1 Introduction

1.1 Problem Definition and Objective of This Work

In recent decades, the number of leased and financed vehicles steadily increased and the used-car market became more and more important for financial institutions and car manufacturers. In Germany, one third of all newly registered cars were leased in 2015.[1] Due to this development, the residual value risk moved into the focus of financial institutions that are involved in the leasing business. The residual value risk is the risk that at the end of the lease term the value of the leased vehicle differs from the contractual residual value, which was stipulated at the start of the leasing agreement. Beside the residual value risk, the developments of prices in the used-car market can significantly affect the credit risk of banks who participate in vehicle financing. These institutions are interested in the price changes of their underlying vehicles to determine the value of their collaterals and the Loss Given Default (LGD).

To ensure an appropriate residual value risk management, the quality of the residual value forecasts is most important. Hence, an essential challenge for leasing institutes is the identification of all relevant residual-value-influencing factors. Generally, the prediction of residual values focuses on common influencing factors, such as car age, mileage, equipment, etc. However, models' predictions of used cars' future resale values can differ from individuals' willingness to pay because individuals do not necessarily behave rationally or are misguided by simplifying heuristic decision rules during their car's valuation pro-

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[1]See Federation of German Leasing Companies (2016, p. 26 ff.).

cess. Hence, experienced sellers of used cars may be able to exploit the price discrepancy between their model-based residual value forecasts and individuals' vehicle assessments, whereas less informed sellers and buyers may suffer from their exposedness to heuristic decision rules. For this purpose, it is essential to understand the effect of individuals' limited or heuristic information processing on the prices of used cars.

Furthermore, in recent years, the used-car market is strongly affected by political and corporate intervention such as subsidies or scrappage schemes. Examples for the German car market are the scrappage premium in 2009, a governmental bonus for the purchase of electric vehicles since 2016 and the scrappage premium of automobile manufacturers for diesel cars since 2017. These car purchase programs do not only exist for the German market but are rather a widely used measure in industrial countries.

As a consequence of these common policies or corporate measures, vehicles' residual values will be affected by exogenous shocks of supply or demand. Understanding the impact of such an exogenous effect is of central importance for financial institutions' residual value risk assessment because it can systematically affect a large number of cars in the leasing portfolio at the same time.

Against this background, the most important research questions addressed in this thesis are the following:

- Which factors determine automobiles residual values?
- What is the effect of individuals' heuristic information processing on the prices of used cars?
- How do sellers' levels of experience and cognitive abilities affect the used-car prices?
- What is the price effect of supply and demand shocks by governmental interventions on secondary markets?

The first question is analyzed by a comprehensive literature review. Based on hedonic pricing models, physical characteristics and performance variables that significantly affect automobiles' residual values are presented. Subsequently, other relevant price determinants are introduced such as macro-economic factors and characteristics of the

automobile market. The other three research questions are studied by empirical analy-
ses. The second and the third research questions are analyzed in an empirical project,
which considers that sellers' vehicle valuation is subjected to a heuristic called anchoring
and identifies the discrepancy between individuals' price assessments and rational market
prices. The fourth research question is investigated by analyzing the effect of the German
scrappage scheme, which was introduced in 2009, on the prices of used cars. Both empir-
ical projects further examine the price reaction of the studied effects for heterogeneous
seller types regarding their levels of information and knowledge.

The results are beneficial for various market participants. Among others, financial
institutions have to implement an adequate forecast model for the residual values of
their leased vehicles. Taking into account all relevant price-influencing determinants is
therefore an important key factor. Thereby, the price effects of a scrappage scheme and
individuals' limited information processing are of particular interest to ensure a proper
valuation of their risk capital and a quick reaction to market changes. Governments
are also interested in the evaluation of their policy measures' price effects because this
analysis enables them to understand the corresponding welfare effects. Finally, the results
provide simple guidelines for buyers and sellers of both new and used cars and help to
reduce the bias caused by heuristic information processing.

1.2 Course of Investigation

To analyze the research questions stated above, this thesis is structured as follows: In
Chapter 2, fundamentals of the German automobile market are discussed. First, the
German new-car market and used-car market are presented in Section 2.1 to illustrate
the importance of the automobile market. In the following Section, an overview about
the German leasing market is given. Besides the definition and characteristics of leasing,
different contract types are introduced. The last part of this chapter deals with the
structure and economic importance of the leasing market in Germany.

In Chapter 3, a detailed analysis of determinants that significantly affect vehicles' resid-
ual values is given, which have to be implemented in residual value forecast models to
ensure an appropriate prediction of automobiles' resale values. First, the fundamentals
and a motivation are given in Section 3.1. Next, a literature review is presented in Section
3.2. In Section 3.2.1, it begins with various studies that investigate the depreciation rate
and devaluation pattern of automobiles over the lifetime more generally. Subsequently,
in Section 3.2.2, car-specific influencing factors are presented that are analyzed by he-
donic pricing models. Besides the impact of physical variables, the effect of performance
indicators and the car brand on secondary-market prices are investigated. Section 3.2.3
presents the effects of time-dependent price determinant, which are characterized by the
developments in the automobile and the overall market. In Section 3.2.4, other influe-
encing factors are introduced. In the focus of this section are demographic factors and
consumer-specific characteristics such as the level of information and their effects on the
prices of used vehicles. The main results of this chapter are subsumed in Section 3.3.

The empirical setting of Chapter 4 investigates anchoring and price anomalies in the
used-car market. The main focus of this chapter is to examine the price effects of in-
dividuals' heuristic information processing. Due to the great required effort to evaluate
all relevant car information, individuals often base their pricing on simplifying decision
rules, which cause price discrepancies between individuals' car valuation and adequate
market values. Again, at first, the fundamentals and research questions of this chapter are
presented (cf. Section 4.1). Afterwards, a literature review about price effects of heuris-
tic information processing is given in Section 4.2. In Section 4.3, the hypotheses of this
empirical study are derived. An overview about the data set is provided in Section 4.4.
The empirical study itself is in the focus of Section 4.5. First, price discontinuities, which
are the result of individuals' exposedness to anchoring on the average car value of similar
cars from the same vintage, are identified in the used-car market. Then, the size of the
anchoring effect with respect to sellers' levels of experience and cognitive abilities are
investigated. The main results of this chapter are summarized in Section 4.6.

The empirical analyses in Chapter 5 determines the price effects of supply and demand shocks on secondary markets. These shocks can be a result from governmental interventions such as the scrappage scheme in Germany in 2009, which is the analyzed event in this chapter. The fundamentals and research questions are presented in Section 5.1. A literature review about the effect of governmental intervention on the automobile market with a focus on new-car sales, manufacturer benefits and the competitiveness and welfare effects of secondary markets is given in Section 5.2. Section 5.3 gives a detailed overview about the scrappage program in Germany in 2009 and its progress. In Section 5.4, a theoretical model is implemented, which is used to derive the hypotheses of this empirical study. An overview about the data sets and the empirical strategy is given in Section 5.5. First, two different data sets used in the upcoming analyses are presented. Second, a description of the empirical strategy is provided. The empirical results regarding the price effects of a demand shock of young and small used cars and of a supply shock of old clunkers are established in Section 5.6. In addition, price effects between dealers' and private sales are analyzed in detail. Section 5.7 provides robustness checks. The key findings of this chapter are summarized in Section 5.8.

Finally, Chapter 6 summarizes the results of the preceding chapters and addresses the importance of their consideration for an appropriate residual value risk management.

2 The German Automobile and Leasing Market

2.1 Fundamentals of the German Automobile Market

In this section, an overview about the German automobile market is provided. The stock of passenger cars has constantly increased in recent years and reached 45.1 millions cars in 2016 (41.1 million cars in 2008).[2] In Germany, on average, each household has more than one car. This shows the high relevance of the automobile market in Germany and emphasize the importance of an understanding of the developments and the current situation in this market for the German population and the German economy.[3] The automobile market can be divided into the new-car market and the used-car market. The importance of both markets can be illustrated by the developments of the yearly new-car registrations and changes of ownership, which are presented in Figure 2.1.
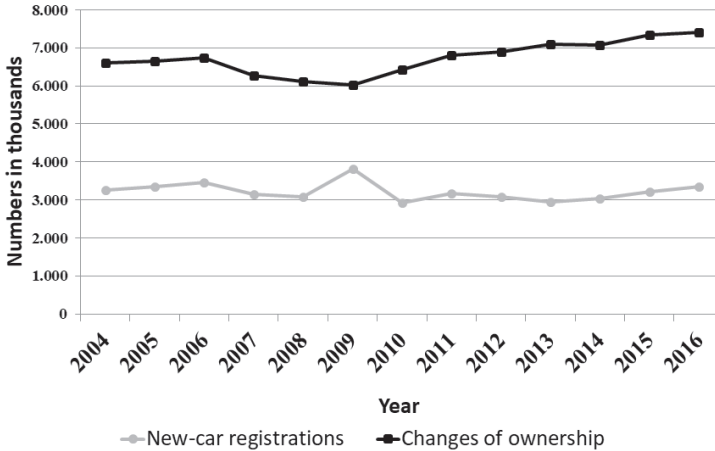
The numbers of new-car registrations were relatively constant over the years 2004 to 2016 and reached approximately 3.2 million cars on average. Noticeably, the numbers of new-car registrations increased to 3.8 million cars in 2009 as a result of the introduction of the German scrappage scheme in the same year. This policy measure was implemented because of decreasing new-car sales as a consequence of the financial crisis

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[2]According to Federal Motor Transport Authority (2016).

[3]This is not only a typical characteristic of the German automobile market but rather a general fact for all developed countries. See Lock (2003), White (2016) and International Organization of Motor Vehicle Manufacturers (2017).

Figure 2.1: **Developments of the New-Car Registrations and Changes of Ownership in Germany (2004-2016)**
Source: Federal Motor Transport Authority (2017a) and Federal Motor Transport Authority (2017b).


of 2007-2008 and is analyzed in detail in Chapter 5. During the years 2014 to 2016 the new-car registrations slightly increased.

Since 2009, the numbers of changes of ownership increased from 6 million to 7.4 million. Again, the low numbers in 2009 can be explained by the introduction of the scrappage scheme but also by the impacts of the great depression, which began in 2007. As a result, the numbers of changes of ownership decreased during the years 2007 to 2009. However, the strong growth of the numbers of changes of ownerships in recent years emphasize the increasing importance of the used-car market. Hence, a detailed analysis of the functioning and price formation process in the used-car market is necessary to be able to react to changes in supply and demand.

The growing importance of the used-car market is also underlined by the developments of the used cars' sales volume. In Figure 2.2 the sales volume of new and used cars in the years 2004 to 2015 are presented.

Figure 2.2: **Sales Volume of the German New-Car Market and Used-Car Market (2004-2015)**
Source: Deutsche Automobil Treuhand (2016, p. 79).
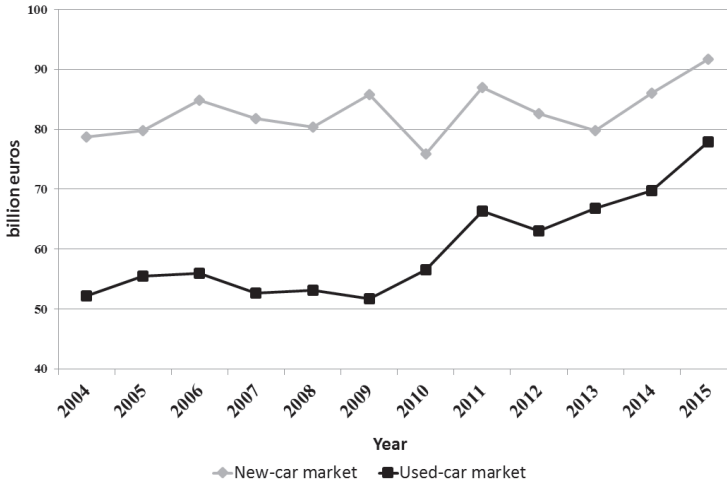
Whereas the new-car sales volume was relatively constant over the last years, the used-car sales volume strongly increased since 2010. The volume of used-car sales was approximately 51.7 billion euros in 2009 and increased to 77.9 billion euros in 2015. Hence, the used-car sales volume came closer to the sales volume level of new cars, which is the result of the increasing numbers of changes of ownership as shown in Figure 2.1.

The new-car registrations are dominated by commercial buyers, which have a market share of more than 66% in 2016. Most new cars were produced by German car manufacturers, which have a share of approximately 64.9% of the total vehicle stock in Germany. Using the car classifications of the European Commission to categorize the car models into the corresponding market segments,[4] the largest-volume car segments are medium cars, small cars and large cars, which make up 26.4%, 19.7% and 15.7% of the existing vehicles in Germany, respectively. Despite the increasing numbers of new registrations of

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[4]Refer to European Commission (2002).

Sport Utility Vehicles (SUVs), their share of the German vehicle stock is only 8%.[5] Table
2.1 lists the car classifications of the European Commission:

Table 2.1: **Vehicle Classification by the Commission of the European Commu-
nities**
The right column lists the three car models for each car classification which
had the highest new-registration numbers in 2014 according to the Federal
Motor Transport Authority.

Vehicle Classification	Models with highest new-registration numbers
A: mini cars	VW up!, Fiat 500, Opel Adam
B: small cars	VW Polo, Opel Corsa, Ford Fiesta
C: medium cars	VW Golf, Audi A3, Skoda Octavia
D: large cars	VW Passat, Mercedes C-Class, BMW 3 Series
E: executive cars	Audi A6, BMW 5 Series, Mercedes E-Class
F: luxury cars	Mercedes S-Class, Mercedes CLS, Audi A8
J: sport utility cars	VW Tiguan, Opel Mokka, Ford Kuga
S: sport coupes	Mercedes E-Class Coupe, Porsche 911, Mercedes SLK
M: multi-purpose cars	VW Touran, VW Transporter, VW Caddy

The right column of Table 2.1 presents the three car models that yielded the largest
numbers of new registrations in 2014 for each car classification.

2.2 The German Leasing Market

This section provides insights into the leasing business and gives an overview about the
German leasing market. The leasing industry is particularly affected by the developments
in the secondary markets because leasing companies usually have to resale their leased
goods at the end of the leasing contract. Hence, leasing companies are challenged to
correctly assess the market value of their leased good at the end of the lease term. Only
a correct valuation of the leased assets at the end of the contract period ensures the
leasing institute's competitiveness and the prevention of future losses. In the remainder
of this chapter, a short introduction into the leasing business is given and a typical leasing

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[5]See Federal Motor Transport Authority (2017c).

transaction is presented. Subsequently, different contract forms and their characteristics
are explained. Finally, the structure and the economic importance of the German leasing
market is demonstrated.

2.2.1 Definition and Characteristics of the Leasing Business

Generally, leasing can be defined as an object's transfer of use in return for a regular pay-
ment for a limited period of time. Typically, leasing objects are capital goods or durable
consumer goods, which have economic value and can be used separately.[6] However, a
uniform definition does not exist in the literature. Many characteristics of the leasing
business are similar to the rental business but there are also some properties which are
more related to credit financing. To illustrate the fundamental functionality of the leasing
business, Figure 2.3 presents the involved parties of a typical leasing transaction including
the dependencies between each other.

Figure 2.3: **General Functioning of a Leasing Transaction**[7]
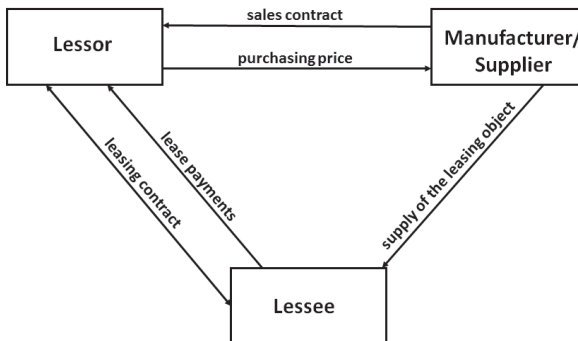
Before the conclusion of the leasing contract, the lessee specifies the desired config-
uration of the required leasing object. For example, in the case of vehicle leasing, this

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[6]See Das (2009, p. 125 ff.).
[7]According to Kratzer and Kreuzmair (2002, p. 82).