ESTIMATION OF HEDONIC PRICING MODEL FOR LIGHT VEHICLES: THE CASE OF UKRAINIAN MARKET FOR NEW CARS

by

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LIST OF ABBREVATIONS

ABS Anti-lock braking system

ESP Electronic Stability Program

SUV Sport Utility Vehicle

TPWS Tyre Pressure Warning System

LED Light Emitting Diode

CHAPTER 1. INTRODUCTION

Facing the impeding recession the consumers all around the world are postponing the purchase of durable goods, and Ukrainians are not exeption. For example, the coronavirus caused the demand for cars in China to fall by 9-12 times (Minfin, 2020). In Ukraine in January-June 2020 the number of purchased new automobiles declined by 4.2% comparing to the same period in 2019 (Ukrautoprom, 2020). On the contrary, the Ukrainian new passenger car market sales increased by 14% in volume in 2019 versus 2018. There is an evidence that some people are switching to buying second-hand cars or setting aside the purchase for better times. Therefore to adjust their pricing and marketing strategies in current situation manufactures and distributors selling their automobiles in Ukrainian market need to know how car attributes are valued by local customers. Using the cross-sectional data from the slowdown period, the hedonic pricing model will provide insights for car sellers on what is the marginal value of certain car attributes.

The main purpose of this research is (i) to assess the marginal willingness to pay for various light vehicles attributes on the Ukrainian new car market using well-established hedonic price techniques, (ii) to determine whether Ukrainians value fuel economy and to which extent, and (iii) to compare the research results with the hedonic pricing estimates from other developed and developing countries (Germany, Sweden, the US and Greece). The hedonic price model includes both quantitative automobile attributes and account for such qualitative variables as brand equity, model type, location of dealer, body type, engine characteristics and some comfort/safety features.

The standard hedonic semi-log model is used to provide insights on how unit charge in car attributes influences the percentage change of new car price. Although the hedonic pricing method for the car market was firstly used back in 1939 (Court, 1939), there is lack of such studies for transition countries and non-existence of them for Ukrainian case. This is also an important factor for conducting this research.

This research provides important implications both for car distributors and individual sellers. This will help businesses to adjust their pricing strategies and offer brands/models which are the most relevant to customers. Moreover, the individuals and small business, which often lack resources for thorough research on market pricing, will know the weight of individual components in the car valuation and be able price their cars according to this information on second-hand market (used cars are the substitutes for new cars, and their pricing mechanism are similar except for accounting for age and mileage in used cars case).

The data for the hedonic model is web scraped using R program from the biggest online marketplace for car ads in Ukraine - Auto.ria. Overall, more than 6000 observations on top 20 brands constituting more than 90% of market volume are collected for the hedonic analysis. The key predictors that may be affecting the new car prices are brands, model types, transmission, wheel drive type, engine fuel and its capacity, various comfort and safety features, horsepower, body type, fuel consumption, car weight, region of sale, car availability and so on. The hedonic pricing regression reveals that brand premium accounts for the largest change in car price and is very intuitive. Across the sample brand premium comparing to the Renault brand (the market leaders in terms of units sold in 2019) ranges from - 13% to +64% ceteris paribus. Car body types also significantly alter the price of a vehicle. In relation to the most frequent body type on the Ukrainian market, crossover, such body types as cabriolet, coupe, SUV, pickup and roadster are more expensive, while sedan, station wagon and fastback have lower prices than crossover cars. Newly produced but analogous cars are only 3% more expensive than those produced year before. The model also indicates that consumers are willing to pay more for cars with automatic or tiptronic transmission types, and hybrid or diesel cars are commanding higher prices than those with gasoline engine. Also, full drive cars are 5% more expensive than front wheel drive ones. Leather interior in the car increases its price by 10% all other being constant. In addition, horsepower has obviously positive influence on car price, which is reflected in 4% increase with 10 hp rise in this variable. Such variables as sale region, car

availability or curb weight have little or no influence on the car prices. Turning back to the question with impact of fuel consumption on new car prices, the hedonic model proves that indeed Ukrainians positively value fuel economy.

The following recommendation stem from the hedonic analysis:

- For car dealerships the decision on what brand/model to offer for purchase must result from the analysis of both volume market share and brand/model premium of certain car.

- As fuel economy affects car prices the marketing campaigns should focus on the promotion of cars with better fuel savings that will benefit both the consumer in terms of fuel costs and the dealer in terms of higher sales.

- There is still greater share of gasoline cars then diesel ones offered by dealerships, while diesel or hybrid cars are more efficient and have higher premium in the eyes of consumers. There is also need for car manufacturers to develop and promote combined types of gearboxes as they are priced higher.

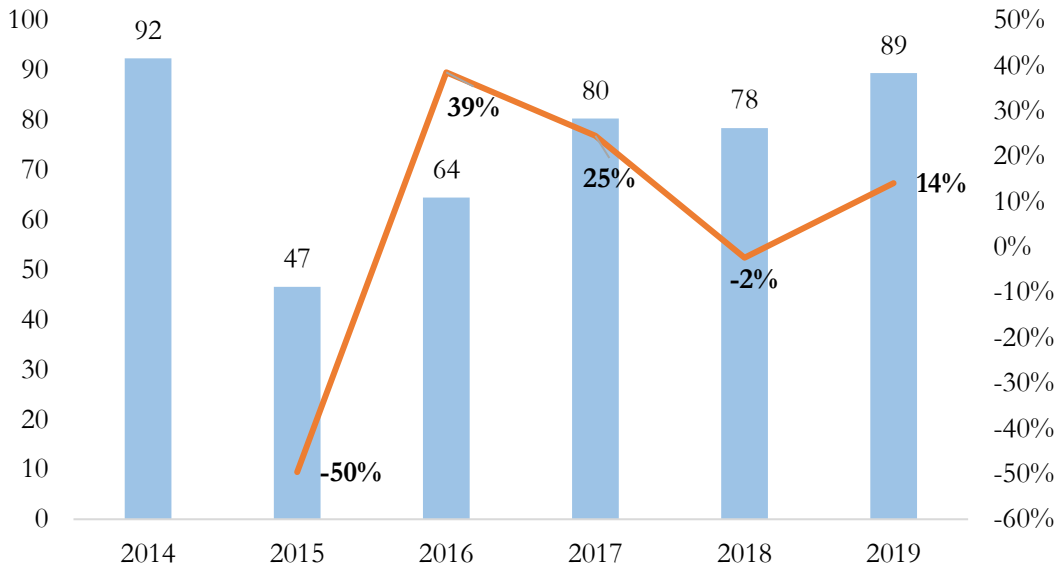
- The cars sold in Kyiv region are only 3% more expensive, while the operational costs for activity in Kyiv are obviously higher. That's why the good strategy nowadays is to advertise cars online and perform the car delivery, while physically being in Center or other region , where operating costs are lower.

The remainder of this paper is structured as follows. The second chapter presents general information on Ukrainian car market and previous findings in this field. The third chapter discusses empirical methodology and model specification followed by a presentation of the data in the fourth chapter. The fifth chapter provides and interprets the results. The final chapter concludes and provides recommendations for businesses.

CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

Before discussing the usage of hedonic pricing model for the cars, it is relevant to discuss the dynamics and situation on the Ukrainian car market. Car market in Ukraine dropped down significantly in 2014 due to the loss of territories where 25% of new car sales were concentrated. That's why we proceed with the analysis from 2014. The Ukrainian market for new cars has been recovering since 2016 (Figure 1). Due to the global slowdown in the first half of 2020 the number of new cars bought declined by almost 4.2% comparing to the same period in 2019 (Ukrautoprom, 2020). However, before the pandemic the market was expected to increase as well in 2020 (Autoconsulting, 2020). The biggest decline was observed in April when the volume of new cars sold decreased by 48% comparing to analogous period in 2019.

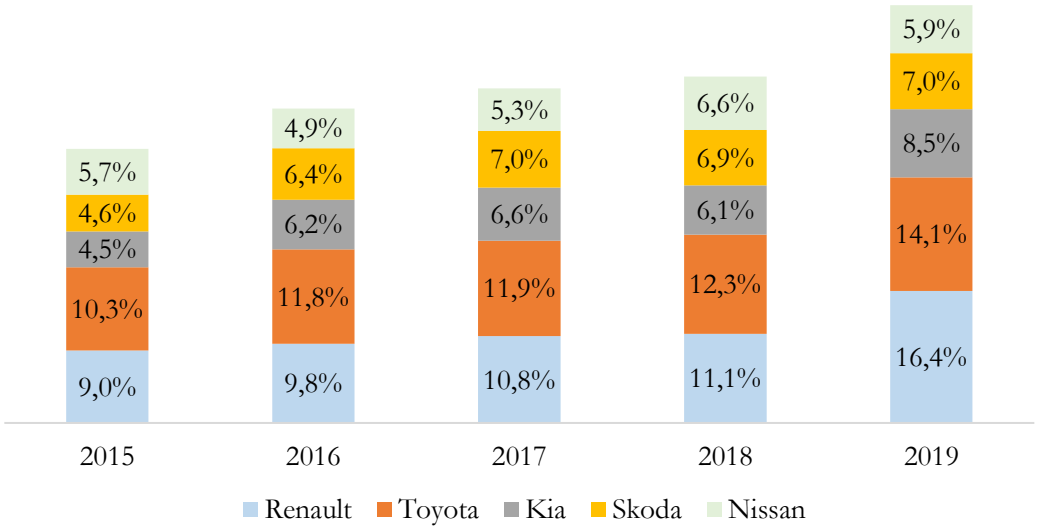
Figure 1. Dynamics (thous. units) and growth of new car market volume



Having examined the dynamics of volume market shares of TOP 5 brands in 2019 in Ukraine (Figure 2), it can be seen that there was gradual process of market concentration

because in 2015 TOP 5 brands constituted only 34% of car market while in 2019 their share was 52%. Moreover, slightly more than 30% of volume in 2019 belongs to Renault and Toyota, which are players in different price categories (value and mainstream segments). Over 2015-2019 years the growth of volume market share of Renault outpaced the growth for Toyota, and as a result in 2019 Renault bacame a leader by volume market share in Ukraine. According to the results of fisrt half of 2020 all top 5 car market players except Renault have lost in terms of sales comparing to the analogous period in 2019. This might indicate that the crisis switched the preference of customers from mainstream car segment to value car segment.

Figure 2. The evolution of shares of TOP 5 car brands, by cars sold



As can be seen from Table 1 the market leaders in 2019 across models were KIA Sportage - 6 027 cars, Renault Duster - 5 202 cars, Renault Logan - 4 489 cars, Toyota RAV-4 - 4 227 cars and Renault Sandero - 3 246 cars (Autoria, 2020). In the 1st quarter of 2020 the list of TOP 5 most bought models remained the same. The market is quite

concentrated in terms of most popular car models, because TOP 10 bought models constituted 34,7% and 42% of total sales volume in 2019 and 1st quarter 2020 respectively.

Table 1. Top 10 most popular new car models in Ukraine

Model, 2019	**Units sold (% of total)**	**Model, 1st quarter 2020**	**Units sold (% of total)**
KIA Sportage	6 027 (6.8%)	Renault Duster	1 479 (7.3%)
Renault Duster	5 202 (5.9%)	Toyota RAV-4	1 312 (6.5%)
Renault Logan	4 489 (5.1%)	KIA Sportage	1 252 (6.2%)
Toyota RAV-4	4 227 (4.8%)	Renault Logan	960 (4.7%)
Renault Sandero	3 246 (3.7%)	Renault Sandero	780 (3.8%)
Skoda Octavia	2 852 (3.2%)	Nissan X-Trail	603 (3%)
Toyota Land Cruiser Prado	1 331 (1.5%)	Skoda Octavia	598 (2.9%)
Hyundai Tucson	1 246 (1.4%)	Toyota Land Cruiser Prado	591 (2.9%)
Nissan Qashqai	1 061 (1.2%)	Hyundai Tucson	525 (2.6%)
Toyota Camry	1 013 (1.1%)	Mazda CX5	443 (2.2%)
Top 10, units sold	30 694	Top 10, units sold	8 543
Total, units sold	88 500	Total, units sold	20 300

In the remainder of the chapter I will consider studies related to the research question in my thesis. The hedonic pricing model was firsty used for the estimation of hedonic price indexes for cars by Court back in 1939. "Hedonic prices are defined as the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specified amounts of characteristics associated with them" (Rosen, 1974). Overall, the usage of hedonic pricing model for cars can be divided into 2 broad applications. First group of papers were dedicated to estimating price indexes to account for the change in light vehicles quality over time (e.g., Griliches 1961; Murray and Sarantis 1999; Matas and Raymond 2009). The second group of scientists were more

concerned with the impact of automobile attributes on the vehicles prices or coeffcients of the hedonic model (e.g., Andersson 2005; Espey and Nair 2005).

This study will contribute to the second stream of aforementioned papers, that's why it worth to proceed with their further examination. The most recent studies in this area were focused on such determinants of car prices as fuel savings, safety, country of origin and brand attributes. For example, Espey and Nair (2005) estimated the marginal value of fuel economy using US data for 2001 year. The authors used the inverse of miles per gallon (gallons per mile) for both city, highway and mixed cycles as measures for fuel economy. Comparing to the previous studies the authors found out that fuel economy is a significant determinant of vehicles prices, what implies that ceteris paribus automobile consumers positively value fuel economy and pay for it via higher automobile prices. Moreover, the authors compared the value of fuel economy obtained from the regression model and fuel cost savings at the fuel prices prevalent around the time of study. It revealed the car buyers discounted savings as a result of fuel economy at rates approximating real low-risk interest rates prevalent around the time of the study. In this study, we will use the measures of fuel economy suggested by Espey and Nair (2005) and Alberini, Bareit and Filippini (2014).

There is a wide array of publications dedicated to the usage of hedonic pricing for car markets, but the majority of them are using data on the markets of developed countries. Therefore it is relevant to review the most recent publications, which either give new grasp for the hedonic pricing models for automobiles, or are related to developing countries such as Ukraine.

Baltas and Saridakis (2010) used the hedonic pricing model to determine the value of particular brand equity and model for Greece car market, while controlling for the other quantitative car characteristics such as engine capacity, fuel consumption, horsepower, speed, number of airbags as well as dummy variables for alloy wheels, air conditioning, ESP-TCS and leather interior. To estimate the effect of brand equity additional dummies

reflecting 48 manufacturer brands and 261 models were included into the final specification. In the final model all dummies for 261 car models were statistically significant at 1%. Hence, the estimated hedonic price model gave empirical evidence of shadow prices (premia) that follows from manufacturer and model brand equity, after accounting for observed product differentiation. Moreover, the estimated model premia are remarkably intuitive with the highest values for the most exclusive brands and models. In addition, the authors conclude that there is a statistically significant and negative relationship between the number of models and the average effect across all brands. This is called equity 'wear-out' effect, when the launch of new model variations might eventually harm brand equity.

Baltas and Saridakis (2014) further study aimed at investigating how the country-of-origin (COO) cue impacts prices on the European new automobiles market in 2010. Firstly, the authors estimated the traditional hedonic price model incorporating 12 COO-specific dummies. Secondly, they allowed all 12 COO-specific dummies to vary across different car type segments (hatchback, sedan, MPV-SUV-SW, coupe-convertible) thought estimation of 4 disaggregated models for each car type. As all 12 COO-specific parameters were significant in both cases, so it allowed the authors to conclude that brand's home country origin is important factor in car choice decisions. Not surprisingly COO dummy coefficients are lower for such countries such as Russia, China, and Korea comparing to countries, which have long history in car manufacturing (Germany, USA, and UK). In addition, the research showed that car type segments are sufficiently heterogeneous to allow discriminatory pricing strategies. It means that the same car characteristic can be implicitly priced at a different price level depending on the certain car type segment.

Although the majority of studies on hedonic prices are concentrated at pricing mechanism on the primary automobile markets, there are several prominent studies investigating the price determinants on the market of used cars, and even the equity transmission between the new and used car markets.

Erdem and Şentürk (2009) conducted the study on price determinant on the used cars market in Turkey. The hedonic pricing model was estimated using semi-log, log-linear and Box-Cox transformation methods on data set including information on prices of 1074 used cars. They concluded that production year of the car is one of the important characteristics influencing used car prices. The number of official vehicle services (contrary to expectations), and place of sale in Istanbul (probably because of the larger number of car accidents in Istanbul comparing to smaller cities) appeared to have negative significant effects on used car prices.

Kihm and Vance (2016) didn't only simultaneously analyzed how the price formation differs in primary and secondary car market, but also explained how the brand equity is carried over between them. The data set size contained impressive number of 371 082 observations on new and used cars from 2008 on German market. They estimated three types of semi-log models: (1) models including both observations on used and new cars containing interactions of used car dummy variable with other attributes and its price as a new car; (2) two separate models on new and used car prices to compare with the 3rd model; (3) specification limited to the sample of used cars with the inclusion of logged new car retail price as a regressor; and (4) 1st and 2nd model reestimated with inclusion of dummies for brand, model, body type. The specification (1) allowed to test for the significance of coefficients near interaction terms and thus conclude whether the technical attributes have the same impact across new and used cars. It appeared that the fact of being used does not significantly alter the effect of most of the technical attributes (except fuel consumption) in the model. What did the authors find through estimating model (3) on used cars including logged retail price of analogous new car? Firstly, the magnitude of coefficient of new car retail price in log was statistically higher than 1 (1.99), that indicated disproportional transfer in value from the primary to the secondary car market. Secondly, almost all coefficients on variables except the retail price became insignificant or had magnitude close to 0. The only economically significant left was fuel consumption,

although its magnitude was reduced by almost half relative used cars model without logged price included.

All in all, Kihm and Vance (2016) shed the light on the following features of German car market: (1) the impacts of technical attributes almost does not differ across the primary and the secondary car markets; (2) only the impact of fuel consumption is different between used and new cars, being higher for the used car market; (3) the ability of car to hold its initial value is heterogeneous among body types and brand/model names. Hence, they concluded that the resale price of car is not only determined by age, mileage and initial retail prices. Such characteristics as fuel consumption, brand name, and model name also contribute a lot.

Unfortunately, Ukrainian car market still remains a blank sheet in terms of studies using hedonic price models. However, the market is very interesting since the domestic car manufacturing in Ukraine is negligible. As was mentioned by Moresino (2019), this feature makes the market an attractive benchmark for studying consumer preferences without facing a domestic bias. This study will contribute to studying the primary car market since unfortunately there is not enough information on used cars to perform the hedonic analysis. It will examine how brand and product attributes drive the prices on the Ukrainian car market. It will also provide insights to which extent distributors may charge brand-specific price premiums. Also the study will pay special attention to the marginal value of fuel economy, as many scholars in studies on developed countries estimated how fuel saving affects car prices. In addition, the estimates obtained will be compared to the results of similar studies on car markets in developed and developing countries.

CHAPTER 3. METHODOLOGY

To define the influence of both qualitative and quantitative car attributes on its price I will use the standard hedonic pricing model presented below:

$$\ln(P_i\ ) = \beta_0\ + \sum_J \beta_j\ \ x_{ij}\ + \sum_k \alpha_k\ \ D_{ik} + \varepsilon_i\ \ (1),$$

where P_i stands for the retail list price of car *i;* x_{ij} represents the value of the quantitative attribute *j* for the automobile *i*; β_j is the regression coefficient for the attribute *j* or the marginal willingness to pay for 1 unit of such attribute; α_k is the coefficient, whose magnitude corresponds to the willingness to pay for qualitative attribute k represented by dummy variable D_{ik}; β_0 is the intercept coefficient; and ε_i stands for the error term for the price prediction of the car *i.* As a dependent variable P_i I will use the list price for car *i*, which is the same as transaction price on the primary car market.

The hedonic pricing model can be estimated in the semi-logarithmic form or logarithmic form. In case of using semi-logarithmic model, the logarithm of independent variable is used and the regression coefficients β_j multiplied by 100% gives an estimate of the percentage change in price caused by the unit change in the corresponding attribute. Moreover, this semi-log functional form means that marginal value of the car has to decline, when, holding everything else constant, the amount of an attribute increases (Asher, 1992). In this study I am going to estimate semi-log specifications, because we are interested in relative rather than absolute price change and it is easier in interpretation comparing to other specifications like Box-Cox transformation.

The hedonic pricing model can suffer from two main issues, which are common for data on automobiles. The first problem is heteroscedasticity, as there are different segments of cars even among the same brand (for example, there may be cars of economy or luxury segments). As a result, (1) the estimated regression coefficients will not be the

best estimators and (2) the hypothesis testing will be misleading because standard errors computed using OLS can be incorrect. To tackle this problem, the White's heteroskedasticity-consistent standard errors will be used.

The second problem, pointed out in previous studies on hedonic pricing, is correlation between one or more predictors in the multiple regression. The Pearson correlation coefficient will be used to calculate correlation between continuous variables, while point biserial correlation will be calculated between categorical and continuous variables. One of the ways to solve (multi)collinearity is to simply exclude variables from the model, however, it may create the omitted variable bias.

The full list of independent variables to include in the hedonic pricing model, their description and expected signs of regression coefficients are presented in the Table 2. The possible predictors were chosen on the basis of previous studies and attributes available on the biggest and most popular online car marketplace in Ukraine - auto.ria.com. Characteristics available on this site can be considered as the characteristics of interest to potential buyers in Ukraine (Andersson 2005).

The important question in conducting this research stemming from studies in other countries, is whether Ukrainian customers positively value the fuel economy of an automobile. And if yes, to what extent? Therefore, the hedonic model will be estimated on a subsample to determine to which extent Ukrainian customers value the fuel economy. This model will use the same variables, however, the hybrid, electric vehicles and ethanol-only cars will be excluded. To capture the effect of fuel economy on the prices of automobiles the variable fuel consumption will be transformed in the following ways suggested by Alberini, Bareit and Filippini (2014).

Table 2. Possible predictors and anticipated signs with respect to car prices

Variable name	Description	Expected sign
Brand	Dummies for 20 most popular car brands on the Ukrainian market	?
Model	Dummies for the models inside certain brand	?
Year	Year when the car was or will be produced	+
Engine capacity	Continuous variable measures in liters	+
Region	Dummies for Kyiv, West, Center and East. South is a reference category	?
Fuel type	Dummies for fuel type: diesel and electrics. Gasoline is a reference category	+
Body type	Dummies for body types. Crossover is a reference category	?
Transmission	Dummy for transmission types. Automatic is a base category	+
Drive	Dummy for wheel drive types. Front is a reference category	+
Horsepower	Continuous variable in hp	+
Fuel consumption	Four possible measures of fuel consumption are discussed in the text	-
Curb weight	Car weight in kg.	+
Availability	Dummy if car is not available and should be ordered	+
Car interior	Dummy for leather interior	+
Complectation	Dummies for base and premium car complectations	-
Other car characteristics	Type of power steering, airbags, EURO emission norms, headlight, ACC, climate control	+

The first one is conversion of the same measure in liters per 100 km into gasoline equivalent by multiplying fuel consumption by 1.12. The reason for that is it takes 1.12 liters of gasoline for each liter of diesel needed to drive the car for 100 km. The second possible measure of fuel economy is fuel consumption divided by the weight of the vehicle. And the third is fuel costs in terms of diesel and gasoline prices for each 100 km. The alternative measure of fuel economy suggested by Matas and Raymond (2009) is calculated as fuel consumption in liters per 100 km. divided by horsepower. I will try to incorporate all of these measures to estimate the influence of fuel economy on car prices and see which measure provides better estimates.

To conclude, several variations of hedonic model will be estimated (1) log-linear model to find out how the price changes in % with the unit change of quantitative attributes and presence of qualitative attributes; and (2) linear regression with only gasoline and diesel engine types included to determine how Ukrainians value the fuel economy and , eventually, (3) hedonic regression on the subsample of top 5 car brands on the market to see the car model effect on the vehicle price (the latter model will be estimated because inclusion of car model dummies in the first model makes its interpretation difficult).

CHAPTER 4. DATA

4.1. Data preparation

The dataset for the research was web scraped using R program from the biggest and most popular online marketplace for automobiles in Ukraine – Auto.ria. Therefore, this sample is representative of Ukrainian market for new cars. There are ads on more than 10 000 new light-duty vehicles posted on this site. It is worth mentioning that approximately 44% of posted cars are available for purchase in Ukrainian dealerships, while the rest can be delivered to Ukraine on order within time range from 5 to 400 days. I gathered data on both types of automobiles. It is also worth noting that not all car dealerships post the full information about cars available for sale, that's why the data on some characteristics can not be considered fully reliable. Due to this reason such qualitative characteristics as presence/absence of certain safety/comfort systems were not included in the dataset. In addition, such important car safety systems as ESP (since 2014) , Brake Assist (since 2011), ABS (since 2003), TPWS (since 2007) became mandatory according to the European law on all the cars sold in EU therefore these systems are present in all cars in Ukrainian market too. The data on 8174 new cars, which represent 20 most popular car brands constituting 92% of all cars sold on the Ukrainian market, was web scraped. Other car brands weren't not included in the sample, because there are a lot of ads for them on Auto.ria, however they constitute only 8% of market share in terms of units sold.

The preparation of dataset included 3 main steps: (1) deleting of car body types, which do not belong to light-duty vehicles; (2) investigating the distribution of car price and subsequent deleting of outliers; and (3) comparison of actual market shares of brands and their shares in the sample. Firstly, the primary web scraped data included such car body types as van, minibus, minivan, which are not light vehicles. When I deleted observations on these body car types, the data set included 6 827 observations on new cars. Secondly, the dataset left obviously suffered from outliers, since the mean car price was

1 141 thous. UAH, while the median was 751 thous. UAH (the maximum price was 26 261 thous. UAH). The density plot of the natural logarithm of car price proves that the distribution of car prices is moderately skewed to the right (Appendix A) with the skewness of 0.94. In addition, boxplot analysis by brands (Appendix B) indicates which brands have distinct outliers, and these are mainly observations for Lexus, BMW, Audi, Mercedes-Benz and Land Rover brands. Therefore, 120 observations for these brands were deleted such that only car prices lower than 6 000 thous. UAH were left. Thirdly, I checked if the sample corresponds to the actual market shares by car brands in 2019 in terms of units sold. There was significant discrepancy because the premium segment car brand, Mercedes-Benz, was overrepresented in the sample with share of 13.7%, while its actual market share in terms of units sold in 2019 is just 2.5%. To tackle this issue, I deleted 366 duplicate observations for Mercedes-Benz to make the sample market share more representative of the actual market share. The comparison of the final dataset versus actual market shares in units sold is presented in Table 3. As can be seen, the difference between market share and sample ranges from -5.2% to 5%., therefore this difference should not be considered as severe one.

4.2. Data description

Among 6 341 observations of the final dataset the fast majority belongs to such brands as Renault (12.3%), Kia (9.3%), Toyota (9.1%), Hyundai (7.7%) and Mercedes-Benz (7.7%). The sample consists of 6 quantitative variables and 18 qualitative variables. However, not all of them will be used in the regression model on the whole sample of cars. For example, specification, a qualitative variable indicating specification type is not standardized across various brands therefore adjusted specification type variable will be used only in regression on the sample of top 5 car brands by the volume sold in Ukraine.

The descriptive statistics for main quantitative variables of interest is presented in Table 4. Vehicle price, dependent variable for hedonic model, ranges from 238 thous. UAH to 5 967 thous. UAH, with average price car of 979 thous. UAH and median price of 715

thous. UAH. As can be seen the distribution of car prices is still right skewed, even after deleting outliers, but it is representative of what is offered on the market and there are cars of entry, mid and premium segments.

Table 3. Comparison of sample and actual market shares in 2019, % of cars

Brand	No. of units	Sample, %	Market share, %	Difference
Renault	782	12.3%	16.4%	4.0%
Kia	588	9.3%	8.5%	-0.8%
Toyota	577	9.1%	14.1%	5.0%
Hyundai	488	7.7%	5.7%	-2.0%
Mercedes-Benz	486	7.7%	2.5%	-5.2%
Nissan	426	6.7%	5.9%	-0.8%
Peugeot	364	5.7%	3.0%	-2.8%
Volkswagen	316	5.0%	5.3%	0.3%
Ford	309	4.9%	1.9%	-3.0%
Mazda	305	4.8%	2.9%	-1.9%
Land Rover	288	4.5%	1.2%	-3.3%
Skoda	243	3.8%	7.0%	3.1%
Chery	234	3.7%	1.9%	-1.8%
Mitsubishi	228	3.6%	2.7%	-0.9%
Citroen	168	2.6%	1.8%	-0.8%
Audi	154	2.4%	1.9%	-0.5%
Suzuki	147	2.3%	2.9%	0.6%
BMW	93	1.5%	2.7%	1.2%
Fiat	82	1.3%	1.4%	0.1%
Lexus	63	1.0%	1.9%	0.9%

Other quantitative variables include engine capacity, horsepower, fuel consumption for the mixed cycle and curb weight. The curb weight of a car is total weight

of a vehicle with standard equipment without passengers and cargo. The distribution of these quantitative variables is presented in Appendix C. The year of car production ranges from 2013 to 2021, while majority of cars are of 2018, 2019 and 2020 year constituting 4%, 43% and 52% of the sample respectively.

Table 4. Descriptive statistics for main quantitative variables of interest

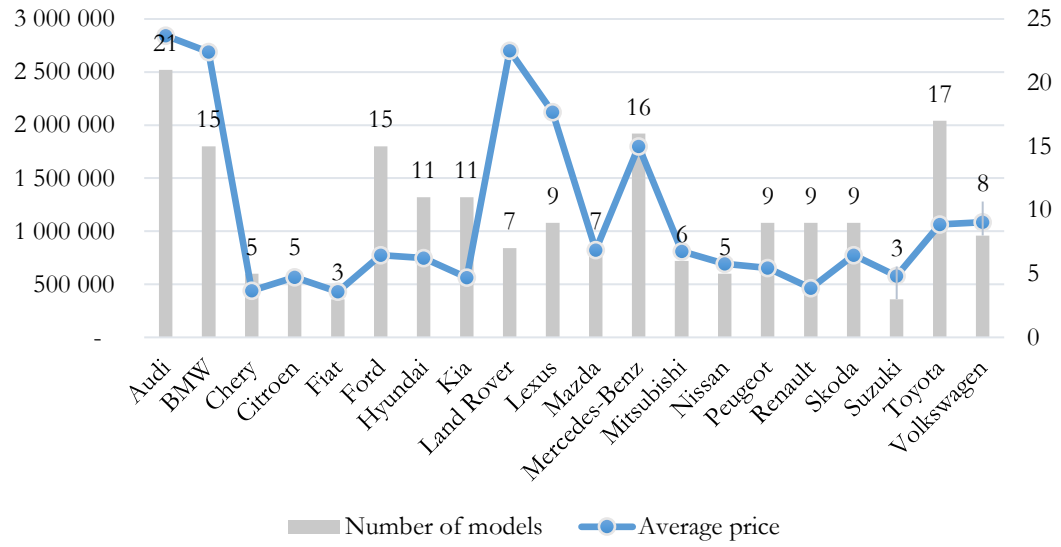
Variable name	Mean	Median	Min	Max	No. of observations
Price, thousand UAH	979	715	239	5 967	6 341
Engine capacity, liters	2.0	1.6	0.9	6.7	6 257
Horsepower, hp	170	147	66	760	6 341
Fuel consumption (mixed cycle), liters per 100 km	6.4	6.3	1.6	18.8	6 199
Curb weight, kg	1 561	1 471	865	3 097	6 219

Note: the number of observations for engine capacity and fuel consumption is different because of missing values, but these variables will be used only for regression on subsample of diesel and gasoline cars.

The categorical variables to be used in the regression model are brand, model, transmission type, wheel drive, fuel type, comfort and safety features as leather interior and airbags, body type, region and car availability for purchase. The number of models offered varies across different brands. The relationship between the number of models across brand and average car price, depicted in Figure 3, is ambiguous. From the visual inspection there is no clear pattern if the number of models offered corresponds to the lower/higher average price. The breakdowns of car observations by transmission and wheel drive are presented in Figure 4. Regarding the fuel type 59% of cars have gasoline engine, while 37%

have diesel engine and the rest of cars are represented by electric cars or combinations of different fuel types. As front wheel drive, automatic transmission and gasoline fuel are the most frequent categories, they will be used as reference categories for the dummy variables.

Figure 3. The relationship between number of models and average car price

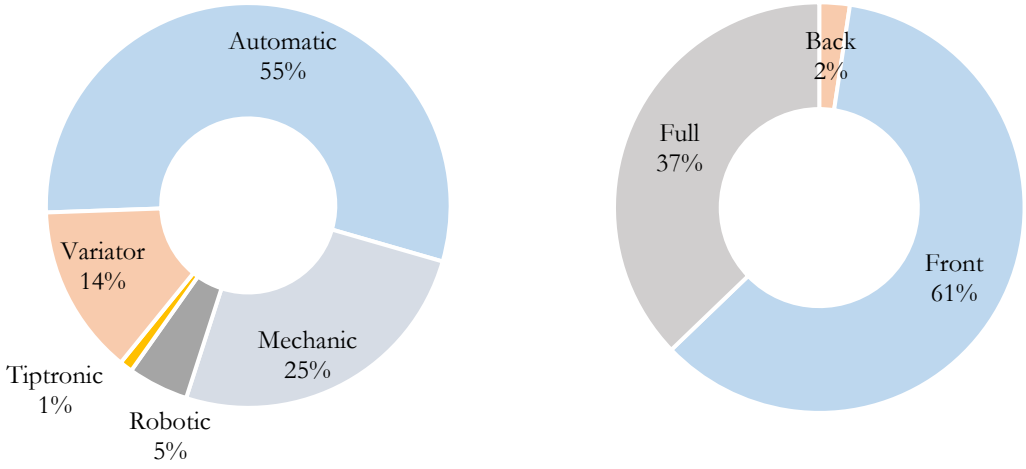


According to the sample, 80% of cars advertised have all three types of airbags (drives, passenger and side airbags) and 40% of car have leather in the interior. 43% of cars are available for immediate purchase in the dealership, while other should be ordered beforehand. The cars offered in Eastern and Western regions constitute vast majority of cars offered for sale with 36% and 21% respectively. Then goes Kyiv oblast and Central region with 18% and 17% of the cars respectively. Only 8% of all cars on Auto.ria are offered by dealerships located in the Southern region.

Car body type is one of the significant factors influencing the sale price. There are 13 body types in the sample. According to the breakdown of car body types across brands (Appendix D), only crossover is produced by all car manufacturers. Crossovers represent

57% percent of the whole sample. Then go sedans, hatchbacks and SUVs with 17%, 11% and 5% of the sample respectively.

Figure 4. Breakdowns of sampled cars by transmission and wheel drive



Car manufacturers differentiate cars even inside the models by offering wide range of specifications from base to premium (ranging from 2 to 8 specifications inside the model for top 5 car brands in Ukraine). As the car specifications have different names even for the same models of the same brand, we were unable to include dummy variables for each specification as presented on Auto.ria. Instead, using their names and comfort/safety features offered in each specification we manually divided car specifications for top 5 brands in Ukraine into 3 groups: base, style and premium. In addition, such important car characteristics as (1) hydraulic or electric power steering type, (2) EURO emission standard, (3) LDE and halogen headlight type, (4) presence of cruise control and (5) availability and amount of zones in the climate control feature, (6) light-alloy or steel wheels, (7) availability of parking sensors will be included in the model on top 5 brands in Ukraine. The total additional impact of other minor comfort, safety and style features are accounted for in the dummy variable for car specification group mentioned above.

Overall, the sample of top 5 car brands contains 2605 car ads with 52% of cars with base specification, 22% of style specification type and the rest with premium features included. The majority of cars (78%) among top 5 brands in Ukraine have the highest 6th EURO emission standard indicating the lowest level of emission limits. However, there are still some cars of 4th (12%) and 5th (10%) EURO emission standards. 81% of cars among these cars are equipped with cruise control and 71% of cars have the climate control while 52% have basic climate control and 16% have dual-zone climate control. 60% of offered car among these 5 brands are equipped with halogen headlights, while 37% have LED ones. Two third of these cars have light alloy wheels and 42% have parking sensors included in the specification.

The important step in analyzing data for the hedonic regression includes calculating correlation both between continuous and categorical variables. First, I calculated the Pearson correlation coefficient between such continuous variables as price, engine capacity, horsepower, fuel consumption and curb weight (Appendix E). Engine capacity measures in liters has high positive correlation with horsepower (0.87), curb weight (0.74) and fuel consumption (0.76). Other correlation coefficients between continuous explanatory variables are less than 0.7. Therefore, to mitigate the collinearity engine capacity will be excluded from the model. Also as noted by Alberini, Bareit and Filippini (2014), while estimating the value of fuel economy, the correlation between fuel type and fuel consumption can significantly influence the results. The correlation was estimated using different measures of fuel economy which may be used in the specifications. The correlation between measure of fuel consumption in liters of car fuel by 100 km. and fuel type is only 0.35. However, this coefficient for fuel consumption by 1000 kg. and fuel type is 0.51 and for fuel consumption by 1000 kg. converted to gasoline equivalent (fuel consumption was multiplied by 1.12, see methodology part for details) is 0.74. Therefore, engine type may be excluded from the model for estimating value of fuel economy.

CHAPTER 5. RESULTS

5.1. Hedonic regression model for the whole sample

The primary model for the whole sample includes such explanatory variables as (1) brand, (2) year dummy, (3) transmission, (4) wheel drive type, (5) engine type, such comfort features as (6) leather interior and (7) all three types of airbags, (8) horsepower, (9) body type, (10) region, (11) availability and (12) curb weight. There are also 191 model types across all brands, which were not included in the model estimated on the whole sample, because the model is too hard for interpretation with the inclusion of all model types. The final model was estimated on the sample containing 6219 variables after deleting missing values of the curb weight (Table 5). Firstly, the White's heteroskedasticity-consistent standard errors for the hedonic model coefficients were estimated, as the null hypothesis of homoscedasticity was rejected using Breusch-Pagan test. Secondly, the correlation between continuous variables was calculated in previous chapter and therefore engine capacity, that is highly correlated with other variables, is not included into the hedonic model. Thirdly, as suggested by the Alberini, Bareit and Filippini (2014), polynomial (square of) horsepower is included into the model to tackle the omitted variable bias, because other important car characteristics as specification type and various safety systems are not included in this model.

The dummy variables for all brands are significant at 1%. Indeed, the brand is the variable that explains the most variation in the car price. Relating to the reference category, which is Renault brand (the first brand in terms of units sold in Ukrainian market), only Chery brand price is cheaper by 13% all other held constant. Such brands as Peugeot, Kia, Citroen are approximately in the same price segment as Renault. Mid price segment in the Ukrainian market is represented by such cars as Fiat, Ford, Hyundai, Nissan and Suzuki.

Table 5. Coefficients of the regression model on the whole sample

Variable	Coefficien	SE	Variable	Coefficient	SE
Brand: Renault is a base category			**Leather**	0.1***	0.004
Audi	0.49***	0.017	**All airbags**	0.07***	0.005
BMW	0.63***	0.017	**Engine: Gasoline is a base category**		
Chery	-0.13***	0.011	**Diesel**	0.15***	0.005
Citroen	0.03**	0.012	**Diesel/Electric**	0.27***	0.048
Fiat	0.07***	0.016	**Electric**	0.11***	0.021
Ford	0.07***	0.011	**Gasoline/Electric**	0.12***	0.01
Hyundai	0.14***	0.009	**Gasoline/Gas**	0.01	0.046
Kia	0.04***	0.008	**Horsepower**	0.004***	0.001
Land Rover	0.64***	0.012	**Body type: Crossover is a base category**		
Lexus	0.54***	0.019	**Cabriolet**	0.12***	0.022
Mazda	0.23***	0.011	**City-car**	0.42**	0.13
Mercedes-Benz	0.43***	0.011	**Coupe**	0.21***	0.018
Mitsubishi	0.08***	0.012	**Fastback**	-0.004	0.03
Nissan	0.13***	0.01	**Hatchback**	-0.08***	0.007
Peugeot	0.06***	0.009	**Liftback**	0.003	0.016
Skoda	0.22***	0.012	**Pickup**	0.04***	0.012
Suzuki	0.14***	0.014	**Roadster**	0.51***	0.056
Toyota	0.26***	0.01	**Sedan**	-0.08***	0.006
Volkswagen	0.29***	0.01	**Station wagon**	-0.03***	0.009
Year (2020)	0.03***	0.003	**SUV**	0.14***	0.01
Transmission: Automatic is a base category			**Region: Center is a base category**		
Mechanic	-0.12***	0.005	**East**	0.003	0.005
Robotic	-0.13	0.009	**Kyiv**	0.03***	0.006
Tiptronic	0.22***	0.022	**West**	-0.002	0.006
Variator	0.006	0.008	**South**	-0.03**	0.008
Wheel drive: Front is a base category			**On order**	0.01**	0.004
Back	-0.04**	0.015	**Curb weight**	0.0002***	0.0001
Full	0.05***	0.005	**Horsepower^2**	-0.000001**	0.0000

The premium car brands, that command the highest brand premium ranging from 43% to 64%, are Audi, BMW, Land Rover, Lexus and Mercedes-Benz. These results are consistent with Kihm and Vance (2016) and Baltas and Saridakis (2010).

Holding all else constant, cars produced in 2020 are 3% more expensive than car produced in the earlier years, which is plausible increase considering the growth of global car market. Regarding the transmission type, the cars with mechanic one are 12% cheaper that those with automatic transmission on Ukrainian market. When the car has tiptronic transmission, which is an automatic one with the ability to change gears manually, it increases its price by 22% comparing with automatic transmission. In comparison with the front wheel drive full wheel drive cars are valued by 5% higher, while back while drive cars are priced by 4% lower, ceteris paribus. The leather interior increases mean car price by 10% and the availability of all three types of airbags (drives, passenger, side) is reflected in 7% higher prices. The gasoline is the most represented fuel category in our sample, however this engine fuel is not the most valued by consumers. Pure diesel engine or hybrid with diesel/electric fuel adds to the mean car price 15% and 27% respectively comparing to gasoline engine. On the contrast, when car is electric only or gasoline/electric its price is 11% and 12% higher than gasoline car. The horsepower variable coefficient is significant at 1%, however it brings just 0.4% increase in the value of car with 1hp increase in this variable.

Regarding the car body type, with crossover being the reference category, such body types as SUV, roadster, pickup, coupe and cabriolet are priced higher than the crossover car ceteris paribus. Roadster is the most expensive car body type. On the contrary, hatchback, sedan and station wagon cars are less valuable then crossover: their prices on average are lower by 8%, 8% and 3% respectively. The region of sale has almost no influence on the same car prices. The price are slightly higher in Kyiv comparing (3%) to the Center region, and slightly cheaper in South (3%). It was surprising but the

availability of car does not alter its price significantly in relation to cars that should be ordered. The weight of a vehicle also has no influence on its sale price.

5.2. Estimating the value of fuel economy

This part is related to the research question for subsample of gasoline and diesel vehicles, in particular I try to answer whether Ukrainian customers value the fuel economy. If yes, to which extent? To answer these questions the four measures of fuel economy are incorporated in the model (one at a time): (1) fuel consumption is liters for the mixed cycle posted on Auto.ria; (2) adjusted fuel consumption in gasoline equivalents, where fuel consumption for diesel is multiplied by 1.12 (suggested by Alberini, Bareit and Filippini (2014)); (3) fuel consumption per 1000 kg. of vehicle weight; (4) adjusted fuel consumption per 1000 kg. of vehicle weight. The model is estimated on the subsample of 5874 cars offered for purchase. Also for each of model variation White's heteroskedasticity-consistent standard errors are computed (Table 6) and fuel type variable was excluded.

The fuel economy measure has expected negative sign in all 4 specifications. For instance, the coefficient for fuel economy in model 2 (-0.03) is comparable with those obtained by Alberini, Bareit and Filippini (2014) for the Swiss car market (-0.0287 for 2005-2011 years). Also it is consistent with findings of Kihm and Vance (2016) for German car market (the estimate was -0.0232 in 2008). Being the relative measure of fuel economy, fuel consumption in liters per 100 km. /1000 kg. of weight in gasoline equivalent (model 3) has higher coefficient value of -0.1.

Table 6. Influence of car fuel spending on its retail price

Fuel economy measure	Model 1	Model 2	Model 3	Model 4
Fuel consumption in liters per 100 km.	-0.04*** (0.002)			
Fuel consumption in liters per 100 km.: gasoline equivalent		-0.03*** (0.002)		
Fuel consumption in liters per 100 km. /1000 kg. of weight			-0.1*** (0.002)	
Fuel consumption in liters per 100 km. /1000 kg. of weight: gasoline equivalent				-0.1*** (0.003)
R^2	0.951	0.948	0.95	0.945

Note: all measures of fuel economy are calculated for the mixed cycle. The curb weight variable is excluded form models 3,4.

5.3. Estimating model premium and impact of additional features

Top 5 brands on the Ukrainian car market (Renault, Toyota, Kia, Skoda and Nissan) together account for 52% in terms of units sold. Therefore, it is relevant to conduct the separate hedonic analysis for models inside these brands. For this hedonic model brand variables were excluded, so the comparison will be only across models (Appendix F). The subsample on top 5 brands includes 2 605 observations. The base category for model dummies is Toyota RAV4 and among 48 model dummies coefficients 43 are statistically significant at not less than 10%. Among 18 models which are priced higher than RAV4 13 also belong to Toyota, 3 to Kia and 2 to Skoda brand. RAV4 is relatively inexpensive model across Toyota models range, however this model is still more expensive than all models offered by Renault and Nissan brands according to the estimated model.

Although Toyota models command higher premium than models of 4 other biggest market participants, its market share is second on the market with 14% of total volume sold. It can be concluded that top 5 market leader brands with wider model range are able to command higher premia for the models and consumers are still willing to pay these premia according to the market shares observed.

The next question is to which extent car price is altered by the change of model specification and availability of specific car materials, comfort features and so on. According to the regression results on the same sample of 2605 cars across top 5 brands on Ukrainian market, cars with base specification are not on average cheaper comparing to the cars with style specification (the regression coefficient is not statistically significant) holding everything else constant. However, comparing to the base and style specifications cars with premium specification are 5% more expensive.

The amount to which the car complies with the EU environmental standards does indeed alter the price in Ukrainian market. The cars with 4^{th} and 5^{th} EURO emission standards don't represent the majority of cars and indeed reduce the vehicle price by 4% and 5% percent respectively comparing to cars with the highest 6^{th} emission standard. The cars equipped with cruise control are just 2.7% more expensive than cars without cruise control holding everything else constant. Regarding the climate control while majority of cars in the sample are equipped with dual-zone climate control, it was used as a reference category in the regression model. Comparing to the cars with dual-zone climate control cars with no such feature at all are 6.7% cheaper and cars with single-zone climate control are 8.4% cheaper while premium cars with four-zone climate control are 22% more expensive ceteris paribus.

As expected cars with hydraulic power steering are 5.3% cheaper comparing to the cars with electric power steering while cars with electromechanical power steering are 7.9% more expensive. This implies that electric and electromechanical power steering are considered as more efficient by the potential buyers. Also presence of the light alloy

wheels instead of the steel ones makes the vehicle more expensive by 3.9%, while the equipment with parking sensors increases car price on average by 6.8%. The marginal impacts of car specification type and material/comfort/safety features are summarized in the following table.

Table 9. Influence of car complectation type and additional features on its retail price

Characteristics	**Marginal effect**
Base complectation (style complectation is a base category)	+0.004
Premium complectation (style complectation is a base category)	+0.046***
EURO emission standard 4 (6^{th} standard is a base category)	-0.04***
EURO emission standard 5 6^{th} standard is a base category)	-0.055***
Availability of cruise control	+0.027**
LED headlights (halogen is a base category)	+0.06***
Light alloy wheels (steel is a base category)	+0.039***
Availability of parking sensors	+0.068***
Hydraulic power steering (electric is a base category)	-0.054***
$\mathbf{R^2}$	0.96

Note: other variables such as brand, year, all quantitative variables are also included but their marginal effect are same to discussed above

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This research paper provides hedonic analysis for new cars prices on the Ukrainian market. It focuses on (1) estimation of hedonic pricing model and determination of new car characteristics, which are highly valued by consumers; and (2) more specifically, on revealing whether and to what extent Ukrainian consumers value the fuel economy. Overall, the influence of 16 car quantitative and qualitative features on the new vehicle prices was measured using the sample of more than 6000 cars offered for purchase on Autoria, the biggest Ukrainian marketplace for cars. The results indicate that car brands explain the vast part of variation in new vehicle prices. When treating the volume market leader, Renault, as a brand reference category, the effect of the brand name on sale price ranges from -13% to +64% all else being constant. Next, car body type is also an important characteristic determining the car price. Crossover body type represent more half of all car ads. Such car body types as cabriolet, SUV, roadster and coupe have higher prices than crossovers, while hatchbacks, station wagons and sedans bodies decrease the price of a vehicle from 3% to 8%. Also, the car with the same characteristics but produced in 2020, will cost 3% higher relating to the previous years.

Regarding the characteristics of car engine, Ukrainian buyers are willing to pay more for the automatic transmission, while the mechanic transmission decreases the mean car price by 12% in comparison to automatic one. When the car has tiptronic transmission customers are willing to pay for it 22% more comparing to automatic gearbox. Front wheel drive cars are dominating the Ukrainian market, and consumers are willing to pay just 5% more for the full drive car. Fuel type significantly influences the new car price. For example, gasoline is treated as the least efficient fuel type, because buyers are willing to pay more for diesel, electric and hybrid cars. Relating the horsepower of the vehicle, the increase by 10 hp leads to the rise in car price by 4%. Such feature as leather interior drives the car prices up as well with 10% increase in the mean car price. It was also determined that sale region, availability in the dealership and curb weight do not impact car price significantly. The

hedonic model on the subsample of gasoline and diesel cars proved the hypothesis that customers are willing to pay more for the fuel-efficient cars. Moreover, the results are consistent with the estimations for other countries. To be more specific with the drop in fuel consumption by 1 liter per 100 km. in gasoline equivalent its price decreases by 3%.

Which recommendations for businesses can the obtained results yield? Firstly, the stocks of cars should be created with emphasis on cars with the high market share and high model and brand premia as well. For example, Toyota cars account for the 14% of volume market share and commands the highest model premia among top 5 brands on the Ukrainian car market according to the results of hedonic model. Secondly, as body type influences the car price to a great extent therefore promotion should be concentrated on such car body types as SUV and crossover, commanding higher premiums, while less promoting station wagons, sedans and hatchbacks.

Thirdly, as fuel consumption influences the car price, marketing campaigns for more expensive cars should be emphasizing the benefits of fuel economy for the customers. This will ensure that the discounted savings from fuel economy will be influencing buying decisions even more in the future and therefore will enable to increase the sale prices more. Moreover, right now 59% of top 20 cars in terms of market volume have gasoline engines, however the diesel fuel is more efficient than gasoline and diesel cars have 15% higher prices ceteris paribus. Therefore, dealers may think in terms of rebalancing their stock in terms of fuel of a car. The message of greater efficiency of diesel fuel should be also included into the communication with the customer. With regard of auto-manufacturers the hedonic model results yield the need for further switching to automatic gearboxes considering alternative gearbox types as they can increase car price.

Fourth, place of a sale does not significantly influence the car prices: cars sold in Kyiv region are only 3% more expensive that those in Center region, however the operating costs are obvious higher. Therefore, it is good strategy nowadays to be located not in Kyiv region, but advertise cars online and perform shipping to the client.

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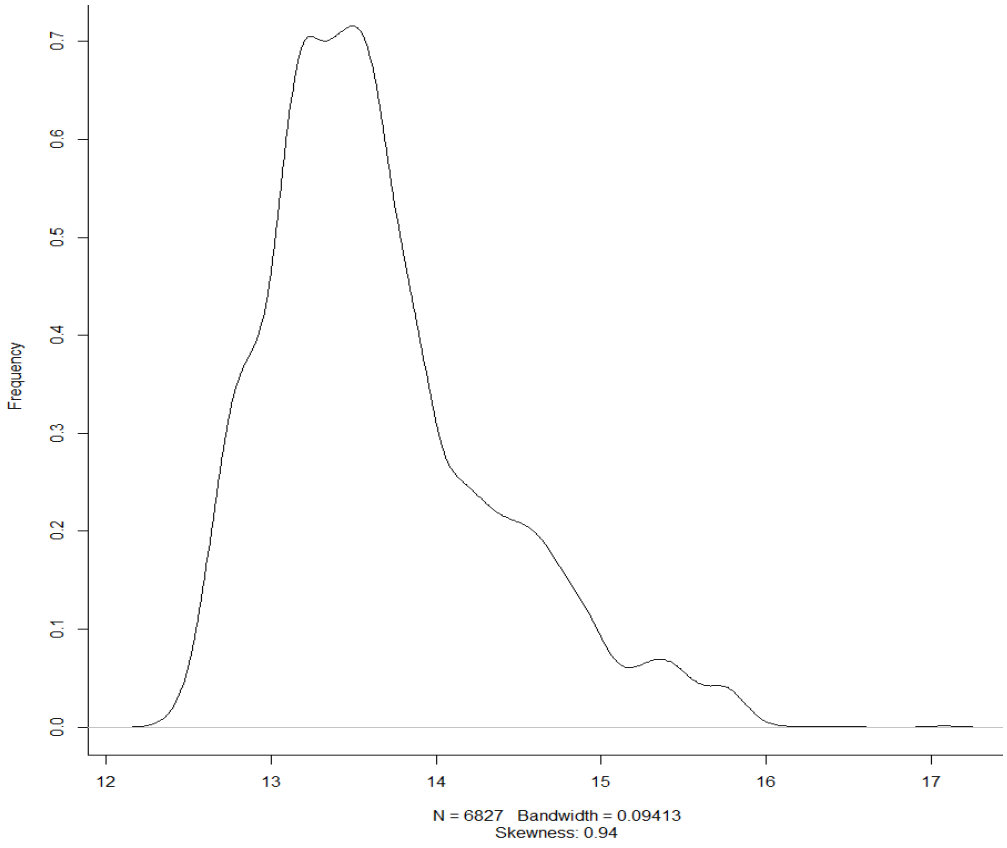
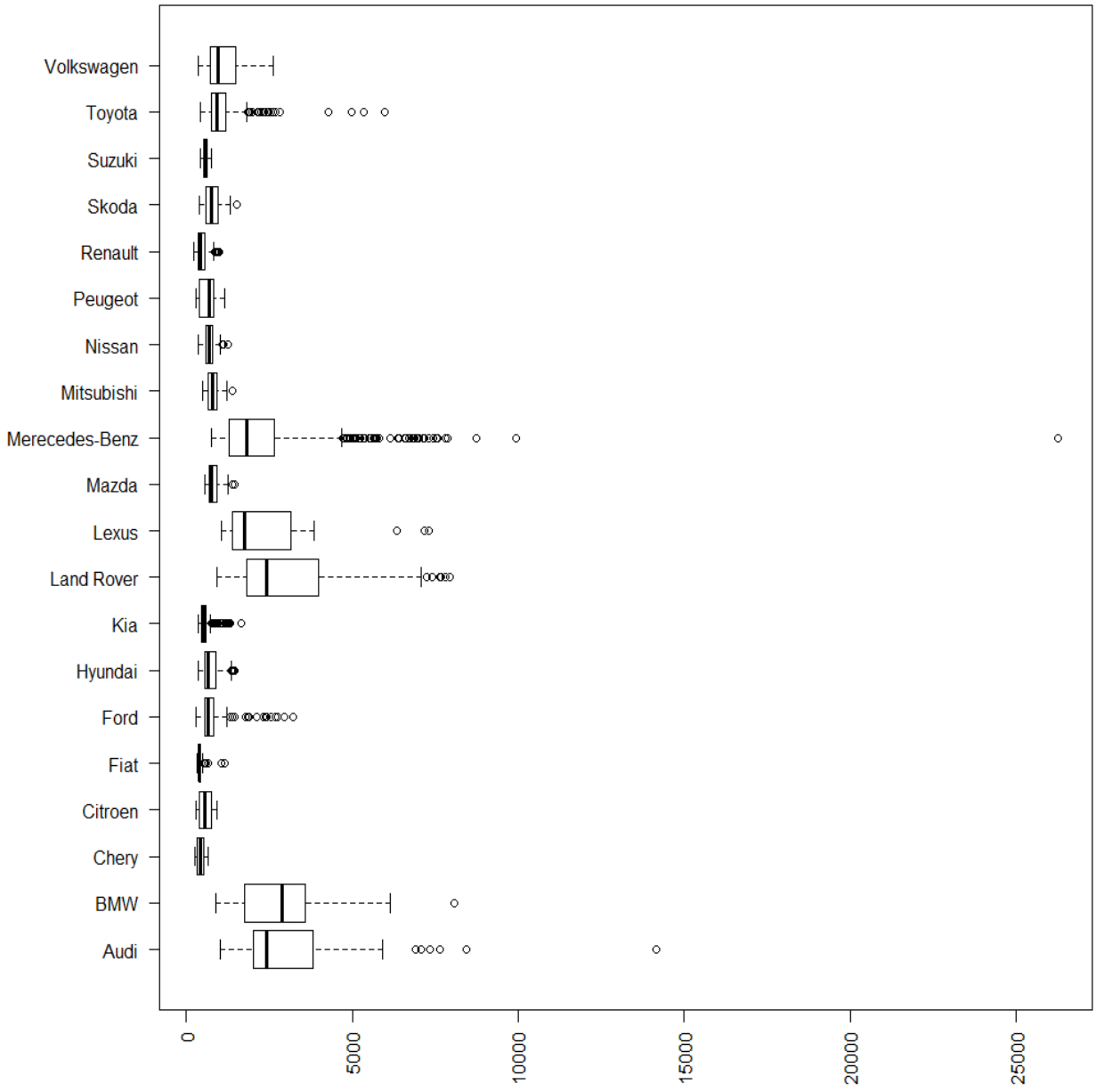
APPENDIX A

Figure 5. Density plot of the natural logarithm of new cars prices



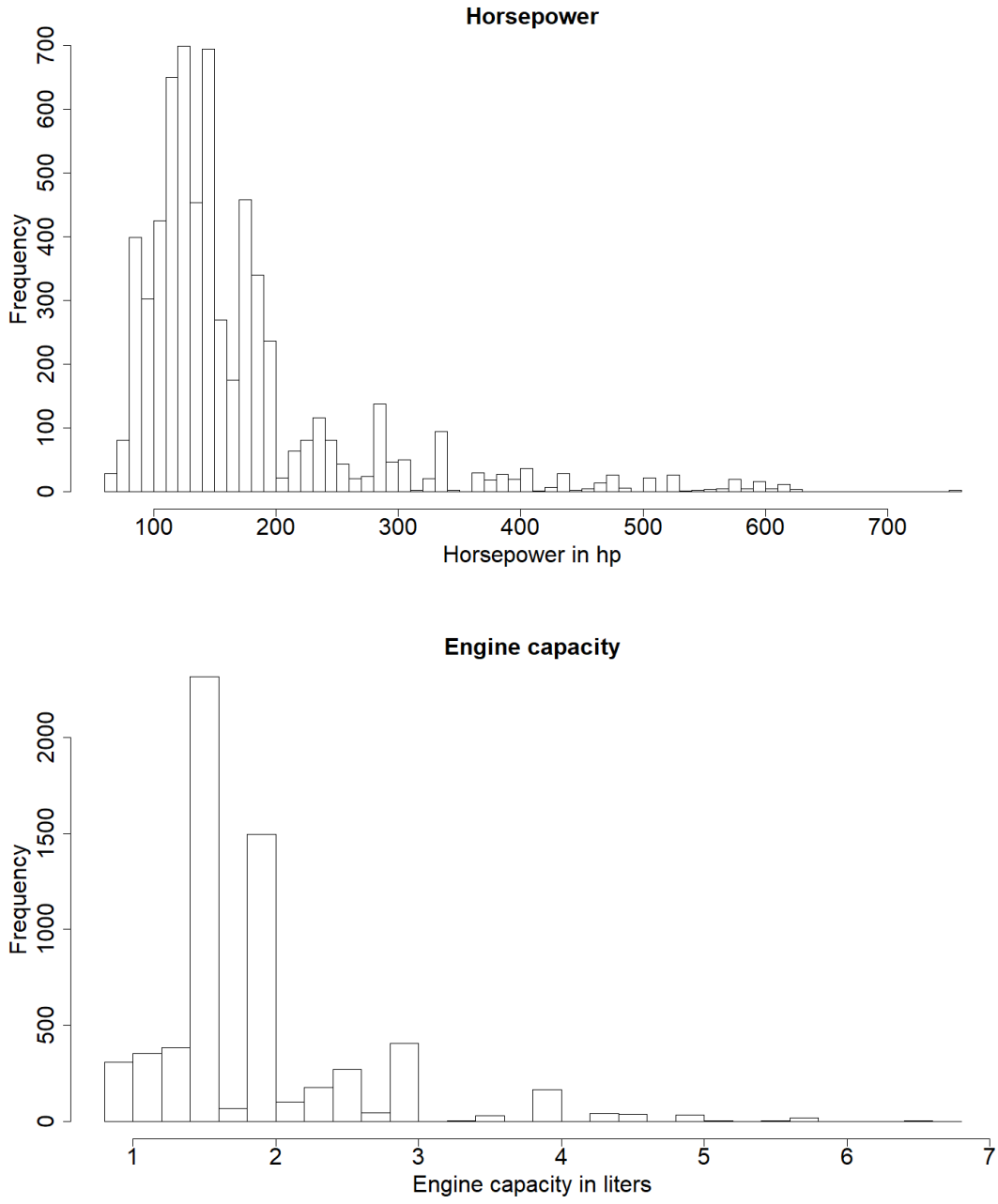
APPENDIX B

Figure 6. Boxplots for visual detection of outliers (price in thous. UAH)



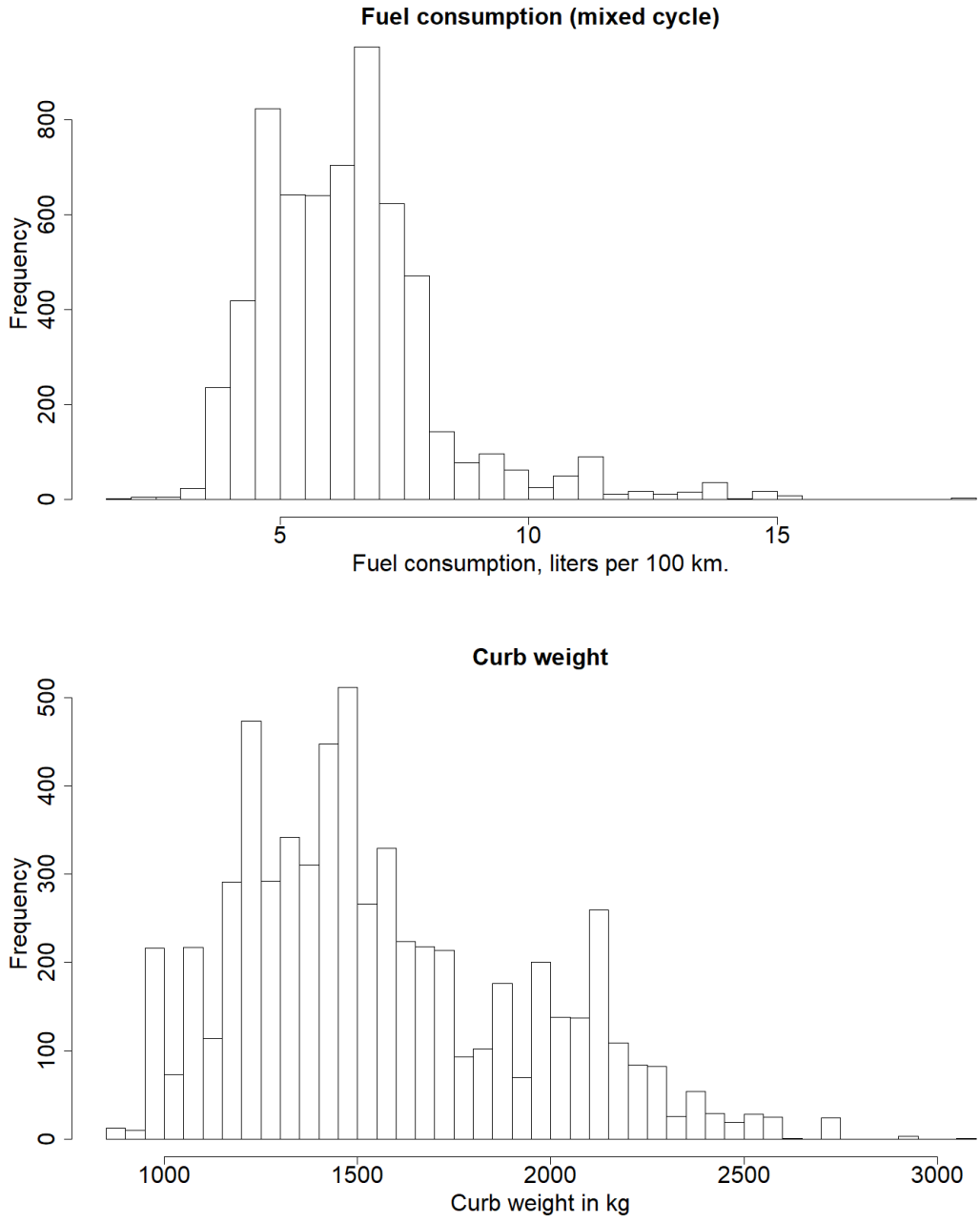
APPENDIX C

Figure 7. Distribution of main continuous variables in the final sample



APPENDIX C

Figure 7. Distribution of main continuous variables in the final sample



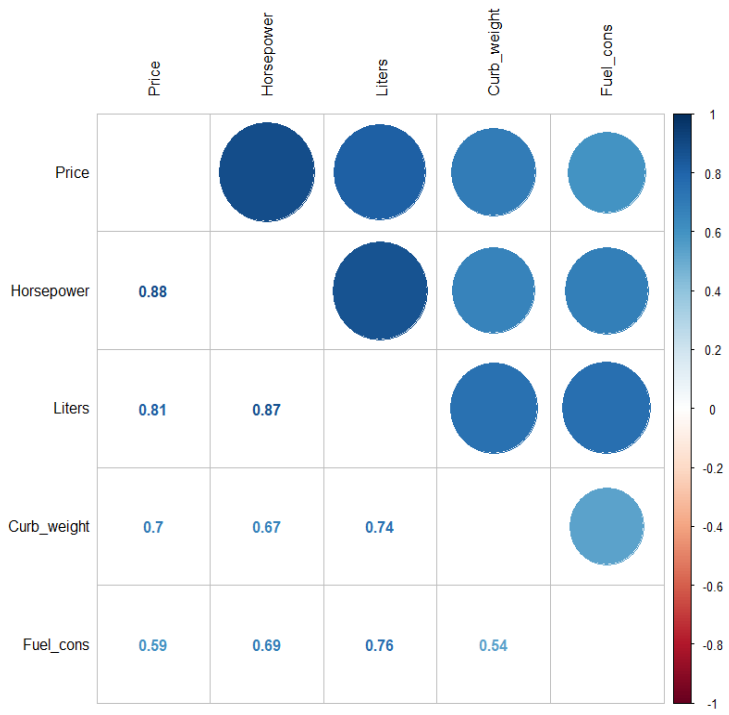
APPENDIX D

Table 7. Breakdown of the car body types across brands

Brand	Cabriolet	City-car	Coupe	Crossover	Fastback	Hatchback	Liftback	Pickup	Roadster	Sedan	Station wagon	SUV
Audi			1	127	5					16	5	
BMW	1		5	66		4	4			13		
Chery				234								
Citroen				78		41				49		
Fiat	3			8		31				38	2	
Ford			7	92		71	18	58		52	11	
Hyundai				308	16	52				100	12	
Kia				394	4	112				25	53	
Land Rover	2			190								96
Lexus			4	29						10		20
Mazda				202		17			9	70	7	
Mercedes-Benz	36		64	157		37			6	102	79	5
Mitsubishi				122				48				58
Nissan				394		7		25				
Peugeot				174		50				121	19	
Renault		1		329		172				202	78	
Skoda				106		33	77				27	
Suzuki				117								30
Toyota				247		11		34		148		137
Volkswagen				220		28		24		44		
Total	42	1	81	3594	20	666	104	189	15	990	293	346
%	**1%**	**0%**	**1%**	**57%**	**0%**	**11%**	**2%**	**3%**	**0%**	**16%**	**5%**	**5%**

APPENDIX E

Figure 8. Correlation matrix for continuous variables



APPENDIX F

Table 8. Model premia across top 5 brands on Ukrainian market

Renault	**Est.**	**Toyota**	**Est.**	**Kia**	**Est.**	**Skoda**	**Est.**	**Nissan**	**Est.**
RAV4 - base category		**RAV4 - base category**		**RAV4 - base category**		**RAV4 - base category**		**RAV4 - base category**	
Duster	-0.41***	Avalon	0.73***	Ceed	-0.39***	Kodiaq	0.06***	X-Trail	-0.08***
Captur	-0.4***	C-HR	-0.008	Niro	-0.06	Fabia	-0.25***	Juke	-0.39***
Kadjar	-0.21***	Camry	0.11***	Picanto	-0.46***	Kamiq	-0.15***	Leaf	-0.17*
Koleos	-0.27***	Corolla	-0.06***	ProCeed	0.06.	Karoq	-0.16***	Navara	-0.09***
Logan	-0.5***	FJ Cruiser	0.51***	Rio	-0.37***	Octavia	-0.1***	Qashkai	-0.27***
Megane	-0.26***	Highlander	0.27***	Rio X-Line	-0.29***	Skala	-0.03		
Sandero	-0.6***	Hilux	0.05*	Sorento	0.09***	Superb	0.13***		
Sandero StepWay	-0.5***	Land Cruiser200	0.59***	Soul	-0.08				
Zeo	-0.09	Land Cruiser 71	0.85***	Stringer	0.26***				
		Land Cruiser 76	0.92***	Stonic	-0.32***				
		LandCruiserPrado	0.3***	Sportage	-0.29***				
		Runner	0.83***						
		Sequoia	0.91***						
		Tacoma	0.85***						
		Tundra	0.71***						
		Yaris	-0.26***						

R^2=0.97, 2 605 observations Note: other variables except brand are included in the regression, although their coefficients are not provided here