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Abstract

The automobile market is one of the most significant sectors of the German economy both in terms of value added and number of employees. This paper focuses on the determinants of automobile demand in Germany from 2008 to 2016. We apply multiple linear regression in order to estimate new passenger vehicle sales, using monthly data on price, product parameters, quality ratings, macroeconomic variables as well as government incentives as explanatory variables. For each car segment, a separate model is built, with the purpose of uncovering similarities and differences between distinct segments. Our results indicate that quality is significant for all groups, while consumers’ attitudes towards vehicle prices vary from segment to segment. Purchasers of large-sized cars are sensitive to the fuel efficiency of vehicles, whereas drivers of small-sized vehicles pay less attention to fuel consumption. Most of the consumers in Germany are not considering vehicle emissions in their purchasing behavior. The results of this study can help automobile manufacturers to make strategic decisions and help policymakers to understand the automobile market better.

Keywords: Automobile Demand, Multiple Linear Regression, Germany

JEL Classification Nos.: C33, D12, L62

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1 Introduction

Since the 20th Century, the automobile industry has become one of the pivot industries around the globe and has expanded prosperously. In the past ten years, however, the car industry faced new challenges and went through a series of troubles. Triggered by the global economic crisis, a downturn in the automobile market in 2008-2010 forced two major automobile manufacturers, General Motors and Chrysler, to file for bankruptcy protection (Roe and Tung, 2013). In 2009-2010, Toyota announced recalls of approximately 9 million vehicles worldwide due to pedal problems, which resulted in a significant decline in Toyota sales and market shares (Fan et al., 2013). On September 18, 2015, the United States Environmental Protection Agency (EPA) revealed that Volkswagen had programmed diesel engines to cheat on government emission tests (Hotten, 2015). The Volkswagen emission scandal raised the awareness for car pollution among the public. A report conducted by ICCT (2016) pointed out other potential exceedances of nitrogen oxides emissions, in which Volvo, Renault, Jeep, Hyundai, Citroen and Fiat were involved. Struggling with decelerating growth rates, strong competition and loss of brand reputation, the improving of sales performance is a crucial issue for automakers. This study estimates the demand for new vehicles from 2008 to 2016, a period which witnessed many ups and downs in the automotive industry.

Germany, along with the United States, China and Japan, is known as one of the biggest automotive manufacturers in the world. In 2015, more than 15 million cars, equivalent to approximately one fifth of global total production, were produced by German automobile OEMs (Original Equipment Manufacturers) and recorded a turnover of €404 billion, which covered about a fifth of the total industry revenue in Germany (GTAI, 2016). We selected Germany as our observed market because it is not only one of the automobile production leaders but also Europe’s biggest market in terms of car sales.
As shown in Figure 1, Germany accounted for more than 20% of all newly registered automobiles in the EU. In 2015, approximately 45 million passenger cars in Germany were on the road, accounting for 14 percent of the EU total market. The average age of passenger cars in Germany was only 8.9 years. In comparison with the average car age of 10.7 years in the European Union, replacements of vehicles in Germany are more frequent (ACEA, 2017). We focus our research on the German automobile market.

The estimation of automobile sales has been one of the most popular fields for econometric studies since the 1980s. Previous research on this topic has mainly focused on the correlation between automobile demand and economic indicators. Several studies have been conducted in this direction, using different econometric techniques. For example, Shahabuddin (2009) employed several economic indicators in a multiple regression model to forecast automobile sales in the US from 1959 to 2006, emphasizing that the correlation between economic variables and automobile demand was strong in foreign markets but weak in the domestic (US) market. Cumhur and Saban (2013), using a panel cointegration analysis model, focus on thirteen EU countries with a time range between 1999 and 2010, and find that vehicle sales in the EU are mainly affected by macroeconomic factors. Gaspareniene and Remeikiene (2014) use correlation analysis and multifaceted regression models to identify the macroeconomic determinant factors of the automobile market in the EU from 1997 to 2012. Gao et al. (2017)
estimated a hybridized particle swarm optimization and ant colony optimization model (HPAE) in both linear and quadratic form to illustrate the relationship between highway mileage, GDP, automobile ownership and CPI in China.

Research on the correlation between car sales, car features and government incentives remains relatively scarce. Only a few relevant studies use econometric methods to indicate the impact of quality variables on automobile sales. Emre Alper and Mumcu (2007), for instance, use dynamic Feasible Generalized Least Squares (FGLS) estimation and conclude that the country of origin and quality of vehicles had a significant impact on automobile demand in Turkey from 1996 to 1999. Tsai et al. (2015) conduct an investigation using the Malmquist productivity index (MPI) on sales performance in the US automobile market, and suggest that there has been an improvement of quality and energy efficiency of automobiles. These studies emphasize that quality variables also play a significant role for customers during their consideration of purchasing a new vehicle. Specific research involving both economic and technical indicators on automobile demand, as done in our study, is still rare. Additionally, we focus on the differences and commonalities between distinct segments of the automobile market, in order to help the automobile OEMs make better strategic decisions. The purpose of this study is to determine the main variables that had an impact on the sales of passenger vehicles in Germany. From this overall objective, the following specific research questions are derived:

(1) Which economic and technical factors affect the market shares of different automobile segments in Germany? (2) What kinds of effects do those factors create on automobile demand? (3) What are the differences and commonalities between distinct automobile segments? (4) Why do those factors play significant roles in the sales performance of vehicles in the German automobile market?

In this study, we build on previous studies and select several possible indicators to estimate the demand for passenger cars during the period from 2008 to 2016 in Germany. The possible indicators are divided into three groups in terms of their origins, namely product-related variables, macroeconomic variables and government incentives. The product-related variables consist of monthly data on price, quality ratings and product parameters. Macroeconomic variables include gross domestic product (GDP), real interest rate and gasoline prices. The government incentive in this study refers to a scrappage scheme, namely the car allowance rebate system (CARS). As for the method, we select the classical multiple linear regression model with the sales of vehicles as the explained variable, and the above-mentioned indicators as explanatory variables. The framework of input and output variables is shown in Figure 2.
Section 2 presents the description of the data. Section 3 provides an overview of the automobile market in Germany and section 4 describes our estimation models. The results and analysis are presented in section 5. Section 6 concludes.

2 Data description

2.1 Vehicles studied
As observed objects, we select 98 different car models from 22 distinct automakers, who, on average, covered 82.8% of the market share in Germany over the period from 2008 to 2016.

The selected models are categorized into 8 different segments, following the method of the Euro Car Segment scheme, which was set and defined by the European Commission in 1999. According to the Euro Car Segment scheme, automobiles are classified by lettered ‘segments’ in order to group certain models into their respective classes. The segments and their descriptions are listed in Table 1.
<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
<th>Example vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Mini cars</td>
<td>Smart Fortwo, Renault Twingo</td>
</tr>
<tr>
<td>B</td>
<td>Small cars</td>
<td>Volkswagen Polo, Mini</td>
</tr>
<tr>
<td>C</td>
<td>Medium cars</td>
<td>Volkswagen Golf, BMW 1-Series</td>
</tr>
<tr>
<td>D</td>
<td>Large cars</td>
<td>Mercedes C-Class, Audi A4</td>
</tr>
<tr>
<td>E</td>
<td>Executive cars</td>
<td>Mercedes E-Class, BMW 5-Series</td>
</tr>
<tr>
<td>F</td>
<td>Luxury cars</td>
<td>Mercedes S-Class, BMW 7-Series</td>
</tr>
<tr>
<td>J</td>
<td>Sport utility vehicles/SUV</td>
<td>Ford Kuga, Volkswagen Tiguan</td>
</tr>
<tr>
<td>M</td>
<td>Multiple purpose cars/MPV</td>
<td>Mercedes B-Class, Opel Zafira</td>
</tr>
<tr>
<td>S</td>
<td>Sports cars</td>
<td>Audi TT, Porsche 911</td>
</tr>
</tbody>
</table>

### 2.2 Data used

#### 2.2.1 Car sales as dependent variable

We use monthly registrations in Germany over the period of 2008 to 2016 in order to describe monthly sales. The data are obtained from the Kraftfahrt-Bundesamt (KBA), which is a higher federal authority in Germany and responsible for the publication of statistics related to vehicle registers and vehicle inspections.

#### 2.2.2 Product-related variables

The product-related variables used in this study consist of price, competitors’ price, gasoline consumption, CO₂ emissions, facelift dummies and quality rating.

- **Price variables**

As for the price variable, we use suggested retail prices, due to the unavailability of actual transaction prices for the different models. Retail prices are collected from price lists that are published by the automobile OEMs. There are several product lines with different configurations in one specific model’s price list. In order to find a better way to present the tendency of price variation, we estimate two data sets as price variables: one is the model’s average price; the other is the base model’s price. The German value added tax (VAT), which has remained unchanged since 2007, is contained in the suggested retail price.

The competitors’ price is also included in the automobile demand estimation. Competitors’ models are defined as automobiles that belong to the same market segment. Like for the model’s prices, there are also two data sets to describe the competitors’ price variables in order to find which one yields the better fit in the estimation. We calculate the sales-weighted average price
as well as the sales-weighted average base model’s price of each segment. The competitors’ prices are the average prices of the automobile’s segment, excluding the model’s own prices. All prices are deflated using the yearly basis average inflation rate of Germany (CPI 2008 = 100) collected from www.inflation.eu.

- **Product parameters**

Variables of product characteristics include two features of the observed automobile models, specifically gasoline consumption and CO₂ emissions. Both variables are gathered from the statistics on emissions and fuels of newly registered automobiles that are published by KBA once a year. Due to the huge variation of gasoline consumption between gasoline and diesel cars, we calculate the sales-weighted average gasoline consumption for each observed model. As for emissions, the data on specific CO₂ emissions per 1000 kg are used as a variable to balance the mass influence of different vehicles. We also include a facelift dummy to include its impact on automobile sales. Considering the possible persistence of the effect, we set the dummy to one in the six months following the facelift.

- **Rating variables**

Other than data on automobiles characteristics, we also take product quality into account. We collect rating data from ADAC (Allgemeiner Deutscher Automobil-Club e.V.), the largest automobile club in Europe. In the quality rating, which ranges from 0.5 (high) to 5.5 (poor), ADAC provides a general score based on realistic testing and objective data, considering the following indicators: interior and exterior design, comfort, engine, driving properties, safety and environmental test. The ADAC provides several testing reports of one specific automobile model with different configurations in the same time period. Therefore, we use the average of these ratings as the quality rating variable in this study.

2.2.3 Macroeconomic variables

As a durable good, the demand for automobiles correlates significantly with several economic indicators. Especially during the period from 2008 to 2009, a temporary downturn of the European economies was triggered by the economic crisis in the US. In this study, we include the Gross Domestic Product (GDP), the real interest rate, and the gasoline price as macroeconomic variables.

- **Gross Domestic Product (GDP)**

The data on GDP are obtained from the Federal Statistical Office of Germany (Statistisches Bundesamt). The GDP time series used in our study is deflated using the average inflation rate of Germany (CPI 2008 = 100). Since monthly data on GDP are unavailable, we use the seasonal
database instead and convert it into a monthly average.

- **Real interest rate**
  We use data on the real interest rate from the federal bank of Germany (*Deutsche Bundesbank*), which represents the private households’ deposits with an agreed maturity of up to one year.

- **Gasoline prices**
  The monthly variable on gasoline price is obtained from ADAC, deflated with the Consumer Price Index (CPI 2008 = 100). Since diesel and gasoline prices are strongly correlated with each other, we use only the latter as an explanatory variable.

2.2.4 Government incentives

In 2009 a new policy, namely the Car Allowance Rebate System (CARS), was promoted in Germany. With a bonus of up to €2500, the program aimed to encourage residents in Germany to replace their old and polluting vehicles with a newer, cleaner, and more fuel-efficient one. Because of the financial crisis, a dramatic decline of car sales hit the German automobile industry in 2007. The main purpose of the program was to stimulate automobile demand and help to accelerate the rapid recovery of the automobile industry from the crisis. Furthermore, the system also helped to reduce air pollution by putting vehicles with more fuel-efficient engines and lower emissions on the road (Böckers *et al*., 2012). In this study, we therefore add a CARS dummy to the model as a possible determinant, aiming to capture its impact on the demand for automobiles.

3 Overview of the automobile market in Germany

3.1 Vehicle sales

3.1.1 By segment

Figure 3 shows the development of automobile sales by segment in Germany from 2008 to 2016. Thanks to the governmental scrappage program “CARS” in 2009, registrations of vehicles peaked in that year at 3.56 million. The CARS scheme had a particularly significant effect on sales of small- and medium-sized vehicles, specifically in segments A, B and C. Sales of mini vehicles (A-segment), for example, more than doubled compared to the previous year.
The year after the CARS scheme expired was considered a difficult time for the German automobile market. The total sales of new passenger vehicles declined by 23.4% from 2009. Since then, there were only three years (2011, 2015 and 2016) in which total sales of passenger vehicles exceeded 3 million. Although total automobile registrations in Germany fluctuated between 2008 and 2016, the sales as well as the market shares of SUVs (J-segment) always enjoyed a remarkable growth. In 2016, about 0.7 million SUVs were registered, more than three times as many as in 2008. Because of their larger capacity, higher ride height and better adaptation performance on different driving conditions, SUVs are considered a convenient and comfortable choice for families and longer-distance travel. Another reason is that gasoline prices have declined since 2013, which makes the purchase of SUVs a more economical investment. While sales of SUVs continued to increase, the market share of multiple purpose cars (M-Segment) dropped from 11% in 2008 to less than 8% in 2016. The possible reason for this decrease might be that the potential minivan buyers are changing their minds and are purchasing more fashionable SUVs instead (Flynn et al., 2001).

3.1.2 By brand
The market shares by brand have not changed a lot in Germany during the observed time period. As illustrated in Figure 4, VW managed to dominate the automobile market continuously, always achieving more than 20% market share for new passenger cars, while no other carmaker
reached more than 11% of market share over the period from 2008 to 2016. Mercedes-Benz remained the second most-registered automobile brand, with the only exception being the year 2009. Audi, exceeding BMW in 2013, became the third best-selling brand in Germany. The top five most favorable brands (VW, Mercedes-Benz, Audi, BMW and Opel) remained unchanged from 2008 to 2016 and all of them came from German manufacturers, making up more than a half of total sales. Skoda, belonging to the Volkswagen Group, surpassed Renault and became the best-selling foreign carmaker since 2013. The “other” category consists of all brands other than the above-mentioned automakers, with a joint market share remaining steady at about 30%.

![Figure 4: Registrations of new passenger cars in Germany from 2008 to 2016, by brand](image)

Data source: KBA

3.1.3 By powertrain

Figure 5, consisting of two grouped columns, depicts the registrations of new passenger vehicles by different powertrains and specifically the alternative powertrains. Conventional gasoline and diesel motors remain the most popular powertrains in Germany, as illustrated in Figure 5 (left plot). Gasoline vehicles continue to dominate the market with more than 50% of total sales. Especially in 2009, because of the CARS scheme, a surge of small-sized vehicle sales boosted the registrations of gasoline cars to 2.6 million, amounting to a market share of 68%.
As can be seen from Figure 5 (right plot), great changes have taken place in the market for alternative powertrains for new passenger vehicles. Due to the maturity of technologies and restrictions on CO₂ emissions, the penetration of electric and hybrid-electric vehicles is developing at a rapid pace. In 2008, only 36 battery-electric vehicles (BEV) were sold in Germany, a number that had risen to more than 11,000 by 2016. During the same period, hybrid-electric vehicles showed a sevenfold increase in sales, from around 6,500 to 48,000, and reached a peak of 1.5% total market share in 2016. The development of liquefied petrol gas (LPG) and compressed natural gas (CNG) vehicles, however, has been sluggish since 2008. Market shares of those alternative powertrains have decreased significantly. If this trend persists, they will fade out from the German automobile market in the near future.

### 3.2 Vehicle prices

Figure 6 displays the development patterns of prices of automobiles and (deflated) GDP (CPI 2008 = 100) in Germany over the period from 2008 to 2016. There is a significant positive correlation between the average vehicle price and the GDP in Germany. In 2009, due to the impact of the financial crisis, the average vehicle price as well as the GDP reached their lowest point, at €21,700 and €2.452 billion, respectively. In the next four years spanning from 2010 to 2014, the price of new registrations remained stable at around €25,000. After that, the average price of vehicles increased remarkably, averaging €28,800 in 2016, approximately 33% more than the average price in 2009. During the same period, the GDP went up gradually after the
2009 recession, reaching €2.9 billion in 2016, 17.3% more than in 2009.

Figure 6: Development of the GDP and the average passenger vehicle price in Germany from 2008 to 2016
Data source: Statistisches Bundesamt, DAT, ZDK

### 3.3 CO₂ emissions

As shown in Figure 7, CO₂ emissions of most automobile segments dropped significantly between 2009 and 2016. The CO₂ emissions of luxury cars (F-Segment), for instance, decreased by approximately 30% during this period. A notable exception, however, is the segment of sports cars (S-Segment), whose CO₂ emissions have been increasing again since 2014. New cars sold in Germany have average CO₂ emissions (green line) of 128.8 g CO₂/km in 2015. This is the highest value in the European Union and only slightly lower than the EU 2015 target of 130 g CO₂/km. Although only four car segments (Mini, Small, Medium and Large) reached the target level in 2015, they commanded 65% of the total market share. Supposing that the reduction of CO₂ emissions will continue in this tendency at a similar speed, Germany will have significant difficulties meeting the 2020 target of 95 g CO₂/km.
Figure 7: Average CO₂ emissions and EU targets for CO₂ emissions of new passenger vehicles
Data source: KBA

4 Model estimation

According to previous studies, multiple linear regression is one of the most commonly applied methods for the estimation of automobile demand (Trandel 1991, Flynn et al. 2001, Emre Alper and Mumcu 2007, Shahabuddin 2009, Kitapçı 2014). Therefore, we combine the data on different variables described in Section 2 and estimate the automobile demand in Germany, using the multiple linear regression method.

4.1 Theoretical basis

4.1.1 Multiple linear regression

The multiple linear regression model is widely used to explicate the correlation between two or more independent factors and the explained variables simultaneously in a linear approach. This kind of model provides us with a predictive method to analyze how several factors jointly affect the explained variable. The general equation can be written as:

\[ y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_k x_k + u, \]  

(1)

where \( y \) is the explanatory variable, \( x_1 - x_k \) are independent factors and \( u \) refers to the error term that includes all other relevant factors. In order to obtain the estimates of \( b_0 - b_k \), the method of ordinary least squares (OLS) is used, minimizing the sum of squared residuals.

Multiple linear regression allows us to make a comparison of predictive accuracy between different models. R², for instance, as a measure of the goodness-of-fit for the regression, is defined as the squared correlation coefficient between the observed outcomes \( y_i \) and the fitted predictor \( \hat{y}_i \), which ranges from 0 to 1. R² can be explained in the equation as follows:

\[ R^2 = \frac{SSE}{SST}, \]  

(2)
where SSE refers to the explained sum of squares and SST is the total sum of squares. $R^2$ can be regarded as the degree of accuracy of the model predictors and used for model evaluation.

4.1.2 Multicollinearity checking
Before the estimation of the linear regression model, we first check whether multicollinearity exists among the explanatory variables. Multicollinearity is defined as a phenomenon in which one independent variable is highly correlated with other variables in a multiple linear regression model. In order to evaluate the degree of multicollinearity, we introduce the variance inflation factor (VIF), which is defined as

$$ VIF_j = \frac{1}{(1-R_j^2)}, $$

where $R_j^2$ refers to the R-squared in the regression of $x_j$ on other independent variables. The variances of the OLS estimator can be stated as:

$$ Var(\hat{\beta}_j) = \frac{\sigma^2}{SST_j} \cdot VIF_j $$

Those two equations show that a higher correlation between independent variables ($R_j^2$) leads to a larger VIF value, and thus results in a higher variance. The VIF is commonly compared with a value of 10: if VIF > 10, it can be concluded that a multicollinearity problem exists and may have a negative impact on the regression result.

4.1.3 Adjustment with heteroskedasticity-robust standard errors
OLS estimation is based on the assumption that the standard deviation of the unobserved error term $u$ is constant and presents no dependence on the explanatory variables, namely $\text{Var}(u|x_1,x_2,...,x_k) = \sigma^2$. However, this assumption may fail during the regression, a phenomenon that is called heteroskedasticity. The presence of heteroskedasticity does not lead to bias or inconsistencies of the regression, but may lead to underestimation of the standard errors. We therefore modified our results with a heteroskedasticity-robust method, which is commonly used in econometrics and is always valid, irrespective of whether the heteroskedasticity phenomenon is present or not.

4.2 Model with macroeconomic variables
For the first regression model, we estimate car sales of all segments in Germany over the period from 2008 to 2016 on the macro level, taking macroeconomic variables as well as government incentive schemes into consideration.

**Model 1a** can be described as follows:
\[
\log(\text{SALES}_{i,t}) = b_0 + b_1 \times \log(\text{SALES}_{i,t-1}) + b_2 \times \log(\text{GDP}_t) + b_3 \times \text{RIR}_t + b_4 \times \\
\log(\text{PP}_t) + b_5 \times \text{CARS} + u_{i,t}
\]  
(5)

where \(\text{SALES}_{i,t}\) are model \(i\)'s sales in each month, \(\text{SALES}_{i,t-1}\) are model \(i\)'s sales of the same month in the previous year, \(\text{GDP}_t\) is the gross domestic product of Germany, \(\text{RIR}_t\) denotes the real interest rate in Germany, \(\text{PP}_t\) is the gasoline price in Germany, and \(\text{CARS}\) is a dummy variable that takes the value 1 during the implementation period of the Car Allowance Rebate System (01/2009 – 09/2009). VIFs of the involved independent variables are listed in Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>(\text{SALES}_{i,t-1})</th>
<th>(\text{GDP}_t)</th>
<th>(\text{RIR}_t)</th>
<th>(\text{PP}_t)</th>
<th>(\text{CARS})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(VIF)</td>
<td>1.00</td>
<td>2.51</td>
<td>1.94</td>
<td>2.48</td>
<td>1.82</td>
</tr>
</tbody>
</table>

As can be seen from Table 2, none of the VIF values for the macroeconomic variables is above 10. Therefore the multicollinearity problem is not significant in this regression model. As illustrated in Section 3, the year 2009 is an anomaly during the observed time range for the automobile market in Germany. Due to the implementation of the scrappage scheme, 2009 was the year with the lowest GDP but highest new registrations. This government intervention could hardly be explained using macroeconomic variables. We therefore estimate model 1b, using the same variables aforementioned for a time range from 2010 to 2016, but excluding the CARS dummy, which only affected car sales in 2009.

### 4.3 Model with product-related variables

For the second regression model, we exclude the macroeconomic variables and use product-related variables in order to estimate the automobile demand on the microeconomic level instead. Model 2 can be described as follows:

\[
\log(\text{SALES}_{i,t}) = b_0 + b_1 \times \log(\text{SALES}_{i,t-1}) + b_2 \times \log(\text{PRICE}_{i,t}) + \\
b_3 \times \log(\text{CPRICE}_{i,t}) + b_4 \times \log(\text{CO}_2_{i,t}) + b_5 \times \text{PC}_{i,t} + \\
b_6 \times \text{ADAC}_{i,t} + b_7 \times \text{FL}_{i,t} + u_{i,t},
\]  
(6)

where \(\text{PRICE}_{i,t}\) is the average price of model \(i\) by time \(t\), \(\text{CPRICE}_{i,t}\) denotes the average price of model \(i\)'s competitors by time \(t\), \(\text{CO}_2_{i,t}\) is the CO\(_2\) emission of model \(i\) per 1000kg by time \(t\), \(\text{PC}_{i,t}\) is the gasoline consumption of model \(i\), \(\text{ADAC}_{i,t}\) is the quality rating from ADAC test of model \(i\). and \(\text{FL}_{i,t}\) is a dummy variable that takes the value 1 if the model had a facelift in the previous 6 months. We also calculate the VIFs for the product-related variables, which are listed in Table 3.
Table 3: VIF values of product-related variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>VIF</th>
<th>PRICE_{it}</th>
<th>CPRICE_{it}</th>
<th>CO2_{it}</th>
<th>PC_{it}</th>
<th>ADAC_{it}</th>
<th>FL_{it}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VIF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SALES_{i,t-1}</td>
<td>1.61</td>
<td>11.54</td>
<td>4.55</td>
<td>3.73</td>
<td>7.92</td>
<td>2.59</td>
<td>1.00</td>
</tr>
</tbody>
</table>

According to Table 3, although the VIF values of the product-related variables are higher than those for the macroeconomic independents, only one of the values is above 10. Therefore, we conclude that multicollinearity is not an issue for our estimation. As for the price variable used in model 2, we compared the data set on the observed model’s base price as well as its average price during the regression. The results show that the data on the average price of the selected car models fits better for the estimation. Therefore, we decided to use the average price to describe the developing trend of price variation.

4.4 Model with integrated variables

In model 3 we integrate all above-mentioned independent variables together. The regression equation is:

\[
\log(SALES_{i,t}) = b_0 + b_1 \times \log(SALES_{i,t-1}) + b_2 \times \log(GDP_t) + b_3 \times RIR_t + b_4 \times \log(PP_t) + b_5 \times CARS + b_6 \times \log(PRICE_{i,t}) + b_7 \times \log(CPRICE_{i,t}) + b_8 \times \log(CO2_{i,t}) + b_9 \times PC_{i,t} + b_{10} \times ADACT_{i,t} + b_{11} \times FL_{i,t} + u_{i,t} \quad (7)
\]

The VIF values for the involved explanatory variables are listed in Table 4.

Table 4: VIF values of all variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>VIF</th>
<th>Variable</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALES_{i,t-1}</td>
<td>1.65</td>
<td>CPRICE_{it}</td>
<td>4.56</td>
</tr>
<tr>
<td>GDP_t</td>
<td>2.79</td>
<td>CO2_{it}</td>
<td>3.92</td>
</tr>
<tr>
<td>RIR_t</td>
<td>2.10</td>
<td>PC_{it}</td>
<td>8.32</td>
</tr>
<tr>
<td>PP_t</td>
<td>2.53</td>
<td>ADACT_{it}</td>
<td>2.71</td>
</tr>
<tr>
<td>CARS</td>
<td>1.82</td>
<td>FL_{it}</td>
<td>1.01</td>
</tr>
<tr>
<td>PRICE_{it}</td>
<td>11.74</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 4, the VIF of all variables except one is below 10. Therefore, there is no remarkable multicollinearity problem in this regression model either. In order to analyze the distinctions and commonalities between different types of vehicles in terms of the possible determinants of automobile demand, we also apply the estimated model with integrated independents in each automobile segment separately. The results of the estimations are reported in section 5.
5 Results and analysis

5.1 Estimation results with macroeconomic variables

The estimation results with macroeconomic data as predictor variables are depicted in Table 5. The coefficient columns directly indicate the elasticity of automobile sales with respect to related predictors. For instance, in model 1a, a 1% increase in GDP would lead to a 0.657% increase in the sales of vehicles. A minus sign of the coefficient implies that the independent variable affects car sales negatively.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>P-value</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.122</td>
<td>1.136</td>
<td>&lt;0.001 ***</td>
<td>-3.746</td>
<td>1.357</td>
<td>0.006 ***</td>
</tr>
<tr>
<td>SALES_{t-1}</td>
<td>0.895</td>
<td>0.008</td>
<td>&lt;0.001 ***</td>
<td>0.888</td>
<td>0.008</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>GDP</td>
<td>0.657</td>
<td>0.182</td>
<td>&lt;0.001 ***</td>
<td>0.654</td>
<td>0.211</td>
<td>0.002 ***</td>
</tr>
<tr>
<td>RIR</td>
<td>0.672</td>
<td>0.464</td>
<td>0.147</td>
<td>-0.807</td>
<td>0.935</td>
<td>0.388</td>
</tr>
<tr>
<td>PP</td>
<td>0.435</td>
<td>0.100</td>
<td>&lt;0.001 ***</td>
<td>0.273</td>
<td>0.140</td>
<td>0.052</td>
</tr>
<tr>
<td>CARS</td>
<td>0.076</td>
<td>0.015</td>
<td>&lt;0.001 ***</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Model 1a</th>
<th></th>
<th></th>
<th>Model 1b (Since 2010)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adj. R²</td>
<td>0.788</td>
<td></td>
<td></td>
<td>0.797</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of obs.</td>
<td>9078</td>
<td></td>
<td></td>
<td>7411</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. Robust standard errors in parentheses.

As shown in Table 5, the differences between models 1a and 1b are not remarkable. Model 1b has a slightly stronger R² with 79.7%, representing that those indicators can explain 79.7% of the variation in automobile sales over the period from 2010 to 2016. Both models indicate that the sales of the previous year and GDP are significant predictors of automobile sales. From model 1 we can also conclude that the scrappage scheme, namely the CARS incentive, encourages the consumers effectively. The implementation of CARS led to a 7.6% increase in automobile sales. The GDP presents a positive effect on automobile demand as well, which is also in line with conventional wisdom. A steady growth rate of GDP indicates a stable economic foundation of an economy, which drives up sales of automobiles. Our results show that the gasoline price has a positive impact on sales. It means that the sales will go up as the gasoline prices increase, which is contradictory to our expectation. The possible reason could be that we only consider passenger cars in our study. Furthermore, rising gasoline prices might encourage consumers to replace their old cars with new, more efficient ones. Several studies (Flynn et al.)
(2001, Shahabuddin 2009) indicate that sales of passenger vehicles are rarely influenced by gasoline prices. Demand for commercial vehicles, on the other hand, might react differently with regard to changes in gasoline price.

5.2 Estimation results with product-related variables

For the second model, we omit all macroeconomic variables and focus on product-related variables, which indicate the preferences of consumers with respect to purchasing a new vehicle specifically. The estimation results are reported in Table 6.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.889</td>
<td>0.214</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>SALES(t-1)</td>
<td>0.799</td>
<td>0.006</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>PRICE</td>
<td>-0.051</td>
<td>0.030</td>
<td>0.091 *</td>
</tr>
<tr>
<td>CPRICE</td>
<td>-0.183</td>
<td>0.021</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>CO2</td>
<td>0.199</td>
<td>0.068</td>
<td>0.003 ***</td>
</tr>
<tr>
<td>PC</td>
<td>-0.039</td>
<td>0.005</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>ADAC</td>
<td>-0.174</td>
<td>0.011</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>FL</td>
<td>0.057</td>
<td>0.007</td>
<td>&lt;0.001 ***</td>
</tr>
</tbody>
</table>

Adj. R\(^2\) | 0.804
No. of obs. | 9078

Notes: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. Robust standard errors in parentheses.

According to Table 6, for the time period from 2008 to 2016 model 2 has an R\(^2\) of 80.4%, slightly higher than models 1a and 1b. Model 2 indicates that vehicle price has the expected impact on automobile demand, as the increase in price leads to a decline in sales. There is a puzzling relationship between car sales and competitors’ average prices though: as competitors’ prices rise, sales fall. The competitors’ average prices are calculated as the sales-weighted average prices of all other models in the segment. This variable can also represent the average price variation trend of the total car segment. Therefore, their negative impact on automobile sales is much easier to understand: consumers prefer more economical car segments to premium segments. From another point of view, if the prices of all automobiles within one segment increase simultaneously (for instance, in the case of a rise in tax rates or steel prices), the demand for automobiles will also suffer from this negative effect.

As we turn our attention to variables on product parameters, we notice that, according to the model, the sales will decrease as the vehicle’s gasoline consumption increases. The correlation between fuel efficiency and automobile sales is quite significant, especially compared with the
price factor. This means that consumers are more likely to take a long-term consideration about the economic efficiency when they are making their vehicle purchase decisions. Those vehicles with lower retail prices but lacking technical improvement might be no longer especially attractive for German consumers. Although the fuel efficiency is positively correlated with CO₂ emissions, our result indicates that, on the other hand, the weight-specific CO₂ emissions have a positive impact on sales. The possible reason is that the weight-specific CO₂ emissions vary from different car segments. Mini cars, for instance, use less fuel but have a higher specific CO₂ emission due to their light body mass. In the next model, we will explain the detailed analysis and comparisons in terms of CO₂ emissions by different market segments.

Our estimation result from model 2 also shows that the ADAC quality ratings of vehicles have a significant impact on sales. Since the rating scores range from 0.5 (excellent) to 5.5 (insufficient), a lower score means a better quality rating. As shown in Table 6, a 1-point decrease of the quality rating score leads to a 17.4% increase in car sales. Compared with the lower significance of the price variable, we can conclude that German consumers are more concerned about vehicles’ performance in terms of safety as well as comfort rather than their price.

The inclusion of both the quality and price variables in the estimation may generate an endogeneity problem, since price and quality have a positive correlation. However, Trandel (1991) and Emre Alper and Mumcu (2007) both confirmed that omitting quality from regression might cause some bias in the estimates of other variables.

An automotive facelift may include aesthetic alterations, some small mechanical changes or new interior design elements, which allows the automobile OEMs to freshen up a car model without a complete redesign. The facelift of vehicles is also an important indicator of variation in sales. Our result implies that every time a car has received a facelift, the sales have increased by 5.7%.

5.3 Estimation results with all variables regarding total market

For the third model, we integrate all possible factors together; the regression results are listed in Table 7. The differences between model 3 and previous models are minor. The R² is slightly stronger than for the first and the second model. Variables on GDP, price, and weight-specific CO₂ emissions are not statistically significant.
Table 7: Regression analysis results for the model with all variables regarding total market, Model 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.509</td>
<td>1.146</td>
<td>0.647</td>
</tr>
<tr>
<td>SALES(_{i,t-1})</td>
<td>0.791</td>
<td>0.006</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>GDP</td>
<td>0.023</td>
<td>0.178</td>
<td>0.899</td>
</tr>
<tr>
<td>RIR</td>
<td>2.097</td>
<td>0.438</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>PP</td>
<td>0.643</td>
<td>0.095</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>CARS</td>
<td>0.071</td>
<td>0.012</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>PRICE</td>
<td>-0.020</td>
<td>0.030</td>
<td>0.504</td>
</tr>
<tr>
<td>CPRICE</td>
<td>-0.175</td>
<td>0.021</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>CO2</td>
<td>0.074</td>
<td>0.069</td>
<td>0.287</td>
</tr>
<tr>
<td>PC</td>
<td>-0.048</td>
<td>0.005</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>ADAC</td>
<td>-0.155</td>
<td>0.011</td>
<td>&lt;0.001 ***</td>
</tr>
<tr>
<td>FL</td>
<td>0.053</td>
<td>0.007</td>
<td>&lt;0.001 ***</td>
</tr>
</tbody>
</table>

Adj. R\(^2\): 0.807
No. of obs.: 9078

Notes: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. Robust standard errors in parentheses.

5.4 Estimation results by segments

We regard model 3 as our standard result and estimate separate models for each car segment, comparing the coefficient and significance of variables between different segments. Since the macro variables just vary across time but not across models, we focus our attention only on the product-related variables during the comparison and analysis. The main estimation results are listed in Table 8.

As shown in Table 8, the impact and significance of possible indicators vary from segment to segment. One common feature is the attitude towards the ADAC quality rating, which has a significant negative impact on all segments except one. This implies that for many consumers in Germany, vehicle quality is a significant determinant in the purchase decision-making process. The implementation of the CARS scheme was particularly effective for small- to medium-sized vehicles. Consumers of large-sized vehicles are more concerned about fuel efficiency than small-sized car drivers, at least in their choices within the segment. However, customers who care more about fuel efficiency might pick a smaller segment in the first place.

In the following, we turn to each segment separately, aiming to uncover important differences between different segments.
The mini-car segment can be regarded as covering the inexpensive vehicles with 2 seats, whose consumers may have a limited budget and/or are just interested in the basic needs of transportation. The regression for mini cars takes 8 different car models into account, with an

### Table 8: Regression analysis results with all variables, by car segment

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mini</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Executive</th>
<th>Luxury</th>
<th>SUV</th>
<th>MPV</th>
<th>Sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARS</td>
<td>0.322***</td>
<td>0.251***</td>
<td>0.165***</td>
<td>0.013</td>
<td>-0.082**</td>
<td>-0.065</td>
<td>-0.015</td>
<td>-0.012</td>
<td>-0.072</td>
</tr>
<tr>
<td>PRICE</td>
<td>1.312***</td>
<td>-0.312***</td>
<td>-0.010</td>
<td>1.083***</td>
<td>1.050***</td>
<td>0.021</td>
<td>-0.744***</td>
<td>-0.039</td>
<td>0.559***</td>
</tr>
<tr>
<td>CPRICE</td>
<td>0.703</td>
<td>-2.400***</td>
<td>1.345*</td>
<td>1.694***</td>
<td>2.432***</td>
<td>-1.412***</td>
<td>0.936***</td>
<td>-0.818***</td>
<td>-1.153***</td>
</tr>
<tr>
<td>CO2</td>
<td>-1.647***</td>
<td>0.727***</td>
<td>1.372***</td>
<td>-0.546**</td>
<td>1.859*</td>
<td>-0.539</td>
<td>0.732**</td>
<td>0.853***</td>
<td>-0.733**</td>
</tr>
<tr>
<td>PC</td>
<td>0.052**</td>
<td>-0.005</td>
<td>-0.119***</td>
<td>-0.050**</td>
<td>-0.139*</td>
<td>0.003</td>
<td>-0.048***</td>
<td>-0.033*</td>
<td>-0.063**</td>
</tr>
<tr>
<td>ADAC</td>
<td>-0.227***</td>
<td>-0.087***</td>
<td>-0.265***</td>
<td>-0.347***</td>
<td>-0.264*</td>
<td>-0.692***</td>
<td>-0.476***</td>
<td>-0.371***</td>
<td>0.781***</td>
</tr>
<tr>
<td>FL</td>
<td>0.038</td>
<td>-0.024*</td>
<td>-0.024**</td>
<td>0.011</td>
<td>0.027</td>
<td>0.135***</td>
<td>0.011</td>
<td>0.112***</td>
<td>0.160***</td>
</tr>
<tr>
<td>SALES_{t-1}</td>
<td>0.464***</td>
<td>0.683***</td>
<td>0.746***</td>
<td>0.701***</td>
<td>0.891***</td>
<td>0.360***</td>
<td>0.402***</td>
<td>0.607***</td>
<td>0.675***</td>
</tr>
</tbody>
</table>

| MACRO\_Vector | - | - | - | - | - | - | - | - | - |
| Adj. $R^2$     | 0.500  | 0.678  | 0.808  | 0.874  | 0.918    | 0.530  | 0.570  | 0.564  | 0.677  |
| No. of obs.    | 832    | 931    | 1267   | 1101   | 527      | 714    | 1227   | 1572   | 729    |

Notes: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. Robust standard errors in parentheses.
R² of 50.0%.

Our estimation indicates that the car allowance rebate system (CARS) had a significant impact on mini-car sales, as sales increased by 32.2% when the scheme was implemented. The CARS incentive is especially economical for potential mini-car consumers, since it can cover up to 30% of the original car price. The car price is another powerful predictor of mini sales: a price decrease of 1% leads to a 1.3% increase in mini sales. The negative price effect suggests that consumers in this segment are sensitive to the price fluctuation, since they may have a limited budget for purchasing a car. The positive gasoline consumption is at first perplexing. If we turn to other segments, however, the gasoline consumption is a negative variable. We suppose the possible reason is that the fuel consumption is already lower than average in the mini car segment. These consumers are therefore not cautious about those little differences of energy efficiency between different models within the mini-car segment. The ADAC quality ratings have a negative effect among all car segments. As for mini cars, a 1-point decrease of the rating score drives up car sales by 22.7%, which indicates that consumers still focus on the quality of vehicles although their budget is limited. Neither the competitors’ price nor the facelift of vehicles are strong predictors of mini-car demand.

- **Small Cars (Segment B)**

Cars in segment B are mostly designed to seat four passengers comfortably. As mini cars are particularly suitable for singles or young couples, small cars can generally satisfy the basic needs of city life for small families. The regression of small cars includes 9 car models with an R² of 67.8%.

As shown in Table 8, the CARS scheme, car price, competitors’ price, specific CO₂ emission and ADAC quality rating are the main indicators of the demand for small cars. The puzzling effects—negative relationships between sales and both the price of observed models and their competitors—exist in the estimation of small-car demands. We suggest that these may indicate that consumers shift their purchases into other segments when the price of small cars goes up. Small-car consumers are not sensitive to fuel consumption but cautious about CO₂ emissions, similarly to the mini-car consumers. It is reasonable if we consider that the best-selling electric vehicles mostly come from those two segments. Electric vehicle consumers are more cautious about the environment and do not need to pay attention to fuel efficiency. The ADAC quality rating also plays an important role in the sales of small cars.

- **Medium Cars (Segment C)**

Medium cars are also regarded as compact cars with 5 seats and a hatchback, which are generally models that can fulfill the need for basic transportation. The medium-car segment
remains the best-selling segment in Germany. Our estimation for medium cars takes 12 car models into consideration, with a moderately higher $R^2$ of 80.8%.

Our results indicate that consumers of medium cars are not sensitive to price fluctuations, since model prices are not significant. What they are really concerned about is the fuel efficiency and the quality parameters. Consumers who choose the mini and small cars are more likely to focus on the retail price, while the medium-car consumers appear to care more about the long-term investment efficiency, since medium-car drivers have to spend much more money on fuel than mini and small-car drivers. Furthermore, medium cars are not just used in cities but may also be responsible for some long-distance transportation. For these reasons, the significant negative fuel consumption variable in the mid-size car segment seems reasonable. The CARS scheme plays an important role for forecasting medium-car demand, but not as strongly as in mini and small cars. The implementation of the scrappage scheme increased mid-size car sales by 16.5%. The ADAC quality rating variable remains significant in the mid-size car segment, while the impact of facelifts is significant but small.

- **Large Cars (Segment D)**
  The large-car segment comprises full-size cars, which are designed to be comfortable for 5 passengers and have enough trunk space for luggage. We select the 12 best-selling car models from this segment to make the estimation; the result shows a higher $R^2$ of 87.4%.

  As we turn to the indicators in this model, it is puzzling to find that both the observed model’s price and its competitors’ price have a positive impact on car demand: higher prices lead to higher sales. We suppose that the possible reason is the positive correlation between car price and car quality. On the one hand, for consumers of large cars, their budgets for purchasing a vehicle are sufficient. Therefore, those purchasers may take the quality of vehicles into first consideration. The strong significance of the ADAC quality rating may also support our argument. On the other hand, the models from BMW, Mercedes Benz as well as Audi remain the most popular cars in this segment, which indicates that consumers may regard their vehicles as a symbol of wealth and status. Therefore, they prefer these relatively expensive cars. The results for the other variables in the large-car segment are straightforward. A negative fuel consumption variable implies that consumers of large passenger cars are cautious about fuel efficiency, which would drive up the operating costs of the vehicle over its life.

- **Executive Cars (Segment E)**
  Traditionally, people see the executive car as aspirational and as a kind of company-owned vehicle. In fact, executive cars are slightly larger than cars in segment D but retain a much better performance and comfort. As the sales of executive cars are mainly concentrated within a few
car models, we just take 5 observed cars into account and the model shows a very high $R^2$ with 91.8%.

The estimation results show that the incentive from the CARS scheme is not effective in this segment. A negative relationship indicates that the possible consumers are shifted into other purchases. The impact from price variation is not significant either. This is a reasonable outcome, since the consumers of executive cars are mostly confident in their ability to afford a higher-priced vehicle. It is much harder to attract them and change their mind just with a lower price. Our results imply that consumers of executive cars are cautious about fuel efficiency but do not care about CO$_2$ emissions, which is a common feature among all similar car segments.

- **Luxury Cars (Segment F)**
Luxury cars describe vehicles with high quality equipment, better performance, comfort, and higher design. More than just a kind of transportation, the luxury vehicles are also regarded as an image of wealth and status. As the sales of luxury cars are also concentrated within a few car models, we collect the data on the 7 best-selling cars and the model result indicates an $R^2$ of 53.0%.

  A remarkably high impact predictor is the competitors’ price: the decrease of the competitors’ price can lead to an increase in car sales. On behalf of the segment’s average price, the decline of the competitors’ price may attract some consumers to moving up to the luxury car segment. Neither specific CO$_2$ emission nor the fuel efficiency are significant variables in the regression. Consumers in this segment are especially sensitive to facelifts of vehicles and the positive coefficient implies that a facelift increases sales by 13.5%, which indicates that luxury car consumers are much more eager to try the most modern and latest models.

- **SUV (Segment J)**
SUV is the abbreviation of “Sport Utility Vehicle” and describes a kind of car with off-road vehicle features that operates as a family vehicle and is often used on city streets or highways. In this study, we integrate both off-roader vehicles and SUVs in the same segment due to their similar features. The estimation of the SUV segment includes 19 distinct car models and yields an $R^2$ of 57.0%.

  The indicators of the SUV segment regression have the expected effect on sales. The implementation of the CARS scheme is not effective for those large-sized and high-priced vehicles. The negative impact of the model price and the positive influence from the competitor’s price indicate that SUV consumers consider price factors. Fuel consumption, as a negative sales predictor, influences SUV buyers, as higher fuel consumption will drive up the operating costs of the vehicle.
• **MPV (Segment M)**

MPV is short for “multiple purpose vehicle”, a type of car with five or seven seats and a capacious as well as flexible interior. We select 17 models in the MPV segment for regression and the result implies an $R^2$ of 56.4%. A negative competitors’ price variable in our analysis suggests that a shift in purchase decisions may occur when the segments’ average price goes up. Two significant variables, the negative ADAC quality rating and the positive facelift dummy, indicate that MPV purchasers are aware of the quality performance and are interested in the new generation of vehicles.

• **Sports Cars (Segment S)**

Sports cars are usually small automobiles, often with two doors and two seats. Main features of sports cars are the spirited performance, a high price and precise control ability even at high speed. This regression consists of 8 car models; the estimation results in an $R^2$ of 67.7%.

The regression result of sports cars is similar to those of the luxury car segment, since both vehicles are high-priced and usually perceived as high quality. Sports car purchasers care more about the design and performance of cars rather than the retail price. The positive price impact and the significant negative quality rating score provide clear evidence for that reasoning. Another interesting variable is the facelift dummy: the sales increase by 16.0% after each facelift of vehicles, which indicates that sports car consumers are willing to experience, and spend their money on, the newest models. Although CO$_2$ emissions have a negative effect on sports car sales, consumers that are concerned about the environment would usually not pick any car from this segment in the first place.

**5.5 Price elasticity of car demand**

In the estimation, we include a lagged dependent variable $SALES_{i,t-1}$ to each model, in order to have a dynamic structure and to calculate the elasticity of automobile demand. We regard the coefficient of the price variable as a predictor of car sales in the short run, thus according to Table 8 (mini car segment), a 1% decrease of the sales price can increase sales by 1.312% in the total passenger vehicle market. The coefficient of the lagged sales variable $SALES_{i,t-1}$ indicates a positive correlation between previous demand and current demand. On the basis on these two coefficients, we can calculate the impact of price variation on car sales for future periods. Taking the mini-car segment, for example, a 1% decrease in a model’s own price will drive up the sales by 2.448% in ten years. Table 9 shows the short-term as well as the long-term price elasticity for each segment.
Table 9: Short-term and long-term price elasticities of automobile sales

<table>
<thead>
<tr>
<th>Segment</th>
<th>Short-term</th>
<th>Long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>All passenger vehicles</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A-Segment: Mini cars</td>
<td>1.312</td>
<td>2.448</td>
</tr>
<tr>
<td>B-Segment: Small cars</td>
<td>-0.312</td>
<td>-0.984</td>
</tr>
<tr>
<td>C-Segment: Medium cars</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D-Segment: Large cars</td>
<td>1.803</td>
<td>3.622</td>
</tr>
<tr>
<td>E-Segment: Executive cars</td>
<td>1.05</td>
<td>9.633</td>
</tr>
<tr>
<td>F-Segment: Luxury cars</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>J-Segment: SUV</td>
<td>-0.744</td>
<td>-1.244</td>
</tr>
<tr>
<td>M-Segment: MPV</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S-Segment: Sports cars</td>
<td>0.559</td>
<td>1.720</td>
</tr>
</tbody>
</table>

As can be seen from Table 9, only two segments, namely small cars and SUVs have the expected price elasticities of sales. For car segments C, E, F and M, the variation of vehicle own price does not affect demand, whereas for car segments A, D and S, higher prices lead to higher sales. The reason behind this seemingly puzzling result could be the positive correlation between quality and price. Consumers prefer vehicles with better performance, even though their prices are relatively higher. Sports cars (Segment S) appear to be typical Veblen goods: sports car consumers prefer more expensive models that are exclusive and indicate identity. The high prices of sports cars make them desirable as status symbols, therefore the demand for sports cars increases as the price increases.

Another reason for the low price elasticity of car sales could be significant brand loyalty in the German automobile market. Car purchasers in Germany feel especially positive towards national manufacturers such as Volkswagen, BMW and Mercedes-Benz, even if their prices are relatively higher than those of their non-German competitors. A typical example of brand loyalty is the emission scandal of Volkswagen in 2015. While affecting brand reputation and image, the scandal did not influence sales in Germany, as VW remained the best-selling brand afterwards.

6 Conclusions

The automobile market is a pivot component of the German industry, where automobiles dominate the manufacturing sector. The decrease in vehicle sales may result in economic consequences on the national level as well as for the people directly. Therefore, it is necessary for automobile manufacturers to plan their business carefully, and it is crucial for policymakers
to be aware of the upturns and downturns of automobile sales that might shock the national economy.

The factors that drive and shape the automotive market are complex and vary among different car segments. In this study, we collect 2008-2016 monthly data of new registration vehicles to estimate the automobile demand in Germany. Using multiple linear regression methods, macroeconomic variables and product-related variables were selected and grouped to establish relationships between those possible predictors and car demands. All passenger vehicles are divided into 9 segments according to their size and utilities. For each segment, a separate model is established, in order to uncover whether the specific predictors change over distinct car segments.

When we examine the total passenger vehicle market, we find that GDP and government incentives are the specifically stronger predictors on the macroeconomic level, while price, gasoline consumption, quality and facelift of vehicles affect the automobile demand significantly on the microeconomic level. As we turn to different car segments, one noticeable common feature among distinct segments is the high significance of the quality variable: vehicles with better quality performance are expected to have a higher sales volume in all car segments. The scrappage scheme of the federal government has a strong correlation with small-to mid-sized car sales, while for the large and expensive car segments the effect is hard to perceive. Consumers of large cars are much more sensitive to the fuel efficiency of vehicles than purchasers of small-sized cars. One interesting finding is that the influence of the price variables on car demand vary from different segments: for mini cars, small cars and SUVs, prices are negatively correlated with sales, as expected. For large and sports cars, on the contrary, higher prices may lead to more sales; for medium, executive, luxury cars and MPVs, the price variables are no significant indicators for car demand. Accordingly, the demand for new passenger cars is found to be price-inelastic in most car segments.

These results indicate a number of important possibilities for the automobile market in Germany. Based on our findings, we present some suggestions to serve as a reference for manufacturers as well as for policymakers to enhance the sales of automobiles in Germany.

- **Focus on quality and fuel efficiency**
  Quality rating is the only variable that indicates a strong significance among all car segments. This result implies that car consumers are always cautious about the safety as well as the performance of vehicles, no matter how much they would spend on purchasing. As for carmakers, their first step to enhance sales is to focus on quality and vehicle performance. One important parameter should be the fuel efficiency, which is also a significant variable of car

...
demand in most large-sized car segments. The quality of low-end cars should not be neglected either. Manufacturers should not allow a concession of quality for these cars, although their gross profit margins might be lower than for premium cars.

- **Technology innovation is encouraged**
  Technological innovations and model reboots are especially welcome for high-end cars, namely the luxury and sports car segments. The newly developed technologies can be applied in those kinds of models in a first step through a facelift, which will not only increases sales, but also elicit real feedback from consumers, allowing further improvements. Note that those new technology innovations should be adapted and applied to all other segments for the next step, which could increase the overall standard of all cars.

- **Government incentive to reduce CO₂ emissions**
  As discussed in section 3, Germany can hardly achieve the EU 2020 CO₂ emission target according to the past data and current trends. Our estimation results also indicate that car consumers are not sensitive to the CO₂ emissions of the vehicles. Therefore, we suggest that it is necessary for the German government to impose stricter regulations of CO₂ emission on the automobile manufacturers, in order to reduce the emissions of new vehicles. Another possible measure is to encourage consumers to buy a much cleaner vehicle through some allowances. We find that the scrappage scheme has stimulated the small- and mid-sized car market effectively. A similar scheme could be repeated but just focusing on particularly low emission models.

  The present study has some limitations that future research should strive to overcome. First, our data size was limited to generalize the changes of indicators across time. A larger data set with a longer observed period would enable researchers to uncover the changes in consumer behavior of automobile purchasing over time. Secondly, our results indicate that product quality matters for automobile demand. Based on this conclusion, further studies could focus on which specific vehicle parameters are the most important for consumers. A better understanding of purchasers’ preferences will help the automobile OEMs to make more powerful strategic decisions.
References


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