Modeling U.S. Automotive Demand: A Multi-Stage Analysis of Price Sensitivity, and Brand Competition

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December 18, 2024

Abstract

This study examines consumer demand in the U.S. automotive market using a multi-stage demand system to analyze, price sensitivity, and competition across car brands and vehicle types. The methodology integrates brand-level and segment-level elasticities to capture the complexity of consumer choice within and across categories such as sedans, SUVs, trucks, and other vehicles. Results show that income elasticities distinguish brands like Ford and Chevrolet as necessities, with stable demand, from luxuries such as BMW and other Brands, which exhibit higher sensitivity to income changes. Own-price elasticities confirm that luxury brands are more price-sensitive, while necessity brands display inelastic demand, reflecting strong consumer loyalty. Cross-price elasticities reveal significant substitution effects, particularly among luxury brands. Complementary relationships between vehicle types, such as SUVs and sedans, further underscore the importance of segment-specific strategies and demonstrate the value of the multi-stage framework.

1. Introduction

The automobile market in the United States is one of the most dynamic and influential sectors of the economy, contributing 3%-4% of GDP (Center for Automotive Research). It is also a vital part of daily life, with 75% of the population reporting access to their own car and an additional 20% relying on a company or family car as of March 2023 (Carlier, 2023). This high demand sustains a robust automotive industry, generating over $1.53 trillion in revenue from road vehicle and parts retail trade. The U.S. is the second-largest automotive market globally, with light vehicle sales reaching 14.5 million units in 2020 and international automakers producing 5 million vehicles domestically during the same year (International Trade Administration, n.d.). The sector's economic significance is further highlighted by substantial investments, including $143.3 billion in foreign direct investment in 2019 (International Trade Administration, n.d.). Understanding consumer behavior in this sector is crucial for automakers to refine pricing strategies and for policymakers to evaluate and guide market dynamics effectively.

Consumer demand for U.S. cars is complex because it involves a wide range of differentiated products, with consumers making choices not only between car categories like sedans, SUVs, and trucks but also among specific brands and models within those categories. These choices are influenced by factors such as price, income, and the availability of substitutes, both within and across segments. Analyzing this demand requires a framework that captures the intricate substitution patterns, reflects realistic consumer decision-making processes, and ensures consistency with economic theory.

In this paper, we use a multi-stage demand system to address such complexity. This approach simplifies estimation by breaking it into levels, reflecting how consumers make decisions, narrowing to segments like sedans or SUVs, and then to specific brands. It captures substitution patterns both within and across segments while ensuring consistency with economic theory. Multi-stage systems improve parameter identification and making them ideal for understanding consumer behavior and conducting competitive analyses, such as evaluating the impact of price changes.

From an economic standpoint, demand theory suggests that consumer preferences and spending patterns are influenced by factors such as price and the availability of substitutes (Mankiw, 2015). The AIDS model offers a robust framework for analyzing these relationships, allowing us to capture the complexities of consumer choice among differentiated products in the automotive market (Deaton & Muellbauer, 1980).

Our primary hypothesis is that the demand for each vehicle type is significantly influenced by its own price, the prices of competing types, and consumer income levels. The results confirm that luxury-oriented types, such as sedans and SUVs, are more sensitive to income changes, whereas mainstream or utility-focused types, like trucks and other vehicles, respond more strongly to price competition.

By analyzing the dynamics of the U.S. automobile market, this study aims to enhance our understanding of consumer behavior in car purchasing decisions, providing valuable insights for industry stakeholders and policymakers.

Our main estimation results show that income elasticities classify Ford and Chevrolet as necessities with stable demand, while BMW and Other Brands are identified as luxuries, exhibiting demand that is highly responsive to income growth. Own-price elasticities confirm that BMW and Other Brands are more price-sensitive, characteristic of luxury goods, whereas Ford and Chevrolet display inelastic demand, reflecting strong consumer loyalty and fewer substitutes. These results align with economic theory, highlighting distinct consumer behaviors across necessity and luxury categories.

More importantly, our multi-stage demand system analysis shows important substitution and competition patterns within segments. For instance, strong substitution effects between BMW and Other Brands in the sedan and truck categories indicate intense competition within the premium market. Similarly, Ford and Chevrolet show overlapping consumer bases with Other Brands, particularly in utility-driven categories, evidenced by substitution effects. Complementarity patterns, such as between SUVs and sedans, suggest distinct consumer needs, providing opportunities for bundled marketing strategies. These results demonstrate the value of the multi-stage framework in uncovering relationships and guiding strategic decision-making.

The remainder of the paper is structured as follows: Section 2 provides a review of the relevant literature, Section 3 outlines the methodology, and Section 4 describes the data. Section 5 presents a summary of our main results, and Section 6 concludes the paper.

2. Literature Review

This section explores the theoretical and empirical applications Multi-Stage consumer demand systems and the Almost Ideal Demand System (AIDS) model, emphasizing its relevance in analyzing consumer preferences and price elasticities in differentiated markets like the automotive sector. Additionally, a brief discussion on the Seemingly Unrelated Regressions (SUR) model is included to contextualize its application within this study. This section ends with a literature review of the concepts behind Elasticity of Demand.

2.1. The Almost Ideal Demand System (AIDS)

The AIDS model, introduced by Deaton and Muellbauer (1980), relates expenditure shares to income and prices to study substitution patterns and price elasticities. It employs a translog price index to account for non-linear interactions across goods, making it suitable for analyzing consumer choices in markets with differentiated products like the automotive sector (Deaton & Muellbauer, 1980).

Green and Alston (1990) highlighted the AIDS model's utility in estimating demand elasticities, emphasizing the importance of using correct formulas for computation. They noted that while the Linear Approximate AIDS (LA/AIDS) simplifies computation by using a Stone's price index, it introduces potential biases when preferences are not homothetic. To address these concerns, researchers have explored alternative approaches, such as chain price indices, to improve accuracy and robustness (Lee, 2011).

Hausman, Leonard, and Zona (1994) demonstrated the application of the AIDS model in competitive analysis of differentiated products. By using a multi-level demand system, they analyzed substitution effects among brands within segments of the beer market. This approach is similar to the segmentation of the automotive market by vehicle type (SUV, sedan, truck) and brand. Their findings underline the model's capability to estimate both own-price and cross-price elasticities, which are critical for understanding competition and consumer choice in markets characterized by product differentiation (Hausman et al., 1994).

Jonq-Ying Lee (2011) contributed to refining the AIDS model by proposing a chain price index to address issues with the translog price index, such as the difficulty of estimating the constant parameter α0. This modification facilitates the model's application in markets with high price volatility and frequent product entry and exit, which are typical characteristics of the automotive industry (Lee, 2011).

Since the AIDS model requires the estimation of multiple demand equations, it is important to use the SUR framework because it allows for the joint estimation of these equations while accounting for the interdependence of errors across them. This is particularly relevant for AIDS models, where cross-equation restrictions and correlated disturbances can significantly affect the precision of elasticity estimates. By improving the efficiency of parameter estimation, SUR ensures more reliable and accurate results, making it an essential tool in the application of the AIDS framework (Zellner, 1962).

2.2. Seemingly Unrelated Regressions (SUR)

The SUR model, introduced by Zellner (1962), is a statistical technique that estimates multiple equations with interrelated error terms. The SUR model is useful for analyzing systems of demand equations, such as the AIDS model. By accounting for correlated disturbances across equations, it improves the efficiency of parameter estimation. As noted by Econometrics Academy, SUR is particularly effective when demand systems are estimated with cross-equation restrictions, as it enhances the precision of elasticity estimates in models like AIDS (Zellner, 1962).

2.3. Elasticity of Demand

Elasticity of demand measures how the quantity demanded of a good or service responds to changes in influencing factors such as price, income, or the price of related goods. This concept is foundational in economics, helping to understand consumer behavior and guiding decision-making in both business and policy contexts.

Price elasticity of demand indicates how sensitive consumer demand is to price changes. When demand is elastic, a small change in price leads to a relatively larger change in quantity demanded. This is often the case for non-essential goods or goods with many substitutes, as consumers can easily switch to alternatives. Conversely, inelastic demand occurs when quantity demanded changes little despite price shifts, often seen with necessities or goods with fewer substitutes. This distinction helps businesses determine optimal pricing strategies, as elastic goods may benefit from price reductions to increase sales volume, while inelastic goods may allow for higher prices without significant demand loss (Mankiw, 2015).

Income elasticity of demand evaluates how demand varies with consumer income changes. Goods with positive income elasticity, known as normal goods, see increased demand as income rises. Luxury goods, which are a subset of normal goods, have higher income elasticity, meaning their demand grows disproportionately with income increases. On the other hand, inferior goods have negative income elasticity, where demand decreases as consumers opt for higher-quality alternatives with higher incomes. This concept is vital for identifying consumer preferences and targeting markets effectively (Varian, 2019).

Cross-price elasticity of demand measures the relationship between the demand for one good and the price change of another. A positive value indicates that the goods are substitutes, as a price increase in one lead to higher demand for the other. A negative value indicates that the goods are complements, where a price rise in one reduces demand for the other. This metric is crucial for understanding market competition and designing strategies to either compete with or complement other products (Pindyck & Rubinfeld, 2018).

2.4. Applications in Automotive Markets

The automotive industry is characterized by highly differentiated products with varying prices, features, and consumer preferences. The AIDS model's ability to capture substitution patterns and elasticity estimates makes it an ideal choice for analyzing this market. Studies applying the AIDS model to consumer goods, such as Green and Alston (1990) and Hausman et al. (1994), provide valuable methodologies and insights that can be extended to the automotive sector. For example, the segmentation approach used in beer markets can be adapted to analyze demand for SUVs, sedans, and trucks, while considering the effects of income and fuel prices on consumer preferences.

3. Methodology

This study uses a Multi-stage Consumer Demand System with the Almost Ideal Demand System (AIDS) model to analyze consumer demand in the U.S. automotive market. The model is implemented in a two-level framework to capture demand dynamics and substitution effects across vehicle brands and types. At the lower level, vehicles are categorized by brand, while at the mid-level, they are grouped by type. This approach facilitates the estimation of elasticities and enables us to analyze substitution patterns across these categories. For comparative purposes, a single-level framework using types as the sole category was also estimated, allowing for additional validation of results and consistency checks with microeconomic theory.

The dataset is grouped as follows:

- **Types**: Sedan, SUV, Truck, and Other (all remaining types grouped together). Similarly, these categories were chosen because they dominate the dataset, collectively exceeding 65% of the market share, as illustrated in Figure 1.

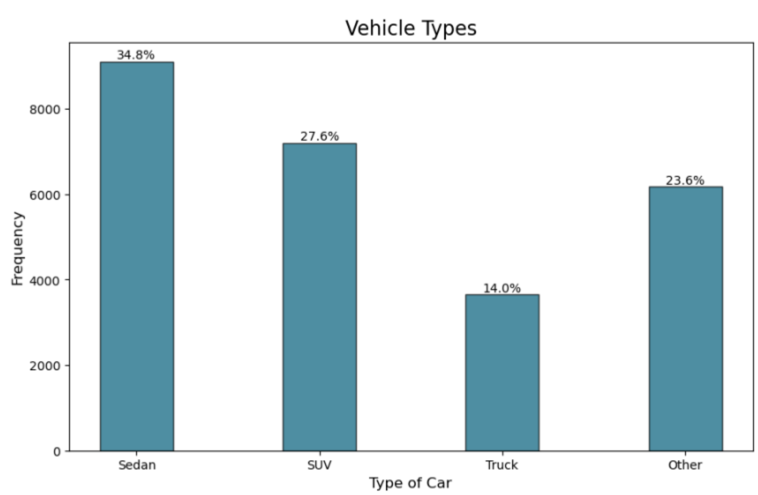

Figure 1: Frequency of Cars by Type

- **Brands**: Ford, Chevrolet, BMW, and Other (all remaining brands grouped together). These brands were selected because they represent the most common brands in the dataset, collectively accounting for 50 % of the market share, as shown in Figure 2.

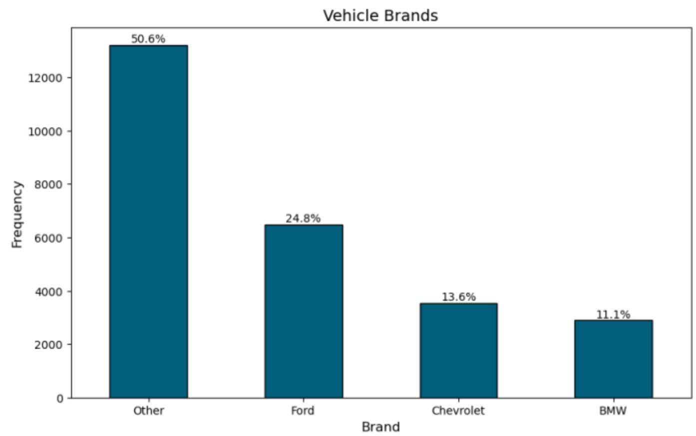

Figure 2: Frequency of Cars by Brand

These groupings reflect the dataset's structure and ensure that the analysis focuses on the most influential segments.

3.1. Addressing Endogeneity

Endogeneity in demand estimation, particularly with respect to prices and expenditure shares, is addressed by employing instrumental variables and fixed effects. Drawing on Hausman and Taylor (1981) and Hausman et al. (1994), we construct an instrumental variable for prices. Specifically, we use the average price of the same vehicle type and year in other states, excluding local observations. This instrument captures relevant price variation while remaining exogenous to local market conditions, mitigating bias from omitted variables or simultaneity.

The predicted prices are derived using a first-stage regression where observed prices are regressed on the instrumental variable and fixed effects for vehicle type, state, and year. The regression equation is:

$$P_{it} = \beta_0 + \beta_1 \cdot \mathrm{Instrumental\_Price}_{it} + \sum_{k=1}^{K} \delta_k \cdot D_k + \epsilon_{it}$$

Where:

- P_{it}: Observed price for vehicle type i in state t,
- $\mathrm{Instrumental\_Price}_{it}$: Average price of the same vehicle type in other states during year t,
- D_k: Dummy variables for type, state, and year fixed effects,
- ϵ_{it}: Error term capturing unobserved factors.

The fitted values from this regression serve as predicted prices in the demand model. This approach reduces bias and enhances the reliability of elasticity estimates, aligning with best practices in econometric demand modeling.

3.2. Estimation of the AIDS Model

Lower-Level: Brands

At the brand level, we estimate the AIDS model using the following equation:

$$w_i = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{X}{P}\right)$$

Where:

- w_i: The budget share for brand i, calculated as the expenditure on brand i divided by total expenditure.
- p_j : The price of brand j sourced from the dataset for each brand.
- X: Total expenditure, representing the total amount spent on all brands.
- P: Price index, accounting for relative price changes and defined as:

$$\ln(P) = \sum_{i=1}^{N} \alpha_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \gamma_{ij} \ln(p_i) \ln(p_j)$$

Here, the price index normalizes prices across all brands. The parameters α_i and γ_{ij} are estimated based on observed data. This model enables us to measure how changes in prices (p_i) or total expenditure (X) influence the proportion of spending allocated to each brand.

Elasticity Calculations

The following elasticities are derived:

- **Income Elasticities**:

$$E_i = 1 + \frac{\beta_i}{w_i}$$

Income elasticities indicate whether a good is normal, inferior, or luxury.

- **Own-Price Elasticities**:

$$E_{ii} = -1 + \frac{\gamma_{ii}}{w_i} - \beta_i \frac{1 - w_i}{w_i}$$

Capturing consumer responsiveness to price changes.

- **Cross-Price Elasticities**:

$$E_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i}$$

Reflecting substitution or complementarity between goods.

These formulas adhere to the theoretical restrictions of symmetry, adding-up, and homogeneity as outlined in Green and Alston (1990).

Mid-Level: (Car Types)

For the mid-level analysis, we group the dataset into four vehicle types: Sedan, SUV, Truck, and Other. This analysis uses an AIDS model specification to estimate income, own-price, and cross-price elasticities for these vehicle types.

3.3. Data Processing and Analysis Steps

1. **Data Cleaning and Integration**: The raw dataset was preprocessed in Python, where outliers were reviewed, data types were converted from strings to numerical formats, and state variables were renamed to ensure consistency. Additionally, typos were corrected, and the dataset was merged with the gas price index sourced from the U.S. Energy Information Administration, 2022.

2. **Hausman Instrument Creation**: Following data cleaning, the Hausman Instrument was constructed using Ordinary Least Squares (OLS) in Python. The resulting predicted prices were utilized as instruments in the subsequent analysis to address potential endogeneity.

3. **Data Aggregation**: The cleaned dataset was aggregated by year and brand. Total quantities were summed, and average prices were computed for each brand-year combination to simplify further analysis.

4. **Data Reshaping**: The dataset was transformed into a wide format to facilitate brand-specific analysis and enable computations required by the Almost Ideal Demand System (AIDS) model.

5. **Price Index Computation**: Logarithmic transformations of prices were applied to generate log-price variables for inclusion in the AIDS model. This step ensured the consistency of the price index with the theoretical framework.

6. **Elasticity Estimation**: Demand elasticities were calculated using parameters estimated through the nonlinear seemingly unrelated regression (nlsur) procedure. This iterative approach aligns with methodologies outlined by Green and Alston (1990) and ensures robust estimation of the AIDS model.

4. Data

The primary dataset contains information on 26,796 cars listed for sale, covering 16 variables. Key variables include the price of the car, its odometer reading, the type of vehicle (e.g., SUV, sedan), the state where the car is listed, and the manufacturer. This dataset provides a broad range of observations across various car types and regions, making it a valuable resource for analyzing state-level differences in car demand and price sensitivity.

However, there are potential limitations, such as missing consumer-level data (e.g., income, preferences) and unobserved variables that could influence demand and prices. These factors will be considered in the analysis to improve robustness

To enhance the analysis, this dataset was merged with gasoline price data from the *Total Gasoline Wholesale/Resale Price by Refiners (Dollars per Gallon)* dataset, sourced from the U.S. Energy Information Administration. This dataset provides state-level gasoline prices over time, expressed in dollars per gallon. Gasoline prices were used as a control for regional economic conditions and as a potential instrumental variable to address endogeneity in the regression models. By combining these datasets, we can better understand how regional fuel costs influence car prices and demand.

The dataset preparation involved cleaning, transforming, and merging data to ensure it was ready for econometric analysis. The original dataset includes 26,796 observations with variables such as price, odometer reading, vehicle type, state, manufacturer, and other economic factors.

Duplicate entries were removed, and rows with missing essential information were dropped. Missing values in categorical variables, like fuel, were filled with the most common category ("gas"), while missing state information was inferred using a mapping based on the region variable. Outliers in numerical data, such as unusually high odometer readings or invalid vehicle years, were addressed by capping extreme values or excluding incorrect entries.

To ensure uniformity, categorical variables were standardized. For example, manufacturer and size categories were converted to lowercase and corrected for inconsistencies, such as variations in how "BMW" was labeled. Broader groupings were created for analysis, with manufacturers categorized into Ford, Chevrolet, BMW, and Other, and vehicle types grouped into Sedan, SUV, Truck, and Other.

The dataset was merged with state-level gasoline price data from the U.S. Energy Information Administration. Gasoline prices, recorded in dollars per gallon, were matched with state and year variables. Any missing gasoline prices were filled using state-year averages or overall dataset means to maintain completeness.

4.1. Summary Statistics:

The dataset contains 26,140 observations of vehicle listings across various regions, manufacturers, and types. Below are the summary statistics for the most relevant variables, which include vehicle price, odometer reading, manufacturing year, gasoline prices, and predicted prices.

Variable	Mean	Standard Deviation	Min	Median	Max	# of Observations
Price (USD)	13,371.38	10,838.02	1,004	9,150.5	96,818	26,14
Odometer (Miles)	117,854.50	59,227.76	22	112,941.5	500	26,14
Manufacturing Year	2008.74	7.51	1981	2011	2022	26,14
Gasoline Price (USD)	2.007	0.766	0.463	2.026	3.298	26,14
Predicted Price (USD)	13,368.45	5,344.32	2,468.50	12,358.47	35,898.22	26,14

Table 1: Summary Statistics of the Dataset

4.1.1. Distribution of Vehicle Prices

The histogram below illustrates the distribution of vehicle prices, which is right-skewed, indicating that most vehicle prices are concentrated in the lower price range.

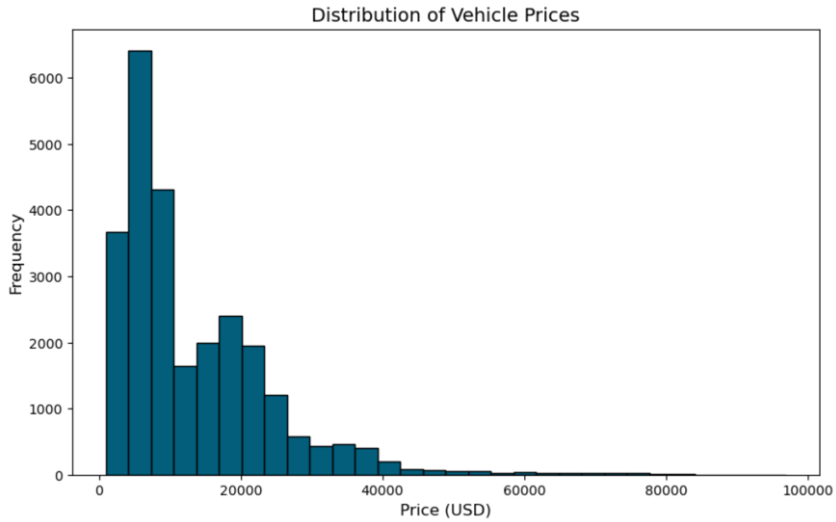

Figure 3: Distribution of Vehicle Prices

4.1.2. Average Vehicle Price Over Time

The trend graph shows the evolution of average vehicle prices over time. Vehicle prices have increased significantly since 2010, with notable growth observed in recent years.

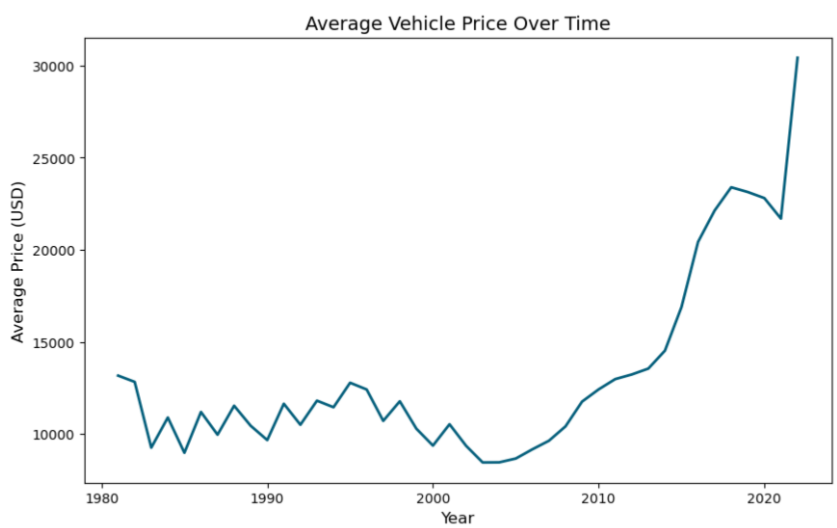

Figure 4: Average Vehicle Price Over Time

4.1.3. Market Concentration:

To measure market concentration, the **Herfindahl-Hirschman Index (HHI)** is calculated for both vehicle brands and vehicle types:

- Market Concentration (HHI) for Brands: 3,477.90
- Market Concentration (HHI) for Vehicle Types: 2,726.19

The high HHI values suggest that both the vehicle brand and type markets are moderately concentrated, indicating a limited number of dominant players in each category.

5. Estimation Results

5.1. Lower-Level Analysis by Car Brand

This section examines the demand for four car brands—Ford, Chevrolet, BMW, and Other—using the Almost Ideal Demand System (AIDS) model. The results focus on income elasticities, own-price elasticities, and cross-price elasticities, analyzed in light of economic theory.

The expenditure elasticities for each brand, which measure how demand changes in response to total expenditure (income), are shown below:

Brand	Expenditure Elasticity
Ford	0.8474
Chevrolet	0.8299
BMW	10.642
Other Brands	11.386

Table 2: Income Elasticities by Car Brand

Brands with elasticities less than 1, such as Ford and Chevrolet, are considered necessities, meaning consumers continue to buy them even with changes in income. On the other hand, BMW and Other Brands, with elasticities greater than 1, are classified as luxuries, where demand rises more than proportionally with income growth.

This classification aligns with Engel's Law, which predicts that spending on luxuries increases as income rises.

The own-price elasticities measure how sensitive the quantity demanded is to a brand's own price changes. The table below provides uncompensated elasticities and those calculated under the AIDS model:

Brand	Uncompensated Own-Price Elasticity	AIDS Own-Price Elasticity
Ford	-0.7841	-0.8419
Chevrolet	-0.2824	-0.3963
BMW	-13.452	-12.945
Other Brands	-13.210	-12.994

Table 3: Own-Price Elasticities by Car Brand

The elasticities confirm the law of demand, as they are negative for all brands. Ford and Chevrolet show inelastic demand ($|E|$<1), indicating that price changes have a smaller proportional effect on demand. This suggests consumers view these as essential products. BMW and Other Brands have elastic demand ($|E|$>1), meaning their quantities sold are more sensitive to price changes. This is consistent with luxury goods, where consumers reduce purchases more significantly when prices rise, also is important to know that there could be an unobserved substitution effect with new cars, since this dataset is only using used cars data.

Cross-price elasticities, which measure how the demand for one brand responds to price changes of another, are presented below:

Brands (i, j)	Cross-Price Elasticity
Ford & Chevrolet	-0.1942
Ford & BMW	0.0414
Ford & Other	0.1547
Chevrolet & BMW	-0.2684
Chevrolet & Other	0.2034
BMW & Other	0.5949

Table 4: Cross-Price Elasticities by Car Brand

Positive cross-price elasticities indicate substitute relationships, while negative values suggest complementary relationships. Ford and Other Brands, as well as Chevrolet and Other Brands, exhibit substitution patterns. This suggests that if the price of Other Brands increases, consumers may shift to Ford or Chevrolet. BMW and Other Brands have a particularly strong substitution effect (E=0.5949), indicating close competition within the luxury segment.

Surprisingly, some negative cross-price elasticities are observed, such as between Ford and Chevrolet (−0.1942) and Chevrolet and BMW (−0.2684), suggesting potential complementarities. These relationships could arise from specific consumer preferences or market dynamics where buyers might pair vehicles from different brands for complementary purposes. However, such patterns may warrant further investigation.

The results highlight distinct consumer behaviors across brands:

1. **Income Elasticities:** Ford and Chevrolet are necessities, as their demand is less responsive to income changes. Conversely, BMW and Other Brands are luxuries, with demand increasing significantly as income rises.

2. **Own-Price Elasticities:** The law of demand holds across all brands, with elasticities reflecting the varying nature of these goods. Ford and Chevrolet, with inelastic demand, are less sensitive to price changes, suggesting strong consumer loyalty or fewer substitutes. BMW and Other Brands show higher sensitivity, characteristic of discretionary luxury goods.

3. **Cross-Price Elasticities:** Substitution effects are strongest between BMW and Other Brands, indicative of competition in the premium market. Complementary relationships observed between some brands may reflect unique consumer behaviors or data-specific anomalies, requiring further exploration.

These findings align with microeconomic theory, providing a robust understanding of consumer preferences in the car market. They serve as a foundation for evaluating mid-level and single-level results in subsequent sections.

5.2. Low and Mid-Level results

In this section we apply the multi stage system methodology to analyze how different brand compete in each price segment. We report below elasticities conditional on each segment, for each of our 4 brand groups:

5.2.1. Sedan:

Brand	Income Elasticity	Ford	Chevrolet	BMW	Other Brands
Ford	0.909	-0.833	-0.121	-0.071	0.171
Chevrolet	0.969	-0.237	-0.916	0.004	0.204
BMW	0.877	-0.093	0.014	-0.551	-0.158
Other Brands	1.080	0.032	0.032	-0.078	-1.062

Table 5: Sedan Elasticity Summary table by Car Brand

The elasticity analysis reveals important insights into the dynamics of the sedan market. Income elasticities indicate that all brands are normal goods, with "Other Brands" exhibiting the highest sensitivity to income changes (1.080). This suggests that this category, likely encompassing a diverse range of vehicles, has demand that is strongly influenced by economic conditions. BMW, with an income elasticity of 0.877, demonstrates lower responsiveness, consistent with its luxury positioning and stable demand base.

Examining own price elasticities along the diagonal, all values are negative, reflecting the law of demand. "Other Brands" is the most price-sensitive category (-1.062), indicating that consumers are highly reactive to price changes within this group. BMW, in contrast, has the least price-sensitive demand (-0.551), underscoring its ability to maintain demand even with higher prices, likely due to its strong brand loyalty and premium market segment.

Cross-price elasticities reveal substitution and complementarity patterns between brands. Ford and "Other Brands" show a mild substitution effect (0.171), suggesting some overlap in consumer preferences between these categories. Chevrolet and "Other Brands" have a stronger substitution effect (0.204), highlighting potential direct competition in shared market segments. In contrast, BMW and "Other Brands" exhibit weak complementarity (-0.158), which suggests limited competition and a distinct consumer base for BMW.

These insights emphasize the importance of strategic pricing and market positioning. Brands like Ford and Chevrolet may need to focus on differentiation to minimize direct competition with "Other Brands." BMW can leverage its less price-sensitive demand by maintaining premium pricing and targeting its niche market. Finally, the high income elasticity for "Other Brands" underscores the need to monitor economic conditions closely, as changes in consumer income levels could significantly impact demand in this category.

5.2.2. SUV:

Brand	Income Elasticity	Ford	Chevrolet	BMW	Other Brands
Ford	0.958	-0.981	0.057	0.027	-0.035
Chevrolet	0.855	0.099	-0.707	-0.130	-0.016
BMW	0.999	0.041	-0.208	-0.949	0.118
Other Brands	1.065	-0.039	-0.040	0.019	-1.003

Table 6: SUV Elasticity Summary table by Car Brand

The elasticity analysis for SUVs reveals distinct dynamics in income and price sensitivity across brands. All brands have positive income elasticities, indicating they are normal goods. "Other Brands" shows the highest income elasticity (1.065), suggesting demand for these vehicles is most sensitive to changes in income levels. Ford and BMW, with income elasticities close to 1, exhibit stable demand that aligns with consumer income trends. Chevrolet, with a lower elasticity (0.855), may be targeting a more price-sensitive segment.

Own price elasticities, reflected along the diagonal, are all negative as expected, signifying adherence to the law of demand. Chevrolet has the lowest price sensitivity (-0.707), potentially benefiting from a loyal customer base or competitive pricing strategies. BMW demonstrates higher price elasticity (-0.949), indicating a stronger consumer reaction to price changes, despite its premium positioning. "Other Brands" (-1.003) is the most price-sensitive, highlighting the diverse nature of this category, which likely includes budget-conscious options.

Cross-price elasticities show patterns of substitution and complementarity. Ford and Chevrolet exhibit mild substitution effects (0.057 and 0.099, respectively) when compared to BMW and "Other Brands." Conversely, BMW and "Other Brands" show both weak substitution and complementarity effects, suggesting limited direct competition between these brands. Notably, the complementarity between Chevrolet and BMW (-0.130) and the substitution effect between BMW and "Other Brands" (0.118) highlight nuanced interactions within the SUV market.

These findings suggest opportunities for brand-specific strategies. Chevrolet can focus on leveraging its lower price sensitivity, while BMW should aim to strengthen brand loyalty and reduce price-related demand fluctuations. For "Other Brands," flexible pricing strategies and targeted marketing may help mitigate high price sensitivity. Monitoring income trends remains critical, especially for "Other Brands," which show the highest responsiveness to income changes.

5.2.3. Trucks:

Brand	Income Elasticity	Ford	Chevrolet	BMW	Other Brands
Ford	0.921	-0.605	-0.193	0.006	-0.118
Chevrolet	1032	-0.446	-0.872	-0.039	0.305
BMW	0.751	0.214	-0.360	-1408	1050
Other Brands	1.092	-0.223	0.171	0.052	-1.123

Table 7: Truck Elasticity Summary table by Car Brand

The elasticity analysis for trucks shows nuanced income and price sensitivity across different brands. Income elasticities are positive for all brands, indicating trucks are normal goods. Chevrolet (1.032) and "Other Brands" (1.092) show slightly higher income elasticities, suggesting demand for these brands is relatively more responsive to income changes. Ford (0.921) and BMW (0.751) exhibit moderate income sensitivity.

Own price elasticities, which appear on the diagonal, confirm the law of demand as all are negative. BMW demonstrates the highest price sensitivity (-1.408), implying that its customers are highly reactive to price changes. In contrast, Ford exhibits the lowest own-price elasticity (-0.605), indicating its relatively stable demand base.

Cross-price elasticities indicate interactions between brands. For example, BMW and "Other Brands" have a significant substitution effect (1.050), highlighting strong competitive pressure between these segments. Chevrolet shows a complementarity effect with BMW (-0.360), potentially pointing to niche market differentiation. Meanwhile, "Other Brands" demonstrates some degree of substitution with Chevrolet (0.305), suggesting overlapping customer preferences.

The findings suggest that Chevrolet and "Other Brands" could benefit from marketing strategies that emphasize income-responsive pricing. BMW should focus on building customer loyalty to mitigate its high price sensitivity. Ford, with its lower price sensitivity, may capitalize on stable demand with minimal pricing interventions. Furthermore, the strong substitution effect between BMW and "Other Brands" underscores the need for strategic positioning to differentiate offerings effectively.

5.2.4. Other Automobiles:

Brand	Income Elasticity	Ford	Chevrolet	BMW	Other Brands
Ford	0.895	-0.922	-0.016	0.053	0.028
Chevrolet	0.889	-0.033	-1153	0.472	-0.097
BMW	0.896	0.134	0.561	-1195	-0.317
Other Brands	1.162	-0.066	-0.079	-0.137	-0.915

Table 8: Other automobile types: elasticity Summary table by Car Brand

The elasticity analysis for the "Other automobiles types" category reveals distinct patterns of income and price sensitivity across brands. Income elasticities are positive for all brands, indicating that vehicles in this category are normal goods. "Other Brands" (1.162) shows the highest income elasticity, suggesting its demand is particularly sensitive to income changes. Ford (0.895), Chevrolet (0.889), and BMW (0.896) have slightly lower and comparable income elasticities, reflecting moderate responsiveness to income variations.

Own-price elasticities, located on the diagonal of the elasticity matrix, are negative for all brands, consistent with the law of demand. BMW exhibits the highest price sensitivity (-1.195), indicating that its customers are highly reactive to price changes. Chevrolet (-1.153) follows closely, reflecting significant price sensitivity. In contrast, Ford (-0.922) and "Other Brands" (-0.915) have the lowest own-price elasticities, signifying a relatively stable demand despite price fluctuations.

Cross-price elasticities highlight the competitive dynamics between brands. Chevrolet and BMW exhibit a strong substitution effect (0.561), signaling considerable overlap in their customer bases. Conversely, BMW and "Other Brands" show complementarity or weak competition (-0.317), which may indicate distinct market niches. Other interactions, such as Ford and Chevrolet (-0.016) or Ford and "Other Brands" (0.028), reveal weak substitution effects, reflecting minimal competitive overlap.

5.3. Robustness test: Single-Level Analysis by Car Types

This section presents the demand patterns across four vehicle types—sedan, SUV, truck, and other—using the Almost Ideal Demand System (AIDS). The analysis estimates income elasticities, own-price elasticities, and cross-price elasticities to understand consumer preferences and substitution patterns.

Income Elasticities

Vehicle Type	Income Elasticity
Sedan	1.30
SUV	1.12
Truck	0.78
Other	0.80

Table 9: Income Elasticities by Car Type (Single-Level)

The income elasticities reveal the relationship between changes in consumer income and the demand for different vehicle types. Sedans and SUVs exhibit elasticities greater than 1, categorizing them as luxury goods. This suggests that demand for these vehicles grows more than proportionally with increases in income. Trucks and Other vehicles, with elasticities below 1, are closer to necessities, reflecting utility-driven purchases. These results align with Engel's Law, which suggests that spending on luxuries increases disproportionately as income rises.

Vehicle Type	Own-Price Elasticity
Sedan	-0.53
SUV	-0.20
Truck	-0.66
Other	-0.29

Table 10: Own-Price Elasticities by Car Type (Single-Level)

All own-price elasticities are negative, consistent with the law of demand, indicating that higher prices reduce demand. Among the vehicle types:

- **Sedans (-0.53)** are moderately price-sensitive, reflecting a balance between being a necessity and a luxury.
- **SUVs (-0.20)** show relatively inelastic demand, suggesting strong consumer preferences or limited alternatives.
- **Trucks (-0.66)** are more price-sensitive, likely due to their utilitarian nature.
- **Other vehicles (-0.29)** exhibit low price elasticity, possibly due to niche markets or specialized features.

These findings indicate varying consumer responses to price changes across vehicle types, with Trucks being the most price sensitive.

Type Pair (i, j)	Cross-Price Elasticity
Sedan & SUV	0.20
Sedan & Truck	-0.33
Sedan & Other	-0.79
SUV & Truck	-0.53
SUV & Other	-0.71
Truck & Other	0.94

Table 11: Cross-Price Elasticities by Car Type (Single-Level)

Cross-price elasticities highlight the substitution and complementarity relationships among vehicle types.

Substitution Effects: Sedans and SUVs have a positive elasticity (0.20), indicating these types compete for similar consumer segments. In the other hand trucks and other vehicles show strong substitution (0.94), likely reflecting overlapping use cases, such as multi-purpose or utility-focused needs.

Complementarity Effects: Sedans and Other vehicles (-0.79) appear to serve distinct markets, suggesting complementary or independent demand drivers. While, SUVs and Trucks (-0.53) exhibit negative elasticity, indicating they cater to different consumer needs and are not strong substitutes.

Interpretation and Implications

- **Income Dynamics:** Sedans and SUVs, as luxury goods, thrive on rising income levels. Marketing efforts for these vehicles should emphasize premium features and aspirational branding. In contrast, Trucks and Other vehicles, being necessities, benefit from stable demand but might require competitive pricing to appeal to utility-driven buyers.

- **Price Sensitivity:** The inelastic demand for SUVs reflects strong consumer attachment, enabling manufacturers to maintain higher prices. Trucks' higher price sensitivity highlights the importance of competitive pricing strategies.
- **Substitution and Market Segments:** The substitution between Sedans and SUVs and between Trucks and Other vehicles points to overlapping consumer segments. Strategic positioning, such as differentiating features or targeting specific demographics, can mitigate competition.
- **Complementarity:** The complementarity observed between certain vehicle types suggests opportunities for cross-marketing, especially in segments where vehicles serve different purposes (e.g., Sedans for commuting and Trucks for work-related tasks).

6. Conclusion

We study the U.S. automotive demand using a multi-stage system to analyze consumer preferences and substitution patterns across different car brands and vehicle types. Our main results highlight that car demand varies significantly with income and price sensitivity. Ford and Chevrolet, with income elasticities below 1, are classified as necessities, maintaining stable demand even as income changes, while BMW and other luxury brands, with elasticities greater than 1, are classified as luxuries, experiencing demand growth more than proportional to income increases.

Own-price elasticity estimates confirm that demand for brands like Ford and Chevrolet is inelastic, reflecting strong consumer loyalty or fewer substitutes, whereas luxury brands like BMW and Other Brands show highly elastic demand, indicating greater sensitivity to price changes. Cross-price elasticities reveal notable substitution patterns, particularly between BMW and Other Brands in the luxury segment, suggesting close competition, while unexpected complementarities, such as between Ford and Chevrolet or Chevrolet and BMW, indicate unique consumer preferences or market-specific dynamics. These findings provide valuable insights for pricing and marketing strategies, emphasizing the need for competitive pricing for necessities, premium positioning for luxury brands, and differentiation to mitigate competition within segments.

Our multi-stage demand system analysis highlights significant substitution and competitive dynamics within segments. For example, the strong substitution effects observed between BMW and Other Brands in the sedan and truck segments point to fierce competition within the premium market. Similarly, substitution patterns reveal overlapping consumer bases between Ford, Chevrolet, and Other Brands in utility-focused categories. Complementary relationships, such as those between SUVs and sedans, reflect distinct consumer needs and suggest opportunities for bundled marketing strategies. These findings underscore the effectiveness of the multi-stage framework in uncovering critical market relationships and informing strategic decision-making.

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