star ratings, in the nascent hybrid market consumers appear to place a higher priority on avoiding safety risks.

The Japanese term is positive and significant, as expected, but the large magnitude stands in stark contrast to previous results. This is probably due to Japanese manufacturers, namely Toyota and Honda, being the first to enter the hybrid market and thus benefiting from first mover advantage. Indeed, ever since the Prius took off at the turn of the century, domestic manufacturers have been left playing catch up. As domestic automakers gain more experience with hybrids and better establish themselves in the market this positive effect of Japanese branding may subside. Note that European and Korean dummies were excluded from the specification due to the fact that no European or Korean hybrids currently exist. Given that European automakers seem to enjoy a nationality-based boost similar to that of the Japanese in the overall market, a European hybrid may have a bit of an advantage over a domestic rival, in spite of its later entry.

Since hybrids are on average significantly smaller than automobiles in general, the positive coefficient on size may simply reflect a desire for an “average” sized vehicle as opposed to a large one. The magnitude associated with weight could be picking up a desire for higher levels of horsepower overall, as again the horsepower term has been scaled by curb weight. Or, like size, it could simply have to do with hybrids being lighter, and consumers having a certain desire for a “normal” vehicle weight. Although the difference in mean weights between hybrids and the overall market is not very dramatic, hybrids are more tightly spread and max out at a much lower weight. Thus, in spite of the relatively close means, interpretation of the weight coefficient should still reflect the fact that a "heavy" hybrid is nowhere near the same as a "heavy" conventional vehicle.

I then turn to the coefficients on gas price and LCV score, the two factors that lie at the heart of the debate on what exactly is driving demand for hybrids. Surprisingly, gas price is found to be insignificant. It is possible, however, that part of the effect of gas price may be picked up by the LCV term. According to the Energy Information Administration, around one-fifth of gasoline price is determined by federal and state taxes, with an additional component entering in the form of local and county taxes (EIA, 2006). These taxes vary from region to region and, at the state and local level, tend to be levied or strengthened in an attempt to reduce gasoline consumption by increasing its price (Fullerton & West, 2002). Higher gas taxes, and by extension higher gas prices, are therefore often found in areas with environmentally-minded officials. Consequently, it is feasible that the inclusion of the LCV score is crowding out the effects of regional variation in gas price. To confirm this, I ran an alternate regression that excluded the LCV score, and as predicted found that the coefficient on gas price turned significant and positive. Thus, these results do not prove gas price to be insignificant; rather, they highlight the limitations of using cross-sectional data. In order to more accurately investigate the effects of changes in gasoline price, I would need panel data, preferably starting before the rise in gas prices and continuing through the recent spike.

The LCV score is found to be positive and significant, as expected. Its relatively small magnitude, however, is somewhat surprising. In light of the fact that many people still believe hybrids are not cost-effective, I had expected environmentalism to have a strong effect on hybrid demand. It is possible that LCV score did not do a good job of proxying for community environmentalism. Or perhaps community environmentalism is irrelevant, as consumers ignore the judgment of their peers and make buying decisions based solely on their own environmental preferences. Further investigation and use of an alternate proxy or more detailed data on environmental sentiment would be needed to determine which is more likely to be the case.

The effectiveness of government incentives appears to be a mixed bag. The insignificance of free parking is understandable, as it only applies to select areas and lots in the DMA, and so could lack broad appeal to those who do not travel to those locations. The insignificance of the size of the federal rebate and exemption from sales taxes may indicate that tax incentives are not very effective at stimulating demand for hybrids. Note, however, that these results can only evaluate the effect of the size of the rebate, not the existence of the rebate itself. There may also be endogeneity issues at play with regards to the rebate, since the size of the rebate is directly influenced by vehicle sales. But because running the regression without the rebate did not significantly change the results, I kept it in the main specification. On the bright side, exemptions from emissions inspection and access to HOV lanes were both found to be positive and significant, with the magnitude for emissions exemption being quite a bit larger than that for HOV access.

Demographic variables were also met with mixed success in terms of having explanatory power for hybrid demand. Education and race are insignificant.
Median household income had a relatively small, positive, and significant effect on demand for hybrids, which can be attributed to the fact that hybrids are on average more

expensive than conventional gas-powered vehicles. Commute time is found to be negative, significant, and somewhat large. This may be related to comfort, as hybrids are often smaller and lacking in amenities compared to similarly-priced gas-powered vehicles. Thus, consumers who spend more time in their cars may view that as more of a drawback. The proportion of the population over 65 is insignificant, but the proportion under eighteen has a large, positive, and significant effect on demand. The proportion of the population under eighteen is positively correlated with the proportion of younger adults. This inverse relationship between age and hybrid demand supports Kayser's earlier results regarding age and implicit preference for fuel efficiency. Also, younger adults have been found to be more likely to adopt new technology that they consider useful, whereas older adults tend to be more concerned with societal norms and the extent to which others see the technology as necessary (Morris & Venkatesh, 2000). Young consumers who see value in hybrid-electric technology are probably more likely to purchase a hybrid regardless of how hybrids are viewed by their social network.

Overall, although inclusion of external influences greatly increases the explanatory power of the model, it seems that the set of variables that constitute the primary determinants of demand for hybrids is not necessarily vastly different from those of automobiles in general. Product attributes still tend to have the strongest effects, even when including government incentives and demographics. Thus, although external influences such as environmentalism and certain government incentives do aid demand, it seems hybrids must first and foremost be able to compete with other vehicles in terms of their attribute-based merits if they hope to gain widespread market penetration. Technological advancement may therefore be the single most important driver of hybrid demand, as improvements in mechanical design could lessen or even eliminate the severity of power and size-related sacrifices for fuel-efficiency.

5.3 Determinants of Demand by Vehicle Segment

Vehicle segment likely exerts great influence on the mix of product attributes consumers prefer most, and would therefore affect relative preference for fuel efficiency and the extent to which a hybrid model would be able to penetrate the market. Consequently, the final set of regressions breaks the market into six segments, within which vehicle models are distributed as follows:

Table 5.3: Distribution among vehicle segments

Segment	Hybrids	All Models
Compact	3	53
Sedan	3	87
SUV	5	104
Minivan	0	18
Truck	0	20
Sport	0	56

With the exception of "Sedan," all segment labels reflect official vehicle classifications. Vehicles classified as full-size or mid-size are categorized as sedans for the purposes of this study. Note that, as of 2006, hybrids had only entered three of the six segments. Results for minivans, trucks, and sports cars should therefore be particularly interesting.

I then split the dataset according to these six segments and ran product-attribute based regressions for each one. Results are presented below. Brand nationality and prestige dummies were occasionally dropped due to a lack of such vehicles in the segment. Since the sports cars segment contains an unusually high concentration of MSRP- or power-based outliers that would skew the results, observations sold for an MSRP of over $80,000 were dropped.

Table 5.4 – 2SLS estimation by vehicle segment

$Log(S_j/S_0)$	Compact β	Compact p-value	Sedan β	Sedan p-value	SUV β	SUV p-value
MSRP	-2.773	.01	-0.565	.00	-1.208	.09
HP/Weight	3.255	.04	0.912	.01	-0.694	.27
Miles per dollar	2.017	.00	2.197	.01	-0.234	.71
Size	-0.173	.41	0.835	.00	0.332	.06
Cargo room	-1.314	.00	1.168	.00	-0.063	.13
Weight	2.643	.00	-4.599	.51	1.496	.00
Years	0.026	.00	-0.047	.00	0.015	.03
Prestige	0.811	.27	1.543	.36	0.528	.08
Five star	-0.476	.38	0.740	.00	1.043	.00
Three star	-0.038	.85	-0.933	.00	0.755	.00
Japanese	1.402	.00	-1.513	.23	0.268	.01
European	1.282	.06	-2.344	.21	-0.997	.00
Korean	0.781	.00	0.970	.51	-0.175	.02
Constant	-16.09	.00	-15.34	.00	-8.517	.00
N	1003		1286		1681	
R-Squared	.173		.311		.202	

	Minivan β	Minivan p-value	Truck β	Truck p-value	Sport β	Sport p-value
MSRP	1.320	.00	-0.164	.00	-1.677	.00
HP/Weight	3.942	.00	9.228	.00	5.278	.00
Miles per dollar	1.287	.24	0.449	.67	2.588	.00
Size	-0.871	.01	-0.530	.69	-0.374	.15
Cargo room	0.174	.00	0.246	.01	-0.526	.03
Weight	-1.521	.61	1.561	.02	2.073	.00
Years	0.174	.00	0.072	.00	-0.038	.00
Prestige			-0.783	.05	3.328	.00
Five star	5.399	.00	1.583	.00		
Three star	-1.524	.01	-0.757	.00		
Japanese	-3.335	.00	-1.544	.01	-0.574	.00
European					-1.578	.33
Korean	-0.022	.06				
Constant	-16.09	.00	-17.42	.00	-13.126	.00
N	322		374		566	
R-Squared	.722		.649		.233	

I begin with compacts, which unsurprisingly yielded results that were closest to hybrids. The greater magnitude of the MSRP coefficient may be related to the fact that compacts tend to be less expensive, since there is some evidence that own-price elasticity of demand is higher in cheaper vehicle types (Bresnahan, 1981). The relative balance between horsepower and fuel efficiency is very close to that of hybrids, and once again it is important to keep in mind that compact horsepower is lower than average, and compact fuel efficiency is higher than average. Thus, compact owners seem to exhibit a preference for moderately powerful vehicles on top of a very strong preference for greater fuel efficiency. The coefficient on weight is positive, significant, and quite large, reflecting a possible preference for greater overall strength of the vehicle. Combining the insignificance of prestige with the positive coefficient on Korean branding, it appears that compact owners do not care much about brand image when making purchasing decisions. Finally, the coefficients on Japanese and European branding are positive and significant, with a greater magnitude on Japanese branding, as was expected.

The bulk of the results for sedans make intuitive sense. MSRP enters as negative and significant. Horsepower and fuel efficiency both come out positive and significant, however for the first time fuel efficiency is much greater in magnitude than horsepower. Excepting sports cars, sedans had the highest values of horsepower per weight, while sedan fuel efficiency was merely average. Thus, it seems that sedan owners would like to continue purchasing relatively powerful cars, but now also desire a much greater level of fuel efficiency. Weight coming back as insignificant lends further credence to the hypothesis that sedan owners care more about relative horsepower given the vehicle’s size rather than a high level of overall power. Both size and cargo room are positive, significant, and relatively high in magnitude. It is worth noting that the strength of the coefficient on cargo room is stronger for sedans than for any other segment. Five star ratings have a positive and significant impact on demand, while three star ratings have an even larger negative and significant effect. Sedan owners therefore are concerned with safety, but seem to be more concerned with avoiding risk than seeking out safer-than-average vehicles.

Unfortunately, the insignificance of the prestige and brand nationality dummies in the sedan regression is very surprising and quite difficult to explain. I find it extremely unlikely that prestige has no effect on consumer demand for sedans, especially given that many of the most widely recognizable and best-selling luxury vehicles fall into this segment. Likewise, although it is possible that sedan owners do not have a preference for one brand nationality over another, it strikes me as very strange that such a preference would exist for literally every other segment, but disappear in the sedan market. I am therefore quite skeptical of the accuracy of these particular results. There may be issues with omitted variable bias at play, perhaps related to the necessity of a more detailed set of brand dummies rather than generalized prestige and nationality descriptors.

Results of the SUV regression are mostly understandable. The coefficient on MSRP conforms to expectations. The large, positive, and significant coefficient on weight is also expected, as is the smaller, positive, and significant result for size. SUVs tend to grow in height faster than they grow in length and width, so the stronger effect of weight as opposed to horizontal cross-sectional area makes sense. The strength of the coefficient on weight likely explains the insignificance of horsepower per ten pounds as well, as consumers in search of an SUV seem more concerned with overall rather than relative power. The insignificance of fuel efficiency may also make sense, as the fact that SUVs sell quite well despite being considerably less fuel efficient than other vehicle types could reflect an outright disinterest in fuel economy on the part of SUV owners. Cargo room being insignificant is somewhat unexpected. This may be related to the way in which cargo room was imputed into the dataset. I used the measurement of cargo room when all seats were in place in order to keep the variable consistent across models and vehicle segments, since not all models offer the option of folding up seats, nor would all consumers want to sacrifice seating for storage space. SUVs, however, were much more likely to have foldaway seats as an option, and the disparity between maximum and baseline cargo space tended to be very pronounced. Thus, the cargo room term as imputed into the dataset may not accurately reflect the vehicle's true storage capacity in the minds of SUV consumers.

Most of the results for the SUV dummy variables make intuitive sense. Prestige is positive, significant, and fairly strong. The effects of the brand nationality dummies, on the other hand, are a bit different than what we have previously seen. Though the coefficient on Japanese branding remains positive and significant, it is much smaller in the SUV regression than in others. In addition, the effect of European branding remains significant but has turned negative. Although Japanese and European manufacturers tend to have reputations of higher quality or desirability, SUVs are marketed less based on quality or prestige and more on the basis of a tough, rugged, very individualistic image (Gunster, 2004). This fits better with consumer perceptions of American as opposed to foreign branding. Thus, even if a consumer thinks foreign-made vehicles are better than domestic counterparts in general, when purchasing an SUV they may prefer a more rugged "American" image.

A five star safety rating has a strong, positive, and significant effect on SUV demand. Interestingly, however, the three star rating also has a fairly strong, positive, and significant effect. At first glance this seems very counter-intuitive. In the case of SUVs, however, three star ratings were almost always granted in the rollover tests, not the crash tests. This is a common problem in SUV design, as increasing height without adequately increasing width moves the vehicle's center of gravity upwards and makes it much more prone to rollover (Penny, 2004). Thus, the positive coefficient on the three star term seems to have inadvertently caught a taste for height.

Results from the minivan regression are a bit harder to understand. Most obviously, MSRP has a strong positive effect on demand, which flies in the face of basic economic intuition. Referring back to the summary statistics, minivans were the most tightly clustered in terms of price, with an overall range of only fifteen thousand dollars. Given that price has been shown to influence a consumer's perception of product quality (Zeithaml, 1988), minivan owners could be using price as a partial proxy for the quality of the model. The absence of any quality measures in my specification could therefore be the cause of the positive coefficient on MSRP. Fuel efficiency, size, and weight all return insignificant. As was the case with SUVs, minivans are less fuel efficient than average and owners may simply not care about fuel economy. And similar to MSRP, the distribution of size and weight is quite tightly clustered in the minivan segment. This apparent lack of variety probably leads consumers to ignore those factors when deciding which minivan to purchase. The magnitude of the positive and significant coefficient on horsepower is somewhat surprising, as one would not expect minivan owners to be overly concerned with their vehicle's power. Because minivans have on average fewer horsepower per ten pounds than vehicles in every other segment, this could reflect a desire for moderately more powerful options in the minivan market. Both Korean and Japanese branding have a negative and significant effect. While the Korean results are expected, I cannot think of a good reason as to why minivan owners would so strongly want to avoid Japanese vehicles. Similar to the problems with nationality dummies in the sedan regression, there may be brand-level effects muddying the nationality-level results.

Fortunately, the effects of the three remaining terms in the minivan regression make intuitive sense, especially in light of the fact that minivans are specifically developed for and targeted towards families with children (Porac et al, 2001). The positive and significant coefficient on cargo room likely reflects a desire for enough storage space to meet the needs of transporting or shopping for a family. Five star safety ratings seem to be the strongest determinant of minivan demand, and three star ratings are more strongly negative than usual. This makes sense, as parents are extremely concerned with keeping their children as safe as possible and would want to avoid potentially unsafe vehicles more than any other type of consumer.

Most of the results for the truck regression fall in line with expectations. MSRP is negative and significant. Fuel efficiency is insignificant, which again is probably a result of trucks being less fuel efficient than average and owners not placing a high priority on fuel economy. Cargo room is positive and significant. Its magnitude may seem small, but we must keep in mind that trucks already have by far the highest storage capacity of any segment. Extra cargo capacity on top of that may not be very important, especially given that truck owners can simply attach a trailer to haul large loads. The results for weight must be discussed alongside the unusual results for horsepower per ten pounds. Although both return positive and significant, as expected, the magnitude of the coefficient on horsepower is extremely large, perhaps too much so. It does make sense, however, that truck owners would be most concerned with the power of their vehicles relative to its mass, as they need their trucks to be strong enough to handle heavy cargo loads and tows. The smaller but still relatively large coefficient on weight probably reflects both a desire for more overall power and a need for greater strength and bulk.

Coefficients on the prestige, safety, and nationality dummies in the truck regression also make sense. A five star safety rating has a strong, positive, and significant effect on demand, while a three star rating has a somewhat weaker but still significant negative effect. While the negative direction of the prestige coefficient might seem counterintuitive, it is worth noting that there was only one qualifying model in the truck segment, so the prestige coefficient is probably picking up consumer taste for unobserved characteristics of that particular model more than anything else. The negative, significant, and relatively large magnitude of the Japanese term matches expectations. Pickup trucks are seen as distinctly American, and although Japanese models have been making some headway in recent years, the market for trucks is still unambiguously dominated by American brands.

Finally, the results for sports cars are quite interesting. MSRP is negative and significant, as is cargo room. Given that sports cars are built for performance rather than convenience, and therefore tend to have very little storage space, the latter is not at all surprising. The coefficient on prestige is positive, significant, and quite large. Sports cars are often thought of as "trophies" of sorts, so it makes sense that prestige associated with either the brand or the specific model would be very important. The negative and significant coefficient on Japanese branding and the insignificance of European branding, on the other hand, are somewhat unexpected. Similar to trucks and SUVs, this could be another case in which a "performance" vehicle gets a boost from domestic branding. Also note that safety ratings were excluded from the regression. A high proportion of sports cars did not have crash test data available and the exclusion of these models when specifically investigating demand for sports cars would bias the results.

Of particular interest, however, are the results for horsepower per ten pounds, fuel efficiency, and weight. Unsurprisingly, horsepower per ten pounds is by far the strongest determinant of demand. Its very high coefficient comes on top of the fact that sports cars already have a much higher mean horsepower than the rest of the dataset. The strong positive and significant coefficient on weight may also reflect a desire for a high level of horsepower overall. What is interesting, however, is that fuel efficiency also returns a strong, positive result. In fact, only horsepower and prestige exert a stronger influence on demand. Keep in mind that the average fuel efficiency of the sports cars used in this regression is already quite close to the industry average, so the strength of the coefficient on gas mileage does in fact reflect a desire for superior fuel economy. It therefore seems like sports car owners may in fact think practically when making purchasing decisions, at least in the matter of fuel efficiency.

I can now use these results to discuss the possibility of successfully introducing new hybrids in each segment, as well as the extent to which we might be able to expect further hybrid penetration of segments that already have hybrid models. Consumers of compacts and sedans, both of which currently house a few hybrid models, display a pronounced preference for greater fuel efficiency. In the case of sedans, this preference actually outweighs the desire for greater horsepower. Thus, hybrid sedans may be able to attract consumers in spite of lower horsepower if they are able to make up for the loss in power with significant gains in fuel efficiency. The same could be said for compacts, but the relative weight given to horsepower over fuel efficiency in the compact results means producers should tread more carefully. It is certainly fine for a compact to be less powerful than the average automobile, but a hybrid compact should take care to not further reduce power by too much compared to other compacts. As proven by the Honda Insight, a dismal amount of engine power can prove disastrous.

Most surprisingly, the mainstream sports car market also looks like it would be a viable candidate for hybrid-electric success. Certainly, horsepower and other performance-based attributes reign supreme. But the strength of the coefficient on gas mileage shows that the average sports car owner is not closed to the idea of taking mileage into account when choosing one model over another. Thus, if a hybrid-electric engine could provide a comparable or superior level of horsepower to the average gas-powered sports car, it could be a great success. Releasing the model under a prestige brand would act as an added boost. Whether or not the technology necessary to achieve this currently exists, however, is unclear. A substantial dip in horsepower for the sake of improving fuel efficiency would certainly not be advisable. Thus, despite the market's apparent readiness for a hybrid-electric sports car, it may be several years before a viable candidate can be introduced.

In contrast, fuel economy does not appear to be of great concern to consumers in the SUV, minivan, and pickup truck segments. In all three estimations, fuel efficiency returned insignificant. In addition, both minivans and trucks place a great deal of importance on relative horsepower, with trucks adding in an extra focus on weight. Although the insignificance of horsepower per ten pounds for SUVs could be seen as encouraging, the importance of weight likely accounts for both size-related preferences and desire for vehicles with an overall high horsepower rating. Both power and weight act as significant barriers to improving fuel efficiency and existing hybrid technology has not yet found a way around this. Indeed, the hybrid SUVs in the dataset either made great sacrifices in terms of horsepower or did not make significant strides with regard to fuel efficiency. The extent to which hybrids could make significant gains in market share in any of these segments therefore appears uncertain.

In light of that, it might seem like GM's vice chairman was wrong to claim that high-margin fuel-inefficient vehicles are, from a manufacturer's standpoint, a better choice for hybrids than compacts and sedans. It is important, however, to keep the limitations of this study's approach in mind before writing off his statement. I only studied demand, while an executive in an automotive firm would also have to consider factors influencing supply. It could be that the cost of developing hybrid technology for compacts and sedans cannot be recuperated through the low profit margins earned on their sales. Thus, even if demand for SUV, minivan, or pickup truck hybrids would not be as strong, the higher profit margins could go further to recover the costs of necessary research and development. In addition, the estimations presented in this paper can only describe consumer preferences among already existing options. As of 2006, very little in the way of fuel efficient SUVs, minivans, or trucks were on the market. It could very well be the case that there exists a substantial base of consumers that would have liked to purchase more fuel efficient versions of those vehicles, but were prevented from doing so by the dearth of options available to them. Introducing hybrid SUVs, trucks, and minivans could therefore take advantage of an untapped market, the potential size of which would be unknown. Finally, we should keep in mind that the vice chairman's statement comes from the perspective of an American manufacturer. According to this paper's results, domestic producers enjoy a competitive advantage over foreign brands in the SUV, pickup truck, and perhaps even minivan segments. Thus, by introducing high-powered SUV, truck, or minivan hybrids, an American producer would be taking advantage of an existing competitive edge. It is therefore unsurprising that Ford and General Motors have favored sport utility hybrids.

VI. Conclusion

In my paper, I utilized the Berry logit framework and data on year 2006 vehicle registrations to estimate three sets of automobile demand functions. These demand functions varied in scope, covering the overall market, the hybrid market, and separate vehicle segments. I found that primary determinants of demand are relatively similar between the overall market and hybrids, but that they vary wildly among class-based vehicle segments. Horsepower per ten pounds, fuel efficiency, and weight have a relatively consistent and strong effect on demand in the overall market, the hybrid market, and several vehicle segments. The sports car segment in particular returns a high priority on fuel efficiency, although it is unsurprisingly overshadowed by a much stronger preference for horsepower. The importance of weight was likely increased by the nature of the specification, as horsepower was scaled by vehicle curb weight, leaving the overall weight term to partially reflect the engine's raw power. In addition, the existence of a weight-based tax incentive for small business owners increased the magnitude of weight's effect. The fact that this particular set of attributes consistently returns positive and mostly significant points to the importance of balance in positioning new vehicles in the market. Hybrids benefit from the demonstrated consumer preference for fuel efficiency, but are hurt by the often stronger preference for horsepower and weight. It may therefore take technological advancements that allow for significantly increased fuel efficiency without the loss of power and weight before hybrids break out of their current niche markets. The compact and sedan segments, however, do appear to be more forgiving of lost horsepower and weight than the SUV, minivan, truck, and sports car segments. Thus, compact and sedan hybrids are free to place a greater emphasis on fuel efficiency, while SUV, minivan, truck, and sports car hybrids need to be more careful to not sacrifice too much in terms of power.

Manufacturers should also be wary of weakening other product attributes shown to have an effect on demand. Safety ratings, for example, exert a relatively consistent influence on demand. Hybrid manufacturers need to be particularly careful to avoid low safety ratings, as the negative effect of perceived safety risk outweighs the positive effect of exemplary safeness in the hybrid market. The importance of these non-performance based attributes also varies between segments. Safety reigns supreme in the minivan segment, while cargo room is very importance in the sedan and pickup truck markets. Thus, in terms of non-performance-based determinants of demand, manufacturers should take care to position hybrids as closely to successful existing gas-powered models as possible. They could also try to lure consumers by improving on these features in their hybrids; however, given the strength of consumers' preferences for performance and the relatively low sales of hybrids, from the manufacturer's standpoint there is little reason to specifically limit improvements in these product attributes to hybrid models and to not extend the upgrades to their conventional gas-powered counterparts as well.

In the overall market, the hybrid market, and some vehicle segments, Japanese branding aids demand relative to the effect of a domestic nameplate. The same holds true for European brands when applicable. But in performance-based segments such as SUVs, trucks, and sports cars, domestic manufacturers have an advantage over their foreign rivals. With the exception of compact, Korean branding always returns as a negative influence. Thus, domestic manufacturers may find particular success in introducing hybrid SUVs and trucks, but this nationality-based competitive advantage should be evaluated against the greater preference for fuel efficiency present in other vehicle segments. Korean manufacturers may find success with hybrid compacts, but should probably work to improve their overall image before attempting to introduce hybrids into other segments. The effect of prestige on demand for hybrids is inconclusive due to the relative newness of luxury brands in the hybrid market. Brand or model-based prestige does, however, positively affect demand after controlling for price in the overall market and in most segments. The consistency of the results on prestige, combined with the fact that hybrids sold better in markets with higher median incomes, means there is little reason to believe that prestige branding would not have a positive effect on hybrid demand once the hybrid market matures and offers a greater array of luxury options.

External influences such as demographics, government incentives, and measures of environmentalism are shown to have an effect on the demand for hybrid, but these effects are never so pronounced that they overtake product attributes in importance. Thus, it seems consumers primarily view hybrids as just another option in the overall automobile market and make their purchasing decisions based mostly on how well a model fits their transportation needs and wants. That is not to say, however, that external influences do nothing to lure consumers to or away from hybrids. Environmentalism as quantified by LCV score has a positive effect on demand, so increasing environmental awareness and emphasizing the environmental benefits of driving a hybrid could certainly improve hybrid sales. Median income also has a positive effect, meaning there may exist special opportunities for luxury brands in the hybrid market. Age appears to have an inverse effect on demand, implying that marketers should focus their immediate efforts on younger consumers and wait for widespread changes in attitudes regarding the importance of fuel-efficiency before aggressively targeting older adults. Commute time, on the other hand, has a negative effect on demand, so hybrid manufacturers may want to make their models more comfortable and inviting to consumers who must spend extended periods of time inside their cars.

Although tax incentives and free parking return insignificant, access to HOV lanes and exemption from emissions inspection return as positive and significant. What is particularly interesting is that both these incentives are convenience-based rather than cost-based, as the primary benefit to consumers relates to saving time rather than saving money. Given the apparent success of these two incentives, policy makers may find it in their best interest to investigate other ways to stimulate demand for hybrids through saving their owners time. One possibility for densely populated urban areas could relate to increasing access to parking rather than simply decreasing its monetary costs. Hybrid owners could be exempt from time limits on metered parking spots, or be allowed to park in areas that normally have time and day-based restrictions on public access. Whatever the approach, convenience-based incentives certainly seem to be an avenue worth further exploration.

There is great potential for further research on the topic of hybrid demand. The market for hybrids is fast-growing and constantly changing, with models being added to and dropped from manufacturer lineups every year. A panel study of the growth of the hybrid market from its inception in the late 1990s could be very illuminating. Adding a level of time variance to gas prices would almost entirely disentangle them from the effects of legislative environmentalism, thus offering a much clearer picture of the effects of both gasoline prices and environmentalism on hybrid demand. Better data on environmentalism would also be of great value. Although the proxy used in this paper may have been valid, a more direct measure of a community's level of environmentalist sentiment, such as membership in environmental organizations, would add much to an analysis of environmentally-motivated consumption. It would be important, however, to keep in mind that a certain degree of the recent rise in demand for hybrids is likely a result of their moving out of the early adopter stage and into more mainstream acceptance, a phenomenon common to newly introduced technologies and entirely separate from changes in gas price or environmental attitudes.

Individual or household-level data would be extremely useful, as that would allow for a much more nuanced picture of how factors such as personal environmentalism, education, age, and other demographics affect demand. Unfortunately, household level data is quite hard to come by, especially with regards to recent automobile purchases. Even moving down to the county level, however, would add a great deal of detail and credence to the results on demographic and geographic influences on demand, as there was often significant variation within the DMAs themselves. Data on a wider cross-section of the country may also be helpful, although there does not seem to be any reason to believe that the selection of DMAs biased this paper's results in any way.

There certainly exists potential for improvement on this paper's specification. For example, a model that disentangles the effects of horsepower and weight would clear up the ambiguity regarding that particular relationship found in my results. Factoring height into the measurement of size may be useful, as consumer preference for the increased height of SUVs, trucks, and minivans was never directly measured. Brand-level effects would also be quite interesting and could potentially shed light on some of the odd results yielded on the nationality dummies by a few segment-based regressions. Finally, a more extensive set of explanatory variables, similar in spirit to the data gathered for hybrid demand, could add a great deal of explanatory power to the segment-specific estimations. For example, age may have an effect on the demand for sports cars, while family size could influence demand for minivans.

In spite of its limitations, this paper still offers valuable insight into the determinants of demand for various types of automobiles and the implications for the future of hybrid-electric vehicles. As hybrids diversify and enter new areas of the automobile market, it will be very interesting to see how they are met by varying levels of success in different vehicle segments, and how external factors such as the continuing rise of gasoline prices influence consumer preferences. Although it is impossible to predict future consumer response with any kind of certainty, the results presented here offer a starting point for manufacturers and policymakers as they investigate how to best manipulate product characteristics, local incentives, and environmentalist sentiment in order to attract a larger number of consumers to the hybrid market.

Appendix

Summary statistics for scaled product attributes. Note that vehicles with an MSRP of over $80,000 were dropped from the sports car segment.

Variable	Scale	Mean	Std. Dev.	Min	Max
MSRP	$10,000				
Overall		4.187	5.298	0.943	144.080
Hybrid		2.966	0.998	1.933	5.490
Compact		1.841	0.675	0.943	3.933
Sedan		5.749	7.474	1.335	38.600
SUV		3.439	1.491	1.555	10.750
Minivan		2.533	0.395	2.055	3.689
Truck		2.309	0.667	1.505	3.813
Sport		3.976	1.583	1.767	7.834
HP/Weight	HP/10 lbs				
Overall		0.641	0.216	0.351	2.405
Hybrid		0.516	0.161	0.351	0.820
Compact		0.514	0.072	0.375	0.704
Sedan		0.600	0.160	0.444	1.246
SUV		0.555	0.079	0.351	0.846
Minivan		0.507	0.060	0.413	0.623
Truck		0.566	0.097	0.443	0.851
Sport		0.806	0.211	0.571	1.589
Miles per dollar	10 MPG/$				
Overall		0.949	0.265	0.416	2.966
Hybrid		1.620	0.534	1.019	2.966
Compact		1.245	0.369	0.603	2.966
Sedan		0.973	0.186	0.503	1.849
SUV		0.838	0.176	0.418	1.476
Minivan		0.869	0.089	0.588	1.031
Truck		0.787	0.171	0.418	1.229
Sport		0.980	0.154	0.571	1.391
Size	10 sq ft				
Overall		9.572	1.274	6.595	13.748
Hybrid		8.837	0.682	7.184	9.502
Compact		8.232	0.532	6.595	9.108
Sedan		9.996	0.835	8.152	13.135
SUV		9.740	0.945	7.599	12.594
Minivan		10.408	0.370	9.478	10.999
Truck		11.128	1.463	9.032	13.748
Sport		8.365	0.709	7.005	9.648
Cargo room	10 cu ft				
Overall		2.273	1.462	0.150	8.326
Hybrid		1.865	1.001	0.750	3.830
Compact		1.484	0.587	0.560	4.440
Sedan		1.573	0.358	0.750	3.590
SUV		3.211	1.206	0.750	6.180
Minivan		2.883	0.853	1.290	4.360
Truck		5.088	1.802	2.370	8.326

Sport		0.956	0.456	0.150	2.240
Weight	1000 lbs				
Overall		3.844	0.845	1.850	7.189
Hybrid		3.521	0.699	1.850	4.365
Compact		2.950	0.421	1.850	3.935
Sedan		3.780	0.643	2.749	6.340
SUV		4.396	0.811	2.866	7.189
Minivan		4.219	0.270	3.763	4.632
Truck		4.525	0.958	2.994	6.395
Sport		3.156	0.541	1.984	3.957

References

Arguea, N.M., Hsiao, C., & Taylor, G.A. (1994). Estimating consumer preferences using market data: An application to US automobile demand. *Journal of Applied Econometrics, 9,* 1-18.

Beresteanu, A. (2007). Discrete and static choice models based on the Logit model.

Berry, S. (1994). Estimating discrete choice models of product differentiation. *RAND Journal of Economics, 25* (2), 242-262.

Berry, S., Levinsohn, J., & Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica*, *63* (4), 841-890.

Bresnahan, T. F. (1981). Departures from marginal-cost pricing in the American automobile industry: Estimates for 1977-1978. *Journal of Econometrics, 17* (2), 201-227.

Calef, D. & Goble, R. (2007). The allure of technology: How France and California promoted electric and hybrid vehicles to reduce urban air pollution. *Policy Sciences, 40* (1), 1-34.

Dreyfus, M. K. & Viscusi, W. K. (1995). Rates of time preference and consumer valuations of automobile safety and fuel efficiency. *Journal of Law and Economics, 38* (1), 79-105.

Energy Information Administration. (2005). A primer on gas prices. Washington, D.C., National Energy Information Center.

Fullerton, D. & West, S.E. (2002). Can taxes on cars and gasoline mimic an unavailable tax on emissions? *Journal of Environmental Economics and Management, 43* (1), 135-157.

Greene, D.L. (1998). Why CAFE worked. *Energy Policy, 26* (8), 595-613.

Green, D.L., Patterson, P.D., Singh, M., & Li, J. (2005). Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy. *Energy Policy 33* (6), 757-775.

Gunster, S. (2004). You belong outside: Advertising, nature, and the SUV. *Ethics and the Environment, 9* (2), 4-32.

Isidore, C. (2004). GM: Hybrid cars make no sense. *CNN/Money*. Retrieved March 22, 2008, from http://money.cnn.com/2004/01/06/pf/autos/detroit_gm_hybrids/

Kayser, H.A. (2000). Gasoline demand and car choice: estimating gasoline demand using household information. *Energy Economics, 22*, 331-348.

Kahn, M.E. (2006). Do Greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice and the aggregate ecological footprint. *Journal of Environmental Economics and Management, 54* (2), 129-145.

Kenworthy, J.R., & F.B. Laube (1999). Patterns of automobile dependence in cities: An international overview of key physical and economic dimensions with some implications for urban policy. *Transportation Research, 33,* 691-723.

Kerwin, K. (2005). The Green American car company. *BusinessWeek*. Retrieved March 22, 2008, from http://www.businessweek.com/magazine/content/05_39/b3952096.htm

Lave, L. B. & MacLean, H. L. (2002). An environmental-economic evaluation of hybrid electric vehicles: Toyota's Prius vs. its conventional internal combustion engine Corolla. *Transportation Research, 7* (2), 155-162.

Maynard, E. (2007, July 4). Toyota Prius sales benefit from unique design. *International Herald Tribune*, pp C4.

Morris, M.G. & Venkatesh, V. (2000). Age differences in technology adoption decisions: Implications for a changing workforce. *Personnel Psychology, 53* (2), 375-403.

Nevo, A. (2001). Measuring market power in the ready-to-eat cereal industry. *Econometrica, 69* (2), 307-342.

Parameswaran, R. & Pisharodi, R. M. Facets of country of origin image: An empirical assessment. *Journal of Advertising, 23* (1), 43-56.

Penny, D. N. (2004). Rollover of sport utility vehicles. *The Physics Teacher, 42* (2), 86-91.

Porac, J., Rosa, J., Spanjol, J., & Saxon, M. (2001). America's family vehicle: path creation in the US minivan market. In: Garud, R. & Karnoe, P. (Eds.), *Path Dependence and Creation.* Lawrence Earlbaum Associates, Mahwah, NJ, pp. 213–242.

Santini, D. J., Patterson, P. D., & Vyas, A. D. (1999). The importance of vehicle costs, fuel prices, and fuel efficiency to HEV market success. Proceedings from *79th Annual Meeting of the Transportation Research Board*, Washington, DC.

United States Internal Revenue Code. Election to expense certain depreciable business assets. 26 U.S.C. § 179.

Zeithaml, V.A. (1988). Consumer perceptions of price, quality, and value: A means-end model and synthesis of evidence. *Journal of Marketing, 52* (3), 2-22.