The Impact of the Model Life Cycle on the Residual Car Value in the Leasing Industry

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II. Abstract

This research takes place in a Dutch car leasing and insurance company. Setting the residual value is a difficult task, as it involves making estimates about the future. Although, there are known determinants like the effect of age and kilometers on the value of cars, other determinants are quite difficult to estimate and calculate. In line with literature and company experts it is hypothesized in this thesis that the model life cycle of cars has a negative effect on the residual value. In order to test this hypothesis a multivariate analysis is applied to test whether cars whose model design becomes older have a more negative effect on the residual value than cars whose model design is still new. Therefore, the residual car value of lease cars sold between 2006 to 2016 on the Dutch market is examined. The sample contains four different car brands, with cars models being divided into three segments. The regression results show in a few cases a negative effect on residual car value by the model life cycle. However, those results often lack significance, which does not allow to draw conclusions for each and every car model. Possible explanations for the results are consumer perceptions, market conditions, and seasonal fluctuations which cannot be captured in the analysis. Overall, the findings for age and kilometers are consistent with previous findings, however, the findings show different effects (negative) for diesel which is a determinant with a positive effect in previous studies. Engine power (kW) shows a positive effect on residual car value, but results are not consistent for all models.

Keywords: residual (car) value, car leasing, model life cycle

III. List of Abbreviations

ABS	Anti-lock Breaking System
AC	Air Conditioning
ARMAX	Auto-Regressive-Moving-Average-Model
CPI	Consumer Price Index
DSL	Diesel engine
Euribor	Euro Interbank Offered Rate
EUR95	Petrol engine
GDP	General Domestic Product
GLM	General Linear Model
IAS	International Accounting Standards
IFRS	International Financial Reporting Standards
MLC	Model Life Cycle
n/a	not available
NADA	National Automobile Dealer Association
OLS	Ordinary Least Squares
PPI	Producer Price Index
R_{act}	Actual residual value
R_{est}	Estimated residual value
RV	Residual Value
VIN	Vehicle Identification Number

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1. Introduction

This research is carried out at Company A one of the largest leasing companies in the Netherlands. More specifically at the Leasing department, which is responsible for the residual car value estimations. In order to stay competitive, it is important for the leasing company to set the market value of cars as precisely as they can. The difficulty in this task is, that many determinants can have an effect on the car value which are hard to predict and to capture. Residual values are exposed to fluctuations due to new technological developments, market conditions, and the political climate. Moreover, the risk is that the actual market value at sale is lower than what has been estimated at the beginning of the contract (Rode et al., 2002). Furthermore, to stay competitive, the residual values can neither be set too low as it results in a high lease prices, nor too high as the car will not receive such high value on the used market.

Leasing has become quite popular over the last decades, this trend can be explained by the increasing "desire for personal mobility" (Fujimoto 2014, p 8). The leasing industry in Europe "accounted for a volume of 65% (…) of total new leasing contracts granted in 2014" (Glue et al., (2017). This increase in demand shows promising market perspectives for car leasing companies and car manufactures and their subsidiaries. However, leasing is also associated with risks. According to Cooke (2009) the car leasing industry has seen a drop in the accuracy of residual value predictions. This negative trend in residual value forecasting is further identified by the Oliver Wyman Report (2010) arguing that residual forecasts in recent years did not outperform their market values having a negative impact on the profitability of car manufacturers and leasing companies. Therefore, it is important for leasing companies to have a precise estimation on the residual value of cars, as they are mostly the sole risk taker and their profitability depends on their accuracy.

The next sections will give a detailed description on the business activities of Company A and the leasing department, which is followed by the problem statement, research objective and practical relevance.

1.1. Company A

Company A is one of the largest leasing and insurance companies in the Netherlands. It has a large product range, from providing financing and leasing options for passenger cars, light and heavy commercial vehicles, bicycles, and busses. Its services, among other things, include private and business leasing, fleet leasing, financing and insurance products, and other products related to mobility. All those products are tailor-made for its customers.

1.1.1. Leasing Department

The department consists of seven people. Their day to day business includes the residual value estimation of new cars being introduced, monitoring and (re-)evaluation of residual values of cars in the portfolio. They estimate the residual value of cars based on the customer´s wish to drive a given car for a specific time and kilometer range per year. Sometimes, a customer would like to change its contract. For instance, a customer would like to drive the car for more kilometers, it is then up to the department to decide whether granting additional kilometers can be done with or without increasing the lease payment. Furthermore, it is responsible for requests on new cars and what their lease would cost.

Confidential

The (re)-evaluation process and analysis of residual values of existing cars and new cars is not done solely by the leasing department, but by other departments as well. This takes place in the *committee meeting*. Team leaders of the departments meet every month to discuss the residual values for new, as well as cars that are already in the system. In the meetings, the members of the *committee* decide by majority whether the car´s residual value will be adjusted.

During meetings, the team leaders of the departments decide based on their experience of day-to-day business activities, the market analysis for the new and used car market, and their *gut feeling* about the residual values. However, their decisions are solely based on experience or personal opinion but not on statistical analysis.

As there is no statistical analysis on which determinants effect the residual car value, this research will be the first analysis provided to the department on the residual car value. The problem statement and research objective will be explained in the following sections.

1.2. Problem Definition

Over the years, the model cycles have decreased significantly from averaging around eight years to approximately five to six years (Holweg & Kattuman, 2006.; Purohit & Desai, 1998, Sabadka, 2013, Volpato & Stocchetti, 2008). Furthermore, residual values have been fluctuating (Swayer, 2003; Cooke, 2009). According to Sundaram in Swayer (2003) on reason for this is the model life cycle of cars. According to industry experts, the introduction of upgrades and facelifts can diminish the declining demand for car models with improving the models look and technical aspects (Bryant, 2013). Furthermore, the older the model design becomes, the less likely the model is to retain its residual value as it did at the beginning of the model life cycle.

The literature to date provides only little information and empirical evidence on the effect of model cycles on the residual value. However, there are studies that analyzed the effect of model cycles, new product introductions and the linkage between the new and the used market, for example the studies of Purohit (1992), Pierce (2012) and Holweg & Kattuman (2006). Nau (2012) showed in her analysis that model introductions and updates have a significant influence on the residual value causing the increasing and decreasing patterns over time in the car value. The study by Moral & Jaumandreu (2007) shows that the age of the car model not only has an effect on the residual value but also on the demand for that car model. Purohit (1992) shows how new car models being introduced to the market have a negative impact on the residual value of cars. This effect depends, however, on the consumer perception. He empirically showed that prices for used cars respond to changes in the new market. Another study by Jost & Franke (2005) argues that a new model introduction influences the residual value, however, smaller updates and facelifts are less strong.

Making estimation about the future market value of cars is a difficult endeavor. The current residual values at Company A are said to be not competitive with industry competitors. According to critiques the values are set too low, making the lease contract more expensive, and thus, less attractive for customers. As mentioned above, the leasing department has currently no statistical analysis on determinants of residual car values other than contract duration and mileage.

Additionally, with decreasing model life cycles of cars, more updates and facelifts introduced during the model life cycle, the leasing department has no information about how the residual values behave over the model life cycle. However, the *committee* recognizes such effect in their monthly meetings, where each individual car model is being discussed and their residual values are being evaluated. The *committee* decides for new residual value based on voting and finding agreements between its members.

1.3. Research Goal

The main research goal is to see whether or not the model life cycle of cars has a negative effect on the residual value of cars. With ageing model design, a car becomes more and more obsolete in comparison to other models, and the new or facelifted version that will be introduced at the end or during the model life cycle. Moreover, customers might rather wait until the latest version is available for lease or for sell in the used market instead of leasing or buying the end-of-range model. The effect of the model life cycle states that a car which is introduced in 2009 and enters a lease contract of 3 years will have a certain value in 2012. The same car model will then enter a lease contract of 3 years in 2011, when the model design is already two years old. It will be sold on the used market in 2014. It will probably not receive the same residual value as the car which started its contract in 2009. Moreover, the second car will be sold when the model life cycle comes to an end, and the new model will be introduced soon. With technical improvements, more standard equipment and newer look it is not implausible that the customers rather wait for a newer model.

Therefore, the following research question will be posed:

Does the model life cycle have an effect on the actual residual value of leased cars?

?

Model cycle of cars → Actual residual value of lease cars

In order to answer the research question, the following sub-questions are posed:

- *How can the model life cycle be defined?*
- *What factors determine the residual value of cars?*

The first sub-question will be answered based on the Vehicle Identification Number (VIN) of cars which is defined in the methodology chapter. The second sub-question is answered based on the literature review discussing previous findings.

1.4. Practical Relevance

There has been no prior research on the model life cycle of cars in the Dutch leasing sector. Although, similar research has been applied, few studies put their focus on the effect of the model life cycle on the residual value. One possible explanation for missing research or lack of available public research on the residual car value is the fact that most data on leased cars is held private and confidential by car manufacturers and car leasing firms. Moreover, if research has been applied on model life cycle, it has not been done individually for each car model. Analyzing each individual car has the advantage of being more specific and considers the mid-life cycle upgrades or facelift versions. If the analysis is based on the model year design and includes a variety of cars, those effects will be lost.

There is no statistical evidence on the relationship between the model life cycle of cars and their residual value in the company. However, the *committee* recognizes such effect in their monthly meetings, where each individual car model is being discussed and their residual value is being evaluated. Although, there is consensus on the effect of the model life cycle of cars, only few studies have analyzed this problem empirically. For The leasing department, this study is adding to their knowledge by having an empirical analysis about another determinant which could have an influence on the residual value. Evidence of this research would make the work more efficient, as no voting and discussions would be needed because decisions would be based on empirical significant results. Thus, the contribution is to see whether their *gut feeling* on the influence of the model life cycle is correct or not. In addition, it will be tested if there are differences between different car models from different brands, or if there are differences in the effect between different car segments. For the leasing department, this can be a helpful contribution to their current understanding on the residual value determinants.

This research has implemented an OLS regression with fixed time effects analyzing the residual car value of different models with sales data between 2006 to 2016. Results confirm that mileage and age have the strongest negative effect. It can also be confirmed that diesel cars have a negative effect although results are not significant in all instances. Engine power did not show a positive effect for all models. Concerning the effect of the model life cycle, only in a few instances results were significantly negative.

1.5. Study Structure

This research will start with a literature review in Chapter 2, followed by the methodology part in Chapter 3. Chapter 4 and 5 discuss the regression results. In the last chapter the conclusion, limitation of the research, and recommendation for the company and future research are discussed.

2. Literature Review

Financing durable goods instead of buying them has become quite popular in recent years. Low interest payments on loans make this very attractive. Although leasing in the automobile industry dates back to the 1950s, in recent years the amount of private leasing has become very large. Holweg & Kattuman (2006) even go so far as to say "that some vehicle manufacturers only build cars in order to finance them later¨ (p. 3.). Without estimating the residual value of cars, a lease contract cannot be established. Therefore, it is a crucial task of the leasing department to set and evaluate the residual values of cars. Residual value influences the profitability of the company. If the actual price achieved is much lower than the estimated value then the company makes a loss on the car. According to the literature the residual value is most commonly estimated ¨based on the historical depreciation of the vehicle and its predecessors" (Holweg & Kattuman, 2006, p. 3). Therefore, the residual value must be forecasted as precisely as it can (Glue et al., 2017). Being as precise as possible is not only important as to lower the risk of under valuating the future market value (residual value). What is also important is to have precise estimations to stay competitive on the market (Glue et al., 2017). The residual value is by most studies defined as the expected market value, ¨market price or value of the leased vehicle at the maturity of the lease contract¨ (Nau, 2012, p. 57). The capitalized cost of the car is subtracted by the depreciation which is in most formulas based on the running time (in months) and the annual mileage driven of a car (Holweg & Kattuman, 2006; Hughes et al, 2015; Halonen, 2008, Prieto et al., 2015).

However, as residual value involves making estimations about the future, it is quite difficult to make precise and accurate estimations. It involves making assumptions about future economic factors that might influence the residual value development of cars, like gas prices, inflation, and interest rates. Other factors like political climate and tax policy influence the residual value. Furthermore, there are very large differences in the rate of depreciation between cars based on the characteristics (Halonen, 2008, Abstract; Purohit, 1992). The lower the residual value of the car will be, the more depreciation the leasing company will have to charge the customer. However, having high monthly payments on the car makes the car less attractive for customers. Thus, the leasing company will have to set the residual value in such a way ¨that it will maximize its forecasted profit, not too high because it would mean losses and not too low because it would hurt the selling volume" (Halonen, 2008, p. 2).

Due to the nature of this research topic and data not much scientific literature is available for the public. This is due to the fact that data of leasing firms and residual car values is mostly treated as confidential. However, some authors have discussed the residual value of leased cars which is presented below.

2.1. Model Life Cycle of Cars

Brockhoff (1967) describes the product life cycle (plc), in this research referred to as the model life cycle (mlc), as the time from the introduction of the product to the market to then end of its sale. He makes use of Forrester´s distinction of the plc into "product introduction, market growth, market maturity, and sales decline" (Brockhoff, 1967, p. 472). In his research, he confirms the hypothesis that product sales increase to a peak, and then decrease again due to new(er) products or substitutes. Wykoff (1970) studies in his paper the depreciation trends by analyzing the actual depreciation of cars' list prices to test "the relationship between new and used machinery" (p. 168). The author analyzes relative car rental prices of 19 automobiles makes between 1950-69. Results empirically show that different car segments have different depreciation rates, for example luxurious cars depreciate faster than station wagons. He empirically rejects the hypothesis of fixed depreciation patterns arguing that "(…) different types of automobiles display individualistic characteristics as they age (…)" (Wykoff, 1970, p. 172).

Purohit (1992) analyzes in his research the relationship between the new and the used markets in the automobile sector. According to his findings, the introduction of a new car has an effect on the value of cars in the used market, "prices adjusted in response to changes incorporated in new models" (p. 155). He distinguishes between an obsolescence effect, causing an increased depreciation of older cars, and an enhancement effect, causing a decreased depreciation of used cars (Purohit, 1992). Obsolescence is the case where the new car is desired by consumers, and enhancement if the new product is not perceived well. Purohit (1992) confirms what Wykoff (1970) tested, that the depreciation between car segments is different. He found out that for instance increasing horse power is increasing the depreciation only in smaller segments. Model cycles are said to have an influence in the residual value behavior of cars, when a new model is available in the in the used car market its residual value will increase until the upgrade enters the used market (Jost & Franke, 2005). They argue that the introduction of a new model life cycle car to the market has a higher significant impact on the residual value than facelifts. As Purohit (1992) confirmed, changes in new cars can have an effect on the prices in the used market. This relation was already confirmed by Brockhoff (1967) who argued that cars will be substituted once another car is introduced to the market. However, the author also states that if the same manufacturer introduces a different car model, its design can lead the customer to view this car as a complementary car (Brockhoff, 1967, p. 474).

According to Copeland et al. (2005) the selling prices for used cars, their actual residual value, declines by 9.4 percent over the model year, "a higher model age (…) implies a lower price in the used market" (p. 15). Moreover, do they argue that the same car model which only differs in the model year, the older model year has about 8,8 lower actual residual value than the newer one (Copeland et al., 2005, p. 6). According to the authors the selling price for a model is highest when the new model is just introduced "and they trend downward in a consistent pattern" (Copeland et al., 2005, p. 8). Moral and Jaumandreu (2006) empirically prove in their study that cars "tend to increase until the course of the fourth year in the life of a model" (p. 3). The introduction of cars to the market can be divided into three categories, the annual model changes, the facelifts in the mid-model cycle, and the new model design (Holweg & Kattuman, 2006, p. 6). At the beginning of a model life cycle the car is highly demanded, as changes are new market wide, however, "the residual value is likely to degenerate close to the end of the lifecycle" (Holweg & Kattuman, 2006, p. 6). According to their empirical findings each year the model becomes older, the residual value decreases by 2.52%.

As proved by previous studies, the authors confirm that different car models have different depreciation patterns, where some hold their value better than others. Moreover, results show no clear results concerning the enhancement or obsolescence effect discussed by Purohit (1992), the effect of a new model introduction is "either obsolescence or enhancement" (p. 19). Halonen (2008) confirms the effect on model design age on the residual car value proving in his analysis that "the residual values are first higher but then gradually decrease before new generation again replaces it" (p. 11). In her dissertation on residual value risk, Nau (2012) confirms that model changes or facelifts "have a highly significant impact on its residual value causing jumps in its pattern" (p. 83). Moreover, she argues that cars with a longer life cycle are less attractive in holding their value "than used cars with a short model history" (p.66). Pierce (2012) empirically proves that the introduction of model redesigns between the years influence the price of used cars from that model and that of substitutable products. Hughes et al. (2015) test different determinants of residual car value, among others, the car model life cycle of the cars, saying that there are “different depreciation rates across the life cycle of the model, with the fastest (…) in the first few years” (p.3).

Based on the literature review on residual car value and the model life cycle, the following two hypotheses will be tested;

H1a: The model life cycle has a negative effect on the residual value.

Hypothesis H1a will be tested based on evidence found in existing literature and what expert views in the lease industry suggest, namely that the model life cycle of cars has a negative effect on the residual car value. A study conducted by Glue et al. (2017) analyzed the residual value risk by applying a linear model and artificial neural networks. In their research, they implement the model age, which refers to the model cycle. They hypothesis that “the residual value of identical vehicles of exactly the same age and with the same mileage is not constant over time” (p. 1206). Based on the theory, the car value will decline the older the car model is.

H1b: With each additional year in its model life cycle the car model´s value on the used market decreases.

Hypothesis H1b is formulated based on the theory that with increasing age, the car will lose its value. For similar cars, it is expected that the car which is just introduced to the market will have a higher value on the used market, than the same car, but whose model life is already in the subsequently year. The theory behind this hypothesis is the finding by Copeland et al. (2005) and Holweg & Kattuman (2006) the residual value of the car model decreases with each additional year since its product launch. According to the latter arguing that “each year the design ages, the residual value drops (…) the further the design advances in its life cycle (…) the less well it retains its value” (p. 18).

2.2. Physical Depreciation

The physical depreciation of cars is described by two variables, namely age and mileage. Most literature measure age in months which is defined by the lease contract duration, or the time since the car is first registered and used. The relationship of age with the residual value is straightforward, the older the car, the higher the depreciation (Halonen, 2008; Purohit, 1992). According to Stockmann (2004) "annual rentals will decrease as the asset ages" (p. 374). As Prieto et al. (2015) state, "car age has a strong negative and decreasing effect on price" (p. 211). Hughes et al. (2015) measure age as the number of years since the car was introduced to the market, and measure age "as the difference in years between the auction date of a used car and vehicle model year" (p. 3). Nau (2012) measures age as the months since the model was first introduced adjusting her car samples to the standard lease contract of 36 months. Thus, a car sales price in October 2007 is "a car registered in November 2004" (p. 62). Mileage is an indicator of usage which is simply the total kilometers a car has driven so far. Dexheimer (2003) applies a hedonic pricing method to measure the effect of age and relative kilometers driven in a month, which show negative significant results. The relationship between mileage and residual value is negative, like for age, the more kilometers are has driven throughout its life, the less value it will retain (Halonen, 2008; Hughes et al., 2015; Prieto et al., 2015; Dexheimer, 2003).

2.3. Car Characteristics

Griliches (1961) was one of the first authors who analyzed the price development of cars. Applying a hedonic pricing method, he established the relationship between cars' quality changes and their effect on the price development. The author included two types of variables, namely numerical variables and indicator variables. The former corresponds to a car´s horse power, lengths and weight, whereas the latter measures the effect of transmission type, hardtop, power-steering, brakes, compact cars and if it is a V8 engine or not (Griliches, 1961). All but the V8 have a positive effect on the price. The results have been confirmed by the author by testing the variables on new list prices and on used car prices that were one year old (Griliches, 1961).

The study of Ohta & Griliches (1976) builds on Griliches (1961) by including more car characteristics and the brand effect in the analysis. After critique on hedonic pricing models, they re-evaluated the method by reminding academics that it is no ¨perfect price index for any commodity¨, which it was never intended to be (p. 326). Rather it is an econometric tool to capture the effect of unobserved qualities on the price (Ohta & Griliches, 1976). Ohta & Griliches (1976) confirm that physical car characteristics like horsepower, weight, and lengths have a significant effect on used car prices. Purohit (1992) empirically shows the different depreciation patters of different car sized or segments, conforming that smaller cars depreciate faster when ageing than larger cars that have a more constant depreciation Dexheimer (2003) applies the hedonic pricing method to study the depreciation effects of 16 different brands on the residual value of cars.

Halonen (2008) analyzes in his paper the brand effect in residual car value in Finland. Results show that there is a significant effect of brand, but also “significant difference of the age and kilometers effect on residual value between brands” (p. 11). These results are in line with aforementioned differences in depreciation trends between car models, but also between segments, and cars in general where some hold their value better than others. According to Schiraldi (2011), like Prieto et al. (2015) diesel cars have a positive significant effect on the residual value as “it captures the increasing utility over time to buy diesel cars” (p. 281). Prieto et al. (2015) apply a hedonic pricing method on used car prices and include prospect theory to analyze differences in car prices. They find that the engine power cruise control, air condition, and metallic paint have a positive influence on the residual value of cars, whereas white and red have a negative influence on the residual value (2015, p. 211). According to them diesel cars have a positive influence on the resale value of cars.

2.4. Macroeconomic characteristics

Some authors include macroeconomic determinants in their analysis the residual value of used cars. However, results show rarely significant results. Holweg & Kattuman (2006) test five macroeconomic variables as controls for the analysis on the residual car value, including the GDP growth rate, the unemployment rate, the real estate index, exchange rate and the oil price. Results show constant and significant results for the oil price, which is a small negative effect on the price and a small but positive effect of the real estate index. Nau (2012) analyzed the effect of the monthly unemployment change on the residual value which shows negative but no significant results. Other variables included like GDP, price adjustments, monthly petrol prices and EURIBOR interest rate showed no significant results on the residual car value (Nau, 2012).

Purohit & Desai (1998) hypothesize in their article that “a jump in off-lease vehicles could drive down the value of used cars” (p. 21). Copeland et al. (2005) state that an increase in cars coming back from lease contracts, it will decrease the selling price of those cars. Moreover, Hughes et al. (2015) stated that the quantity of cars sold influences the residual value as “an increase in new-car sales will lead to a higher supply of late models (…) and more supply will lead to depressed used-car prices” (p. 3). Research showed that a decrease in new car prices results in substitution effects between new and used cars, as new cars become more attractive due to decreased prices (Hughes et al., 2015).

Prieto et al. (2015) show that the geographical situation of dealerships where cars are sold has a significant effect on the price of used cars as well. Because of non-significant results of macroeconomic indicators in most studies, those indicators will not be included. However, there are two car taxes in the Netherlands, the BPM and the bijtelling, which will be included in the analysis. Moreover, the quantity of cars sold will be included as a control variable to see whether the number of cars being sold in one month's influences the actual residual car value. In order to capture seasonal trends and/or to deal with exogenous variables many authors applied fixed year or months effects. Holweg & Kattuman (2006), Ohta and Griliches (1976), and Purohit (1992) use year effects by applying year dummy variables. Nau (2012) captures seasonal trends in the selling prices by applying monthly dummy variables

3. Methodology

3.1. Method

This paper analyzed the effect of the model life cycle on the residual car value in a Dutch Leasing Company, using sales data for the years 2006-2016. Analyzing sold cars during those 11 years, allows to study at least one full model life cycle of cars, including at least one but up to four generations of car models.

Purohit (1992) analyzes the dynamic relationship of the depreciation of used cars with changes applied in new cars. He uses data from NADA on high car sale models, which includes 57 different models sold between 1976 – 1988, dividing them into eight segments. The author applies an OLS fixed-effects model, transforming the data with the Prais-Winsten method to account for autocorrelation, with a log linear transformation.

Pierce (2012) examines the limits of knowledge sharing in the car leasing industry, pointing out conflicting interests of managers and manufacturing firms in setting the residual value. Pierce used data from 180.000 California lease contracts between 1997-2001, applying an OLS fixed-effect regression using the estimated residual value as the dependent variable. Although, the author applied different independent variables, he included three which relate to the model life cycle. First, he measures with one variable the number of days until a redesign is introduced, second, he applies a dummy variable which is equal to 1 if the redesign is major, and 0 if otherwise, and third, he uses a dummy variable which is equal to 1 if the car is in its first design year (Pierce, 2012).

Prieto et al. (2015) analyze the price differences of used cars with a hedonic pricing model to test whether prospect theory holds in the used car market. They use data of 1735 French used car ads, which represent the four most sold cars, having price data between January to March 2012. Including various car characteristics variables, their study shows how different car characteristics effect the residual value. To test the relationship, Prieto et al. (2015) use a semi-log simple hedonic pricings regression and a two-stage least square regression (TSLS).

Therefore, this research is conducted by applying a multivariate, OLS regression analysis with fixed year effects which is similar to those of Pierce (2012) and Purohit (1992).

Purohit (1992) applied OLS regression with a time fixed effect as well, transforming the variables with a log transformation. According to him the advantage of log is that is “its simplicity, its robustness, and its ability to approximate more complicated, unknown functions” (p. 159). Time dummies account for the effect of exogenous variables, such as variations in gas prices, insurance and income over time. Pierce (2012) uses OLS fixed effects regression as well. With the fixed effect model, Pierce can consider between the effects of time, car models and manufacturers. The variation will be captured by the dummy variable. Glue et al. (2017) used a different model, however, they also included the time effect as a variable. The reason behind opting for this is that “prices are influenced by general market conditions” which can be captured by including a time variable (p. 1206). Including a fixed effect in the regression will allow me to capture the effect of possible omitted variables.

Before applying a multivariate regression five assumptions have to be checked (Hair et al., 1998).

Firstly, the linearity assumption states that the dependent variable needs to have a linear relationship with all of the covariates. Dummy variables are excluded from this assumption. In this study, the dependent variable will be transformed based on the natural logarithm as it shows the best fit (Hair er al., 1998).

Secondly, the expected value of the error terms has to be 0. The variables need to be normally distributed, this assumption is best tested with a histogram for each variable. If the skewness remains to be a problem then the variables will be transformed for example with the log transformation to fit it into a normal distribution (Hair et al, 1998).

Thirdly, the homoscedasticity assumption can be tested with a scatterplot, plotting the standardized predictors on the x-axis and the standardized residuals on the y-axis. The plot will show if there is a tendency in the error terms or not. If they have the same variance with each other than the analysis can be continued, if not than a logarithmic transformation can be applied Hair et al, 1998).

Fourthly, no autocorrelation assumption argues that the residuals need to be stationary, and no time trends can be accepted. This means that the residuals need to be independent. With a scatterplot with time on the x-axis the independent assumption can be measured (Hair et al, 1998).

Lastly, the independent variables cannot be collinear with each other, multicollinearity can be checked with the VIF indicator. A VIF of less than 5 is considered as an appropriate degree of multicollinearity. A VIF between 5 to 10 is considered as grey zone, some scholars argue that it is still acceptable others disagree. However, the former supporters argue that with primary/observational data (not studied in an experiment) there is almost always a relationship between the independent variables. If multicollinearity is considered too high than the variables can be excluded from the analysis (Hair et al., 1998).

3.2. Model Specification

As has been mentioned above, the method chosen in this research is the OLS fixed effect regression which is used by Purohit (1992) and Pierce (2012) with minor deviations. Model 1 measures the residual value of cars based on the model life cycle, which is referred to as the registration year. If the model is registered in the year of its introduction, that year will be registration year 1 which indicates the beginning of the life cycle. Model 2 can be seen as an additional analysis, to test whether the bijtelling has a negative effect on the residual car value.

3.2.1. Regression by Registration Year (Model 1)

Based on the literature on determinants of residual car value, and the studies which applied the model design in their analysis two regression models are set up. The first regression, from here on referred to as Model 1, intends to measure the effect of the model life cycle of cars on the residual value (H1a and H1b). According to expectations, we assume that with increasing design age the residual value decreases, that means that a lower residual value in reference to the first registration year is expected. Therefore, I will divide each car model into registration year 1 to registration year n. Registration year is an indicator of where the model is in its model cycle. Where registration is equal to the year the car was first registered. Another definition for registration year would be model year. For example, the 1X_4.0 was introduced in 2009, therefore, registration year 1 is equal to 2009, registration year 2 is equal to 2010, and so on.

$$lnRVP_{act,i,t} = \alpha_0 + \beta_1 Age_{i,t} + \beta_2 Mileage_{i,t} + \beta_3 Fuel_i + \beta_4 BPM_{i,t} + \beta_5 kW_{i,t} + \beta_6 Quantity\_Sold_{i,t} + \beta_7 Reg\_Year_{i,t} + \beta_8 Time + \varepsilon_{i,t}$$

Where *i* corresponds to the specific car model at time *t*. The dependent variable is transformed at the natural logarithm as it shows a better R^2, and improves the linearity assumption. Model 1 is an OLS regression with two variables measuring the physical depreciation of cars. Age, which is defined in the contract duration measured in months. Mileage, which is the total kilometers the car has driven since its first registration. Fuel is an indicator variable which is equal to 1 if the car is a diesel, and 0 if otherwise. This variable captures different depreciation trends between the engine types. Engine power (kW) is a car characteristic which represents the strength of the engine. BPM will be applied to measure the effect of the tax charge on the car, which depends on the CO_2-emission of the car. The variable registration year is a dummy variable which measures the model life cycle of the car. If the car is registered in its first year of introduction, the indicator variable registration year 1 is administered to that model. If the car is being registered for the first time after a year since the model introduction, then the indicator variable registration year 2 is administered.

3.2.2. Regression by Year Sold (Model 2)

With the second regression model, from here on referred to as Model 2, it is intended to see whether the amount of bijtelling charged to a car has an influence on the residual value. According to the literature, the number of cars being sold has a negative influence on the residual car value. The time period in this regression is 2012 to 2016 due to the fact that no data for the bijtelling variable no data is available before 2012.

$$lnRVP_{act,i,t} = \alpha_0 + \beta_1 Age_{i,t} + \beta_2 Mileage_{i,t} + \beta_3 Fuel_i + \beta_4 BPM_{i,t} + \beta_5 kW_{i,t} + \beta_6 Bijtelling_{i,t} + \beta_7 Quantity\_Sold_{i,t} + \beta_8 Car\ Model_{i,t} + \varepsilon_{i,t}$$

Where *i* corresponds to the specific car model at time *t*. The dependent variable is transformed at the natural logarithm as it shows a better R^2, and improves the linearity assumption. Model 2 is a multivariate linear regression that includes, like Model 1 variables that represent the physical depreciation, car characteristics, but also macroeconomic indicators like the BPM and bijtelling tax.

3.3. Data Variables

3.3.1. Dependent variable

The dependent variable applied in this research is the residual value percentage (RVP). This variable is calculated based on the actual selling price that is paid for the car at auction, adding the *waarde vermindering* to the selling price. The *waarde vermindering* is the amount of repair, like scratches or smaller bumps, when the car is returned at lease end. After adding this amount to the actual selling price, the amount is divided by the list or consumer price. This list price corresponds to the price at the beginning of the lease contract. Adjusting the prices for inflation prior to the analysis allows to include one less variable.

3.3.2. Independent variables

In order to be able to make judgements about the model life cycle of cars I need to know to which generation the cars belong, and whether it is a new or facelift version. This will be done by deriving for each car model the VIN code. The VIN code is the serial number for a specific car that includes information about the manufacturer, model year, model type, factory region and a serial number. An example for the VIN can be seen in Table 1.

TABLE 1 VIN CODING

Digit	Definition	Code	Meaning
1-3	Region, manufacturer, vehicle type	[1]	
4-6	Fill in	ZZZ	/
7-8	Model type		
9	Fill in	Z	/
10[2]	Model year	9	Model year 2009
11	Factory region	P	Model, Germany
12-17	Serial number	410615	Serial number

With the VIN number, I can give each car its model year and model type. With that information, I know in what year the car was build and to what generation it belongs. A drawback for the VIN number is that not all include a specific upgrade or facelift coding in the model type number. For example, the Model 1X introduced in 2009 has the coding …[2], whereas its facelift that was introduced in 2014 is defined with the code ….[2] With the model code, I can categorize the car into model year and generation. For cars where the model code is the same over a facelift or two generations I will rely on the one hand on the model year (when the car was build) and on the other hand on information based on car specifics like engine size or specific equipment lines. For example, for a lot of cars new engine sizes are introduced with the facelift versions. For example, a 1.2 TDI is replaced by the 1.4 TDI in the facelift version. In Appendix A to C, there

[1] Hidden due to confidentiality.
[2] Hidden due to confidentiality.

are three tables for each segment which includes all car models that are included in the analysis, with their specific introduction year and model coding. The top row is the model name of a given car *i*, where .1 means that the car is the facelift version.

In order to measure the effect of the MLC on the residual value, the cars will be attributed to the model life cycle based on the registration year. The registration year is, as the name suggests, the year in which the car is first registered. Therefore, a car model which is introduced to the market and becomes available for lease in year X, will be administered to registration year 1. Cars that are attributed to registration year 1, are cars which are in their first model design year. Cars that are already for one year on the market, whose model design is already one year old, are administered to registration year 2.

The independent variable age will be measured in months, and defines the lengths of the leasing contract. This will be measured in excel by defining the months between the starting date of the contract end the end of the contract. Mileage is defined as the kilometers a car has driven. It refers to the physical depreciation of the car which shows how much the car has been driven during its life time measured in kilometers.

Fuel

As the residual value of cars can change according to the type of fuel the car has I will add dummy variables for the petrol (EUR 95) and the diesel (DSL) cars. Diesel cars are usually driven for a longer period which could also influence the price development. Furthermore, diesel prices are much lower than petrol prices which can also have an influence on the price development of cars. With the inclusion of the dummy variables fuel type I can distinguish between the two and see whether depreciation shows different trends for a diesel.

Engine power, measured in kW is another variable implemented in the analysis. It will be interesting to see if cars with more power have an increasing or decreasing effect on the residual car value. Furthermore, one can draw conclusion if this differs between the segments or not. More power is also associated with higher fuel consumptions, making the cars may be less attractive to the customer.

Taxes

BPM is a tax that is related to the CO_2 emission of cars and the fuel type. The more inefficient the car is, the more taxes are charged to the car. Bijtelling is another tax that is related to cars that care company cars but used privately. If a private person drives more than 500km with its car in a year the tax will be charged. It is also higher for less efficient cars. Information on the bijtelling tax are only available from 2012 to 2016, which is why they will not be in Model 2 for years before 2012.

In order to see whether the car market has an influence on the selling price of cars, the quantity of cars being sold per months is included in the analysis. It is expected as mentioned in the hypothesis, that increasing numbers of cars being sold will decrease the price of the used cars.

Table 2 summarizes the variables implemented and gives a short definition of those.

TABLE 2 DEFINITION OF VARIABLES

Variables	**Definition**
Dependent variable	
RVP_{act}	Selling Price, including BTW and repair costs[3] divided by the List Price
Independent variable	
Age	Actual contract duration in months since the car was registered
Mileage	Total kilometers the car has driven
Fuel (diesel (DSL) as reference variable)	Dummy variable; if diesel (DSL) = 1, then petrol (EUR95) = 0
kW	Engine power in kilowatt
BPM	CO_2 and fuel type related tax charge, in €
Bijtelling	Tax charge for business cars that are used privately, dummy variable, if 14%=1, else 0, if 20%=1, else 0, if 25%=1, else 0
Quantity_End	The number of cars sold per months
Reg_Year	Year of introduction since car has been introduced, 1= introduction year 1, 2= one year after introduction, and so on, dummy variable which equals 1 for a given car model m at time t that was registered in year n, where n start
Car_Model	Indicating the model type, generation, and model cycle; Dummy variable which equals 1 for a given car model *I* at time *t*
Year	Dummy variable for time, t = 2006,…,2016
$Quarter_t$	Dummy variable for time, t=Q1,…Q4
$Make_m$	Dummy variable which equals 1 for a given car brand *m*
Model	Dummy variable which equal 1 if the car is a modern model, and 0 if the car is a facelift

In this section, variables applied in previous papers on residual car value will be described and their findings, if significant, will be discussed.

One of the first streams of literature on residual car values in the application of the hedonic pricing method to the car industry. Hedonic pricing method was first applied to the housing industry to measure the quality effects of housing criteria on the price. Griliches (1961) was one of the first authors to apply this method by analyzing how quality changes applied to automobiles

[3] Adjusted for inflation

influence new, as well as used car prices. His method is a regression, applying the semi-log to the "price to the absolute values (…) of the qualities" (p. 175). His dependent variable is the suggested retail market price at the beginning of the model year, not accounting for possible discounts granted by retailers, due to lack of data availability. Numerical quality variables applied in this study are horse power, shipping weight, and wheel-base length. The second set of quality variables include dummies, which take the value of 1 if it applies, and 0 if otherwise. Those dummies include if the car has a V-8 engine, hardtop, automatic transmission, power steering, power brakes, and whether it is a compact or not. According to his findings, horse power is significant and positive, but varies in magnitude over time, whereas length is not significant. Cars with a V-8 engine are significantly negative indicating that they are cheaper to comparable cars. Hardtop cars have always a significantly higher price, nut automatic transmission shows no consistent results (Griliches, 1961). Tomat (2002) revisited the hedonic price index applied by Griliches in 1961, between the years 1988 – 1998, having a total of 14 042 observations. The author applied the same variables in her model, adding the quality dummy variables of sunroof, driver´s airbag and passenger´s airbag to the analysis. Her findings were consistent with those of Griliches (1961).

Purohit (1992) applied in his research horse power, but as the percentage change between a car model and its predecessor. Findings were only significantly negative for the predecessor in two car segments, however. Age, measured in years, shows a negative effect in the first years, becoming stronger in later years. Furthermore, Purohit (1992) applies dummy variables that take the value of 1, in cases where a car experiences a minor or major styling change, is downsized or on a new platform. Findings suggest that those cars that are being discontinued experience enhancement effects, but cars on new platforms have no effect at all.

Glue et al. (2017) measure the model cycle, referring to it as model age, by the difference in time when the model was first introduced or launched on the new market and the time of the selling, once the car is returned form the lease contract (p. 1206).

Pierce (2012) uses various numerical and dummy variables on the residual car value. For example, he differentiates between trucks and SUV, and other cars, whether it is a captive lessor or not, if the car had a major redesign, and if it is in its first design year. Numerical variables include the new prices of cars, duration of the lease contract measured in months, the model market share, days until a redesign is introduced, the number of cars in the portfolio, and the number of cars per model year.

Prieto et al. (2015) use variables which define the physical depreciation of cars, like vehicle age measured in years, total mileage in kilometers. Other variables included are engine power, the asking price, and whether the car is a diesel or not. To see the effect of car characteristics like car segment, color, and extras they apply a number of dummy variables which equal 1 if it is applicable and 0 if otherwise. Those variables include four segment types, dividing cars into colors such as blue, red, green, brown, and white. In order to analyze the effect on the residual value of extras, they look at the prices of cars which have metallic paint, ABS, cruise control, AC and navigation. Furthermore, they distinguish with dummy variables between the regions where the cars are sold, to see for geographical effects on the residual value. According to their findings diesel cars have a positive influence, such as horse power, metallic paint, AC, navigation and cruise control. Regarding the effect of color, black has the strongest positive effect on price, and green the strongest negative effect.

Brockman & Mu (n.d.) analyze the reputation of car dealers for used market based on asymmetry information, applying an OLS and logistic regression on dealer-to-dealer transaction prices. The authors apply various variables, numerical and indicator variables. To capture the physical depreciation of used cars they test the variables, age of the car (defined in years) and mileage (total kilometers a car has driven at point of sale). Both variables are significantly negatively related to the price. In order to test the reputation, the authors show how the lack of information about a car has a significant negative effect on the price. Moreover, negative disclosure, low volume of cars being sold, and the lemon problem show significant negative results on the price. Compared to other studies on the residual car value, Brockman & Mu (n.d.) apply a monthly price index which captures the demand and supply situation of the used car market, which shows positive and significant results.

Halonen (2008) studies the residual car value on the Finished used car market, estimating a functional form based on the brand effect which estimates the residual value as a percentage of the list price. He uses only cars that have an age of 36 months and total mileage of 90 000 km. His results show that brand has a significant effect on the residual value, where used prices vary not only between brand, but show also different effects based on mileage and age. That is, he proved statistically that some brands hold their value better as they age than other brands (Halonen, 2008).

Holweg & Kattuman (2006) analyze the dynamic relationship between the new and the used car market, showing how incentives in one market have an effect on the other market. The authors test three propositions; sales incentives in the new market have an immediate effect on the residual value in the used market, sales incentives in the new market have a lagged effect in the used market on the residual value, and shorter life cycles have a negative effect on the residual value in the used market. In order to test their hypothesis, the authors apply a GLS and OLS regression method. Holweg & Kattuman (2006) applied a variable measuring the discount granted on new cars as the percentage which has significant negative results. Moreover, they tested the effect of the age of the car design which is also negative and significant. Moreover, introduction of a new model to the used market has a significant positive design, showing an obsolesce effect for predecessor models that are already available for a longer time. Controlling for macroeconomic variables like oil price, exchange and interest rate, GDP, unemployment rate as a percentage, and the real estate index, only the latter has a significant and positive effect (Holweg & Kattuman, 2006).

Nau (2012) analyzes the determinants on residual car value by applying an OLS regression with lagged independent and depended variables. In cases where serial correlation is present, an ARMAX regression is used, without a lagged dependent variable. As the dependent variable Nau (2012) takes the residual value percent, by dividing the used car price of a car by its MSRP of the year it was first registered in. In order to control for the economic situation of potential buyers, the author considers the EURIBOR rate, oil price fluctuations, the GDP, the price adjusted quarterly spending, and the monthly percentage change in the unemployment rate. None of those variables, however, show significant and consistent results. A variable which captures the effect of the supply side, is the trading volume variable, which it set up as the number of cars that change owners (Nau, 2012). Applying two dummy variables, Nau (2012) measures the effect of the model life cycle on the residual car value by indicating a 1 to cars which belong to the given model life cycle, and 0 if otherwise. The second dummy refers to whether or not the car is a facelift. Results show that the modern variable is significantly negative which proves that cars lose value the longer their model life cycle. Other variables, like the number of cars that change ownership, and the trade volume show significant positive results, however, not for all models under analysis.

3.4. Data

The data for the analysis is extracted from the excel files at the leasing department containing information about the sold cars. For each year the leasing department has a file of data on the selling of leased cars. As the time frame of this analysis is 2006 to 2016, excel files for the 11 years have been merged. Having the data on for the time frame merged results in a data set of over 65.000 passenger cars. The files contain various information. Administrative information like object code, contract and license plate number. Information about the party who leased the car and who it was sold to at auction. Furthermore, information about the odometer of the car is given. This is important as only new cars will be considered. Moreover, the starting data and end date of the lease contract are given, which is needed to calculate the actual contract duration in months. Total mileage in kilometers was a given variable. Two columns referred to the make and the car model. The car model did not distinguish between the model generation, only for the 1Z it is indicated whether it is the fifth, sixth or seventh generation. Therefore, data on the VIN number had to be extracted from leasing department or online matching it with the license plate for each car. With the VIN number the model code and therefore the model generation can be seen. This is important in order to distinguish between the car model generations. Data is also available for the estimated residual value in euros and the actual residual value in euros including the BTW (the latter is used for calculating the RVP). The cars´ list price is given including the BTW with and without options. Another column provides information on the *waarde vermindering* which is the amount of damage the car has after it is returned from the lease contract. One column differentiates between the different engine types (diesel, petrol and so on).

3.5. Sample

The first decision that had to be made included which car brands to use. Here the decision rests on Make 1[4], Make 2, Make 3, and Make 4. These car brands are the most representative with a high number of leasing cars in the system. Next to deciding on which brands to choose I have to

[4] The car brand and model name of the cars have been changed due to confidentiality. The name of the Models is composed of number 1 to 4 indicating the brand, followed by X, Y, or Z indicating to which segment they belong. The last two digits indicate to which generation the car belongs, where .1 indicates the facelift version.

decide on the car models. Here I decided to focus on three car segments, which are defined as compact, middle, and higher segment. For the compact segment, I will use the 1Z, 2Z, and the 3Z. For the middle segment, I will use the 1Y, 2Y, and 3Y. Lastly, the higher segment includes the 1Z, 2Z, and 4Z. Those were the cars with most leasing contracts. The argument for analyzing each car model separately is explained by Wykoff´s (1970) findings who confirmed his hypothesis that different car segments have different depreciation patterns. As the fuel type's petrol (EUR 95) and diesel (DSL) are the most representative fuel types I disregard hybrids, electrical, and plug-in cars.

Having made the selection for brand, car models, and segments, the cars need now to be further selected based on the following criteria, running time, list price, selling price and total kilometers. Some cars have a selling price of less than 100 euros. These are cases where company cars are taken over internally, and will be neglected for the analysis. When the cars will be returned at lease end, they are checked for damages like scratches or bumps. Those damages are called *waarde vermindering*. This amount will have to be added to the selling price before the analysis can be done. A repair costing more than 3.000 euros will be excluded from the analysis, as according to Company A this damage is considered too high for not effecting the selling price. Cars with an actual residual value percentage of less than 5 percent and more than 95 percent will be neglected from the analysis. After a pre-selection, the selling price and the list price are both adjusted to inflation, and the residual value percent with inflation adjusted prices is calculated. Moreover, I will disregard cars that have a duration (age) of less than 12 months and more than 72 months.

In the following table the criteria for the sample selection is summarized.

TABLE 3 SAMPLE SELECTION CRITERIA

Criteria	
Type of car	Passenger cars only
Brand or Make	Brand 1, Brand 2, Brand 3, Brand 4
Segments	Compact X, Middle Y, Higher Z
Cars in compact segment	Model 1X, Model 2X, Model 3X
Cars in middle segment	Model 1Y, Model 2Y, Model 3Y
Cars in higher segment	Model 1Z, Model 2Z, Model 4Z
Beginning Odometer	<500km
Contract Duration	>12 monnths and <72 months
Engine Type (Fuel)	Diesel and Petrol
Waarde vermindering	<3000€
RVP	>5% and <95%
Selling Price	<100€

4. Analysis Model 1

In order to analyze whether the model life cycle of cars has an influence on the actual residual value of cars, I conducted a regression analysis per segment and car model that studies the residual value of cars based on its registration year. Where the registration year is equal to the design age of the car model. This model will analyze whether models with increasing design age experience increasing a negative effect on the residual value with time (negative coefficients). This is a reflection of the model life cycle of cars, as it is an indicator of the model age. With the market introduction of a car model, the car is new, however, as time passes its design becomes older, more technical and design advanced models are on the market. Therefore, the expectation is that as the model cycle continues and the car model design becomes older, its residual value will be lower.

Due to the higher number of descriptive and correlation tables in the analysis, only for the compact segment the descriptive statistic table and the correlation matrix is presented in the text. For the middle and higher segment only the regression result tables are shown. However, a short description on the descriptive statistics as well as the correlation matrix is given, whose tables can be found in Appendix F starting on page 65.

4.1.1. Compact segment

4.1.2. Descriptive Statistics

Table 4 reports the descriptive tables for the compact segment between 2006 and 2016. Looking at the table one first notices two different numbers of observations, which is due because for the variable kW information was not available for all cars. The mean selling price for cars in a compact segment is around … €[5], or around ...%[6] in actual residual value. The average car in the compact segment has a mean list price (including options and BTW) of around 18 500 €. With a mean contract duration of ...[6]months the average car has a standard contract duration. Considering the mean contract duration of … [6]months, the mean total kilometers of …[6]appears to be a bit higher, suggesting that the annual mileage corresponds to around …[6] km per year. The 0.5398 for

[5] Confidential information.

the diesel variable can be interpreted as a percentage, saying that 53.98 percent of the cars in this sample are diesel cars.

TABLE 4 DESCRIPTIVE STATISTICS COMPACT SEGMENT C1, FULL SAMPLE

	Full Sample				
	N[6]	Minimum	Maximum	Mean	Std. Deviation
Selling Price[6]					2327,63
List Price		10290,04	34921,97	18658,41	2406,41
RVP[6]					12,65
kW		40,00	180,00	66,53	15,32
Age[6]					12,95
Mileage[6]					43986,36
BPM		0,00	8225,00	2543,19	2017,113
DSL		0,00	1,00	0,53	0,498
Quantity[6]					

All variables are defined in Appendix E

Appendix F shows Table 13 for the descriptive statistics of the sub-samples in the segment (see page 62). The mean selling price for the car models is between …[6] € and ...[6] €. One can notice, that for all car models, beside the latest 2X_2.1 facelift the list price increased for each model. The actual residual value percent for the cars appear to be quite similar, however, the 1X-4.0 stands out. There is quite some variation in the total km, ranging from …[6] km to over … [6]km. Furthermore, the distribution between diesel and petrol cars is not quite similar for all the car models. For the maximum mileage, it appears as if there are still outliers in the final data set, however, this is not the case, as those cars with really high amounts of total mileage correspond to cars with the lowest actual residual value of 5 to 10 percent.

The descriptive Table 14 for the middle segment can be found in Appendix F. Cars in this segment are sold for an average price of …[6] € and have an average list price of 28 500 €. In residual value percent, this is equal to around …[6] percent. Compared to the compact segment, cars in the

[6] Confidential information.

middle segment have more engine power, with a mean kW of 90. The average contract duration of leasing cars in this segment is around …[7]months. The leasing cars that are returned at the end of their contract have average total kilometers driven of around …[7] km. The middle segment is evenly split between diesel and petrol cars.

Regarding the descriptive statistics for the sub-samples in Table 15 a noticeable difference between the selling prices of the models, it that the 1Y_6.0 has the highest selling price with around …[7] € and the 3Y_1.1 has the lowest selling price on the market with around …[7] €. Looking at the actual residual value percent, the 1Y_6.0 appears to retain its value on the used market best, followed by the 3Y_2.1.

Descriptive statistics for the higher segment can be found in Appendix F, Table 19 as well. With a mean selling price of …[7] €, and a mean list price of around 38 000 € cars in this segment have an average actual residual value percent of …[7]%. The mean engine power is a bit higher than it is for the middle segment with 108 kW. The mean duration of lease contract in the higher segment is …[7] months, in which cars have an average of …[7] kilometers on their odometer. With more powerful engines and a higher portion of diesel cars the BPM tax in this segment has a mean of 9 000 €. The portion of diesel cars for this segment is 63.74 percent.

In Table 20 it is noticeable that the 4Z has the most expensive list price, followed by the Model 1Z. The selling price between the car models differs as well, with the 1Z_6.0 having the lowest residual value (…[7] €), and the 4Z_8.0 facelift having the highest residual value (…[7] €). This is reflected in the actual residual value percent as well, where the former has a value of …[8] percent and the latter a value of …[7] percent. One can see that with each new model, the average engine power (kW) increases. The mean duration of lease contracts is more or less the same for all car models (…[7] months to …[7] months), only the 4Z_6.0 has a longer contract duration on average, which is around …[7] months. The average car returns from the lease contract with a total mileage of more than …[7] km.

It is difficult to compare the descriptive mean statistics with prior studies due to the following. Firstly, this study is unique in the way that it defines the cars based on segments and analyzed each segment separately. Other studies implement dummy variables for segment type,

[7] Confidential information.

for example luxury, middle and higher class (Holweg & Kattuman, 2006, Pierce, 2012). Only Purohit (1992) divides its sample into different segments as well. Therefore, the cars are much more diverse, including lower and higher class cars. Secondly, studies of Prieto et al. (2015) and Brockman & Mu (n.d.) make use of cars that are much older when being sold. With a mean car age of 5, 67 years (Brockman & Mu, n.d.) and 6, 78 years (Prieto et al., 2015). Interestingly, the study of Prieto et al. (2015) have a total mean mileage of 99 755 km, whereas that of Brockman & Mu (n.d.) is much lower with 68 979 km. Compared to cars in this research, cars in their sample had a much lower annual mileage. For instance, cars in the compact segment that are three years old when sold already have a mean mileage. The difference can be seen in engine power as well, where the analysis shows a mean engine power of 66, 90, and 108, whereas the mean statistic in Prieto et al. (2015) is 101.

4.1.3. Pearson´s Correlation

Pearson´s correlation in Table 5 is conducted in order to test for multicollinearity between the variables that could potentially harm and bias the analysis. A correlation of > 0.7 regardless of the sign (- or +) is considered as multicollinearity and therefore, a threat to use in the analysis. Although, some of the variables show significant correlations with each other, only age and total km are quite high with 0.519. This positive relationship is explained by the fact that older cars most likely have more kilometers driven. Also, the positive correlation between diesel and total km (0.394) seems plausible, as diesel cars drive for longer periods and therefore have more kilometers. The correlation matrix shows no serious indications about the threat of multicollinearity therefore, the regression analysis can be conducted with the variables.

The correlation matrix for the middle and higher segment can be found in Appendix F, Tables 16 and 21 respectively. Both matrices show similar correlations between the variables with the compact segment. The correlation between age and mileage is the highest (0,532 in Table 16 and 0, 481 in Table 21). Furthermore, the correlation between mileage and diesel is significantly positive (0, 428 in Table 16 and 0, 438 in Table 21). There is a positive correlation between BPM and diesel (Table 16 = 0,492, and Table 21 = 0, 221).

All three segments show correlations with the dependent variable (ln_RVP) that are similar in sign and significance. The variables age (between -0,579 and -0,684) and mileage (between -

0,635 and -0,641) show the strongest negative relationship with the dependent variable. The relationship between diesel and RVP is negative, but the relationship appears to be stronger in the compact segment (-0,327 compared to -0,279 and -0,219). A reason behind this is that diesel cars are not that popular in the compact segment which is due to the higher costs associated with owning a diesel. Engine power is the only variable with a positive relationship, which is 0,104, 0,137 and 0,176 respectively. Although mileage and age seem to explain most of the effect on RVP, diesel, BPM and engine power have an effect as well, though it is much smaller.

TABLE 5 PEARSON´S CORRELATION MATRIX COMPACT SEGMENT, C1

	lnRVP	**Age**	**Mileage**	**DSL**	**BPM**	**kW**
lnRVP	1					
Age	-0,579**	1				
Mileage	-0.635**	0,519	1			
DSL	-0.327**	0,117**	0,394	1		
BPM	-0,106**	0.007	0,016	-0,286	1	
kW	0,104**	-0,029*	-0,013	-0,099**	-0.321	1

** * Correlation is significant at the 0,01 and 0,05 level respectively
All variables are defined in Appendix E

Comparing the correlations with Prieto et al. (2015) the correlation of kilometers and age show the same sign (-0, 593 and -0,782). In contrast to this research, the correlation between price and engine power is higher (0, 525). The correlation between the dependent variable and diesel the signs are different. Whereas in this research the correlation is negative (-0,327), it is positive (0, 277) in Prieto et al. (2015). The reason for this difference, however, is that diesel cars in France are much more popular than in the Netherlands.

4.1.4. Regression results

This section gives the regression results for the compact segment. First, the Table 6 presents the results for the compact segment, followed by Table 7 with results for the middle segment, and lastly, Table 8 presenting the higher segment results.

Recalling the hypothesis stated in the literature review chapter, it is expected that the model life cycle (MLC) of cars has a negative effect on the residual car value. Moreover, it is expected that this effect becomes even higher as the model passes through its MLC. This means that one would expect an increasing negative coefficient as the car model design becomes older. The longer the model is already on the market, the older its design becomes, and the lower its residual value is expected to be. Therefore, the variable of interest to answer the hypotheses is the registration year variable, which should be significantly negative, and with increasing negative effect with higher registration years.

What can be seen in the analysis is that only the 1X_3.0 and the 3X_2.0 show the expected significant negative coefficients. Compared to the second registration year (reference year in case of the 1X_3.0), cars of the 1X_3.0 that are already two years old, their value is 6,7 percent lower than for those cars which are only one year old (-0,067**). Looking at the following year, cars of the 1X_3.0 which are three years old have an even lower residual value than those cars which were registered when the car model was one year old (-0,076**). Those cars have a 7,6 percent lower value on the auction market already, compared to those that were just one year old. For those models that were already at the end of the MLC, the effect is even higher, (-0,115***). According to the results, cars of the 1X_3.0 whose design is already four years old have a 11,5 percent lower residual value on the auction market compared to the car models that were one year old. In the case of the 1X_3.0 the hypotheses can be confirmed, showing that the MLC has a negative effect on the residual car value, which is increasing in effect as the MLC continues.

The 3X_2.0 shows for two years significant and negative coefficients, however, the last year in the mlc is not significant. Compared to the registration year 1, when the car model was just introduced to the market, cars of the 3X_2.0 with a one year old design made a lower residual value at auction compared to those cars, which were registered in the year the car was being introduced. With a negative coefficient (-0,424*) the effect seems rather big; however, it proves that an older model design perceives already a lower value. This effect is even bigger for cars whose design age is already 2 years old, which receive an even lower residual value on the auction market (-0,459*).

For the 1X_3.1 results are significantly negative for the first three years, however they become positive for the last two years in the model life cycle. Looking at the coefficient results, cars of the 1X_3.1 receive a 5,1 percent (-0,051***) lower residual value at the auction when their model design is already one year old than those where the model was just introduced. Against the second hypothesis, and expectations this effect is not increased for the model, where the design is two years old. Although, the car makes a 4,6 percent (-0,046**) lower value than those cars whose model design was new, this is lower than for cars which were registered when the design was one year old. Cars that were registered when the model was three years old, received at the auction a 2,8 percent (-0,028**) lower value than those cars where that were registered when the design was just introduced to the market. However, unlike hypothesized, cars whose model design is already four years old have a 6,8 percent (0,068*) higher residual value at the end than those cars whose model design was new. This effect is even stronger for cars in the following year, where the model design is five years old, which have a 19,5 percent (0,195*) higher resale value.

For the 1X_4.0 all MLC variables show positive significant regression results. This shows that there is no negative effect of the MLC on the residual car value. Therefore, for the 1X_4.0 the hypotheses are both refuted. For the 3X_1.1 and 3X_2.1, the 2X_2.0 and 2X_2.1 most results on the MLC are not statistically significant, therefore, no conclusion can be drawn regarding MLC hypothesis in those cases.

In this regard, one can see that there is an effect of the MLC on the residual car value, however, this is not supported by all car models that are included in the sector. Results cannot confirm what Holweg & Kattuman (2006) have found, namely that with each year the model design becomes older, the residual value decreases by around 2,5 percent (p. 18).

Regarding the determinant of age, as the contract duration measured in months, one can clearly see a negative effect on the residual car value. The older the car is, or the longer the car is being used, the lower its value will be at the end. It is noticeable, however, that the degree of the negative effect is different for the different cars analyzed in the segment. For example, the highest significant effect of age can be found for the 1X_3.0 (-…***)[8], whereas the lowest significant effect of age on the residual value is found for the 3X_1.1 (-…[8]*).

Concerning the effect of mileage, one can see a significant negative effect of kilometers driven on the residual value. The more kilometers the car is being driven over its lifetime, the

[8] Confidential Information.

lower the residual value is at the end of the lease contract and the lower the value will be when it is sold at auction or on the used car market. What can be seen in the regression coefficients, like for the age variable, is that the negative effect is different for each car model. For instance, the 1X_3.1 experiences the lowest effect of mileage on the residual car value (-0,…**)[9], and for the 3X_1.1 this effect is the highest (-0,…[9]***).

As has been discussed in the literature review, the engine power (measured in kW) is expected to have a positive effect on the residual car value. Looking at the regression coefficients, however, this effect cannot be confirmed by the data. First, only two cars show significant results (1X_3.0 and the 1X_3.1), and second, one of them has a positive effect (0,233***) and the other one a negative effect (-0,106***). Results by Prieto et al. (2015) show positive results for engine power (0,624). Purohit (1992) results are more similar to the outcomes of this regression, although, he measured the percentage change in horse power between the model and its predecessor. As his findings are different between segments, -0,112 and -0,198 in the subcompact regular and specialty segment, a positive relationship can be found in the intermediate specialty segment (0,067).

The BPM variable is included in the analysis to see whether the amount of BPM tax that is charged to a car has an influence on the residual car value. It is expected to be negative in sign. Although the majority shows negative coefficients, only one of them is significant (-0,546***). Therefore, it cannot be said for sure, that the BPM is influencing the residual car value.

The dummy variable fuel measures the effect of the diesel cars on the residual car value. It is expected for the Dutch market, that diesel cars have a negative effect on the residual car value compared to petrol cars. The reason behind this, is that diesel cars are charged with higher taxes (BPM) and the list price for diesel cars is higher as well. The results show that there is indeed a negative effect on the residual value. Only for one car model, the 1X_3.0, the effect is positive (0,228***). For all other cars, the coefficients show a negative sign, where three of them are positive. In those cases, the effect of the diesel on the residual value ranges from (-0,164***) to (-0,650***). On the French market, the diesel has not such tax-disadvantages as on the Dutch market. Therefore, its effect on the residual value is rather positive, which is confirmed by Prieto et al. (2015).

[9] Confidential Information.

Quantity was added to the analysis to capture the demand effect on the residual value. It is expected that the number of cars being sold will lower their residual value. Therefore, the coefficients should be negative. Looking at the results, however, one can only see one negative significant effect for the 3X_1.1 (-0,002*).

Although, not all variables showed significant coefficient results, the adjusted R^2, which is an indicator for the model fit, shows good results. With the variables included the adjusted R^2 ranges from 0,397 to 0,520. Only the R^2 for the 3X_1.1 shows a rather poor model fit in comparison to the others, with an adjusted R^2 of 0,145. Although, other studies have presented the R^2, most have a higher variation that can be explained. For example Prieto et al. (2015) have a R of 0,852. Purohit (1992) shows the same variation in R^2 between the segments as this study shows between the types of models. The author´s model fit ranges from 0,68 to 0,92.

TABLE 6 RESULTS COMPACT SEGMENT, C1

	1X_3.0	1X_3.1	1X_4.0	3X_1.1	3X_2.0	3X_2.1	2Y_2.0	2Y_2.1
Age[a]	-[10] (-13,989)***	- (-22,957)***	- (-12,924)***	- (-1,916)*	- (-1,472)	- (-3,322)***	- (-2,392)**	- (-1,684)**
Mileage[a]	- (-6,902)***	- (-8,006)***	- (-9,702)***	- (-1,954)*	- (-2,127)**	- (-7,662)***	- (-5,077)***	- (-2,747)***
kW[a]	0,233 (2,940)***	-0,106 (-2,504)***	-0,052 (-1,511)	-0,073 (-0,378)	0,043 (0,093)	-0,094 (-0,282)	0,039 (0,238)	-0,106 (-0,526)
BPM[a]	-0,546 (-5,536)***	-0,016 (-0,397)	0,025 (1,425)	0,094 (0,459)	-0,058 (-0,162)	0,082 (0,811)	-0,160 (-1,347)	-0,087 (-0,728)
Fuel	0,228 (4,136)***	-0,164 (-8,491)***	-0,194 (-11,604)***	-0,117 (-1,086)	-0,196 (-1,109)	-0,009 (-0,87)	-0,082 (-1,304)	-0,650 (-4,855)***
Reg_1	n/a	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Reg_2	Reference	-0,051 (-3,280)***	0,070 (3,844)***	0,141 (1,578)	-0,424 (-1,755)*	0,188 (2,700)***	-0,026 (-0,376)	0,093 (0,578)
Reg_3	-0,067 (-2,424)**	-0,046 (-3,085)***	0,123 (4,978)***	0,125 (1,613)	-0,459 (-1,861)*	0,212 (1,697)*	6,625E+5 (0,001)	0,300 (1,859)*
Reg_4	-0,076 (-2,988)**	-0,028 (-1,904)**	0,112 (3,945)***	0,089 (1,075)	-0,428 (-1,565)	-0,096 (-0,458)	0,087 (1,039)	0,165 (1,194)
Reg_5	-0,115 (-3,955)***	0,068 (2,993)*	0,115 (4,450)***	0,030 (0,346)	n/a	n/a	-0,083 (-3,20)	-0,193 (-1,175)
Reg_6	n/a	0,195 (1,756)*	0,187 (6,769)***	0,155 (1,587)	n/a	n/a	n/a	n/a
Quantity	-0,001 (-0,906)	6,962E+5 (0,895)	9,725E+6 (0,100)	-0,002 (-1,320)	0,001 (0,738)	-0,002 (-1,770)*	5,995E+5 (0,183)	-0,001 (-0,993)
Quarter_Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[10] The coefficients age and mileage were hidden for confidentiality.

Constant	10,801 (14,302)***	6,459 (23,609)***	6,142 (34,095)***	5,275 (4,112)***	7,024 (4,600)***	5,883 (4,112)***	8,152 (8,302)***	8,422 (5,801)***
N of Obs[11]								
DW-Test	1,755	1,578	1,673	1,772	2,063	2,342	2,015	1,780
Adjusted R^2	**0,464**	**0,520**	**0,491**	**0,145**	**0,397**	**0,426**	**0,473**	**0,413**

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix E
[a] variables transformed with natural logarithm

[11] The number of observations were hidden for confidentiality.

4.2. Middle Segment

4.2.1. Regression Results

What can be seen in the analysis is that only the 2Y_2.0 shows significant negative coefficients for the MLC variable. However, it is not increasing with increasing model design age. In reference to the residual value of cars that were registered when the car was just introduced, in its first model year, the following years show negative effect on the residual value. In comparison to the cars auctioned that entered the lease contract when they were still new, car models that are one year old in design have a 16,2 percent lower value (-0,162***). This effect increases for those whose model design is already two years old, to a 20,2 percent lower value (-0,202***). For cars, registered when the model design was already three years the effect is lower, but still negative (-0,074**). For cars of the 2Y_2.0 that are already four years old, the effect on the residual value is still negative, however, it is lower than it was for the previous model design years (-0,053*).

Other cars, like for instance the 1Y_5.0, show positive instead of negative coefficients regarding the MLC. For instance, a 1Y_5.0 whose model design is one year old has a positive effect on the residual value compared to the cars which were entering the lease contract when the model was just introduced.

Like for the compact segment, the degree of the negative age effect is also for the different cars analyzed in the segment. For example, the highest significant effect of age can be found for the 1Y_5.0 (-… [12]***), whereas the lowest significant effect of age on the residual value is found for the 3Y_2.1 (-…[12]***). Mileage is consistently negative and significant. For instance, the 1Y_6.0 experiences the lowest effect of mileage on the residual car value (-…[12]**), and for the 3Y_2.0 this effect is the highest (-…[12]***).

The regression results show for two cars significant positive effects of engine power on the residual value, with the 1Y_5.0 (0,079***) and the 3Y_1.1 (0,422). In contrast to the compact segment, the coefficient results for the middle segment on BPM tax show negative coefficients for all car models, and significant negative in four instances. The results show that there is indeed a negative effect of fuel on the residual value, which is significant in five cases. The lowest negative

[12] Confidential Information.

effect of the diesel engine on the residual value is for the 3Y_2.1 (-0,011***) and the highest negative effect of the diesel engine on the residual value of the 2Y_2.0 (-0,091***).

The adjusted R^2 in the middle segment show a better model fit compared to the compact segment, with an adjusted R^2 ranging from 0,416 for the 3Y_2.1 to 0,705 for the 3Y_1.1

TABLE 7 RESULTS MIDDLE SEGMENT, M1

	1Y_5.0	1Y_6.0	3Y_1.1	3Y_2.0	3Y_2.1	2Y_2.0
Age[a13]	- (-36,075)***	- (-27,447)***	(-6,660)***	- (-12,532)***	- (-2,996)***	- (-15,481)***
Mileage[a]	- (-9,007)***	- (-7,389)***	- (-3,591)***	- (-9,073)***	- (-2,449)**	- (-8,041)***
kW[a]	0,079 (2,559)***	-0,002 (-0,083)	0,422 (2,146)**	0,059 (1,436)	0,056 (0,708)	-0,003 (-0,057)
BPM[a]	-0,258 (-7,623)***	-0,098 (-5,668)***	-0,339 (-1,534)	-0,213 (-4,755)***	-0,031 (-0,400)	-0,061 (-1,834)*
Fuel	-0,042 (-2,727)***	-0,088 (-7,924)***	0,011 (0,029)	-0,042 (-2,043)**	-0,011 (-3,059)***	-0,091 (-4,822)***
Reg_1	Reference	Reference	Reference	Reference	Reference	Reference
Reg_2	0,121 (10,881)***	0,008 (0,241)	0,010 (0,239)	0,090 (2,474)**	0,059 (1,128)	-0,162 (-4,716)***
Reg_3	0,071 (5,738)***	-0,012 (-0,312)	-0,053 (-1,347)	0,056 (1,514)	-0,041 (-0,652)	-0,202 (-5,886)***
Reg_4	0,013 (1,065)	-0,041 (-1,041)	-0,124 (-2,496)**	-0,002 (-0,044)	0,014 (0,177)	-0,074 (-2,273)**
Reg_5	0,011 (0,945)	-0,014 (-0,345)	-0,094 (-1,137)	0,031 (0,830)	n/a	-0,053 (-1,726)*
Reg_6	-0,073 (-1,673)	n/a	n/a	n/a	n/a	0,019 (0,639)
Reg_7	-0,082 (-1,986)*	n/a	n/a	n/a	n/a	-0,022 (-0,814)

[13] The coefficients for mileage and age were hidden for confidentiality.

Quarter_Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	8,191 (37,574)***	6,737 (41,316)***	8,157 (5,586)***	8,227 (21,823)***	6,059 (7,389)***	7,258 (23,441)***
N of Obs[14]						
DW-Test	0,814	1,023	1,834	0,746	0,923	0,809
Adjusted R^2	**0,557**	**0,615**	**0,705**	**0,543**	**0,416**	**0,542**

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix E
[a] variables transformed with the natural logarithm

[14] The number of observations were hidden for confidentiality.

4.3. Higher Segment

4.3.1. Regression Results

The MLC has an influence in the residual car value. However, this effect is not negative and significant in all instances. For the 1Z_6.0 results of the MLC are significant and negative, though not significant for the first two years after the design is introduced. However, cars of the 1Z_6.0 show a negative effect of the residual value, which is 4,0 percent lower than for cars that were sold of the model year introduction (-0,040***). Against expectation, the effect for the following registration year is not higher, however, it is still significant with (-0,027**). This negative effect is increased again for the model design which is five years old (-0,053**). The 1Z_7.1 shows for cars where the model design is one year old when registered, a positive coefficient of (0,024**). However, in the following three years they become negative, but only significant for registration year 4 (-0,061**) and year 6 (-0,366**). Car models like the 4Z_6.0 and 4Z_7.0, as well as B8.5 show no significant coefficients of the MLC at all.

For example, the highest significant effect of age can be found for the 4Z_6.0 (-…[15]***), whereas the lowest significant effect of age on the residual value is found for the 1Z_7.1 (-…[15]***). The same holds for mileage, for instance, the 1Z_5.1 experiences the lowest effect of mileage on the residual car value (-…[15]**), and for the 1Z_7.1 this effect is the highest (-…[15]***).

The regression results show for three cars significant positive effects of engine power on the residual value, with the Model 1Z_5.1 (0,110***), Model 1Z_6.0 (0,213***), and the Model 4Z_6.0 (0,148*). The BPM shows in all but one instance significant and negative results, suggesting a negative effect of the BPM on the residual car value. Results in the previous two segments probably lacked significance as the payment for bigger cars is much higher as they are heavier and have higher CO_2-emissions. Compared to the previous two segments, the fuel variable in this segment is expected to be rather positive than negative. The reasoning behind this, is that diesel cars in this segment are relatively less expensive than they are for cars in the compact and middle segment. This is, because the price premium of a diesel engine is more or less the same, no matter how much the list price of the car. However, the regression results show only positive

[15] Confidential information.

significant results in three instances, namely the 1Z_5.1 (0,065***), 1Z_7.1P (0,057***), and the Model 4Z_8.0 (0,020*). Regression results show no relationship between the number of cars being sold (Quantity) and the residual car value. Only for one case, the Model 1Z_7.1 the coefficient is significantly negative, (-0,001**).

The R^2 in the higher segment shows a good model fit, with an adjusted R^2 ranging from 0,493 for the 4Z_6.0, to 0,697 for the 1Z_6.0.

TABLE 8 RESULTS HIGHER SEGMENT, H1

	1Z_5.1	1Z_6.0	1Z_7.1	4Z_6.0	4Z_7.0	4Z_8.0	4Z_8.1
Age[a]	- [16] (-26,628)***	- (-31,224)***	- (-14,850)***	- (-5,773)***	- (-20,387)***	- (-20,797)***	- (-16,480)***
Mileage[a]	- (-6,257)***	- (-16,783)***	- (-20,279)***	- (-5,260)***	- (7,356)***	- (-12,740)***	- (-12,445)***
kW[a]	0,110 (2,496)***	-0,022 (-0,984)	0,213 (4,308)***	0,148 (1,713)*	0,037 (0,807)	-0,013 (-0,435)	-0,007 (-0,273)
BPM[a]	-0,421 (-8,017)***	-0,184 (-8,956)***	-0,053 (-1,247)	-0,503 (-5,773)***	-0,289 (-6,125)***	-0,287 (-9,503)***	-0,094 (-4,473)***
Fuel	0,065 (2,683)***	-0,011 (-1,115)	0,057 (3,486)***	0,041 (1,119)	0,003 (0,185)	0,020 (1,793)*	-0,014 (-1,159)
Reg_1	n/a	Reference	n/a	n/a	Reference	Reference	Reference
Reg_2	n/a	-0,017 (-1,322)	Reference	Reference	0,035 (1,183)	0,043 (2,725)***	0,008 (0,555)
Reg_3	Reference	-0,001 (-0,028)	0,024 (2,446)**	0,078 (1,433)	-0,018 (-0,605)	0,024 (1,461)	-0,019 (-0,624)
Reg_4	0,033 (0,975)	-0,040 (-3,380)***	-0,061 (-2,489)**	0,006 (0,125)	0,014 (0,453)	0,061 (3,363)***	-0,001 (-0,009)
Reg_5	-0,018 (-1,017)	-0,027 (-2,235)**	-0,053 (-1,247)	0,017 (0,329)	-0,026 (-0,619)	-0,016 (-0,646)	n/a
Reg_6	-0,040 (-2,485)**	-0,053 (-4,395)***	-0,366 (-2,472)**	n/a	n/a	-0,222 (-3,132)***	n/a
Reg_7	-0,054 (-3,276)***	n/a	n/a	n/a	n/a	n/a	n/a

[16] The coefficients for mileage and age were hidden for confidentiality.

Quantity	0,001 (0,783)	-3,582E+5 (-0,442)	-0,001 (-2,878)***	0,001 (0,836)	5,030E+5 (0,265)	0,001 (1,471)	5,067E+5 (0,313)
Quarter_Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	9,975 (24,805)***	8,584 (46,754)***	8,289 (31,286)***	11,461 (17,340)***	9,011 (22,383)***	9,263 (35,849)***	7,529 (26,578)***
N of Obs	[17]						
DW-Test	1,958	1,948	1,954	2,082	2,006	1,988	1,993
Adjusted R^2	**0,599**	**0,697**	**0,680**	**0,493**	**0,607**	**0,610**	**0,629**

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix E
[a] variables transformed with the natural logarithm

[17] The number of observations were hidden for confidentiality.

4.4. Robustness Test

Recalling from the methodology chapter Model 1 regression is to capture the effect of the model life cycle on the residual value of cars. In order to do so, the model takes the perspective from cars' registration year. The registration year in this model is equal to the model year, or design age of the car. That is, registration year 1 corresponds to the year in which the car is first introduced to the new market and available for the lease contract. According to theory and experts at the department leasing, car models depreciate more with higher design age. It was hypothesized that next to showing a negative depreciation over the years, that cars also have an increasing depreciation for each additional model year.

Based on the regression results discussed in the paragraphs above, one can see a trend for most cars, which indeed shows that with increasing age cars cannot hold their value as much as in their first years of introduction to the new market. However, only for a limited number of cars the results showed an increasing depreciation effect on the residual car value over the model life cycle. Hypothesis 1 will therefore be rejected, as it does not hold for all cars in the model.

If the coefficients are positive, it means that the hypotheses need to be rejected as the model life cycle shows no negative effect on the RVP: One reason for this can be that the car is valued and demand is high during the whole model life cycle. If customers are satisfied with the technological aspects, the design and functioning of the car, they do not mind driving a car whose model cycle is already old. Another reason for a positive coefficient can be that the number per registration year for the cars is quite high, so that outliers could influence the results. Another reason for positive coefficients could also be that not all cars behave the same. As has been mentioned in articles, for instance in Holweg & Kattuman (2006) some cars retain their value between than others, "models have a differential performance" (p. 18).

A robustness test can be found in Appendix D which confirms the findings of the analysis. This test has been run for the compact segment by excluding the age variable, engine power, BPM and the quantity variable. As engine power and BPM have a rather low correlation with the dependent variable (0,104) and (-0,106) respectively, those variables were excluded. Age was excluded as it shows the highest correlation between two independent variables (0,519). Coefficient results show the same negative or positive coefficients. The results show that the effect of the MLC does not change by using a different model to test the relationship. Regarding the registration year variable measuring the MLC the robustness test supports the results of the main findings showing no constant significant negative coefficients. In the robustness test, the effect of fuel is in more cases significant.

5. Analysis Model 2

5.1. Compact Segment

5.1.1. Descriptive Statistics

Table 8 presents the descriptive statistics for the Model 1X from 2012 to 2016. With a mean total mileage of …[18] and a mean contract length of …[18] years, the 1X had a mean residual value …[18] percent. Around 44 percent of the cars in this sample had a bijtelling tax charge of 14 percent, where around 22 percent had a charge of 20 percent, and hardly any Model 1X was charged with 25 percent bijtelling tax. The average Model 1X sold per months were 118.

TABLE 9 DESCRIPTIVE STATISTICS, 1X 2012-16

	N[18]	Minimum	Maximum	Mean	Std. Deviation
RVP[18]					12,73
Age[18]					13,18
Mileage[18]					43412,37
BPM		0,00	6983,00	1390,82	1623,59
kW		40,00	180,00	73,63	14,54
Modern		0,00	1,00	0,8674	0,33
DSL		0,00	1,00	0,6500	0,47
Bijtelling14		0,00	1,00	0,4438	0,49
Bijtelling20		0,00	1,00	0,2185	0,41
Bijtelling25		0,00	1,00	0,0017	0,04
Quantity[18]					

Appendix F shows the descriptive statistics for the Model 1Y between for each year between 2012 and 2016. The average Model 1Y in this sample has a mean residual value of …[18]%, by an average contract duration of ..[18] months, with a total mileage of … [18]km. 40 percent of the cars have a diesel engine. Since there was no clear linear relationship found with the quantity variable, this variable is not included in this sample.

[18] Confidential information.

Compared to the previous two segments, this regression does not focus on a specific model, but includes all cars of the higher segment in the analysis that were sold between 2012 and 2016. Table 21 shows the average cars in this segment were …[19]months old, holding a mean residual value of [19] %, by …[19] kilometers driven on average. On average …[18] cars are being sold per months in the time period under study.

5.1.2. Correlation Matrix

Table 9 shows the Pearson Correlation Matrix. The correlation between age and mileage is with 0,503 the highest. The correlation between diesel and mileage is significantly positive, which can be explained by diesel cars driving more than petrol cars. The bijtelling is highly correlated with the BPM tax, however, both more or less measure the same. The more emissions a car has, and whether it is a diesel or not depends on the amount being charged.

Appendix F presents the Pearson Correlation Matrix for the Models 1Y, 2012-2016 and the higher segment for 2012-2016. The variable Bijtelling14 and 20 shows a high positive and significant correlation with engine power (kW). This can be explained by the fact that more engine power is associated with a higher tax charge, as the emissions increase with increasing engine power. Diesel, as in the previous segment, has a positive correlation with mileage. Moreover, mileage and age are positively correlated with 0,528, however, this is not a concern to multicollinearity. For the higher segment, as in the previous segments, mileage is positively and significantly correlated with diesel and age. Diesel is also significantly positive correlated with BPM, explaining the diesel premium that is charged in addition to the regular BPM tax.

[19] Confidential information.

TABLE 10 PEARSON´S CORRELATION

	lnRVP	Age	Mileage	BPM	Modern	kW	DSL	Bijtelling14	Bijtelling20	Bijtelling25
lnRVP	1									
Age	-0,65**	1								
Mileage	-0,66**	0,50**	1							
BPM	-0,01	0,13**	-0,06**	1						
Modern	-0,18**	-0,19**	-0,09**	-0,49**	1					
kW	0,24**	-0,16**	-0,14**	-0,10*	0,307**	1				
DSL	-0,38**	0,11	0,37**	-0,60**	0,101**	-0,144**	1			
Bijtelling14	-0,26**	0,11**	0,23	-0,69**	0,212**	0,156*	0,655**	1		
Bijtelling20	0,39**	-0,25**	-0,26**	0,27**	0,107**	0,483**	-0,546**	-0,472**	1	
Bijtelling25	0,05*	-0,01	-0,04*	0,08*	0,016	0,106**	-0,056**	-0,037*	-0,022	1
Quantity	0,01	0,09*	0,033	-0,24**	0,155**	0,318**	0,094**	0,280**	0,163**	0,008

**, * Correlation is significant at the 0,01, and 0,05 level respectively

5.1.3. Regression Results

Table 10 shows the results for the Model 1X for each year between 2012 and 2016. Age and Mileage have both a significant and negative effect on the residual car value. The effect on the residual value is weaker in the last two years, as those years include the Model 1X_4.1 (Facelift) which was just introduced in 2014. The effect of the facelift introduction in 2014 can be seen for the year 2016. The coefficient of -0,056** indicates that the Model 1X_4.0 is experiencing an obsolescence effect due to the market introduction of the facelift 1X_4.1. In this model, it can be seen that a diesel engine has a negative effect on the residual value. Although, only two years show significant negative results for the effect of the BPM, one argue that the BPM has a negative effect. Higher engine power (kW) does not seem to have a positive effect on the residual car value, as only the year 2016 shows significant results. The bijtelling seems to have a negative effect on the residual value of cars, however, this effect is not stronger for the bijtelling 20. Also, most coefficients are not significant. The quantity of cars being sold has no significant effect on the residual value in this model.

Looking at the adjusted R^2 one can argue that the variables chosen for this model are quite good, with R^2 ranging from 0,502 in 2013 to 0,716 in 2016.

TABLE 11 REGRESSION RESULTS

	2012	2013	2014	2015	2016
Age	- [20] (8,977)***	- (-6,969)***	- (-9,177)***	- (-12,006)***	- (-8,619)***
Mileage	- (-3,900)***	- (-5,725)***	- (-10,416)***	- (-16,914)***	- (-16,511)***
BPM	-4,824E006 (-6,956)***	-1,452E005 (-1,706)*	-8,721E006 (-1,070)	-1,747E006 (-0,173)	-1,496E005 (-0,941)
kW	-0,07 (-1.221)	0,041 (0,549)	-0,031 (-0,484)	-0,063 (-1,300)	0,041 (5,215)***
Modern	-0,059 (-1,453)	-0,062 (-1,416)	0,111 (2,273)***	0,009 (0,124)	-0,056 (-2,320)**
Fuel	-0,117 (-5,812)***	-0,116 (-3,851)***	-0,176 (-5,926)***	-0,239 (-7,533)***	-0,084 (-2,636)***
Bijtelling14	-0,056 (-1,559)	-0,086 (-3,851)***	-0,061 (-2,568)**	0,016 (0,511)	-0,123 (-3,494)***
Bijtelling20	-0,037 (-0,643)	-0,001 (-2,845)***	-0,011 (-0,335)	0,026 (0,816)	-0,127 (-3,908)***
Bijtelling25	/ [21]	0,161 (0,820)	/ [22]	0,006 (0,05)	0,065 (0,532)
Quantity	-0,001 (-0,847)	-0,001 (-0,441)	0,001 (1,537)	0,001 (0,944)	0,001 (1,053)
Intercept	4,919 (18,833)***	4,411 (12,196)***	4,448 (16,005)***	4,672 (22,052)***	2,712 (7,671)***
N[23]					
Adjusted R^2	0,676	0,502	0,509	0,767	0,716

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
[1] n/a = not available
All variables are defined in Appendix E
The coefficient of the independent variables is to be interpreted like the following: $e^{-0.079}$ is equal to decrease of 7.5 percent on the price

[20] The coefficients were hidden for confidentiality.
[21] No models in the 2012 sample with a Bijtelling charge of 25%.
[22] No models in the 2014 sample with a Bijtelling charge of 25%.
[23] The number of observations are hidden for confidentiality.

5.2. Middle Segment

5.2.1. Regression Results

Table 11 presents the regression results for the Model 1Y for the years 2012 to 2016. As was indicated in the compact segment above for Regression Model 2, age and mileage have a statistically significant negative effect on the residual value of cars. Three out of five coefficients show significant positive effects of the engine power on the residual value, only in 2014 the coefficient shows a negative effect on the residual value (-0,060*). The BPM variable confirms in this model a negative relationship between the BPM tax and the residual car value, suggesting that a higher BPM charge leads to a lower residual value. The negative effect of fuel can also be confirmed by the regression analysis, showing for all but one year (2016) a negative effect. The effect of the bijtelling is also negative, suggesting that cars with a higher bijtelling receive a lower residual value at the end.

Compared to the compact segment, the adjusted R^2 shows a slightly better model fit in this segment, with an adjusted R^2 ranging from 0,575 to R^2 of 0,892.

TABLE 12 REGRESSION RESULTS, MODEL 1Y 2012-16

	2012	2013	2014	2015	2016
Age	- [24] (-21,93)***	- (-13,64)***	- (-14,07)***	- (-8,23)***	- (-5,74)***
Mileage	- (-12,07)***	- (-3,30)***	- (-11,81)***	- (-4,96)***	- (-10,53)***
BPM	-1,846E005 (-3,36)***	-5,454E005 (-6,57)***	-1,897E005 (-2,85)***	-4,492E006 (-0,29)	-5,568E005 (-5,32)***
kW	0,055 (1,90)**	0,132 (2,93)***	-0,06 (1,73)*	0,009 (0,09)	0,152 (2,18)**
Modern	0,053 (2,59)**	0,035 (1,32)	-0,011 (-0,59)	-0,028 (-0,69)	0,065 (2,05)***
Fuel	-0,086 (-5,59)***	-0,101 (-4,48)***	-0,023 (-1,17)*	-0,072 (-,174)*	0,020 (0,81)
Bijtelling14	/ [25]	/ [26]	/ [27]	-0,009 (-0,08)	-0,220 (-5,05)***
Bijtelling20	-0,102 (-3,61)***	-0,105 (-3,84)***	-0,08 (-4,79)***	-0,058 (-1,79)*	-0,092 (-3,64)***
Constant	4,213 (32,88)***	3,973 (19,33)***	4,812 (29,03)***	4,626 (9,62)***	3,830 (11,68)***
N[28]					
Adjusted R^2	0,777	0,617	0,757	0,575	0,892

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix E
The coefficient of the independent variables is to be interpreted like the following: $e^{-0.079}$ is equal to decrease of 7.5 percent on the price

[24] The coefficients were hidden for confidentiality.
[25] No models in the 2012 samples with a Bijtelling charge of 14%.
[26] No models in the 2013 samples with a Bijtelling charge of 14%.
[27] No models in the 2014 samples with a Bijtelling charge of 14%.
[28] The number of observations were hidden for confidentiality.

5.3. Higher Segment

5.3.1. Regression Results

Table 12 shows the regression results for the higher segment cars between 2012 and 2016. Like for the previous two segments, on can see a negative effect of age and mileage on the residual value. Noticeable, in this regression is however, that in year 2015 the coefficient is lower than for all other years. One explanation for this could be the introduction of the Model 1Z_8.0 and the 2Z_2.1 facelift in 2014 and 2013 respectively. In year 2013 diesel has a negative significant effect on the residual value, however, for the years 2015 and 2016 this effect becomes positive and significant. One explanation is that in the higher segment more cars have diesel engines than in the lower segments, as a diesel is less costly for more expensive cars. Coefficient results show a positive effect of engine power on the residual value, as three out of four years show positive effects of kW on the residual car value. BPM has, as in most instances in this analysis, a negative effect on the residual car value. The less the tax charge of cars, the better they retain their value. The quantity of cars being sold shows a negative effect on the residual value of cars, however, it is only significant for three years.

The model fit in this segment suggests also a good fit, with an adjusted R^2 of at least 0,540 to a maximum R^2 of 0,732.

TABLE 13 REGRESSION RESULTS, 2012-16

	2012	2013	2014	2015	2016
Age	- [29] (-22,54)***	- (-18,01)***	- (-14,66)***	- (-11.32)***	- (-17,18)***
Mileage	- (-12,472)***	- (-12,329)***	- (-12,656)***	- (-18,052)***	- (-20,319)***
BPM	-1,567E005 (-5,361)***	-1,241E005 (-3,378)***	-4,787E005 (-0,108)	-2,056E005 (-3,948)***	-2,431E005 (-4,851)***
kW	0,116 (3,191)***	-0,029 (-0,709)	0,026 (0,715)	0,174 (4,660)***	0,227 (7,915)***
Modern	0,038 (3,191)***	0,044 (3,623)***	0,021 (1,565)	0,002 (0,132)	-0,024 (-1,793)*
Fuel	-0,004 (-0,298)	-0,023 (-1,646)*	-0,001 (-0,036)	0,046 (2,959)***	0,063 (4,522)***
Bijtelling20	-0,035 (-1,298)	-0,049 (-2,213)**	-0,055 (-2,738)***	-0,017 (-0,702)	-0,025 (-1,979)**
Bijtelling25	-0,033 (-1,161)	-0,004 (-0,163)	-0,036 (-1,674)*	0,003 (0,115)	/ [30]
Quantity	-0,001 (-4,684)***	-0,001 (-2,307)***	-0,001 (-0,810)	-0,001 (-0,882)	-0,001 (-3,608)***
Constant	3,957 (24,44)***	4,648 (24,39)***	4,302 (24,01)***	3,564 (19,46)***	3,403 (23,20)***
N[31]					
Adjusted R^2	0,740	0,702	0,583	0,540	0,732

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix E
The coefficient of the independent variables is to be interpreted like the following: $e^{-0.079}$ is equal to decrease of 7.5 percent on the price

[29] The coefficients were hidden for confidentiality.
[30] Bijtelling25 was excluded due to high multicollinearity in 2016 (VIF > 10).
[31] The number of observations were hidden for confidentiality.

6. Conclusion and Limitations

6.1. Conclusion

The hypothesis that with increasing design age the residual value of lease cars becomes lower cannot be confirmed by the data. Although, for certain models it can be confirmed that increasing design age lowers the residual value, and thus has a negative effect on the car value, this is not constant for all cars. However, most cars show that with increasing design age, cars depreciate more in reference to the first year of market introduction, or first couple of years when the cars are still new. It was expected that with increasing model age, cars experience an obsolescence effect. This was confirmed for a number of cars, however, some cars still experienced enhancement effects with advancing model age.

This is consistent with previous findings by Holweg & Kattuman (2006) and Purohit (1992) who could neither confirm that car models with older design always have lower residual values than cars whose model year or design is still new, nor do new models when introduced for the first time, always experience an enhancement effect. Holweg & Kattuman (2006) did confirm, however, that with each year the model design becomes older it loses value of 2,5 percent. Nau (2012) who empirically showed a significant effect of the model life cycle, however, no clear and consistent results have been found. One explanation for not finding the expected results for all cars is the effect of consumer demand which is hard to estimate, as Copeland et al. (2005) argue, “consumers view vehicles from one model year as poor substitutes in another model year” (p. 4). That cars with more engine power have higher selling prices holds true for most cases, but the effect is less than in previous studies.

In contrast to Prieto et al. (2015) diesel cars have a negative effect on the selling price compared to petrol cars. However, these results are specific to the Dutch market, where diesel cars are exposed to higher tax charges than petrol cars. Thus, the fact that it is more expensive to drive a diesel car can explain this difference. What could be seen in the analysis is the impact of whether the car is a diesel or a petrol car. The diesel cars almost in every instance had a negative impact on the price of the cars in the used market. One explanation for this is the BPM tax which is based on the CO_2 emission of cars. The more CO_2 the car is producing the more taxes are put on the car. Moreover, is a diesel premium charged to the car.

Model misspecification can always be a possible reason for why results were not as expected, or coefficients may not represent the real data. Moreover, is the threat of omitted variable bias present, meaning that effects in the results are due to factors that have not been included in the model. When running the analysis different models have been applied. For example, an adjusted price was calculated based on the standard lease contract of 36 months and 40 000 km per year. That way, the cars in the sample were adjusted to have all the same age and mileage. The regression based on the adjusted selling price as the dependent variable, and the exclusion of age and mileage resulted in no other results. Coefficients remained similar to the findings presented in this study. Running the regression without inflation adjusted numbers did also not change the results.

One possible reason for insignificant coefficients can be that the number of observation per registration year, is not for all car models high. A solution to this problem could be to combine the car models per segment based on the registration year. This method would then increase the number of observation per registration year, and might lead to more significant results. On the other hand, the leasing department and the *committee* evaluate and decide upon each specific car individually. Not only per car model, but also based on the engine size and equipment line. Therefore, a model as applied in this study seems to be a better fit which looks at each car separately. Moreover, if one would combine the car models, the effect of platform changes cannot be accounted for. Furthermore, as could be seen in the results, the effect for each variable is different for each car model. These effects would be lost when the cars would be taken together.

In conclusion, no relationship between the model life cycle and its effect on the residual value was found. However, to measure the effect of the life cycle is a difficult endeavor as there exist many variables which may or may not have an influence on the selling price. As Prado (2009) has supported her decision not to include the model life cycle "because of the difficulty to collect and to standardize the information" in a statistical model (p. 3). This thesis can be seen as a first attempt that should be improved with the application of different variables, cross-validation by applying different regression methods and statistical programs.

6.2. Limitations

One limitation of the analysis is the impact of the tax system in the Netherlands. In the Netherlands, there are three taxes imposed on cars that have an impact on the price and demand for a car. Tax regulations are, however, not stationary, this means that they change and evolve over time. Today a car can have tax advantage at start of the leasing contract, but in three years' time when it will return, the taxes can already have changed influencing the demand and selling price of that car. Another limitation is that certain demand factors cannot be explained by variables. Today the demand for a specific car model can be quite high with people willing to pay higher prices, then they are when demand for that specific model is going down. One limitation which is minor, but needs to be mentioned is the lack of available VIN codes and model codes for some cars in the system. Therefore, I used the starting date of the contract as a reference point for the model year, and the model year as a reference point for deciding whether the model belongs to the modern or facelift lifecycle.

Omitted variable bias like economic and political factors, time trends in selling prices which cannot be captured by the analysis. Some price differences cannot be captured by any variable or prediction model. For instance, two cars of the same model have been sold on the same date that has similar age and total kilometers. However, one car had 17 inch tires with metallic blue paint, and the other 16 inch tires with metallic black paint. Against expectation there was a price difference of 4 000 € between the two cars.

Although other studies looked at the geographical effect on the residual value, this would not be a relevant variable in this model. The reason is, that although the company knows who the buyer is, it does not know beforehand. As all cars are being sold via auction, the highest bidder wins, considering the type of car buyer would be a different analysis.

6.3. Recommendation

Subject of this thesis was to see whether there is an effect of the model life cycle of cars on the residual value. Although the hypothesis of increasing depreciation with increasing design age cannot be confirmed by the results, the analysis nevertheless shows that there is an effect.

For future research, it is suggested to include more variables that can capture the trend in used car market prices. One possibility is to make use of the AOX index, which is a used car price index that measures, like inflation, the price changes over time of used cars sold in the Netherlands. For example, Brockman & Mu (n.d.) have included a monthly price index of cars sold "to account for supply and demand dynamics in the used car market" (p.18), with results showing a positive and significant effect on the selling price of used cars. Another possibility is the creation of a company index of the selling price fluctuations. First, it should be analyzed whether there are different price fluctuations or trends over time for different market segments, fuel types or if the trend is the same for all cars in the company´s portfolio. The price fluctuations could then be weighted with the quantity of cars being sold. Another recommendation for the company is to make use of a model called the Autoregressive Integrated Moving Average model (ARIMA). This is a more sophisticated model approach for time-series forecasting.

Subject of this thesis was to see whether the model life cycle of cars has an effect on the residual value of cars. Empirical results show that there is indeed an effect for some car models, but for most cars the coefficients were insignificant. However, results also show that it is difficult if not impossible to tell by exactly how much the residual value is affected.

Bibliography

Brockhoff, K. (1967). A test for the product life cycle. *Econometrica, Journal of the Econometric Society*, 472-484.

Bryant, C. (2013, September 10). Facelifts whet appetite for older car models. *Financial Times*. Retrieved from: http://www.ft.com/content/f592a452-1a22-11e3-93e8-00144feab7de

Cooke, P. (2009). Residual values, forecasting and risk minimization. *A Report for BCA*. Retrieved from: https://www.buckingham.ac.uk/wp-content/uploads/2011/05/pnc-residual-working-paper-1-jan09.pdf

Copeland, A., Dunn, W., & Hall, G. (2005). *Prices, production and inventories over the automotive model year* (No. w11257). National Bureau of Economic Research.

Desai, P., & Purohit, D. (1998). Leasing and selling: Optimal marketing strategies for a durable goods firm. *Management Science*, *44*(11-part-2), S19-S34.

Dudenhöffer, F., & Neuberger, K. (2007). Die PKW-Restwertentwicklung und die Auswirkung auf die Leasinggesellschaften. *CAR- Center Automotive Research.*Retrieved from: https://www.uni-due.de/~hk0378/studien/2007/Restwerte-Studie-Juni2007.pdf

Dexheimer, V. (2003). Hedonic methods of price measurement for used cars. *Statistisches Bundesamt(Destatis).*Retrieved from: https://www.destatis.de/EN/FactsFigures/NationalEconomyEnvironment/Prices/HedonicUsedCars.pdf?__blob=publicationFile

Fujimoto, T. (2014). The long tail of the auto industry life cycle. *Journal of Product Innovation Management*, *31*(1), 8-16.

Engers, M., Hartmann, M., & Stern, S. (2009). Annual miles drive used car prices. *Journal of Applied Econometrics*, *24*(1), 1-33.

Glue, C., Eilers, D., von Mettenheim, H. J., & Breitner, M. H. (2017). Decision Support for the Automotive Industry: Forecasting Residual Values using Artificial Neural Networks.

Griliches, Z. (1961). Hedonic price indexes for automobiles: An econometric of quality change. In *The Price Statistics of the Federal Goverment* (pp. 173-196). NBER.

Lucko, G. (2003). *A statistical analysis and model of the residual value of different types of heavy construction equipment* (Doctoral dissertation). Retrieved from: https://theses.lib.vt.edu/theses/available/etd-12032003-122642/unrestricted/Gunnar_dissertation.pdf

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (1998). *Multivariate data analysis* (Vol. 5, No. 3, pp. 207-219). Upper Saddle River, NJ: Prentice hall.

Halonen, M. (2008). The residual value function – including the estimated brand effects on residual values. *Korea Automotive Research Institute, IJAIM, 2: 1-14.*

Holweg, M. and Kattuman, P. (2006). Dynamic determination of the residual value product value: empirical evidence from the automotive industry. *In: OM in the new world uncertainties: POMS Annual Conference, 17th, 28 Apro-1 May 2006, Boston, MA.h* .

Hughes, T., Liu, Z., and Castro, P. (2015). Resdiual Car Values Forecasting Using AutoCycle™. Moody´s Analytics. Retrieved from: http://www.economy.com/home/products/samples/2015-07-13-Residual Value-Forecasting-Using-AutoCycle.pdf

IAS – Lease. (2016). Iasplus. Retrieved from: http://www.iasplus.com/en/standards/ias/ias17

Jost, A., and Franke, A. (2005). Residual Value Analysis. Retrieved from: http://www.systemdynamics.org/conferences/2005/proceed/papers/JOST158.pdf

Lease. (2016). In *investopedia.com*. Retrieved from: http://investopedia.com/terms/I/lease.asp

Moral, M. J., & Jaumandreu, J. (2007). Automobile demand, model cycle and age effects. *Spanish Economic Review*, 9 (3), 193-218.

Nau, K. (2012). An Empirical Analysis of Residual Value Risk in Automotive Lease Contracts. Retrieved from: http://d-nb.info/1027353908/34

Ohta, M., & Griliches, Z. (1976). Automobile prices revisited: Extensions of the hedonic hypothesis. In *Household production and consumption* (pp. 325-398). NBER.

Oliver Wyman Report. (2010). The future belongs to electric vehicles. Automotive manager. Retrieved from: http://www.oliverwyman.com/content/dam/oliver-wyman/global/en/files/archive/2010/automotivemanagerI2010EN.pdf

Pierce, L. (2012). Organizational structure and the limits of knowledge sharing: Incentive conflict and agency in car leasing. *Management Science*, *58*(6), 1106-1121.

Pirotte, H., & Vaessen, C. (2008). Residual value risk in the leasing industry: A European case. *European Journal of Finance*, *14*(2), 157-177.

Prado, S. M. (2009). The European used-car market at a glance: Hedonic resale price valuation in automotive leasing industry. *Economics Bulletin*, *29*(3), 2086-2099.

Purohit, D. (1992). Exploring the relationship between the markets for new and used durable goods: The case of automobiles. *Marketing Science*, *11*(2), 154-167.

Residual Value. (2016.). International Financial Reporting Tool. Retrieved from: http://www.readyratios.com/reference/accounting/residual_value.html.

Residual Value (2016). In *businessdictionary.com.* Retrieved from: http://www.businessdictionary.com/definition/residual-value.html.

Rode, D. C., Fischbeck, P. S., & Dean, S. R. (2002). Residual risk and the valuation of leases under uncertainty and limited information. *The Journal of Structured Finance*, *7*(4), 37-49.

Sabadka, D. (2013). Impacts of shortening Product Life Cycle in the Automotive Industry. *Transfer inovácií*, *29*, 251-253.

Sawyers, A. (2003, November 10). Mercedes loses first place in residual ranking; Cadillac, Infiniti score big gains. *In Autoweek*. Retrieved from: http://autoweek.com/article/car-news/mercedes-loses-first-place-in-residual-ranking-cadillac-infiniti-score-big-gains

Schiraldi, P. (2011). Automobile replacement: a dynamic structural approach. *The RAND journal of economics*, *42*(2), 266-291.

Sharpe, S. A., & Nguyen, H. H. (1995). Capital market imperfections and the incentive to lease. *Journal of Financial Economics*, *39*(2), 271-294.

Tomat, G. M. (2002). Durable goods, price indexes and quality change: An application to automobile prices in Italy, 1988-1998.

Volpato, G., & Stocchetti, A. (2008). Managing product life cycle in the auto industry: evaluating carmakers effectiveness. *International Journal of Automotive Technology and Management*, *8*(1), 22-41.

Wykoff, F. C. (1970). Capital depreciation in the postwar period: Automobiles. *The Review of Economics and Statistics*, 168-172.

Appendices

Appendix A: Model Coding[32] Compact Segment

Model 1X			Model 2X			Model 3X		
Model Year	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**
2001-2005	3rd modern	3.0	1999-2007	1st modern	1.0	2002-2008	3rd modern	3.0
2005-2009	3rd Facelift	3.1	2004-2007	1st Facelift	1.1	2006-2008	3rd Facelift	3.1
2009-2014	4th modern	4.0	2007-2014	2nd modern	2.0	2007-2017	4th modern	4.0
2014-today	4th Facelift	4.1	2010-2014	2nd Facelift	2.1	2012-2017	4th Facelift	4.1

Appendix B: Model Coding[33] Middle Segment

Model 1Y			Model 2Y			Model 3Y		
Model Year	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**
2003-2008	5th modern	5.0	2000-2010	1st Facelift	1.0	1999-2006	1st modern	1.0
2008-2012	6th Facelift	6.0	2004-2012	2nd modern	1.1	2002-2006	1st Facelift	1.1
2012-2017	7th	7.0	2009-2013	2nd Facelift	2.0	2005-2012	2nd modern	2.0
			2012-today	3rd modern	2.1	2009-2012	2nd Facelift	2.1

[32] Model Codes have been changed due to confidentiality of information
[33] Model Codes have been changed due to confidentiality of information

						2012-today	3rd modern	3.0

Appendix C: Model Coding[34] Higher Segment

Model 1Z			Model 2Z			Model 4Z		
Model Year	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**	**Model Year**	**Generation**	**Model Code**
2000-2005	5th Facelift	5.1	2001-2006	1st modern	1.0	2000-2004	6th modern	6.0
2005-2010	6th modern	6.0	2006-2008	1st Facelift	1.1	2004-2008	7th modern	7.1
2010-2014	7th Facelift	7.1	2008-2013	2nd modern	2.0	2007-2015	8th modern	8.0
2014-today	8th modern	8.2	2013-2015	2nd Facelift	2.1	2011-2015	8th Facelift	8.1
			2015-today	3rd modern	3.0	2015-today	9th modern	9.0

[34] Model Codes have been changed due to confidentiality of information

Appendix D: Robustness Test Compact Segment, C1

	Make 1			Make 3				Make 2		
Model	1X_3.0	1X_3.1	1X_4.0	3X_ 3.0	3X_3.1	3X_4.0	3X_4.1	2X_1.1	2X_2.0	2X_2.1
Mileage[35]	- (-17,23)***	- (-27,18)***	- (-35,81)***	- (-4,29)***	- (-4,60)***	- (-25,02)***	- (-8,98)***	- (-9,56)***	- (-11,84)***	- (-11,48)**
Fuel	0,064 (3,06)***	-0,130 (-11,75)***	-0,133 (-12,95)***	0,012 (0,20)	-0,142 (-1,66)*	-0,125 (-5,54)***	-0,142 (-1,66)*	-0,106 (-2,22)***	-0,029 (-0,68)	-0,268 (-6,21)***
Reg_1	n/a	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Reg_2	Reference	-0,043 (-2,43)***	0,128 (7,06)***	-0,186 (2,23)**	-0,338 (-1,44)	-0,001 (-0,01)	-0,338 (-1,44)	-0,014 (-0,82)	-0,056 (-0,89)	0,046 (1,09)*
Reg_3	-0.042 (-1,29)*	-0,026 (-1,59)*	0,083 (4,18)***	0,164 (2,28)**	-0,348 (-1,45)	-0,03 (-0,90)	-0,348 (-1,45)	0,005 (0,09)	0,009 (0,13)	0,128 (2,73)**
Reg_4	-0,001 (-0,01)	-0,003 (-0,17)	0,113 (5,51)***	0,081 (1,03)	-0,264 (-1,04)	0,013 (0,39)	-0,264 (-1,04)	-0,011 (-0,16)	0,065 (0,87)	0,006 (0,93)
Reg_5	-0,092 (-3,15)***	0,09 (3.81)***	0,156 (7,08)***	0,073 (0,86)	n/a	0,048 (1,29)	n/a	0,014 (0,12)	0,022 (0,23)	-0,209 (-1,95)*
Reg_6	n/a	0.386 (3,12)***	0,237 (9,70)***	0,172 (1,83)*	n/a	0,058 (0,89)	n/a	n/a	n/a	n/a
Quarter Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	4,588 (48,03)***	4,459 (112,07)**	4,423 (153,28)***	3,947 (24,24)***	4,859 (17,23)***	4,502 (82,72)***	4,332 (47,27)***	4,341 (49,57)***	4,494 (55,47)***	4,554 (63,65)***
N of obs.[36]										

[35] The coefficients for mileage were hidden for confidentiality.
[36] The number of observations were hidden for confidentiality.

Adjusted R^2	0,314	0,425	0,504	0,132	0,432	0,559	0,463	0,548	0,517	0,512

***, **, * represent significance at the 1 percent, 5 percent, and 10 percent levels respectively
dependent variable transformed at the natural logarithm
t-statistics in parenthesis
n/a = not available
All variables are defined in Appendix H
The coefficient of the independent variables is to be interpreted like the following: $e^{-0.079}$ is equal to decrease of 7.5 percent on the price

Appendix E: List of Variables

Variables	Definition
Dependent variable	
RVP_{act}	Selling Price, including BTW and repair costs[37] divided by the List Price
Independent variable	
Age	Actual contract duration in months since the car was registered, calculated by the difference in return date of contract and starting date of contract
Mileage	Total kilometers the car has driven
Fuel (diesel (DSL) as reference variable)	Dummy variable; if diesel (DSL) = 1, if petrol (EUR95) = 0
kW	Engine power in kilowatt
BPM	CO_2 and fuel type related tax charge, in €
Bijtelling	Tax charge for business cars that are used privately, dummy variable, if 14%=1, else 0, if 20%=1, else 0, if 25%=1, else 0
Quantity_End	The number of cars sold per months
Reg_Year	Year of introduction since car has been introduced, 1= introduction year 1, 2= one year after introduction, and so on, dummy variable which equals 1 for a given car model m at time t that was registered in year n Example 1X_4.0 introduction in 2009 1X_4.0 registered in 2009 =1, else = 0 1X_4.0 registered in 2010=1, else = 0 end so on
Car_Model	Indicating the model type, generation, and model cycle; Dummy variable which equals 1 for a given car model *I* at time *t* For example 1X_4.0=1, else = 0
Year	Dummy variable for time, t = 2006 - 2016 2006 = 1, else = 0 … 2016 = 1, else = 0
$Quarter_t$	Dummy variable for time, t=Q1,…Q4 $Q1_t$ =1, else 0; $Q2_t$ = 1, else 0; $Q3_t$ = 1, else 0; $Q4_t$ = 1, else 0
$Make_m$	Dummy variable which equals 1 for a given car brand *m* Make 1 = 1, else 0; Make 2 = 1, else 0; Make 3 = 1, else 0; Make 4 = 1, else 0

[37] Both Selling Price and List Price adjusted for inflation.

Appendix F: Descriptive Statistics and Correlation Matrices

TABLE 13 MEAN STATISTICS COMPACT SEGMENT C1, SUB-SAMPLES

	Sub-Samples									
	1X_3.0	1X_3.1	1X_4.0	3X_ 3.0	3X_3.1	3X_4.0	3X_4.1	2X_1.1	2X_2.0	2X_2.1
Selling Price[38]										
List Price	17437,57	18664,84	18853,24	19464,06	16534,37	18702,02	19187,25	18591,10	19571,68	17774,83
RVP[38]										
kW	50,67	55,75	74,59	70,79	66,05	72,86	79,33	62,70	67,11	75,52
Age[38]										
Mileage[38]										
BPM	3993,95	4257,58	1147,30	4508,72	3409,61	1200,88	1157,17	4301,45	3873,54	705,06
DSL	0,36	0,36	0,64	0,55	0,18	0,69	0,81	0,37	0,51	0,76

All variables are defined in Appendix E

[38] Confidential information.

Table 15 Mean Statistics Middle Segment M1, Sub-Samples

	Sub-Samples						
	1Y_5.0	1Y_6.0	3Y_1.1	3Y_2.0	3Y_2.1	2Y_2.0	2Y_2.1
Selling Price[39]							
List Price	28519,14	28788,61	22823,90	28125,93	25292,55	29793,43	27757,10
RVP[39]							
kW	83,83	100,6	83,56	90,19	103,21	89,25	101,31
Age[39]							
Mileage[39]							
BPM	6876,38	5100,22	5547,93	6762,99	4526,46	6910,38	4971,67
DSL	0,58	0,34	0,44	0,58	0,25	0,74	0,37

All variables are defined in Appendix E

Table 14Mean Statistics Middle Segment M1

	Full Sample				
	N[40]	Minimum	Maximum	Mean	Std. Deviation
Selling Price[40]					3921,17
List Price		17268,56	59207,56	28507,62	4842,26
RVP					12,12
kW		55,00	210,00	90,48	22,516
Age					12,94
Mileage					48144,12
BPM		0,00	23042,00	6229,72	1894,59
DSL		0,00	1,00	0,54	0,49

All variables are defined in Appendix E

[39] Confidential information.
[40] Confidential information.

Table 16 Correlation Matrix Middle Segment, M1

	lnRVP	**Age**	**Mileage**	**DSL**	**BPM**	**kW**
lnRVP	1					
Age	-0,651**	1				
Mileage	-0.636**	0,532**	1			
DSL	-0.297**	0,015**	0,428**	1		
BPM	-0,271**	0.001	0,191	0,492**	1	
kW	0,137**	-0,085	-0,167**	-0,282**	-0.053**	1

All variables are defined in Appendix E

Table 17 Descriptive Statistics Middle Segment, M2

	N[41]	**MINIMUM**	**MAXIMUM**	**MEAN**	**STD. DEVIATION**
SELLING PRICE[41]					3737,98
LIST PRICE		18942,66	58227,56	28893,18	5003,53
RV[41]					11,65
AGE[41]					13,09
MILEAGE[41]					46958,20
BPM		0,00	14693,00	5273,26	1776,62
MODERN		0,00	1,00	,7985	,40119
KW		55,00	210,00	98	25,154
DSL		0,00	1,00	,4015	0,49
BIJTELLING14		0,00	1,00	,0073	0,08
BIJTELLING20		0,00	1,00	,2738	0,44

All variables are defined in Appendix E

[41] Confidenital information.

Table 18 Correlation Matrix Middle Segment, M2

	lnRVP	Age	Mileage	BPM	Modern	kW	DSL	Bijtelling14
lnRVP	1							
Age	-0,71**	1						
Mileage	-0,66**	0,53**	1					
BPM	-0,47**	-0,30	0,34**	1				
Modern	-0,29**	-0,21**	-0,28**	0,57**	1			
kW	0,23**	-0,18**	-0,21**	-0,02	-0,05*	1		
DSL	-0,32**	0,01	0,43**	0,42**	-0,41**	-0,20**	1	
Bijtelling14	0,08**	-0,09**	-0,01	-0,21*	0,04	0,53*	0,11**	1
Bijtelling20	0,19**	-0,22**	-0,15**	-0,38**	-0,38**	0,35**	-0,06**	-0,05**

All variables are defined in Appendix E

Table 19 Descriptive Statistics Higher Segment H1, Full Sample

	Full Sample				
	N[42]	Minimum	Maximum	Mean	Std. Deviation
Selling Price[42]					5246,19
List Price		23191,00	124249,69	37795,13	5795,80
RVP[42]					10,42
kW		74,00	280,00	108,40	26,00
Age[42]					11,74
Mileage[42]					47983,47
BPM		0,00	37869,00	9030,64	2684,45
DSL		0,00	1,00	0,6374	0,48

All variables are defined in Appendix E

[42] Confidential information.

Table 20 Mean Statistic Higher Segment, H1, Sub-Samples

	1Z_5.1	1Z_6.0	1Z_7.0	4Z_6.0	4Z_7.0	4Z_8.0	4Z_8.1
Selling Price[43]							
List Price	36987,10	38944,22	38600,40	42559,15	46117,15	46722,68	45097,11
RVP[43]							
kW	88,94	98,60	117,61	97,86	105,53	114,83	142,98
Age[43]							
Mileage[43]							
BPM	9653,90	8944,45	6532,22	10904,65	11808,67	10530,10	7801,48
DSL	0,87	0,65	0,56	0,61	0,57	0,66	0,31

All variables are defined in Appendix E

Table 21 Correlation Matrix Higher segment, H1

	lnRVP	Age	Mileage	DSL	BPM	kW
lnRVP	1					
Age	-0,684**	1				
Mileage	-0.641**	0,481**	1			
DSL	-0.219**	-0,024	0,438**	1		
BPM	-0,126**	-0,008	0,002	0,221**	1	
kW	0,176**	-0,064**	-0,216**	-0,415**	-0.007	1

All variables are defined in Appendix E

[43] Confidential information.

Table 22 Descriptive Statistics Higher Segment, H2

	N[44]	Minimum	Maximum	Mean	Std. Deviation
Selling Price[44]					4685,16
List price		23191,00	145424,32	40844,82	7025,99
RVP[44]					9,74
Age[44]					11,2126
Mileage[44]					46367,98
BPM		0,00	37868,00	7773,14	2280,21
Modern		0,00	1,00	0,3890	,48757
kW		77,00	280,00	117,98	26,78
DSL		0,00	1,00	0,5647	0,50
Bijtelling20		0,00	1,00	0,0959	0,29
Bijtelling25		0,00	1,00	0,2006	0,40
Quantity[44]					33,88

All variables are defined in Appendix E

Table 23 Correlation Matrix Higher Segment, H2

	lnRVP	Age	Mileage	BPM	Modern	kW	DSL	Bij20	Bij25
lnRVP	1								
Age	-0,71**	1							
Mileage	-0,61**	0,48**	1						
BPM	-0,13**	-0,01	0,01	1					
Modern	0,02	-0,07**	-0,07**	0,19**	1				
kW	0,18**	-0,06**	-0,22**	-0,01	-0,08**	1			
DSL	-0,21**	-0,02*	0,44**	0,22**	-0,01	-0,411**	1		
Bij20	0,05**	-0,01	-0,01	-0,53*	-0,28**	0,239	0,01	1	
Bij25	0,11**	-0,06**	-0,06**	-0,09**	-0,13**	0,441**	0,123**	-0,16**	1
Q	0,03**	0,01	-0,04**	-0,13**	0,02	0,11**	-0,059**	0,10**	0,05**

All variables are defined in Appendix E

[44] Confidential information.