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Robust and Resistant Estimations of Hedonic Prices for Second Hand Cars: An Application to the Istanbul Car Market

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ABSTRACT

In this study, the “hedonic price model” has been used in order to determine car characteristics that affect second hand car prices. The hedonic price model is estimated with 1032 observations involving Istanbul second hand car market data. In such a heterogeneous data set, there is often a problem of outliers. Standardized residuals, studentized residuals and DFBETAS criteria were applied to detect them. The hedonic price model is estimated by using robust and resistant methods because ordinary least squares method is sensitive to outliers. According to the results of the study, automobile features such as kilometer, fuel type, drivetrain type, body type, engine cylinder volume, transmission type, cruise control, sunroof, trip computer, rain sensor and changing parts affect car prices.

Keywords: Hedonic Price Model, Outlier, Robust Estimation, Resistant Estimation
JEL Classifications: C12, C13, L62

1. INTRODUCTION

Vehicles, one of the human being’s earliest requirements, are demanded by consumers as a symbol of status besides transportation purposes such as travel, cargo and passenger transportation. Various types of vehicles have been developed in order to meet these needs via sea, air and road. The automotive industry, which produces motor vehicles to meet transportation services by road, has grown rapidly along with technological developments and the impact of globalized markets. It has become easier for consumers to access the vehicles they need. As of 2016, there are 21090424 registered motor vehicles in Turkey, and about 53% of this number is composed of automobiles. When we look at the statistics of total motor vehicles landed on the road for the year 2016, it is seen that cars are headed again at a rate of 58%. In the year of 2016, 4727073 of the 6728894 motor vehicles, which are the subject of second-hand trading, are made up of automobiles. Therefore, automobiles constitute 70% of the total vehicles involved in the transfer. As indicated by the numbers, the second hand automobile market in Turkey is seriously big. In this study, the factors affecting car prices in the second hand car market, where a large number of transactions are carried out, were determined and the effect of these factors on the prices was examined.

The second-hand automobile market is the one where differentiated goods are formed by the combination of heterogeneous and diverse characteristics. Consumers will choose ones that will provide the maximum benefit from the cars that they can purchase at the price they are willing to pay. At the market such as one of the automobile, where the differentiated products with heterogeneous structure are located, one of the economic theories that determine covered prices of product features based on the benefits of each property by linking the prices of the products with their properties is the hedonic price theory. According to the hedonic price theory, automobile prices are determined by automobile characteristics. The relationship between product price and its properties described by Rosen (1974) is shown below:

$$p(z)=p(z_1,z_2,\ldots,z_n) \qquad i=1,2,\ldots,n \qquad (1)$$

In the above equation, p(z) is the market equilibrium price. $Z = z(z_1,z_2,\ldots,z_n)$ is the vector of n properties that make up the product. The effect of the properties forming the product on the prices is obtained by calculating derivatives according to each i^{th} feature.

The aim of this study is to estimate the hedonic pricing model to determine the factors affecting second hand car prices through robust and resistant methods by using the dataset obtained from Istanbul second hand car market. Estimating the hedonic price equations of automobiles taking into account outliers in the framework of hedonic price theory makes this study different from the others available in the literature. There may be extreme valued observations in non-homogeneous markets such as the automobile market. Therefore, the use of the ordinary least squares (OLS) method would not be appropriate for estimating model with data containing outliers or extreme observations. In case of outliers, if the hedonic price equation is estimated by OLS method, the estimators will not be efficient and may even be biased depending on the type of outliers and the assumptions of homoscedasticity and normal distribution of error terms in the model will also not be met. In this study, since OLS method is extremely sensitive to outliers, hedonic price models are estimated by robust and resistant regressions that are not sensitive to them. Robust and resistant regression methods used in the study are least absolute deviation (LAD; Bickel, 1973), M (Huber, 1964), least trimmed squares (LTS, Rousseeuw, 1984), S estimation (Rousseeuw and Yohai, 1984), MM estimation (Yohai, 1987). In the study, because of the use of robust and resistant regression methods without outliers being excluded, information loss was not caused. The study consists of 6 sections in total. These sections are respectively as follows; introduction, the second section in which the literature is reviewed, the third section in which the methodology is explained, the fourth section in which the data set is given and the fifth section in which the estimation results are interpreted. In the last part, the result section of the study is included.

2. EARLIER STUDIES

In this section, we briefly provide information on the empirical studies examining the factors affecting car prices with the hedonic price model. When the literature is examined, it is likely that this study will contribute to the literature as the first study to analyze the automobile hedonic price model via robust and resistant regressions.

In the pioneering work of automobile hedonic price model, Court (1939) investigated the effects of length, weight and horsepower on prices on the US automobile market.

Cowling and Cubbin (1972) calculated the automobile hedonic price index for the UK in their work. They estimated the hedonic price model under two different functional forms which are linear and semi logarithmic. According to the estimation results, the variables of fuel consumption and passenger area affect the prices of automobiles negatively while the variables of transmission, length, braking power, luxury interior standard affect them positively.

Mertens and Ginsburgh (1985) investigated the determinants of European and Japanese car prices in 5 European countries with the hedonic model. They estimated the hedonic automobile price model under semi-logarithmic functional form. According to the estimation results, variables such as length, weight, diesel fuel type and engine cylinder volume have positive effects on the car prices.

In his study of the structural demand model for the automobile market, Bajic (1993) estimated a hedonic price model for the US auto market. According to the estimation results, the width affects car prices in the negative direction, while the variables of weight, import and axle distance affect them positively. Another finding is that the automobile brand has a significant effect on prices.

Arguea et al. (1994) estimated the automobile hedonic price model in linear form for the United States via the OLS method. As a result of the work; horsepower, luggage volume and fuel efficiency of the car have reached a positive effect on prices.

In their study of the hedonic price of the environmental and safety features of the car on the French automobile market, Couton et al. (1996) have found that these features have a statistically significant positive effect on car prices.

Murray and Sarantis (1999) used the weighted LS method to avoid heteroscedasticity problem in their estimations of the automobile hedonic price model for the UK. According to the estimation results; comfort, luxury equipment, economy, performance, maneuverability features of the car have strong effects on prices.

Pazarlıoğlu and Güneş (2000) estimated the hedonic price model for the Turkish automobile market using Weighted LS method to avoid heteroscedasticity problem. The main features of the car which affect car prices according to the model estimation results are ABS braking system feature, engine cylinder volume, engine power and fuel consumption.

In the calculation of the hedonic price index, The German Federal Statistical Office (2003) estimated the hedonic price model for the second hand automobile market under semi-logarithmic functional form. Robust t values are calculated against heteroscedasticity problem. As a result, it was determined that the price of the new cars positively affected the prices of the second hand cars, while age and kilometers variables affected them negatively. As a result of the study, it was determined that automobile brands have a statistically significant effect on the second hand prices.

Andersson (2005) aimed to determine the value of traffic safety for the Swedish automobile market by the hedonic regression model. According to the findings of the study, there is a negative relationship between the automobile prices and the natural risk level of the car.

Reis and Silva (2006) examined the effects of quality changes on the automobile price index for the Portuguese new automobiles. They estimated the hedonic automobile price model with the weighted LS method in order to obtain efficient estimators in case of heteroscedasticity. According to the estimation results, the effect of the front-wheel drive of the car on the prices is negative, while the variables of the car characteristics such as diesel fuel type, engine cylinder volume, maximum speed, coupé and cabriolet body type, sunroof and fuel consumption affect the car prices positively.

Erdem and Şentürk (2009) estimated the hedonic price model in order to determine car characteristics affecting the prices in the second hand car market in Turkey and to determine the effect of these characteristics on the prices. They have excluded marginal vehicles in order to avoid the problem of outliers in the data set of 1074 observations. The hedonic price model is estimated under logarithmic, semi-logarithmic and Box-Cox functional forms, including year of production, engine cylinder volume, fuel type, production place, color, transmission type, sunroof, service supplier number and sale place characteristics as independent variables. White (1980) covariance matrix was used to avoid the heteroscedasticity problem. According to the estimation results; production place, diesel fuel type, whether the car is black or gray, automatic transmission, sunroof, production year and engine cylinder volume affect automobile prices positively. The number of service suppliers and the fact that the sale place of the car is İstanbul have negative effects on the second hand car prices.

Matas and Raymond (2009) estimated the hedonic price model for the Spanish automobile market and investigated the effects of car characteristics on prices. They preferred White method against heteroscedasticity in the model they estimated under semi-logarithmic functional form and calculated the variance-covariance matrix. According to the estimation results, the performance of the car, driving convenience, size, safety and comfort have positive effects on car prices. Diesel fuel type affects them positively, while fuel consumption affects them negatively.

Hadinejad and Shabgard (2011) estimated the hedonic price model for Iranian automobiles and determined car characteristics that affect car prices. They estimated the hedonic price model by the ordinary LS method under logarithmic functional form. According to the estimation results, the 5 groups of properties such as performance, ease of driving, size, fuel and security are influential on automobile prices and these effects are positive. They came to the conclusion that the most influential feature on car prices is the size of the car in the above – mentioned five groups.

Abounoori and Rezvani (2012) aimed to estimate the hedonic price of each character of the automobile for Iranian automobile market. According to the estimation of the hedonic price model obtained by the OLS method, the variables of the safety characteristics of the car are the most important variables affecting car prices. It has been found that the security variables affect car prices positively and the fuel consumption variable has a negative effect on them.

In his study of determinants of second hand car prices in Turkey with hedonic price model, Ecer (2013) estimated the model with ordinary LS method. In order to remove negative effect of the heteroscedasticity, it is used White (1980) standard error correction method while constructing the variance-covariance matrix of the estimators. According to the estimation results, the main determinants of second hand car prices are engine power, kilometers, age, fuel type, drivetrain type, car brand and car model.

Balce (2016) conducted a multi-factor design-based analysis of variance to determine factors affecting used car prices in the study. After the assumption of normal distribution was not met, it was determined that an observation was an outlier and after removing it from the data set, normality and homoscedasticity assumptions tests resulted in that normal distribution with zero mean and homoscedasticity assumptions were met. According to the estimation results, year of manufacture, transmission type, damage status and type of hardware are main factors affecting used car prices. Although color and kilometer are not main factors, they have interaction effects with other factors. The effect of the position announced in the advertisement is unimportant on the prices.

Daştan (2016) estimated a hedonic price model using cross-section data with 1000 observations in order to determine the characteristics that affect second hand car prices in Turkey. There are three different models which are linear, logarithmic and semi-logarithmic. In these models, variables such as brand, model, age and motor characteristics are included as explanatory variables besides the characteristics of the interior and exterior of the car. The semi-log model was judged to be most appropriate from the models estimated by OLS and White robust standard errors were used to remove negative consequences of the heteroscedasticity problem. According to the estimation results, variables such as brand, model, kilometer, number of changing parts, driver and roof airbag and variables including comfort oriented features such as heated steering wheel, refrigerated torpedo have statistically significant effects on car prices. Features such as hardtop, sunroof, start/stop, back view camera affect car prices positively. Finally, manual transmission, front-wheel drive, number of changed parts, cool torpedo, etc. affect second hand car prices negatively.

3. METHODOLOGY

The main purpose of the regression analysis is to determine the line that fits data best and to examine the relation between variables. The model for examining the relationship between variables,

$$y=X\beta+\varepsilon \tag{2}$$

Can be shown through this equation. Here, y is the dependent variable vector, X is the matrix of explanatory variables and β is the coefficient vector. The OLS method is commonly used in the regression analysis. The OLS method is related to conditional averaging and based on minimization of the sum of squared residuals. The LS estimator is calculated as follows:

$$\hat{\beta}_{LS} = \arg\min_{\beta} \sum_{i=1}^{n} e_i^2 \tag{3}$$

Here, $\hat{\beta}$'s are estimated parameters. Residuals are obtained via $e_i = Y_i - \hat{Y}_i$. This method gives biased and inefficient estimates in case of outliers. In this instance, estimates can be made with the help of robust and resistant methods because these are less sensitive to them. The main purpose of robust and resistant methods is to obtain parameter estimates that are consistent with the desired assumptions that provide robust and stable results in case of outliers. When the methods are examined, it is seen that the robust estimators are resistant to vertical outlier situations and the resistant ones are strong against both vertical outliers and leverage points.

LAD (Bickel, 1973), one of the robust estimators, is one of the L estimators and is also called the L1 estimator. This estimator also provides information about the midpoint (median) of the new conditional distribution of the dependent variable. The LAD estimator is based on the minimization of the sum of residuals in absolute value. Although this approach is resistant to vertical outliers, it does not show the same resistance to leverage points.

M (Huber, 1964), another robust estimator, uses a decreasingly increasing function of the observation values rather than the squares of residuals to limit the effects of outliers in the estimators and in this way, residuals are weighted differently, not equally. M estimators try to maintain both high breakpoint and efficiency. This estimator provides transition between the efficiency of the OLS estimators and the robust nature of the LAD estimators.

Even if the robust estimators show resistance to vertical outliers, leverage points can suppress these estimators. For this reason, estimators with high breakdown limits, which we will consider as resistant estimators, are needed. These respond to the problem of obtaining reliable parameter estimates in the presence of both X and Y directional outliers.

One of the resistant estimation methods LTS was proposed by Rousseeuw (1984). LTS performs a minimization similar to the OLS. Other commonly used resistant estimators are S and MM.

S estimators (Rousseeuw and Yohai, 1984) are called by this name for the reason that they are obtained from the scale statistics. S estimators have been developed against the problem of low breakpoint of the M estimator and estimate parameters via minimization of dispersion of residuals. S estimators estimate scale before estimating the parameters contrary to the M estimators, although they are based on them. MM estimators (Yohai, 1987) have taken this name because of their M estimations several times. For these, we first obtain estimators with high deterioration limits. Then the residuals are used from the resistant regression line with an M scale estimate with a 50% distortion limit. Finally, estimates are made using this information. MM estimators aim to provide both high breakpoint and high efficiency.

Parameter estimates for these models are given in Table 1.

Table 1: Robust and resistant estimators

Method	Estimator	β estimators
Robust	LAD	$\hat{\beta}_{LS} = \arg\min_{\beta} \sum_{i=1}^{n} \lvert e_i \rvert$
	M	$\hat{\beta}_M = \arg\min_{\beta} \sum_{i=1}^{n} \rho\left(\frac{e_i}{\hat{\sigma}}\right)$
Resistant	LTS	$\hat{\beta}_{LTS} = \arg\min_{\beta} \sum_{i=1}^{h} e_{(i)}^2$
	S	$\hat{\beta}_S = \arg\min_{\beta} S(\beta)$
	MM	$\hat{\beta}_{MM} = \arg\min_{\beta} \sum_{i=1}^{n} \rho\left(\frac{e_i}{\hat{\sigma}^s}\right)$

(i) Residuals are obtained via $e_i = Y_i - \hat{Y}_i$. (ii) $\rho(.)$ is the loss function. (iii) h is some number less than n and h is defined in the range $\frac{n}{2}+1 \le h \le \frac{3n+p+1}{4}$ s (β). (iv) The dispersion of is the solution of $\frac{1}{n-p}\sum_{i=1}^{n}\chi\left(\frac{e_i}{S}\right)=\theta$. (v) is the robust estimator of scale

4. DATA

The dataset used in this study was obtained in May 2016 from the website www.sahibinden.com, which is very popular in Turkey and where second hand car sales announcements are included. In order to examine the factors affecting second-hand car prices for Istanbul through the second hand automobile hedonic price model, the announcements in Istanbul city were taken into consideration. The reason for choosing Istanbul is that 23% of the total number of registered cars in Turkey is in Istanbul and more importantly, the rate of automobiles that form the basis of second-hand car buying and selling is about 23% in Istanbul compared to Turkey. 1032[1] observations were used to estimate models. Variables and descriptive statistics included in the study are presented in Table 2. The logarithmic automobile selling price is taken into account as dependent variable. The average logarithmic car sales price given in Table 2 is approximately 10.76, and the average automobile kilometer is 86840. As can be understood from descriptive statistics on engine cylinder volume, automobiles with a maximum engine cylinder volume of 1401-1600 have been included in the analysis. In the automobile sector, engine cylinder volume plays an important role because it is an important indicator of the level of taxation. According to this information, it can be argued that automobiles with engine cylinder volume up to 1600 occupy an important place in the sector.

5. EMPIRICAL RESULTS

$$\begin{aligned}\text{lnPrice}_i = {} & \alpha_0 + \alpha_1 \text{Kilometer}_i + \alpha_2 \text{Diesel}_i + \alpha_3 \textit{Gasoline}_i \\ & + \alpha_4 \textit{Front Wheel Drive}_i + \alpha_5 \text{Body Type}_i \\ & + \alpha_6 \text{CV2}_i + \alpha_7 \text{CV3}_i + \alpha_8 \textit{Gear}_i + \alpha_9 \text{Cruise Control}_i \\ & + \alpha_{10} \text{Sunroof}_i + \alpha_{11} \text{Trip Computer}_i \\ & + \alpha_{12} \text{Rain Sensor}_i + \alpha_{13} \textit{Changing Parts}_i + \varepsilon_i \end{aligned} \quad (4)$$

The hedonic price model given in equation four constructed for the second hand automobile market was firstly estimated by OLS method. Findings obtained by the OLS method are summarized in

1 Sample size (n) was calculated by this formula: $n=(NpqZ^2)/((N-1)d2+pqZ^2)$, here N: population size, Z: Normal distribution critical value at the (1-α) confidence level, d: significance level, p: The probability of preferring to buy automobile, q=The probability of not preferring to buy automobile. Despite the fact that the number of observations is 661 according to the given sample size calculation formula, it has been worked out with a greater number of observations.

Table 2: Variables and descriptive statistics of the variables

Variable	Description	Mean±Standard deviation	Jarque-Bera	Probability
lnPrice	Logaritmic automobile selling price (TL)	10.7578±0.6181	18.0458	0.0001
Kilometer	Automobile kilometer	86840.18±65629.66	228.0468	0.0000
Diesel	1 if fuel type is diesel, otherwise 0	0.6259±0.4841	175.1603	0.0000
Gasoline	1 if fuel type is gasoline, otherwise 0	0.2625±0.4418	226.7029	0.0000
LPG	1 if fuel type is LPG, otherwise 0	0.1065±0.3087	1989.378	0.0000
Front wheel drive	1 if drivetrain type is front wheel drive, otherwise 0	0.8391±0.3675	671.5842	0.0000
Body type	1 if body type is sedan, otherwise 0	0.6162±0.4865	174.2491	0.0000
	CV1, 1 if engine cylinder volume is 1000-1400, otherwise 0	0.3197±0.4402	230.2834	0.0000
Engine cylinder volume	CV2, 1 if engine cylinder volume is 1401-1600, otherwise 0	0.5116±0.5001	172.0002	0.0000
	CV3, 1 if engine cylinder volume is 1601-2000, otherwise 0	0.1686±0.3745	594.2987	0.0000
Gear	1 if transmision type is manual, otherwise 0	0.5310±0.4992	172.0103	0.0000
Cruise Control	1 if automobile has cruise control, otherwise 0	0.5245±0.4996	172.0038	0.0000
Sunroof	1 if automobile has sunroof, otherwise 0	0.2965±0.4569	199.1112	0.0000
Trip computer	1 if automobile has trip computer, otherwise 0	0.7606±0.4268	267.8218	0.0000
Rain sensor	1 if automobile has rain sensor, otherwise 0	0.4418±0.4968	172.1292	0.0000
Changing parts	1 if automobile has changing part, otherwise 0	0.1434±0.3506	909.1430	0.0000

the second column of Table 3. According to the estimation results, the coefficients of explanatory variables are statistically significant at the 1% significance level. The model is also significant as a whole according to the result of the F test. The coefficient of determination, calculated as 0.8166, indicates that about 82% of the variations in the dependent variable are explained by explanatory variables in the model. Homoscedasticity and normal distribution of error terms are very important in terms of F and t tests validity in the model estimated with the use of the OLS method. The result of the White (1980) test carried out according to the results of the OLS method indicates that there is heteroscedasticity problem. According to the Jarque-Bera (1980) test result, the null hypothesis of normality is rejected. Although the estimated coefficients both individually and as a whole are significant, as a result of the violation of homoscedasticity and normality assumptions, these findings will not be valid. Heteroscedasticity causes standard errors to be biased. When heteroscedasticity is present, robust standard errors tend to be more trustworthy. The values in square brackets in the second column of Table 3 are robust standard errors.

Studentized residuals, standardized residuals and DFBETAS were calculated respectively, in order to determine whether there are outliers in the model and to detect them if any. After these calculations, it is determined there are outliers in the data set. Vertical outliers are detected by applying studentized and standartized residulas criteria. Also, leverage points are detected by DFBETAS criterion. Outliers determined by Studentized residuals (RStud), standardized residuals (R Stand) and DFBETAS criteria are presented in Tables 4-6, respectively. It was detected there are outliers in 60, 28 and 61 observations according to the criteria of studentized residuals, standardized residulas and DFBETAS, respectively.

As a result of the presence of heteroscedasticty, non-normality and outliers in the model, robust and resistant regression methods were performed. The second hand automobile hedonic price model was estimated by robust and resistant regression methods. The estimation results of robust regression methods called LAD (L1), M and the estimation results of resistant regression methods called LTS, S, MM are given in Table 3.

When the estimation results of robust and resistant regression are evaluated, it is observed that all the variable coefficients, except changing part in S regression, are statistically significant. The signs of estimated robust and resistant regressions coefficients are in accordance with the expectations and they are in the same directions with the signs of coefficients obtained from OLS. Estimated coefficients do not change in sign but they differ in magnitude. Vertical outliers and leverage points are detected in the data set according to studentized residuals, standartized residuals and DFBETAS criteria. As explained in the methodology part of the study, robust estimators are resistant to vertical outliers but leverage points can supress them. Resistant regression methods provide robust estimators to vertical outliers and leverage points. The estimation result of the LTS regression is taken into account when making coefficient interpratation because LTS regression has the biggest explanation power among resistant regression models estimated in this study.

According to the estimation results of the second hand automobile hedonic price model, the variables of kilometer, fuel type (diesel, gasoline), front wheel drive, body type, engine cylinder volume, transmission type, cruise control, sunroof, trip computer and changing part were determined to have statistically significant effects on the automobile prices. In the light of these findings; kilometer, fuel type, front wheel driving or rear wheel driving, body type, cylinder volume, transmission type, cruise control, trip computer, sunroof, rain sensor and changing parts are the basic features of the automobile that determine second hand automobile prices.

The regression results show that there is a negative relationship between the automobile kilometer and automobile prices. This finding also corresponds to expectations. Ten thousand unit increase in kilometer variable will decrease automobile prices 3.19%. It has been determined that the front-wheel driving feature

Table 3: The results of regressions

Variables	Methods					
	OLS	LAD	M	LTS	S	MM
Constant	10.9570*	11.07004*	11.03815*	11.03*	11.10*	11.0363*
	(0.0511)	(0.0626913)	(0.0479829)	(0.0436)	(0.0559)	(0.0479)
	[0.0675]					
Kilometer	−0.00000339*	−0.00000329*	−0.00000347*	−0.00000319*	−0.00000310*	−0.00000347*
	(0.000000156)	(0.000000191)	(0.000000746)	(0.000000131)	(0.000000170)	(0.000000146)
	[0.000000172]					
Diesel	0.3408*	0.3345772*	0.3226071*	0.3571*	0.3077*	0.3225*
	(0.0305)	(0.0374574)	(0.0286692)	(0.02545)	(0.0334)	(0.0286)
	[0.0361]					
Gasoline	0.1856*	0.1898943*	0.1708238*	0.2151*	0.2028*	0.1704*
	(0.0337)	(0.0413907)	(0.0316797)	(0.02811)	(0.0369)	(0.0316)
	[0.0401]					
Front wheel drive	−0.5393*	−0.6471241*	−0.5874483*	−0.6171*	−0.6557*	−0.5857*
	(0.0290)	(0.035565)	(0.0272208)	(0.02564)	(0.0317)	(0.0271)
	[0.0398]					
Body type	0.0750*	0.0590703*	0.0781739*	0.07348*	0.0606*	0.0782*
	(0.0185)	(0.0226921)	(0.0173681)	(0.01546)	(0.0202)	(0.0173)
	[0.0191]					
CV2	0.0645*	0.0789845*	0.073364*	0.08918*	0.0973*	0.0728*
	(0.0206)	(.0252614)	(0.0193346)	(0.01710)	(0.0225)	(0.0193)
	[0.0212]					
CV3	0.2630*	0.2326377*	0.2406577*	0.1073*	0.0709***	0.2404*
	(0.0350)	(0.042892)	(0.0328288)	(0.0304)	(0.0382)	(0.0327)
	[0.0456]					
Gear	−0.2177*	−0.1970285*	−0.2029899*	−0.1936*	−0.1760*	−0.2034*
	(0.0208)	(0.0255968)	(0.0195913)	(0.01723)	(0.0228)	(0.0195)
	[0.0199]					
Cruise control	0.1072*	0.1159603*	0.1022716*	0.1091*	0.1134*	0.1023*
	(0.0221)	(0.0270797)	(0.0207263)	(0.01838)	(0.0241)	(0.0206)
	[0.0201]					
Sunroof	0.1278*	0.0858848*	0.1064534*	0.0860*	0.0665*	0.1072*
	(0.0223)	(0.0273291)	(0.0209172)	(0.01871)	(0.0243)	(0.0208)
	[0.0239]					
Trip computer	0.1551*	0.1194365*	0.130692*	0.09235*	0.0615**	0.1318*
	(0.0227)	(0.0278554)	(0.02132)	(0.01923)	(0.0248)	(0.0212)
	[0.0260]					
Rain sensor	0.1700*	0.1717769*	0.1610488*	0.1599*	0.1726*	0.1612*
	(0.0227)	(0.0279078)	(0.0213601)	(0.01890)	(0.0248)	(0.0213)
	[0.0221]					
Changing parts	−0.0712*	−0.0620619**	−0.0627127*	−0.0588*	−0.0121	−0.0633*
	(0.0241)	(0.0295709)	(0.022633)	(0.0201)	(0.0263)	(0.0225)
	[0.0245]					
	R^2=0.8166	Pseudo R^2=0.5777	R^2=0.6416	R^2=0.8515	R^2=0.5774	R^2=0.6478
	Adj.R^2=0.8143		Adj.R^2=0.6371	Adj.R^2=0.8495	Adj.R^2=0.5720	Adj.R^2=0.6433
	F*=348.7951		F=382.56*	F=422*		
			Scale=0.2197	Scale=0.2486	Scale=0.2251	Scale=0.2251
	White*=279.98					
	Jarque-Bera*=72.98					

(i) Dependent variable is the logarithmic price of automobile. (ii) Numbers in parentheses are standard errors. Numbers in square brackets are robust standard errors. (iii) *, **, *** indicate significance at the level of 1%, 5% and 10%, respectively. (iv) White test (1980) indicates that the null hypothesis of homoscedasticity is rejected at the 1% significance level. (v) Jarque-Bera test (1980) indicates that the null hypothesis of normality is rejected at the 1% significance level

of the automobile reduces car prices. When the coefficient value of front-wheel drive variable is interpreted[2] in the estimation results of the LTS regression, the average price of the front-wheel drive automobiles is 46% lower than that of the rear-wheel drive automobiles. According to the findings, the manual transmission reduces the automobile prices. The average price of the automobiles which have manuel transmission are 17.6% lower than those with

2 Dummy variable coefficient interpretations were performed according to the Halvorsen-Palmquist (1980) approach, which is recommended for semi-logarithmic regression models.

Table 4: Studentized residulas

Observation	Rstud	Observation	Rstud	Observation	Rstud	Observation	Rstud
4	2.87	169	2.20	374	−4.55	840	4.19
10	−2.45	181	1.99	403	2.47	851	−2.58
21	−2.36	192	2.64	462	1.99	862	2.92
28	−2.55	218	−2.34	502	−2.28	874	2.18
40	2.25	223	2.52	535	−2.49	875	3.83
51	−2.75	224	−2.52	540	3.08	882	3.24
64	−2.43	246	3.87	541	−2.79	929	−2.58
68	−2.26	252	−1.99	544	2.05	931	−2.94
90	2.28	279	2.06	591	2.14	969	−2.75
113	2.70	281	−2.40	677	2.06	1011	3.41
115	2.17	286	−2.78	756	−2.11	1023	2.01
120	−2.98	299	−2.27	762	2.93	1030	2.28
126	2.13	307	−2.28	778	2.30		
145	2.14	343	−2.63	800	−2.94		
160	2.16	359	−2.12	817	−2.33		
162	−2.17	360	−2.44	822	2.06		

(i) Studentized residual values (Rstud) were compared to the value of 1.96. (ii) Observations with Rstud values greater than 1.96 in absolute value were determined as outliers. (iii) Rstud values were obtained from the formula $e_i^* = \frac{e_i}{\sqrt{MSE_i(1-h_i)}}$. MSE_i is the mean squared error calculated without ith observation and h_i is the diagonal element of the hat matrix

Table 5: Standardized residulas

Observation	Rstand	Observation	Rstand	Observation	Rstand	Observation	Rstand
4	2.86	160	2.16	544	2.05	862	2.91
40	2.25	169	2.19	591	2.14	874	2.18
90	2.27	223	2.51	677	2.06	875	3.81
113	2.69	246	3.84	762	2.92	882	3.22
115	2.16	279	2.05	778	2.30	1011	3.39
126	2.12	403	2.46	822	2.05	1023	2.01
145	2.14	540	3.07	840	4.16	1030	2.28

(i) Standardized residual values (Rstand) were compared to the value of 2. (ii) Observations with Rstand values greater than 2 in absolute value were determined as outliers. (iii) Rstand values were obtained from the formula $e_i^s = \frac{e_i}{\sqrt{MSE_i(1-h_i)}}$. MSE is the mean squared error and h_i is the diagonal element of the hat matrix

Table 6: DFBETAS

Observation	DFBETAS	Observation	DFBETAS	Observation	DFBETAS	Observation	DFBETAS
19	0.07	273	−0.07	588	0.09	848	−0.09
28	−0.07	293	0.09	591	0.16	851	0.15
51	0.11	299	−0.08	611	0.07	864	−0.07
69	0.07	309	0.09	614	−0.11	874	−0.07
90	−0.07	332	−0.07	629	−0.07	882	−0.07
115	0.19	354	−0.11	662	−0.09	929	0.15
145	−0.08	359	−0.14	688	−0.09	931	−0.07
162	0.08	360	−0.19	691	0.11	935	−0.07
181	−0.07	374	0.21	706	−0.07	939	−0.07
192	−0.11	406	0.09	762	0.23	972	−0.10
218	−0.13	487	−0.07	776	−0.07	990	−0.07
223	−0.10	489	−0.17	778	0.09	1023	−0.08
239	0.07	494	0.10	784	−0.08	1030	−0.07
240	0.08	540	0.38	793	−0.07		
246	0.13	544	0.07	800	0.22		
255	0.06	571	−0.06	822	−0.13		

(i) DFBETAS criterion was performed for km only, since all the explanatory variables except km in the model are dummy variables. (ii) $DFBETAS_{ij} = \frac{\hat{\beta}_J - \widehat{\beta_{J(1)}}}{\sqrt{MSE_i h_{jj}}}$ βj (i) is the jth parameter calculated without ith observation. MSE_i is the mean squared error calculated without ith observation and h_{jj} is the jth diagonal element of the $(xx)^{-1}$. (iii) DFBETAS values were compared to the value of 2/√n and observations with DFBETAS>0.06 in absolute value were determined as leverage points

automatic transmission. Automobiles with automatic transmission type provide more comfortable driving in metropolitans such as İstanbul where there is heavy traffic. Automobiles with manual transmission type are more tiring in terms of driver in challenging traffic conditions while automobiles with automatic transmission type are comfort oriented and provide ease of driving. For these reasons, automobiles with manual transmisssion type have an decreasing effect on the automobile prices when compared with those with the automatic transmision. According to the estimation results, another variable which reduces the automobile price is the changing part. Changing parts at the automobile can be caused by automobile accidents or the replacement of old parts. As a result, it is in accordance with expectations. The availability of changing part at the automobile reduces the prices and the avarage price of the automobiles which have changing part are 5.7% lower than other ones without changing parts.

According to the findings, it is observed that the coefficients of diesel and gasoline variables have positive signs. Fuel types like diesel and gasoline increase automobile prices compared to LPG (gas). This finding shows that the avarege price of automobiles functioning with diesel and gasoline is higher than the average price of those with LPG. The average price of automobiles with diesel fuel type are 42.9% higher than that of automobiles with LPG and the average price of automobiles with gasoline fuel type are 23.9% higher than that of cars with LPG.

This result may be induced by the fact that drivers are prejudiced about safety against automobiles with LPG and there is a limited using of services for them like parking garage. When the coefficients of the diesel and gasoline variables are considered in terms of magnitude, the impact of the diesel fuel type is greater than that of gasoline fuel type on prices. Due to the fact that the price of diesel is cheaper than that of the gasoline and fuel economy for the diesel automobiles is bigger than that of the gasoline automobiles, diesel fuel type has a more increasing effect on the prices compared to the automobiles with gasoline.

The regression results show that the sedan body type of automobile increases automobile prices. According to the estimation results, the average price of automobiles with sedan body type, is 7.6% higher than those with non-sedan body type. This is caused by the fact that sedan-type cars provide a larger internal volume than those of hatchbacks and they are superior in quality perception compared to station wagons. According to the findings, it is observed that as the engine cylinder volume increases, the price of automobile increases. The avarege prices of the automobiles with engine cylinder volume between 1401 and 1600 are %9.3 higher than the automobiles with engine cylinder volume <1401. Additionaly, the avarege price of the automobiles with engine cylinder volume between 1601 and 2000 are 11.3% higher than the automobiles with engine cylinder volume <1401. It has been found that the average price of automobiles with engine cylinder volumes between 1401 and 2000 are higher than those with engine cylinder volume <1401. The most important factor supporting this finding is that the higher the engine cylinder volume, the better the performance of the automobile.

According to the estimation results, comfort-oriented features such as cruise control, trip computer and rain sensor have a positive effect on prices. The presence of a cruise control, trip computer and rain sensor features on the automobile play an increasing effect on prices. The avarege price of the automobiles with features such that cruise control, trip computer and rain sensor is 11.5%, 9.6%, 17.3% higher respectively than those without these features. It has been observed that the sunroof is another variable that affects prices positively. According to this finding, the avarage price of the automobiles with sunroof is 8.9% higher than those without sunroof. The sensation of freshness in the car and providing a more aesthetically pleasing appearance of the automobile make the sunroof a feature that increases the price.

6. CONCLUSION

In this study, the factors affecting second hand automobile prices and the magnitude of these factors on them have been examined via hedonic price theory using data set consisting of 1032 observations obtained from Istanbul car market. The results of hedonic price model estimated by OLS show that assumptions of homoscedasticity and normal distribution of error terms are not fulfilled. Existence of outliers in the data set is determined by standardized residuals, student t residuals, and DFBETAS criteria. After detection of outliers, the hedonic price equation was estimated by robust and resistant regression methods without excluding any outlier in the analysis. These robust and resistant regression methods, called LAD, M, LTS, S, and MM are less sensitive to outliers and this makes the estimation results more reliable than OLS results.

The empirical findings indicate that kilometer, fuel type, front wheel drive, body type, engine cylinder volume, transmission type, cruise control, sunroof, trip computer, rain sensor and changing part are the features which have a statistically significant effect on the automobile prices. Manual transmission, front-wheel drive, kilometer, changing part are the features of the automobile which decrease prices, while other variables analyzed in the study increase prices. In addition to the features such as transmission type, engine cylinder volume and fuel type that have significant effects on prices, it is determined that comfort-oriented features are also important factors that affect automobile prices.

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