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The European used-car market at a glance: Hedonic resale price valuation in automotive leasing industry

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Abstract

In the leasing industry, the risk of loss on sales at the end of the contract term, as well as pricing are critically impacted by the forecasted resale price of the asset (residual value). We apply the Hedonic methodology to European auto lease portfolios, in order to estimate the resale price distribution. The Hedonic approach estimates the price of a good through the valuation of its attributes. Following a discussion on Hedonic prices, we propose an operational model for the automobile resale market. The model is applied to four European countries (France, Germany, Spain and Great Britain), and distributions are calculated on two vehicle versions (Audi A4 & Ford Focus) allowing a comparison of market depreciation patterns and residual value risks.

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1 Introduction

In the auto lease industry, a large part of the rent paid by the customer during a life contract is the difference between the list price and the residual value. The leasing company makes or losses money depending on whether it accurately predicts the value of the asset at the end of the contract (fair market value). If residual values are forecasted to be higher than what the asset is actually worth at lease-end, then there will be a loss. At the opposite, if residual values are forecasted to be lower, then there will be a gain on resale. The estimated resale price of the car at the end of the contract term appears as a key component for the pricing, the risk of losses and the reserve calculation.

We propose a methodology for operational applications to estimate the distribution of resale price. To this end, we apply a Hedonic model (a method of estimating value through constituent characteristics of the asset) on historical information from a major leasing company[1]. Further to this, we estimate a value according to vehicle characteristics and country singularities. Resale price distributions of two vehicles (Ford focus C-max, Audi A4) are calculated in various European markets (France, Germany, Spain and Great Britain).

Regarding theoretical issues, Ohta and Griliches (1976) state that Hedonic model usage 'has an air of "measurement without theory", but one should remember the limited aspirations of the Hedonic approach and not confuse it with attempts to provide a complete structural explanation of the events in a particular market'[2]. All along the referenced studies, methodology moved from a remaining service approach to a Hedonic model including essentially the vehicle characteristics (physical or not). Yerger (1995) used this method to discuss an article written by Hoffer and Pratt (1990) which was inspired by Akerman (1973) approach. Following these authors, our approach is mainly empirical. We select the model structure that best fits to reality and choose exogenous variables with a statistical and economic significance.

[1] GE Fleet Services.

[2] Ohta and Griliches (1976) p326.

2 Some characteristics of the Model

Coefficients interpretation depends on used market substitution to new market: Berndt (1983) pointed out an argument against the Rosen identification problem[3] for the used market: under specific conditions, equation parameters can be directly interpreted as reflecting demand (rather than cost or supply) and there is no identification problem. The structure combination would be determined by the demand. The difference of price level among products could be interpreted unambiguously as providing implicit measures of consumers' evaluation of the characteristic combinations. So coefficients of the equation are well identified, as well as estimates of the demand function parameters. Because the total quantities are fixed (assuming that there is a non significant link with new market), the equation only reflects demand in the used car market.

Two main conclusions can be stated: All referenced automotive studies use single equation techniques, and remarketing professionals usually believe in a substitution relation for young resale automotive market only which is a situation where demand and supply characteristics are quite similar. Therefore we apply a single equation and we exclude short term duration (less than 12 months age) vehicles.

Others products interact with price: Defining a framework on the demand analysis, Berndt (1983) discussed the input price-dependent quality adjustment case: the quality of a good (i.e. fuel efficiency) is dependent on the quantity (or price) of another good (i.e fuel price). Berndt states that we could test the dependent (or independent) price hypothesis using classical testing procedures (i.e. economical and statistical significance of fuel price on auto price). Fuel price has a significant part in the total cost of automobile usage, and then monthly fuel price constitutes our model.

Multicollinearity is a main issue in Hedonic models: In the automotive area, physical characteristics are often correlated (i.e. four wheels correlated to fuel capacities). According to the Gauss Markov theorem, OLS has the smallest variance. As a consequence, parameter correlations present a major issue for forecast applications. The simplest solution is to exclude variables at risk (i.e all variables related to the engine power, number of cylinders, kilowatt, fuel consumption, fuel capacity...) in the case of non economical significance[4].

Triplett (1969) highlights another problem. Because a small amount of variables is able to explain most of the variance (i.e. the weight of the vehicle correlated with engine power and price), there are some risk of biases in the Hedonic model and a substantial number of innovations are missed throughout this 'trickle down' hypothesis.

[3] See Brown and Rosen (1982). If the price function is non linear, it may not be possible to find closed solutions. A lot of conditions must be imposed and partial differential equations must be solved when there is more than one characteristic.

[4] An advanced solution is the ridge regression estimator or principal component methodology. The problem is that we lose visibility on coefficients meaning.

Therefore, the selected parameters of our model cover four axes of depreciation effects: the level of usage, the original equipment cost, the market interactions and the pure physical characteristics of the vehicle.

$$\begin{aligned} Resaleprice &= fct_1(age, mileage, mileage\ per\ month) \\ &\quad + fct_2(list\ price, make * list\ price) \\ &\quad + fct_3(pump\ price,\ industrial\ production\ index, sale\ date) \\ &\quad + fct_4(car\ physical\ attributes) \end{aligned}$$

Which functional form ? Rosen (1974) states that the functional form is an empirical matter. In the same logic, Grilitch and Otha (1976) choose a semilogarithmic form for their regression because 'it provided a good fit of the data'. Most of the literature suggests the log form, others studies apply the log-log form[5], and the Box Cox test[6] has also been used to compare several functional forms. We followed the Grilitch and Otha position (1976) ('a good fit of the data') and empirical results lead us to the linear form of Cowling and Cubbin (1972). Their linear model includes multiple physical variables like horse power and length and to allow approximation to a non linear form, square transformation, cubic transformation and log transformation were applied to exogenous variables. Interactions terms were also included.

Unobserved tastes create heteroscedasticity: We follow Bartik's approach[7] including the index of industrial production[8] as a proxy of the economic situation of the buyer (we propose a *temporal* budget constraint shifter). Because most of buyers are professionals impacted by a market seasonality, we include a seasonality variable on a quarterly basis. Finally, in order to manage unobserved characteristics (i.e. brand name perception and reputation...), we also insert a manufacturer effect [9].

[5] See Hogarty (1975).

[6] See Atkinson and Halvorsen (1990), Van Dalen and Bode (2004).

[7] See Bartik (1987)

[8] Excluding energy and construction.

[9] We do not work with a model car type level, because our goal is to apply a methodology flexible enough to include new cars and non exhaustive data. Moreover, our model does not include the life cycle of vehicles ('honey moon' effect for new models...) because of the difficulty to collect and to standardize the information. In the list of unobserved characteristics, there is also the remarketing performance. The value could be impacted by the remarketing team in charge of the resale process. Finally, we do not include macroeconomic impacts (which need a proper analysis). Therefore unobserved effects mentioned above constitute the random variable of the statistical model.

3 Data and Model

Statistical models are slightly different by country[10]. The real resale price is explained by a first group of variables indicating the level of usage: age and mileage are in logarithm due to the well known non linearity property of car depreciation. An indicator of usage intensity, the mileage per month, is also included and significant. The second group of variables is related to the list price. A cubicle variable of list price is added (high initial price increase devaluation). The make effect is introduced through a dummy variable of manufacturer multiplied by the list price. Variables bringing market information contitute the third group: the diesel pump price, the industrial production index and the quarter sale date. The last group includes pure physical characteristics that are slightly different from a country to another (average fuel consumption, body type, number of seats, engine power, number of cylinders, automatic transmission, number of doors).

In order to quantify the Hedonic price[11], we apply the model to four European markets (France, Germany, Spain, and Great Britain[12]) using internal sales data from January 1st 2004 to December 31st 2008 of a major leasing company. Statistics are based on random samples of cars sold in various channels (auction, dealers, private sellers, etc). Vehicle age samples range from 1 to 10 years, and have mileage ranging from 1,000 to 400,000 km. As expected for leasing companies resale statistics, a concentration of vehicles with high mileage and short age spans (concentration on 24, 36 and 48 months of age with a mileage between 80000 km and 120000 km) constitutes a large part of our sample. All monetary values (sales prices, diesel prices) are adjusted according to the inflation. According to the company position in markets, the amount of data is significantly different by country but sufficient for calculation (Fr: 112,875 units, Ger: 7,398 units, Sp: 14,674 units; Gb: 33,506 units).

[10] See models details in Appendix, Table 1.

[11] An adjustment removes uncertain variables effects: All the exogenous variable values are known with certainty, except the fuel pump price and the production distribution index. We limit our analysis to fixed contract with no purchase option and no rewrite, therefore age, mileage and sale dates are known with certainty. We aim to remove the product interaction effect (Dp) and the temporal budget constraint (Ip) in order to focus on the vehicle valuation. Assuming that the diesel price and the production price follow a normal distribution, we calculate the mean and the variance from 2004 to 2008 and we estimate a risk neutral distribution of the resale price. The integrals are calculated with numerical integration.

[12] Great Britain has a sterling pound currency and very limited cross bordering sales with others European countries because of the right hand side weel of the car. Therefore, GB statistics add an original perspective of european markets analysis.

4 Empirical findings

All variables have a significant economic value[13]. Contrary to some referenced studies applying the Hedonic model to the car market, we do not limit our analysis to a segment or version of cars. As a consequence, the explained variance (R^2) is slightly lower (and even more to applied studies on the much more stable new car market). To estimate the manufacturer effect, statistics include several manufacturer names (Fr: 9, Ger: 4, Sp: 6, Gb: 8) by country. The explained variances of the OLS regressions are between 0.75 and 0.8. Characteristics adding quality to the car (engine power, number of seats, etc) as well as the industrial production index (as a proxy of budget variation) have a positive sign. According to the Hedonic theory, the price of fuel is an additional cost of the driving activity and has therefore a negative effect. The variables of age, mileage and usage intensity (mileage per month) reduce the resale price, there are parameters correlated to obsolescence and wear. A slight seasonal effect exists in all markets. The well known and better valuations of German manufactured cars (positive make effect) are verified in all countries.

The analysis on Ford focus and Audi A4 give additional informations: France, Germany and Spain share the same currency (Euro) and results estimate the resale price distribution of a vehicle, according to the amount of information available from historical sales. The samples of the four countries have two manufacturers in common: Audi and Ford. We choose the characteristics of the Ford Focus (C-max 1800 TDCI 115 Ghia 5P) and Audi A4 (1.9 Tdi 130 Pack 4P) as a basis to compare the four markets. The information provided by the model could be summarized by two elements. On one hand, a higher valuation of car at the end of the contract reveals better opportunities for leasing business. On the other hand, a higher volatility implies uncertainty on the resale price, and therefore a higher risk of loss on sale.

Bucket results: A first analysis approach on the bucket of a 36 month age group, and 90000 kilometers emphasizes three points[14]. First, the Audi A4 has a better valuation than the Ford Focus in every country. As mentioned previously, German cars benefit from a *'positive make effect'*; they are objects of prestige and share a reputation of good quality cars. Secondly, the high level of standard deviation in all markets reveals a huge volatility. Acknowledging that the second hand market is not as liquid as a financial market, it illustrates that a car, as an asset in a balance sheet of a company, constitutes a significant risk. Thirdly, in Germany, cars get a better valuation. A high resale price constitutes a good element for a leasing business; however the German market also has a higher standard deviation, and therefore a higher risk of loss on sales.

[13] An indicator of automatic transmission was tested and statistically significant for France. Because the coefficient sign was negative, we removed it.

[14] Results are presented in Appendix, Table 2

Graphical results: The graphics of distribution through age and mileage give an additional perspective of the depreciation[15]. The variance is not economically different when we modify age and mileage parameters (whatever the currency, the age and the mileage, the standard deviation does not exceed two Euros). Age and Mileage do not increase the volatility. Regarding average depreciation, German vehicles are highly correlated with mileage, but Spanish cars are not. Surprisingly, the graphical analysis of age impact on vehicles, reveals that British cars are heavily impacted by the level of usage (kilometer per month variable coefficient) and as a consequence, 12 month age vehicles have a resale price equivalent to 24 age month vehicles.

5 Conclusion

The Hedonic theory has been widely used for the automotive market analysis. We discuss and propose an application to second-hand vehicles in the leasing industry, where the residual value is a critical parameter (residual value risk). The model is based on attributes in order to estimate the resale price distribution. Focusing on the pattern of depreciation of two vehicles (Ford Focus and Audi A4), the approach illustrates the different levels of probability of losses according to the resale information available by a leasing company. The approach also allows the comparison of market opportunities, through pricing analysis and risk[16]. Results indicate that Hedonic valuations are significantly different by country. European markets are not homogeneous, and residual value distributions are always singular. On a business perspective, leasing contracts would be impacted by country specificities.

[15] See Graphics in Appendix.

[16] The impact of mileage, for instance, will vary according to the country. All things being equal, a Ford Focus with a low mileage (i.e. 30,000 km) has a better valuation in Germany than in Spain. The same contract could produce, at the end of the lease, a profit in Germany and a loss in Spain.

Appendix: Regressions, Buckets Results and Graphics.

Table 1: Regressions

Variables Details and Definitions:

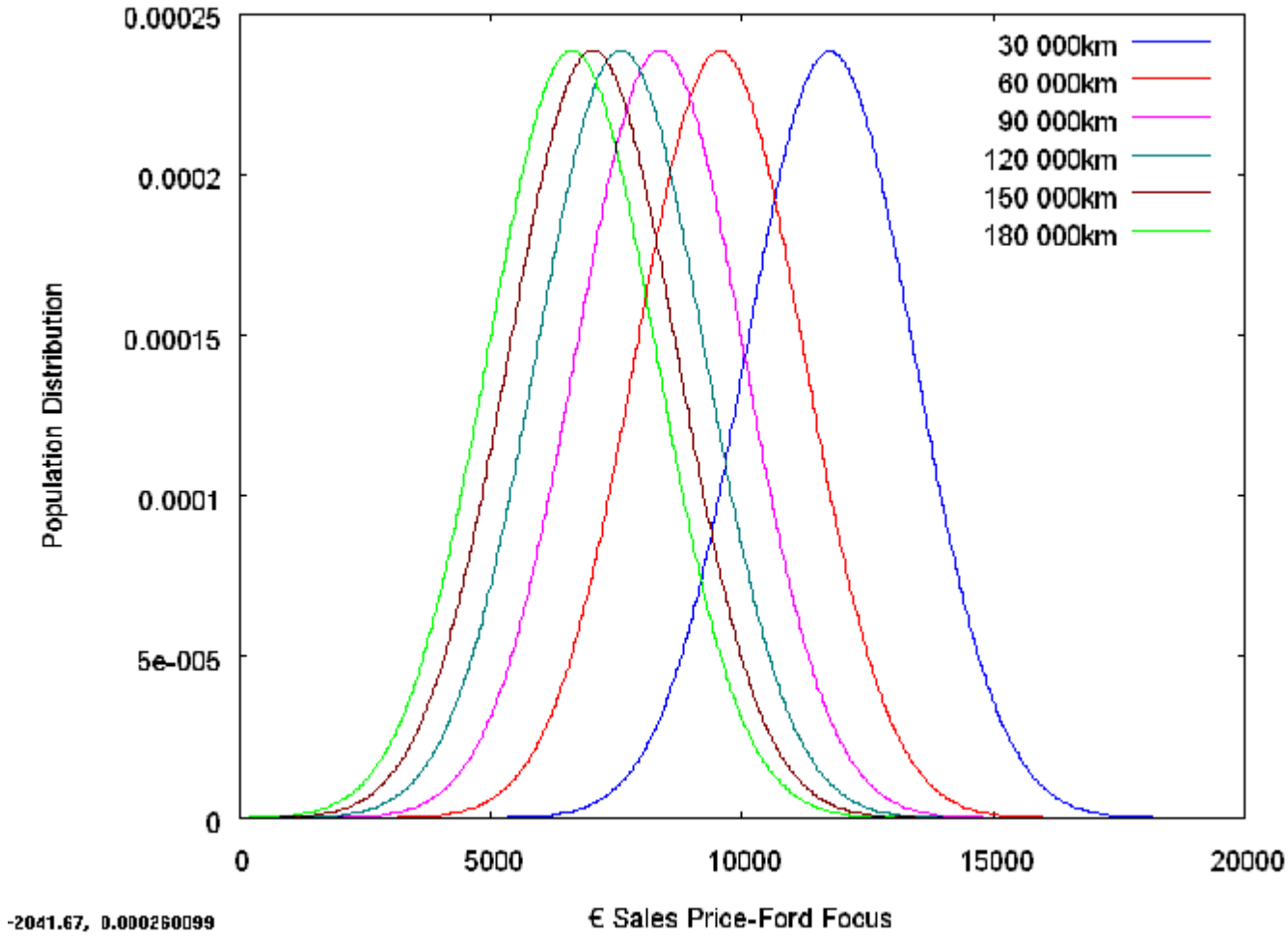
- The **real resale price** is the dependant variable.
- **Age** is number of month between the registration and the sale date. **Dis** is the distance travelled including any distance done on an odometer that has been changed. **Kpm** is the distance travelled per month.
- **Audi*LP**, **Bmw*LP**...are dummy variables indicating the manufacturer name multiplied by the Liste price amount. France: Audi, Bmw, Citroen, Ford, Mercedes, Opel, Peugeot, Renault, Volkswagen. Germany: Audi, Bmw, Ford, Volkswagen. Spain: Audi, Ford, Opel, Peugeot, Renault.Seat. UK: Audi, Bmw, Ford, Toyota,Vauxhall, Volkswagen.
- **Real LP**^{2} is the cubic of the real least price (including option price). **Option Price** is the real Option price
- **Indxpdrt** is the Industrial production by monthly index (adjusted by working days). **Diesel price** is the diesel pump price euro per liter all taxes included.
- **QTR2**, **QTR3**, **QTR4** are dummy variables indicating the quarter.
- **AvgFuel1** contains average fuel consumption figures as given by the manufacturer (urban and road). It is a company decision as to which statistical figure goes into this attribute.
- **Seat** is the number of seat.
- **Body_type** are dummy variable indicating the body type (France: berline, monospace. Germany: kompact, Spain: estate, berline UK: estate car, or saloon (sedan)).
- **EngnCap** is the actual number of ccs the engine has. **Kwt** is the power of the engine expressed in kilowatt given by the manufacturer.
- **AutoT** is equal to 1 if the vehicle has a form of automatic transmission fitted as standard or not.

Variables	France	UK	Germany	Spain
Intercept	30.120.237	21.883.429	46.867.564	27.890.151
	(140.15)	(52.82)	(46.18)	(82.00)
log (Dis)	-1.167.706	-405.836	-3.476.957	-989.410
	-(42.40)	-(7.90)	-(45.33)	-(36.97)
log (Age)	-3,825.492	-4,112.101	-2,632.024	-3,587.242
	-(116.08)	-(71.03)	-(27.34)	-(70.95)
Kpm	-0.371	-0.747	0.266	
	-(40.34)	-(22.72)	(29.35)	
Audi*LP	0.081	0.294	0.168	0.137
	(71.29)	(80.16)	(16.00)	(53.75)
Bmw*LP	0.060	0.297	0.177	
	(42.33)	(84.21)	(16.97)	
Citroen*LP	-0.061			
	-(47.28)			
Ford*LP	-0.087	0.126	0.073	-0.013
	-(62.34)	(30.69)	(6.40)	-(5.80)
Mercedes*LP		0.298		
		(81.79)		
Opel*LP	-0.070			
	-(48.60)			
Peugeot*LP	-0.029	0.161		0.027
	-(25.25)	(31.81)		(14.39)
Renault*LP	-0.086			-0.011
	-(74.47)			-(5.31)
Toyota*LP		0.170		
		(37.59)		
Vauxhall*LP		0.140		
		(30.16)		
Volkswagen*LP	0.029	0.253	0.132	
	(22.69)	(58.76)	(11.94)	
RealLP²	0.000001296	-0.000000102	0.000000667	0.000001322
	(87.61)	-(10.42)	(14.27)	(16.14)
Option Price	-0.087	0.027		-0.020
	-(50.89)	(18.10)		-(14.57)
Indxp drt	792.512	3.175.558	1.993.892	1.473.386
	(19.45)	(18.96)	(6.71)	(12.83)
Diesel price	-2.030.615	-4.383.453	-2.233.624	-4.328.357
	-(54.72)	-(49.10)	-(10.23)	-(31.17)
QTR2	237.051	141.757	161.228	245.764
	(22.62)	(5.69)	(3.22)	(8.51)
QTR3	263.770	-117.032	96.974	362.026
	(24.31)	-(4.99)	(2.03)	(12.15)
QTR4	-102.636	-666.336		
	-(10.07)	-(28.78)		
AvgFuel1	583.977	-10.431	241.456	-67.190
	(71.26)	-(8.58)	(5.46)	-(18.47)
Seat	136.886		501.813	
	(16.99)		(4.73)	
Body type berline	-1,430.725			-1,696.353
	-(29.03)			-(21.68)
Body type monospace	-848.781			
	-(17.40)			
Body_type_est		-140.166		-1.959.638
		-(7.17)		-(24.11)
Body_type_sal		-475.814		
		-(20.88)		
Body_type_kom			-799.155	
			-(15.77)	
EngnCap	17.541	156.413		132.207
	(7.07)	(29.19)		(15.91)
Kwt	56.665		29.174	39.059
	(131.12)		(14.00)	(40.07)
Fuel_Capc_Nbr			42.855	
			(15.20)	
AutoT		236.924		
		(7.28)		
R²	0.81	0.80	0.75	0.79

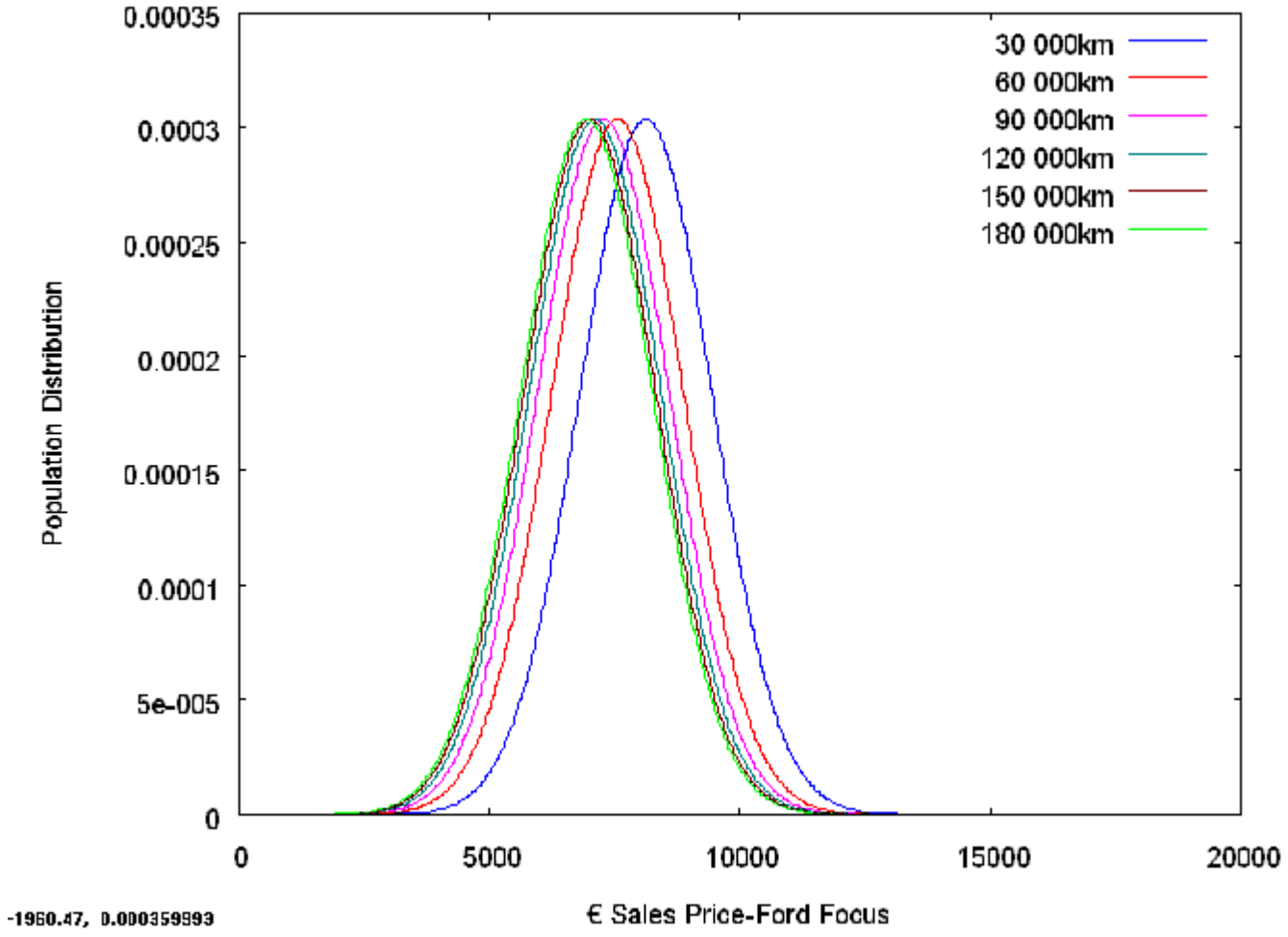
Table 2: Bucket 30 months and 90000 kilometers

	Ford Focus		Audi A4	
	Average Local Currency	Standard Deviation	Average Local Currency	Standard Deviation
France	7390	1210	11084	1210
UK	4793	1420	10310	1420
Germany	8369	1672	12924	1675
Spain	7282	1315	7751	1316

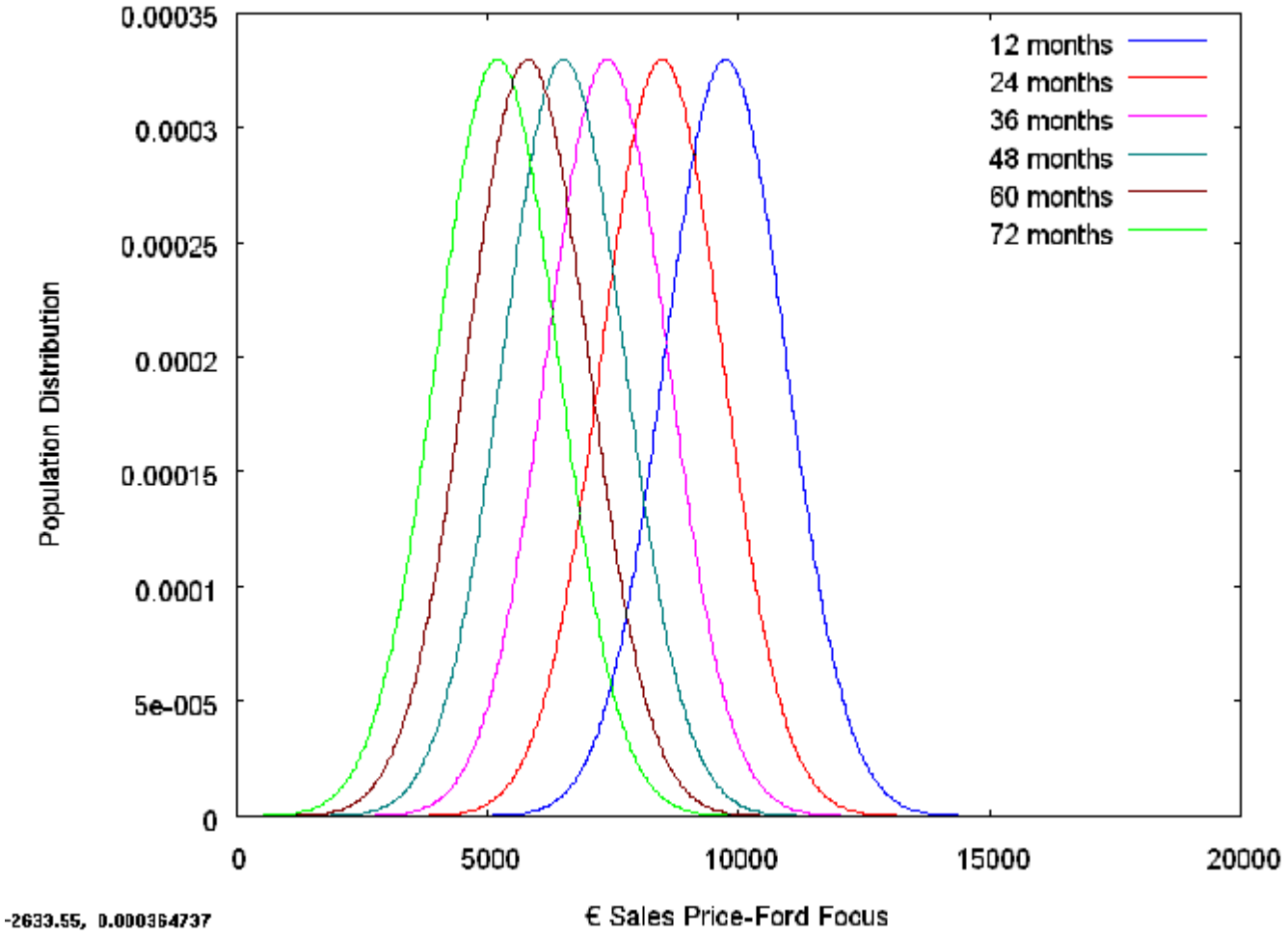
Graphic 1: Mileage impact / Germany



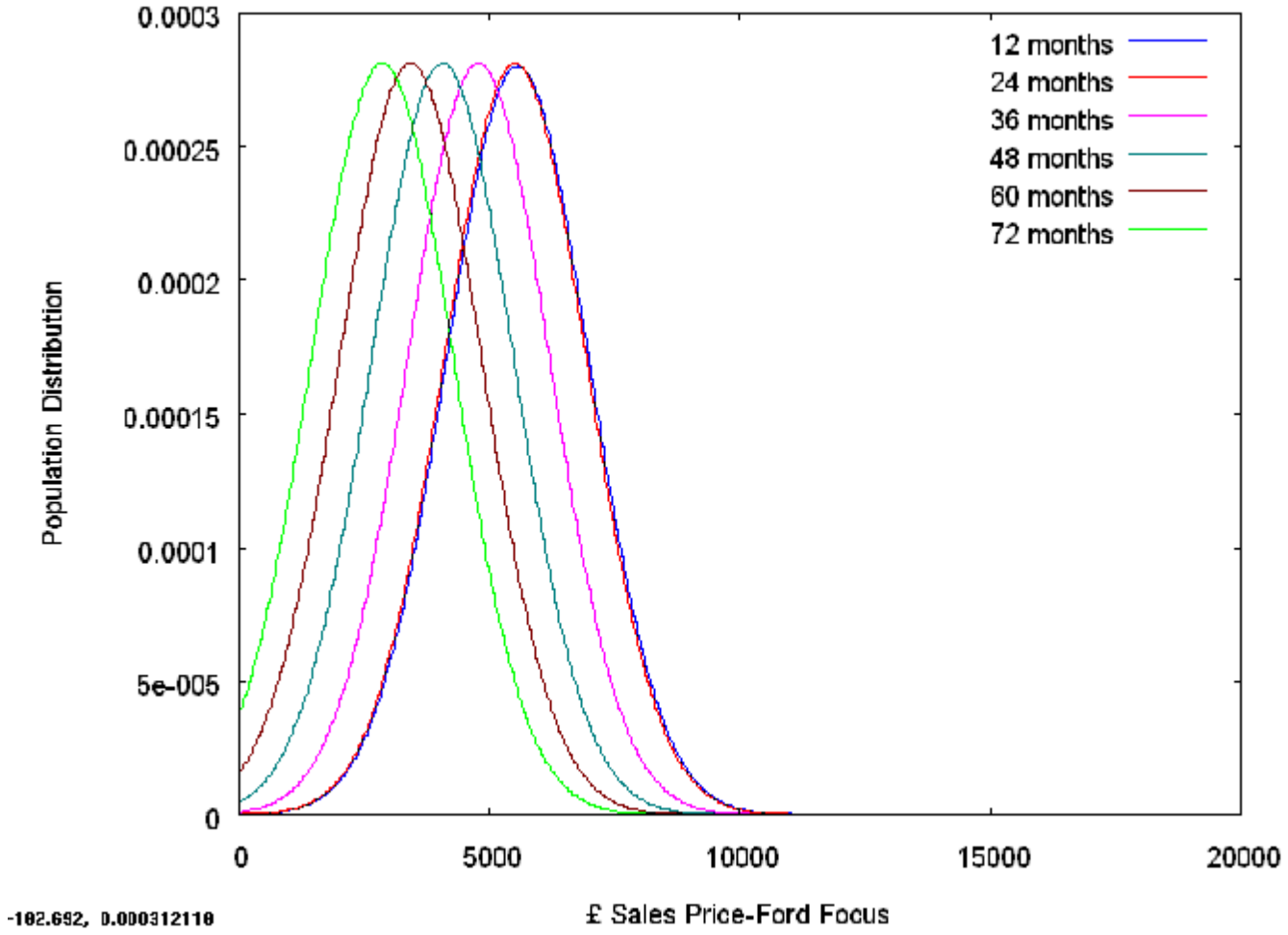
Graphic 2: Mileage impact / Spain



Graphic 3: Age impact / France



Graphic 4: Age impact / Great Britain



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