Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV CO_2 regulations

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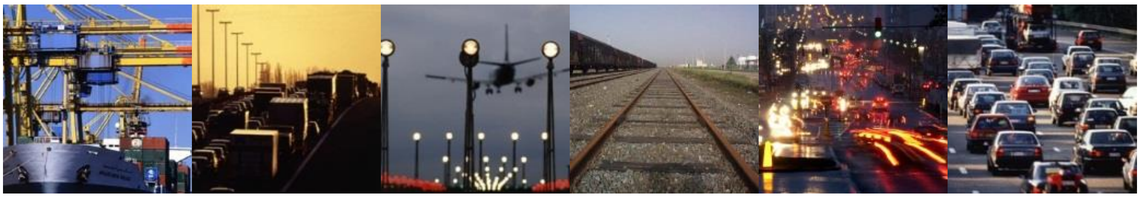

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1 Introduction

1.1 Background

EU Regulations set new vehicle fleet CO_2 emission targets for 2015 and 2021 for cars and 2017 and 2020 for light commercial vehicles. The vehicles covered by the Regulations have average lifetimes of the order of 15 years as explored in the study "Improvements to the definition of lifetime mileage of light duty vehicles" (Ricardo-AEA - Dun et. al., 2015). These vehicles are typically believed to have 3 or 4 owners over their lifetime with the first owner often keeping the vehicle for around 3-4 years – often as part of a leasing contract. The second hand car market is a number of times the size of the new car market, although the level of change of ownership varies substantially between Member States.

Cost effectiveness and social equity are two factors to be taken into account in the design of legislation for the period after the current Regulations. In addition, the period of time needed to pay back any additional vehicle purchase price increase is pertinent when considering the level of future ambition.

The study on "Improvements to the definition of lifetime mileage of light duty vehicles" also identified that there are significant volumes of second hand vehicles traded between EU Member States. This is likely to be of sufficient volume to have an impact on the average lifetime of vehicles within different countries.

The trade in second hand cars was explored in considerable detail in a previous study[1]. This provided mostly a one year (2008) snapshot of the EU second hand car and light commercial vehicle trade. This trade has implications in that countries where a larger proportion of sales are second hand vehicles imported from other EU Member States are likely to face lower incremental costs if the additional costs of CO_2 reducing technologies are not fully passed on when vehicles are sold second hand. The study concluded that annual average net import of used vehicles of the then recently acceded EU-12 Member States accounted for (at least) 130% of their registrations of new vehicles. The volume of trade in second hand vehicles exported from the EU is also of interest since it can be expected that the CO_2 benefits from these vehicles will continue to be experienced when they are driven in their destination countries.

The above suggests that the dynamics of the used car market affect the distribution of costs and benefits of legislation among the different owners over the lifetime of the vehicles. Moreover, if the different owners have distinct different socio-economic profiles (as is expected), this will result in different "winners" and "losers", both in terms of social equity as well as geographically (as a result of international trade of used cars).

[1] OKO - Mehlhart et al., 2011: European second-hand car market analysis Final Report - http://ec.europa.eu/clima/policies/transport/vehicles/docs/2010_2nd_hand_car_en.pdf

1.2 Objective

The objective of this project is to improve the understanding of the second-hand car and light commercial vehicle markets, and of the implications thereof for the cost effectiveness and social equity of LDV CO_2 regulations.

The scope of this study covers three main elements on the used car market dynamics:

1. The direct link between second-hand vehicle prices and their fuel consumption/CO_2-emission level: are fuel efficient vehicles more expensive in the second hand market and is pricing different for consecutive ownership transfers?

2. The direct link between second-hand vehicle ownership and the buyer's social stratum: does the socio-economic profile differ between new car owners and (different age-classes of) used car owners?

3. The geographic component of the used car market: Which Member States are the main importers and exporters of used cars? Are there specific relations and what are Member States used car market specifics in terms of size and socio-demographic properties?

The main objective is to identify key properties of the used car market dynamics that cause distribution effects of costs and benefits of new EU legislation on CO_2 emission standards for cars.

We go into detail on each of these links and elaborate on the consequences of the combined conclusions of each separate link.

1.3 Executive summary

Incorporating the used car market in the analysis of the costs and benefits of fuel efficiency of passenger cars and LCV's will lead to a better understanding of distribution effects. First owners pay the price for higher fuel efficiency and may or may not recuperate the premium when reselling on the used car market. It is also expected that the socio-economic profile of new car owners and used car owners differs, leading to asymmetric distribution of costs and benefits of fuel efficiency among the different socio-economic groups. The key questions in this respect are: is fuel efficiency priced in the used car/LCV market and can we confirm the different socio-economic profiles of used and new car-owners?

The study concludes that a relation between the fuel efficiency of a vehicle and pricing on the used car market can indeed be identified. We find that CO_2-emissions have a negative effect on the value of a passenger car on the second hand market of around €22 per gram CO_2 emitted per km. This implies that if one owns a car that emits 120 g/km CO_2 instead of one that emits 140 g/km, the value of the car on the second hand market on average increases by about €440.

The price premium associated with higher fuel efficiency is passed on between subsequent car owners and increases with the sequence of owners. We observe a difference in added value passed on for cars aging between 0 to 5 years and cars aging between 5 to 10 years. For younger cars, the average value of reducing CO_2 -emissions with 1 gram/km is €5, while for cars within the age group of 5 to 10 years, this average value is €30. For cars older than 10 years, the average value increases to €42.

We observe a similar trend in pricing of used Light Commercial Vehicles (LCVs). Increasing CO_2-emissions lead to a price decrease on the used LCV market of around €13 per gram CO_2 emitted per km.

The results are statistically significant at a very high rate, and robust to plausible changes in model specification or the removal of outliers in the dataset. This means that from the dataset we analysed, though counter-intuitive, we can conclude with high confidence there is progressive pricing of fuel efficiency with increasing car/LCV age.

Analysis into the socio-economic properties of the used car market confirmed the intuition that there are important socio-economic distribution effects associated with it. Consistently in all EU countries, the used car market is more important for lower income groups. While used cars are more prevalent in lower income groups, the used cars also tend to be older. As a consequence, any policy (environmental legislation, safety, taxation,…) affecting (sales of) new vehicles exclusively, will generate asymmetric impacts in terms of cost and benefits over the different socio-economic groups.

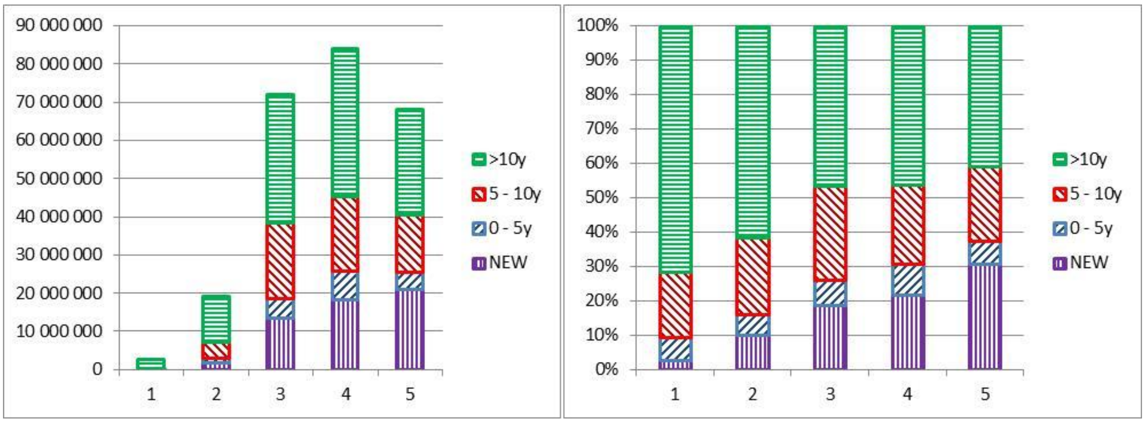


figure 1: EU-27 passenger car fleet, by income group and car category[2]

There are distinct differences in the size and dynamics of the used car market between the EU Member States. The used car market is of substantial larger size than the primary market in terms of volume and this is more outspoken in EU-10 countries[3]. The import of used cars exceeds new registrations in most EU-10 countries. The largest exporting countries are Germany, Italy, Netherlands and most likely France (little data available). Germany is the largest exporter of used cars, likely responsible for 2/3 of all used car exports within the EU. The largest importing countries are Romania and Poland.

We observe minor trend changes in the used car cross-border trade over time. The German scrappage scheme did cause significant knock-on effects on the used car market which consequences clearly impact used car imports in EU-10 for the subsequent years.

An average passenger car has 3 to 4 owners during its lifetime, with average ownership duration of 4-7 years. Average ownership duration increases with subsequent owners.

Combining the conclusion that costs and benefits are unevenly distributed over the different owners with the observation that different owners have different socio-economic profiles, lead to the uneven distribution of costs and benefits over the different socio-economic profiles.

While higher fuel efficiency generates a benefit over the lifetime of the vehicle and for all the different owners during its lifetime, not all owners benefit proportionally. The distributional effects are mainly determined by the initial price premium. Lower income groups proportionally benefit more from fuel efficiency, if the initial cost for increased fuel efficiency is larger than the initial fuel savings for the first owner. The initial cost for increased fuel efficiency is borne by the first owner, on average belonging to higher income groups.

[2] X-axis 1-5 represents household income groups, 1 being the lowest income group and 5 the highest. Bracket threshold values can be found in the main report.

[3] References to "EU-10 countries" in this report should be understood as covering Bulgaria, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia and Slovakia

Table 1: summary of distribution effects for a selected case per car [petrol - 1.5€/l – 50€/g CO_2 initial price premium][4]

	1	2	3	4	5	net cost (-benefit)
NEW	3%	10%	19%	22%	31%	€ 140
young used (4-9)	26%	28%	35%	32%	29%	-€ 641
old used (9-15)	72%	62%	47%	46%	41%	€ 108
TOTAL	100%	100%	100%	100%	100%	

	1	2	3	4	5
NEW	€ 4	€ 14	€ 26	€ 30	€ 43
5 - 10y	-€ 164	-€ 180	-€ 222	-€ 205	-€ 183
>10y	€ 77	€ 67	€ 50	€ 50	€ 44
TOTAL	-€ 83	-€ 99	-€ 146	-€ 125	-€ 96
% annual income	-2.76%	-1.42%	-0.86%	-0.38%	-0.16%

Table 1 above summarizes the distribution of cost and benefits of fuel efficiency among different ownership periods during the vehicle lifetime and the different socio-economic groups. In the top right corner, the net costs (negative if benefits) during ownership of a fuel efficient car are compared to a non-fuel efficient alternative. This model assumes 3 different owners during the lifetime of the vehicle. In this case, the first owner has a cost of 140€ over the ownership period of the first 4 years when choosing the fuel efficient car. The second owner has a benefit of 641€ in case of the fuel efficient option.

The left side of table represents the distribution of the stock of vehicles owned by the different household income groups. "1" represents the lowest income group, "5" the highest. The lower income groups tend to own more and older used cars; the higher income groups have a higher share of new cars. Costs/benefits are proportionally allocated and compared to the annual household income. We find that all income groups benefit from fuel efficiency; in relative terms to household income, the lowest income groups benefit the most.

Geographically, benefits for EU-10 Member States increase if the initial price premium (mainly borne by first owners from EU-15 buying more new cars) is high. The earlier exports happen, the more profound the benefit for the importing partner.

Summarized, fuel efficiency generates a total net benefit for all owners combined over the lifetime of the vehicle. The way benefits are distributed depends mainly on the initial price premium. This value was estimated to be between 10 and 50€/g CO_2, building on findings in the evaluation of the regulation on car/LCV fuel efficiency (Ricardo, 2015). If the initial price premium for fuel efficiency is high, total benefits of fuel efficiency are lower, but still positive and low income groups and car owners in EU-10 Member States proportionally benefit more.

[4] X-axis 1-5 represents household income groups, 1 being the lowest income group and 5 the highest. Bracket threshold values can be found in the main report.

2 Overall methodology and structure

This report is structured as follows:

Chapter 3 deals with the link between fuel economy/ CO_2-emissions and prices on the used car market. The objective is to establish the contribution of different used vehicle properties to its value on the second-hand market, with a focus on fuel efficiency. This includes a combination of data collection and in depth data analysis.

Chapter 4 deals with the link between (used car) ownership and socio-economic properties of the owner. The objective of this chapter is to gather information on and analyse the connection between vehicle owners' social strata and their vehicle ownership patterns. This includes a description of the primary survey dataset and a set of comprehensive set of graphs and figures. This chapter also includes an estimation attempt to decompose the EU passenger car fleet per socio-economic group and new/used car categories by age.

Chapter 5 looks into the cross border trade of used cars in the EU. This basically constitutes an updated of the study carried out in 2011 that produced an estimate of used car flows for the year 2008 (OKO - Mehlhart e.t al., 2011). The chapter includes an overview of collected data and an updated overview of vehicle trade flows by origin and destination between countries.

Chapter 6 brings together results of the previous chapters, and comprises 2 analyses. The first links the price setting on the second hand vehicle market and the fuel efficiency improvements of EU CO_2 regulations to social strata, while the second links those improvements and prices to Member states.

3 Used car pricing, relevance of CO_2-emissions

3.1 Objective

This chapter deals with an econometric analysis of the effect of CO_2-emissions on the value of cars on the second hand market.

It deals with the following questions:

1. What is the effect of fuel efficiency, indicated by the CO_2-emissions, on the value of passenger cars on the second hand market, when taking into account other factors that influence that value?
2. To which degree is the added value associated with higher fuel efficiency, passed on to subsequent owners in the second hand market, notably to third or fourth owners of cars and LCV's?
3. What is the effect of fuel efficiency, indicated by the CO_2-emissions, on the value of light commercial vehicles (LCVs) on the second hand market, when taking into account other factors that influence that value?

To answer these questions, we have performed econometric tests on a model where the trading value of a second hand car is explained by its CO_2-emissions horsepower of the engine, its age and mileage (in kilometres), its weight, the type of fuel, the brand, the country in which a car is traded and its built year.

The chapter is structured as follows: the next section covers the methods used. The third section focusses on data. Finally, we report the results. The annexes present elaborated estimation results, correlation tables, and descriptive statistics and distribution plots of the variables.

3.2 Methodology

3.2.1 General approach

To estimate the effect of CO_2-emissions on the value of cars traded at the second hand market, we have developed a regression model. With this model, we have estimated the effect of CO_2-emissions on the value of cars at the second hand market, while controlling for other factors that affect the value. We have done this by using information on prices, CO_2-emissions and other factors that are provided by sellers and can be readily observed by potential buyers of the car.

As an indicator for the trade-value of a car, we use information from a combination of data sources, including an own dataset and the seller's published price of the car on online advertisements, the CO_2-emissions as well as other relevant characteristics. This information can be readily observed by potential buyers. It thus seems appropriate to assume that sellers as well as most buyers are aware of CO_2-emissions (and hence fuel efficiency) and other relevant characteristic when they determine the value for which they are willing to trade the car.

Unfortunately, we do not directly observe trading prices of cars, but rather the published price by the seller. As long as the assumption holds that the difference between the published price and the trading price is not correlated with CO_2-emissions, this does not affect the outcomes.

3.2.2 Development of regression model

We have formulated a model where the value of a second hand car (P) is explained by its CO_2-emissions (CO_2), horsepower of the engine (HP), its age and mileage (in kilometres) (Age and Mileage respectively), its weight (Weight), the type of fuel (Fueltype), the brand (Make), and the country in which a car is traded (Country).

Theoretically, we expect CO_2 to have a negative linear effect on the price of a car. The linear effect arises, because CO_2-emissions are linearly related with fuel consumption. Hence the effect of CO_2-emissions on saved fuel costs is a linear effect, which we expect to show up in an increase in value of the car on the second hand market. We have thus included CO_2 linearly in our model that explains P.

Concerning the effect of horsepower (HP) of the engine on the value of the car, we have no strong expectations about its exact relationship, except that it should be positive. We have included horsepower in a flexible way in the model, by including 50 indicators for different classes of horsepower (HP classes) running from low to high. We have tested robustness for other specifications that did not influence the results of the model.

Concerning Age, we expect that the impact on the value of the car is negatively related to the % increase in age of the car. Thus, a car getting older from age 1 to 2 years has a similar (negative) effect on the value of the car as one getting older from 2 to 4 years. We have modelled this by including age in (natural) logarithm. However, our theoretical expectations are not very strong. We have thus also allowed for a flexible impact of age on the value of the car, by including an effect for the year of built of the car (Built year) next to the logarithm of the age. The inclusion of an effect for the year of built of the car, allows e.g. to control for the fact that average CO_2-emissions have fallen over the years (see figure 9).

For Mileage, we have modelled the effect on the value of car so that a %-change in the mileage of the car has a negative effect on its value. This reflects how a car is written off as mileage increases. However, we are aware that in the practice of the price formation on the second hand car market, there may be certain threshold values in mileage that are associated with jumps in write-off speed. We have incorporated this in our model by allowing different impacts of the %-change in miles for cars ranging between: 0-10.000 kms, 10.000 – 25.000 kms, 25.000 – 50.000 kms, 50.000 – 100.000 kms, 100.000 – 200.000 kms and 200.000 kms and more.

Concerning Weight, we included this variable as a proxy for the size of the car. As this is a rather rough indicator, we have included 50 weight classes (Weight class) in our model. We have tested robustness for other specifications.

With respect to Fuel type, Make and Country, we have included indicators for the different fuel types, makes and countries that are present in the database.

Formally, the regression model is depicted below. Linear model:

$$P = \beta_0 + \beta_1 CO2 + \beta_2 \log(Age) + \sum_{range} \beta_{3,range} \log(Mileage_{range})$$

$$+Fueltype + Make + Country + Built\ year + HP\ class + Weight\ class + \varepsilon$$

We have used ordinary least squares to estimate the coefficients of the models, with heteroscedasticity and autocorrelation consistent standard errors.

3.3 Data

We have collected data for the variables mentioned above by combining two sources: online advertisement websites and the EEA monitoring database. The first source provides information for the trading value of the car (the published price by the seller), CO_2-emissions, horsepower, age, mileage (in kilometres), fuel type, brand, country and built year. We couple this information with data on weight and wheelbase, based on make and model of the car. The latter data are from the EEA monitoring of CO_2-emissions of passenger cars and LCV's. For both sets, we have cleaned the data from obvious outliers (like negative values) before running the econometric estimations.

We have a dataset that contains information for one or more of the variables, for 398.737 cars

We have used the following rules to clean the data:

- Remove observations that do not have values for all variables[5]
- Keep only second hand cars[6]
- Keep only cars with age below 30 years
- Keep only cars with a price between 100€ and 100.000€
- Keep only cars with an emission value between 50 g CO_2/km and 999 g CO_2/km
- Keep only cars with a positive value for price and weight

3.3.1 Passenger cars

We remain with a sample of 243.898 passenger cars after cleaning. To test for robustness of the outcomes, we have mainly worked with a sample where we have removed data with values that are farther away than 2 standard deviations from the mean of the selected variables listed above. For the estimation of the main model we use further in the analysis, we are then left with 202.055 2^{nd} hand cars in the sample.

Below, we cover distribution plots of selected variables. In the annexes, distribution plots of all variables can be found.

[5] CO_2-emissions, for instance, are not reported for all cars. We have only kept cars in the sample for which these are reported.

[6] To guarantee that we actually have only second hand cars in our sample, we excluded cars with less than 5000 km driven.

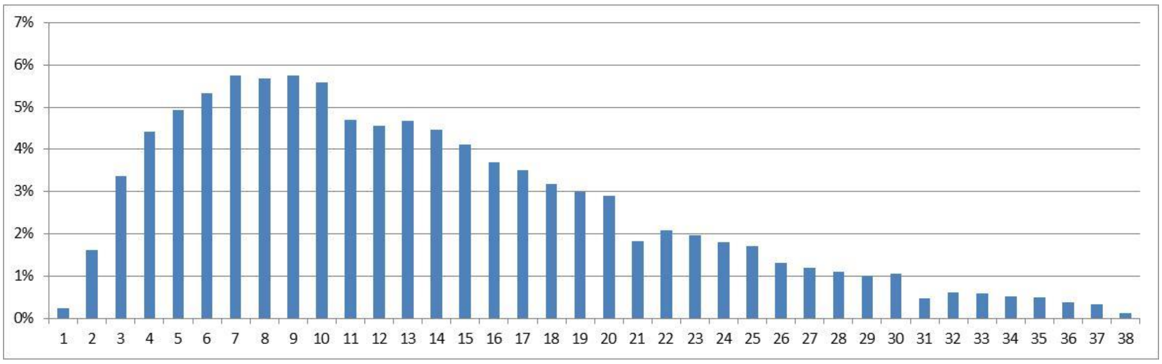


figure 2: The distribution of the value (k€) of second hand passenger cars, cleaned database with values between 2 standard deviations of the mean

We observe that the value of cars ranges from around €1.000 to around €38.000 euros. For the purpose of running a regression, this provides ample variance in this variable. The median value of a second hand car in our database is €11.600; the mean value is €13.106.

Of course, these are advertised prices and not the actual prices paid for used cars. A second database with survey data further referred to as TML-GfK database (GfK, 2014) will be discussed in the next chapter. This database includes published as well as paid prices for about 25.000 used car transactions. Figure below show the relative difference between paid and published price for different price ranges of used cars:

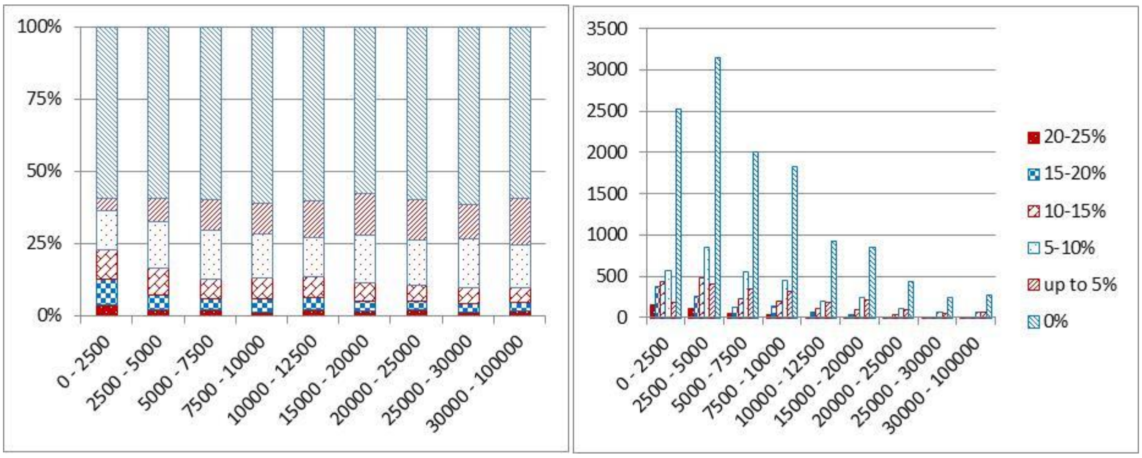


figure 3: relative discount given for used cars in different price ranges – relative share per discount category (left) - number of transactions (right)- (source: GfK, 2014)

We can see in over 50% of the cases no discount is obtained, or the respondent in the survey did not report any discount. Most common discounts are in the order of 0-10%. In general we cannot see any major differences between cars of different prices ranges, although relative discounts are somewhat higher for used cars of lowest value. We conclude no correction is needed and work further with the published prices for the analysis.

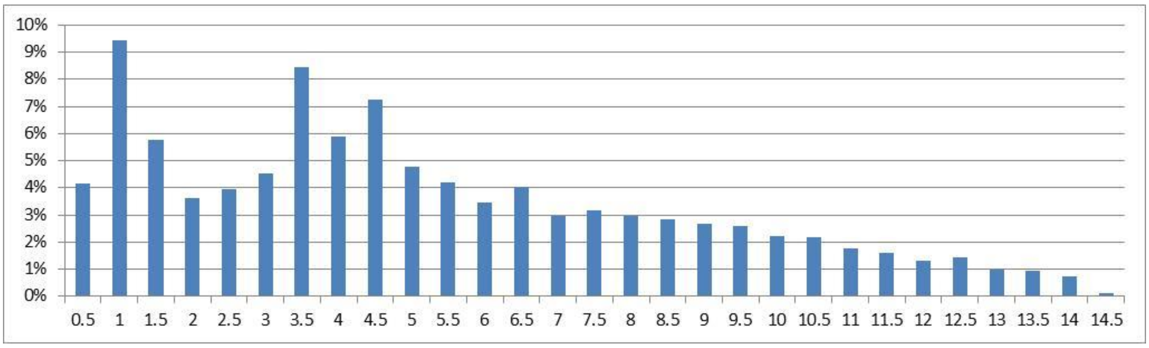


figure 4: The distribution of the age of second hand cars, cleaned database (per 0.5 year)

We observe that the age of traded second hand cars has peaks at 1 year, and around 4 years, and then rather smoothly fades out until the age of 15. The peak at around 4 years can be explained by a substantial supply of young cars from finished lease contracts. A reason for the peak of cars between 0.5 and 1 year old may be that dealers of new cars around that age have an incentive to list the car as second hand, because then they may have more room to give a discount than if the car is listed as new.

To check whether the age distribution in our dataset is representative for the age distribution of cars in the second hand market, we compare the age distribution from cars in our cleaned database with the age distribution of cars in the TML-GfK database (GfK, 2014)[7]

Note that the distribution of the vehicle on sale does not necessarily equal the distribution of the vehicles in the fleet by age. Younger vehicles may be traded more frequently and in such case will be more common in this database, reflecting sales, compared to stock.

We compare the age distribution for the full database, with all cars aged between 0 and 30 years.

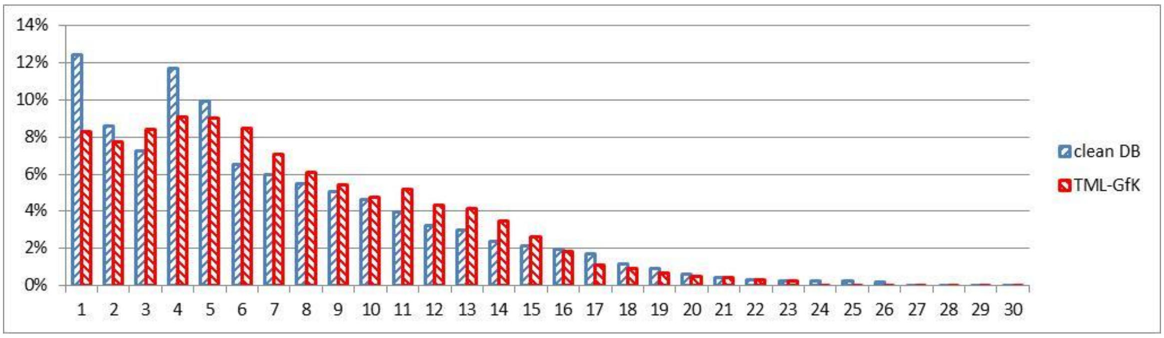


figure 5: The distribution of the age of second hand cars, full database with all cars ageing from 0 to 30 years, TML/GfK (red) – cleaned database (blue)

We observe that in both databases, the distribution peaks at the years 1 and at around 4, although in the database, the peaks are more pronounced. Moreover, in both databases, the distribution is skewed to the left with the majority of mass between years 0 and 5.

We conclude that the shape and peaks of the distribution of the sample used for our analysis is representative, because it is rather comparable to the age distribution of other samples.

We now turn to the distribution of the variable of main interest in our analysis (figure 6).

[7] ideally this should be weighted for vehicle stock by country to make it more representative for this comparison.

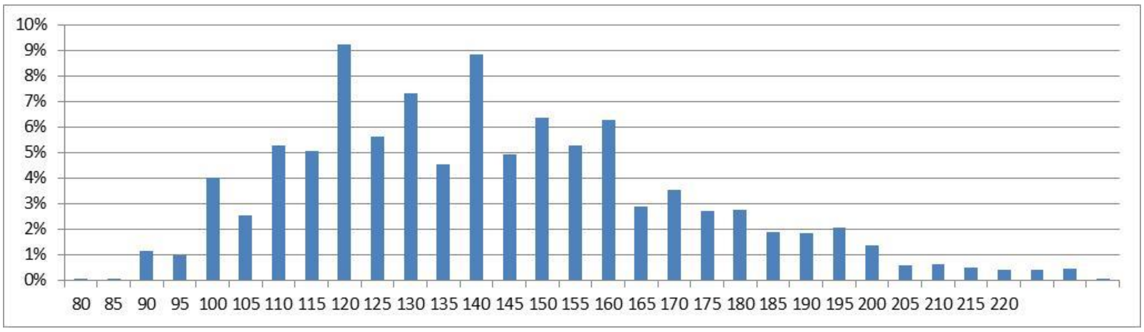


figure 6: The distribution of the CO_2-emissons of second hand cars, cleaned database.

We see that CO_2-emissions vary from around 75 g/km to 230 g/km. The mean and median values are at around 140 g/km.

Below, we plot figures that show the distribution of mileage for cars of different ages.

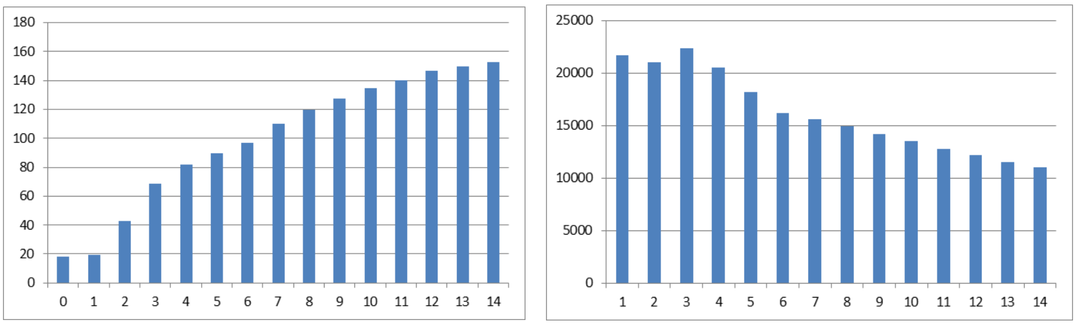


figure 7: Average cumulated mileage for cars of different age (1000skm - left), Average annual mileage for cars of different age (1000 km/year, right), cleaned database.

We observe that the average number of kilometres drive rises with age. However, the average amount of kilometres driven per year falls with age (see figure below)

This reflects that cars that last longer are used less intensely.

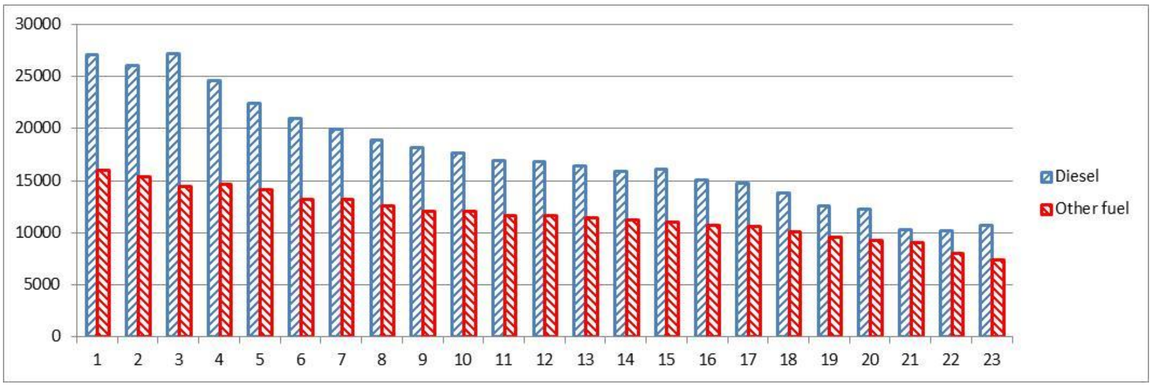


figure 8: Average annual mileage for cars of different ages split by fuel type, cleaned database (1000 km/y)

figure 8 splits the mileage/year for cars of different ages into cars that use diesel and cars that use a different fuel. We observe that the average mileage/year is higher for diesel cars, and that it peaks at cars with an age of around 3 years. The higher average mileage/year is a consequence of diesel cars being more economical and therefore being purchased where driven distances will be higher. The peak at three may be a consequence of diesel cars being more often lease cars (80% of lease cars are diesel compared to 55% in the overall fleet). Lease cars typically drive more km/year (on average about 30,000km), while they return from the lease and are sold at the second hand market typically at around 4 years (average lease period is 41 months).

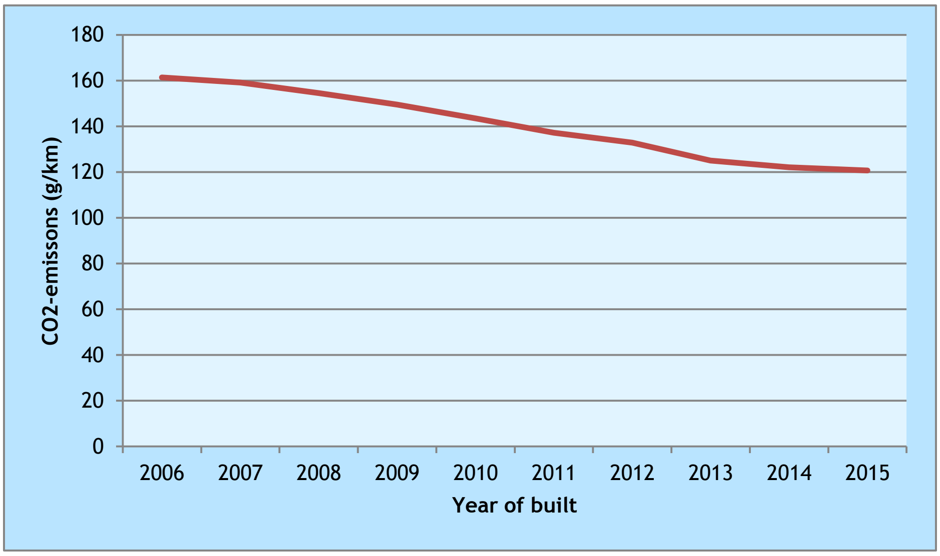


figure 9: Average emissions of CO_2 per year of built of the car

Judging from this figure, average fuel efficiency has risen in recent years. We take account of this characteristic by the inclusion of dummies for the year of built of the car in the estimations. Dummies for year of built should thus control for the variation over the past years.

3.3.2 LCVs

We remain with a sample of 172.817 LCVs after cleaning[8].

To test for robustness of the outcomes, we have mainly worked with a sample where we have removed data with values that are farther away than 2 standard deviations from the mean, as was done for passenger cars.

We are then left with 140.136 2nd hand LCV's in the sample.

Below, we cover distribution plots of selected variables. In the annexes, distribution plots of all variables can be found.

[8] Note that the sum of the LCV's and passenger cars adds up to more than the total sample size. The reason is that there is overlap between make and models of cars that are in the EEA-list of passenger cars and in the list of LCV's.

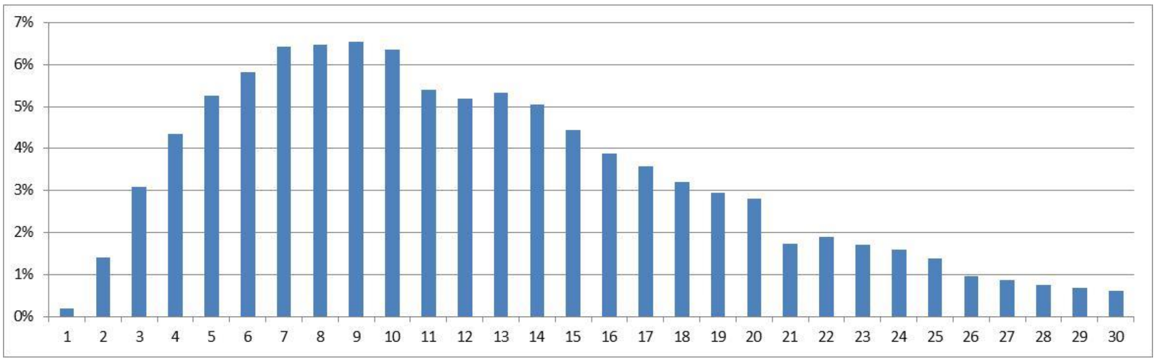


figure 10: The distribution of the value of second hand LCVs (k€), cleaned database with values between 2 standard deviations of the mean

We observe that the price of LCVs ranges from some €1.000 to €30.000. The median value is around €11.842, which is a little larger than the median value for passenger cars (albeit this difference is far from being statistically significant). This provides ample variation for the purpose of a regression analysis.

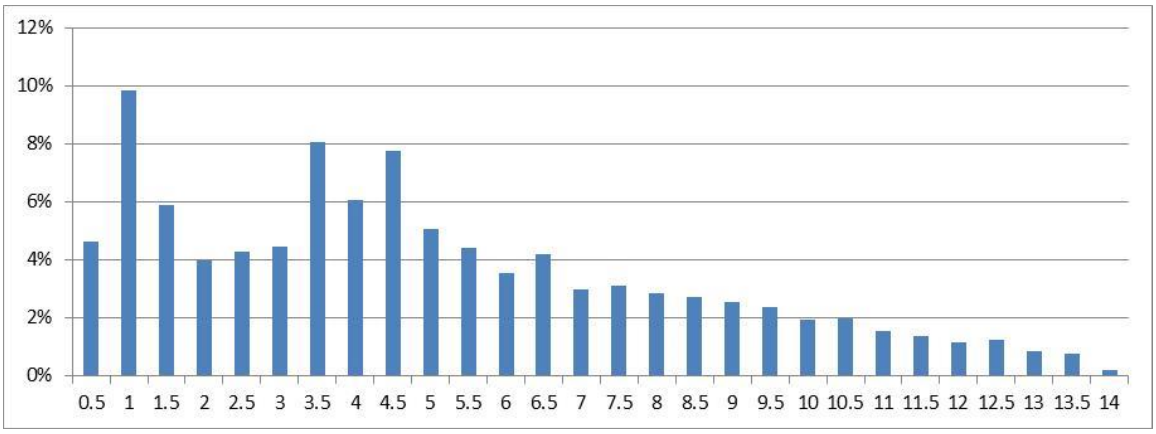


figure 11: The distribution of the age of second hand LCV's, cleaned database with values between 2 standard deviations of the mean.

Looking at the age distribution, we see similar peaks as with the passenger cars.

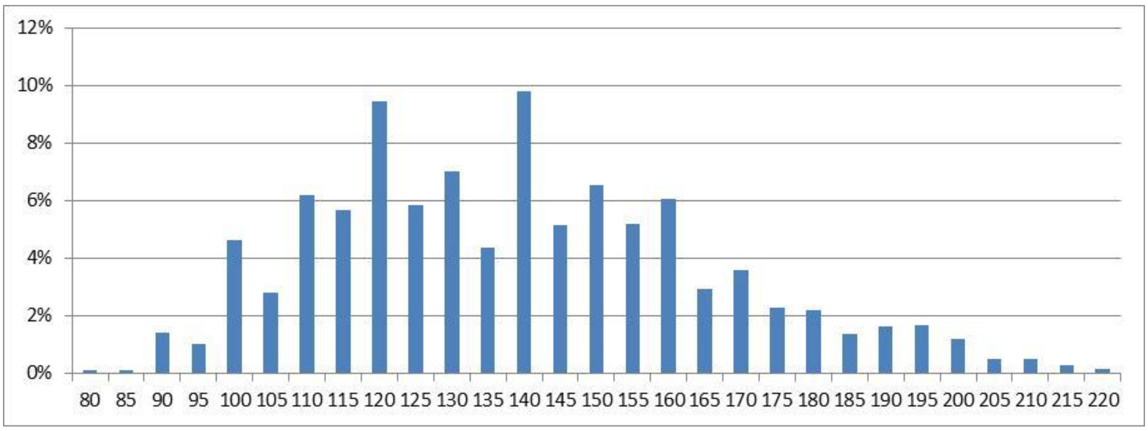


figure 12: The distribution of the CO_2-emissons of second hand LCV's, cleaned database with values between 2 standard deviations of the mean

Median CO_2-emissions for LCV's (135) are comparable with those passenger cars (138). The same holds for weight (see annex). This would suggest that the lighter LCV's, of the type that can be transformed into passenger cars and vice versa by adding/removing seats are included in the sample.

Below, we plot figures that show the distribution of mileage for LCV's of different ages.

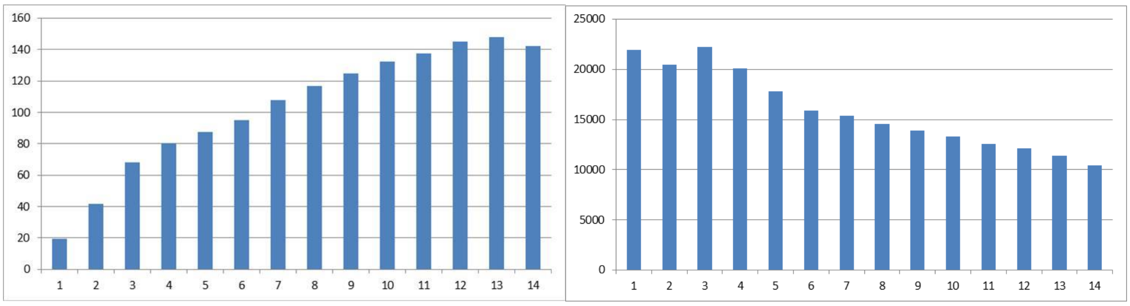


figure 13: Average mileage for LCV's of different age (1000km - left), annual mileager for LCV's of different age (1000 km/year - right), cleaned database with values between 2 standard deviations of the mean

We observe that the average number of kilometres driven rises with age. However, the average amount of kilometres driven per year falls with age (see figure below)

This reflects that LCV's that last longer are used less intensely.

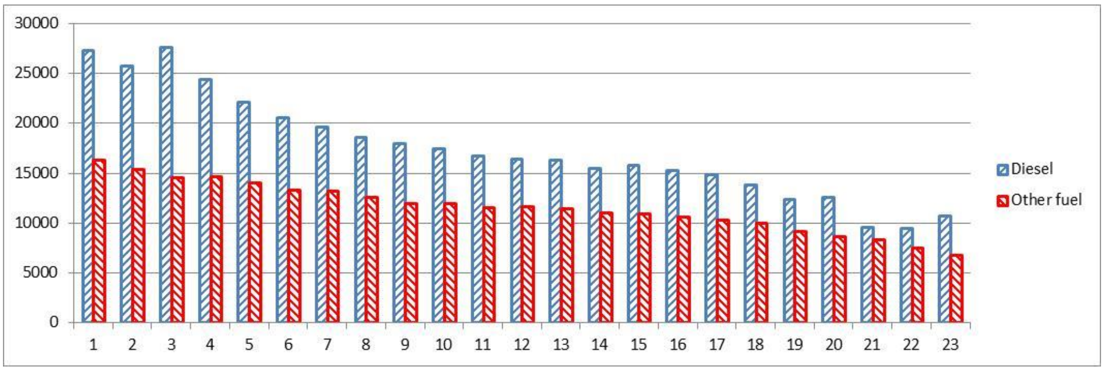


figure 14: Average mileage/year for LCV's of different ages split by fuel type, cleaned database with values between 2 standard deviations of the mean (1000 km/y)

Table 2 displays the distribution of LCV's over weight classes, comparing our database with the total population[9].

Table 2 Distribution of LCV's over weight classes

Class	Weight	Percent in our database	Percent in total population
Class I	Reference mass ≤ 1305 kg	33%	10%
Class II	1305 kg < Reference mass ≤ 1760 kg	61%	31%
Class III	1760 kg < Reference mass ≤ 3560 kg	6%	59%
Total		100%	100%

[9] Numbers for the total population follow from http://ec.europa.eu/clima/policies/transport/vehicles/docs/ldv_downweighting_co2_report_en.pdf, figure 3-22. Ideally this should be weighted by trade-intensity to make the comparison representative.

From the table, we see that indeed the lightest class is overrepresented in our database, while the heaviest class is substantially underrepresented. We take this sample bias into account in our estimation LCV(9).

3.4 Results

Below, we cover the main results of the econometric estimation, by providing an answer to the questions above.

3.4.1 Answers to the research questions

In this section we summarize the key answers to the research questions. A detailed discussion is added in the subsequent section.

Research question one was:

"*What is the effect of fuel efficiency, indicated by the CO_2-emissions, on the value of cars on the second hand market, when taking into account other factors that influence that value?*"

CO_2-emissions have a negative effect on the value of a passenger car on the second hand market of around €22 per gram CO_2 emitted per kilometre. This result is robust and statistically significant at a very high rate.

This result implies that if one owns a car that emits 120 g/km CO_2 instead of one that emits 140 g/km, the value of the car increases by about €440 on the second hand market.

The second research question was:

"*To which degree is the added value associated with higher fuel efficiency, passed on to subsequent owners in the second hand market, notably to third or fourth owners of cars?*"

There seems to be a marked increase in the extent to which the added value of car fuel efficiency is passed on, when the amount of owners increases. For cars aging between 0 to 5 years, the value of reducing CO_2-emisions with 1 gram/km is €5, while for cars within the age group of 5 to 10 years, this value is €30. For cars older than 10 years, this value increases to €42.

The third research question was:

"*What is the effect of fuel efficiency, indicated by the CO_2-emissions, on the value of LCV's on the second hand market, when taking into account other factors that influence that value?*"

We find that CO_2-emissions have a negative effect on the value of an LCV on the second hand market of around €13 per gram CO_2 that an LCV emits per kilometre. This result is statistically significant at a very high rate.

This result would imply that if one owns a car that emits 120 g/km CO_2 instead of one that emits 140 g/km, the value of the LCV increases by about €260 on the second hand market.

As we found with passenger cars, we observe a difference in added value passed on to subsequent owners. For younger LCV's, the value of reducing CO_2-emisions with 1 gram is €3, while for LCV's within the age group of 5 to 10 years, this value is €21. For LCV's older than 10 years, this value increases to €29.

3.4.2 Detailed results

Table 3 presents a summary of the detailed results of our estimations (more elaborate results in annex). Estimation (1) is our main result, on which the answer to research question 1 is based. The other estimation variants are other models, removing or adding variables and should be considered stability checks. E.g. in model 4, built year and mileage class dummies were removed; in model 5, more dummies were removed from the estimation. This leads to a slightly worse estimation (represented by the r^2 value – higher meaning a better fit), though still acceptable with an r^2 in the range of 0.8. Some variables are converted to logarithmic values ('log"). The model results are discussed below.

The results are robust. That is: the sign and significance of the effect are stable for changes in the sample on which our model is estimated, although the magnitude differs somewhat. Furthermore, sign, significance and magnitude are rather stable for changes in the specification of the model, like adding or removing variables to/from the model.

Table 3: Results of models that explain the value (€) of second hand cars by CO_2-emissions and other variables

Type	Main model		Removing or adding variables				Split
Estimation	1	2	3	4	5	6	7
Estimation variant	Main model	Main, but with larger sample	Complete model	Simple model	Fewer dummies	No dummies	CO2 split between types of fuel
Variable							
CO2 (g/km)	-22	-53	-22	-57	-45	-60	no
Age (year), log	-1054	-1560	-1035	-2674	-3231	-2673	-1084
Mileage (1000 kilometres), log	no	no	no	-2465	no	no	no
class 0-10	-3190	-2889	-934	no	5167	-4203	-3141
class 10-25	-2448	-2192	-308	no	3890	-2989	-2427
class 25-50	-2086	-1836	-863	no	3101	-2466	-2078
class 50-100	-1991	-1843	-2680	no	2276	-2394	-1993
class 100-200	-2277	-2186	-6287	no	1400	-2721	-2269
class 200 up	-2636	-2520	-6895	no	736	-3059	-2605
Engine power (hp), log	no	no	5335	no	no	11579	no
Weight (kg)	no	no	5	no	no	9	no
CO2 (g/km), Diesel	no	no	no	no	no	no	-31
CO2 (g/km), other fuel	no	no	no	no	no	no	-12
Fuel type dummies	yes	yes	yes	yes	no	no	yes
Make dummies	yes	yes	yes	yes	no	no	yes
Country dummies	yes	yes	yes	yes	no	no	yes
Built year dummies	yes	yes	yes	no	no	no	yes
HP class dummies	yes	yes	yes	yes	yes	no	yes
Weight class dummies	yes	yes	yes	yes	yes	no	yes
Mileage class dummies	no	no	yes	no	no	no	no
N	202.055	243.898	202.055	202.055	202.055	202.055	202.055
r2	0,877	0,842	0,881	0,850	0,811	0,787	0,878

NOTES:

- All reported coefficients are significant with P-values below 0.1%.
- Estimation (1) is our preferred estimation. It is estimated on the cleaned, complete sample after removal of all observations for which 1 or more of the independent variables contained 1 or more values outside a 2 standard deviation interval of the mean.
- Estimation (2) is estimated on the complete, cleaned sample with obvious outliers removed
- Estimation (3) is as (1) with Engine power, weight and mileage class dummies added.
- Estimation (4) is as (1) with mileage (log) added and the mileage (log) split in classes and built year dummies removed.
- Estimation (5) is as (1), but without dummies for fuel type, make, country and built year
- Estimation (6) is as (1), but with all dummies removed and Engine power, log and weight added
- Estimation (7) splits the effect of CO_2 into an effect for cars using Diesel fuel and for cars using all other fuels.

We proceed discussing the findings.

<u>On the relation between CO_2-emissions and value of second hand passenger cars</u>

Estimation (1) is based on a sample that contains high quality data, while it still has a high degree of variation in the data. The data is of high quality, because in the sample of data on which we have estimated our model, we have manually removed implausible values (e.g. negative weights), and removed extremely large and extremely small values from the dataset (see earlier in section 3.3.1 for more information on the data cleaning process) by only keeping observations that are within 2 standard deviations of the mean for all variables involved in the model. This sample thus strikes a balance between variety and quality of the data.

From estimation (1), we see that the value of reducing CO_2-emissions by 1 gram/km is €22.

The coefficient of the age of the car has to be interpreted with some caution, as we have also included dummies for built year. Disregarding the effect of the built year dummies, every doubling of age implies a €1.054 loss in value. To put things into perspective: the median value of a car in the sample is €11.600. The estimated coefficients of the built year dummies imply that there is some extra loss in value on top of this.

For mileage, the estimated coefficients imply that a doubling in the mileage results in a decrease in value that ranges from €1.991 for cars with a mileage between 50.000 and 100.000 km to €3.190 for the cars with the least mileage.

Estimation (2) presents results from estimating the same model is in (1), but on the complete, cleaned sample, not excluding data points beyond 2 standard deviations of the mean (see earlier for cleaning rules conducted). We observe that the value of CO_2 is larger at -€53, while the value of the other coefficients is either smaller or larger. All signs remain and all coefficients that turned up significant in the main regression. This indicates that "extreme" used cars (very high/low price, mileage, age,…) behave differently. In this sense, the model we used for the analysis is applicable to a "central" sub-set of used cars. As this covers >82% of the volume, this is representing the bulk of the market.

From the correlation table (see annex), we observe that correlation between some of the variables is rather high. This may result in so-called multicollinearity of variables. A feature of multicollinearity is that the estimation results may become instable for inclusion or removing of a variable that is highly correlated with another variable in the model. Another feature is that the variance of estimated coefficients may be inflated if two or more highly correlated repressors are included, which can be indicated by the so-called variance inflation factor (VIF).

To test whether multicollinearity plagues our regression results, we estimate several models in which we add or remove variables from the regression equation. We observe that the coefficient of CO_2 is rather stable for these manipulations, both in magnitude as well as significance. Thus, although some of the variables are highly correlated, this does not result in a multicollinearity problem.

As a limit to removing variables from the model, we adhere to our theoretical notions for which variables influence the value as well as the CO_2-emissions of a second hand car. We include all variables in the model in some form to prevent so-called omitted variable bias. Omitted variable bias arises if a third variable (e.g. engine power) influence both the dependent variable (e.g. value of the car) as well as the independent variable of interest (e.g. CO_2), but is not included in the model. In that case, the estimated coefficient on the independent variable is not just a measure of its effect on the dependent, but also of the indirect of the omitted third variable on the dependent, that runs through its correlation with the independent variable.

To prevent omitted variable bias, we include measures of age (or built year), horse power and weight in all models, next to CO_2. Estimations 3-5 reflect this:

Estimation (3) presents a more elaborate model than estimation (1), in which we have allowed a more flexible effect for Mileage and we have included weight and Engine power (in log-form). Clearly, the estimated coefficient on CO_2 remains the same, in sign, magnitude and significance. The estimated coefficient on age (log) is somewhat smaller in magnitude. The most affected variables are the various classes of Mileage (log), which are marked downwards in magnitude. This is to be expected, as the estimation variant introduces dummies for mileage classes.

Estimation (4) presents a simple model. We have included all variables for which we have some theoretical notion about the form of their relationship with the value of the car in that form. We have removed the more flexible forms of these variables (we have removed mileage (log) split in classes and built year dummies). We observe that the value of CO_2 is inflated (it more than doubles), as is the value of the %-change of age.

Estimation (5) shows the effect of removing dummies for which we have no a priori reason to expect them to affect the relationship between CO_2-emissions and car value: fuel type, make, country and built year[10]. This results in an inflated value of CO_2 of around a factor 2. Age (log) has the expected sign, but the signs of the classes of mileage (log) flip. This may be a result of the removal of the 4 types of dummies combined with the exclusion of mileage dummies, which forces the different classes of mileage (log) to pick up the effect of the mileage dummies.

Estimation (6) removes all dummies from the model, which results in an estimated coefficient of CO_2 of -€60.

Seemingly, removing the dummies results in a somewhat larger estimation of the price premium than in estimation (1) (main model). Note that estimations (5) and (6) may suffer from omitted variable bias as we have removed variables that are significant in estimation (1). Consequently, from an econometric point of view, estimation (1) is to be preferred. However, allowing other considerations to play a role and taking the estimations (5) and (6) at face value, the important thing to note is that the estimated value of the price premium is of the same number of magnitude and the sign remains the same if compared to estimation (1). We conclude that the estimation results are robust. Estimation (7) splits the effect of CO_2-emissions on car value into a separate effect for cars running on diesel and for cars running on a different fuel. We observe that the value of CO_2-emissions for diesel is of larger magnitude, and for other of smaller magnitude. The value remains negative and significant.

[10] We have included age (log) in the model. With this variable included, we may not expect built year dummies to affect the relation between CO_2 and car value.

On passing on added value to subsequent owners of passenger cars

In this section, we focus on answering research question 2:

"*To which degree is the added value associated with higher fuel efficiency, passed on to subsequent owners in the second hand market, notably to third or fourth owners of cars?*"

We analyse this question by looking at differences in the effect of CO_2-emissions for younger cars vis-à-vis older cars. The assumption is that older cars have had multiple owners. Therefore we distinguished three groups of cars depending on their age (0-5 years, 5-10 years, > 10 years) in the model and estimated whether the impact of CO_2-emissions on the second hand car value differ for these three groups. For comparison we repeat our main estimation (1).

Also, we test whether the effect of CO_2 differs between cars from different age groups. Although we interpret this test in light of the possibility of subsequent owners to pass on the added value of fuel efficient cars, we may also interpret it as a direct test for the stability of our estimations for splitting the effect of CO_2 into effects for different age groups. We see that the estimated effect is negatively significant for all age groups, although it differs in magnitude.

Table 4: Results of models that explain the value (€) of second hand cars by CO_2-emissions and other variables, comparing different age groups

Estimation	1	8
Variable	Main model	CO2 split between age groups
CO2 (g/km) all cars	-22	no
CO2 (g/km) cars younger than 5	No	-5
CO2 (g/km) cars between 5 and 10	no	-30
CO2 (g/km) cars older than 10	No	-42
Age (year), log	-1054	-955
Mileage (1000 kilometres), log	no	no
class 0-10	-3190	-3119
class 10-25	-2448	-2399
class 25-50	-2086	-2048
class 50-100	-1991	-1954
class 100-200	-2277	-2240
class 200 up	-2636	-2597
Fuel type dummies	yes	yes
Make dummies	yes	yes
Country dummies	yes	yes
Built year dummies	yes	yes
HP class dummies	yes	yes
Weight class dummies	yes	yes
Mileage class dummies	no	no
N	202.055	202.055
r2	0,877	0,881

From the table, we observe that the effect of fuel efficient cars (with smaller CO_2-emissions) increases in magnitude with age of the car. This implies that it is likely that 3rd owners are better able to pass through the added value of fuel efficient cars than 2nd owners, and e.g. 4th or 5th owners are better to pass the value on than 3rd owners. This may be explained by the notion that, the more owners a car has had and the older it becomes, the more dominant the value of fuel costs becomes in the total use costs of the car.

It was not possible to study from this data whether higher fuel efficiency vehicles are retained longer by their owners, as the data available for this study do not provide any information on the number of times the cars are resold and the intervals between these sales.

The fact that the premium value increases with subsequent ownership transfer, and thus vehicle age, is opposite to the initial hypothesis. One would expect the value to decrease, mainly because of 2 reasons:

1. The value of the car decreases over time; one would expect that also the individual components in the model making the price decrease proportionally.
2. The benefit of fuel efficiency decreases with vehicle age as the future fuel benefits decrease due to decreasing remaining service life as well as decreasing intensity of use (i.e. older vehicles typically have lower annual mileage).

It is striking that we find a robust result that suggests the opposite of our initial hypothesis. We have reviewed the methodology extensively and have considered the following possible explanations and how these effects were controlled:

1. There is a trend in CO2-emissions over the built-years of the vehicle. CO2-emissions decline with recency of built-year. This may distort the estimation of the fuel efficiency premium for different age groups. We have controlled for this by including built-year dummies in the model. These dummies account for this effect so the trend in CO2-emissions over the built-years cannot explain the result.
2. Older cars are typically bigger cars. These are more expensive. This may distort the estimated fuel efficiency premium. We have controlled for this by including weight dummies in the model. These dummies account for the link between bigger and expensive cars so cannot explain the result.
3. Certain more expensive brands may be overrepresented in vehicles in older age cohorts. We have controlled for this by including both make-dummies and age-dummies in the model.
4. Diesel cars may be overrepresented in older age cohorts. As these are more expensive than petrol cars, this may distort the estimated fuel efficiency premium. We have controlled for this by including both dummies for fuel type and age in the model. These pick up the effects of shifts in the distribution of the traded cars over the fuel types.

Possible explanations that substantiate our finding:

- Fuel-efficient cars may be overrepresented in older age cohorts, because the scrappage rate of fuel-efficient cars is lower (hypothesis). That may be a reason for our finding if the premium associated with higher fuel efficiency is more than proportional to CO2-emissions, while the model assumption is that it is exactly proportional.
- Fuel costs represent a larger share of the Total Cost of Ownership for the second owner of a car than for the first owner (and for the third owner this share is even larger), as the investment costs of cars decrease exponentially. Therefore the second/third owner will pay more attention to the fuel efficiency of the car and consequently this will result in a higher premium.
- There is a genuine lack of information in the used car market for later owners of used cars which causes irrational/uninformed purchase decisions.

The project team recommends further research is needed to understand what the underlying mechanism are that drive the increasing purchase cost premium in the used car market we found in this analysis.

On the relation between CO_2-emissions and value of second hand LCV's

This section focusses on answering research question 3. The question reads:

"*What is the effect of fuel efficiency, indicated by the CO_2-emissions, on the value of light commercial vehicles (LCV's) on the second hand market, when taking into account other factors that influence that value?*"

Estimation LCV(1) is based on a sample that contains high quality data, while it still has a high degree of variation in the data. The data is of high quality, because in the sample of data on which we have estimated our model, we have manually removed implausible values (e.g. negative weights), and removed extremely large and extremely small values from the dataset (see section 3 for more information on the data cleaning process) by only keeping observations that are within 2 standard deviations of the mean for all variables involved in the model. This sample thus strikes a balance between variety and quality of the data.

Table 5: Results of models that explain the value (€) of second hand LCV's by CO_2-emissions and other variables

Type	Main model		Removing or adding variables			Split		
Estimation	LCV(1)	LCV(3)*	LCV(4)	LCV(5)	LCV(6)	LCV(7)	LCV(8)	LCV(9)
Estimation variant	Main model	Complete model	Simple model	Fewer dummies	No dummies	CO2 split between types of fuel	CO2 split between age groups	weighted regression
Variable								
CO2 (g/km)	-13	-14	-45	-37	-46	no	no	-11
Age (year), log	-1008	-987	-2446	-2908	-2601	-1035	-944	-1124
Mileage (1000 kilometres), log	no	no	-2130	no	no	no	no	no
class 0-10	-2623	-706	no	3628	-3452	-2585	-2578	-3954
class 10-25	-2027	-327	no	2791	-2464	-2008	-1995	-3011
class 25-50	-1751	-793	no	2208	-2030	-1742	-1727	-2591
class 50-100	-1687	-2232	no	1579	-1980	-1683	-1663	-2431
class 100-200	-1934	-5553	no	878	-2249	-1924	-1911	-2693
class 200 up	-2250	-6739	no	316	-2540	-2224	-2226	-3012
Engine power (hp), log	no	1569	no	no	9325	no	no	no
Weight (kg)	no	9	no	no	8	no	no	no
CO2 (g/km), Diesel	no	no	no	no	no	-21	no	no
CO2 (g/km), other fuel	no	no	no	no	no	-4	no	no
CO2 (g/km), LCV's younger than 5	no	no	no	no	no	no	-3	no
CO2 (g/km), LCV's between 5 and 10	no	no	no	no	no	no	-21	no
CO2 (g/km), LCV's older than 10	no	no	no	no	no	no	-29	no
Fuel type dummies	yes	yes	yes	no	no	yes	yes	yes
Make dummies	yes	yes	yes	no	no	yes	yes	yes
Country dummies	yes	yes	yes	no	no	yes	yes	yes
Built year dummies	yes	yes	no	no	no	yes	yes	yes
HP class dummies	yes	yes	yes	yes	no	yes	yes	yes
Weight class dummies	yes	yes	yes	yes	no	yes	yes	yes
Mileage class dummies	no	yes	no	no	no	no	no	no
N	140136	140136	140136	140136	140136	140136	140136	140136
r2	0,876	0,881	0,845	0,805	0,778	0,877	0,879	no

Notes:

- All reported coefficients are significant with P-values below 0.1%.
- Estimation number LCV(1) is our preferred estimation. It is estimated on the cleaned, complete sample after removal of all observations for which 1 or more of the independent variables contained 1 or more values outside a 2 standard deviation interval of the mean.
- Estimation LCV(3) is as LCV(1) with Engine power, weight and mileage class dummies added.
- Estimation LCV(4) is as LCV(1) with mileage (log) added and the mileage (log) split in classes and built year dummies removed.
- Estimation LCV(5) is as LCV(1), but without dummies for fuel type, make, country and built year
- Estimation LCV(6) is as LCV(1), but with all dummies removed and Engine power, log and weight added
- Estimation LCV(7) splits the effect of CO2 into an effect for LCV's using Diesel fuel and for LCV's using all other fuels.
- Estimation LCV(8) splits the effect of CO2 into an effect for LCV's of different age groups (0-5, 5-10, 10 years up)

- Estimation LCV(9) weights the regression to compensate for the bias in representativeness of LCV's of different weight classes.
- LCV(3)*: An estimation based on the complete, cleaned sample (equivalent to estimation number (2) for passenger cars) turned out not to be possible due to a near complete multi-collinearity of some of the regressors (HP and weight class dummies).

From estimation LCV(1), we see that the value in the second hand market of reducing CO_2-emissions by 1 gram/km is €13.

The coefficient of the age of the LCV has to be interpreted with some caution, as we have also included dummies for built year. Disregarding the effect of the built year dummies, every doubling of age implies a €1.008 loss in value. To put things into perspective: the median value of a LCV in the sample is €10.850. The estimated coefficients of the built year dummies imply that there is some extra loss in value on top of this.

For mileage, the estimated coefficients imply that a doubling in the mileage results in a decrease in value that ranges from €1.687 for LCV's with a mileage between 50.000 and 100.000 km to €2.623 for the LCV's with the least mileage.

We could not estimate the LCV-analogue for estimation (2) for passenger cars. This estimation would have been based on the complete, cleaned sample (see earlier for cleaning rules conducted). However, we encounter a near complete collinearity problem when running this regression.[11] This happens because some of the HP class dummies span some of the weight class dummies. In short, it doesn't make sense to include both variables as a predictor as groups using these variables as a distinguishing factor span the same group of vehicles.

Estimation LCV(3) presents a more elaborate model than estimation (1), in which we have allowed a more flexible effect for Mileage and we have included weight and Engine power (in log-form). The estimated coefficient on CO_2 remains rather stable with a value of -€14. Other variables keep the same sign and significance.

Estimation LCV(4) presents a simple model. We have included all variables for which we have some theoretical notion about the form of their relationship with the value of the LCV in that form. We have removed the more flexible forms of these variables (we have removed mileage (log) split in classes and built year dummies). We observe that the estimate of the impact CO_2 on LCV-value increases to -€45. Age and Mileage have the expected sign.

Estimation LCV(5) shows the effect of removing dummies for which we have no a priori reason to expect them to affect the relationship between CO_2-emissions and LCV value: fuel type, make, country and built year . We see that the value of CO_2 is -€37. Age (log) has the expected sign. Like with estimate (5) for passenger cars, the signs of the classes of mileage (log) flip. This may be a result of the removal of the mileage dummies, which forces the different classes of mileage (log) to pick up the effect of the mileage dummies.

Estimation LCV(6) removes all dummies from the model, which results in an estimated coefficient of CO2 of -€46. Other variables have the expected sign.

[11] https://en.wikipedia.org/wiki/Multicollinearity

Estimation LCV(7) splits the effect of CO_2-emissions on LCV value into a separate effect for LCV's running on diesel and for LCV's running on a different fuel. We observe that the effect of CO_2 is bigger in magnitude for Diesel LCV's than for LCV's running on a different fuel.

Estimation LCV(8) tests whether the effect of CO_2 differs between LCV's from different age groups. We obtain a finding that is consistent with the finding for passenger cars: for younger cars, the value of CO_2 is somewhat smaller in magnitude, albeit it is negative for all age groups.

Estimation LCV(9) compensates for the difference in distribution over weight classes for our sample compared to the total population of LCV's. We weight the sample so that class I LCV's get a small weight in the estimation, while class II and more so class III get a higher weight. The weights are designed, so that the distribution of the weighted database mimics the distribution of the total population over weight classes. Looking at the results, we observe that the coefficient of CO_2 remains rather stable at -€11. The other coefficients seem to inflate somewhat in size.

3.5 Conclusions

We summarize the key conclusions of the analysis:

- Fuel efficient passenger cars have a positive price premium in the second hand market. The value of this premium is estimated to be of around €22 per gram CO_2 emitted per kilometre. This result is statistically significant at a very high rate, and robust to plausible changes in model specification or the removal of outliers in the dataset.
- This value associated with higher fuel efficiency is passed on between subsequent car owners. The value passed on increases with the sequence of owners.
- Fuel efficient Light Commercial Vehicles have a positive price premium in the second hand market. The value of this premium is estimated to be of around €13 per gram CO_2 emitted per kilometre. This result is statistically significant at a very high rate, and robust to plausible changes in model specification or the removal of outliers in the dataset.
- This value associated with higher fuel efficiency is passed on between subsequent LCV owners. The value passed on increases with the sequence of owners.
- The increasing cost premium with age is opposite to the initial hypothesis. A definite explanation could not be found. Further work is needed to understand the driving mechanisms.

4 Socio-demographic properties of the used car market

4.1 Objective

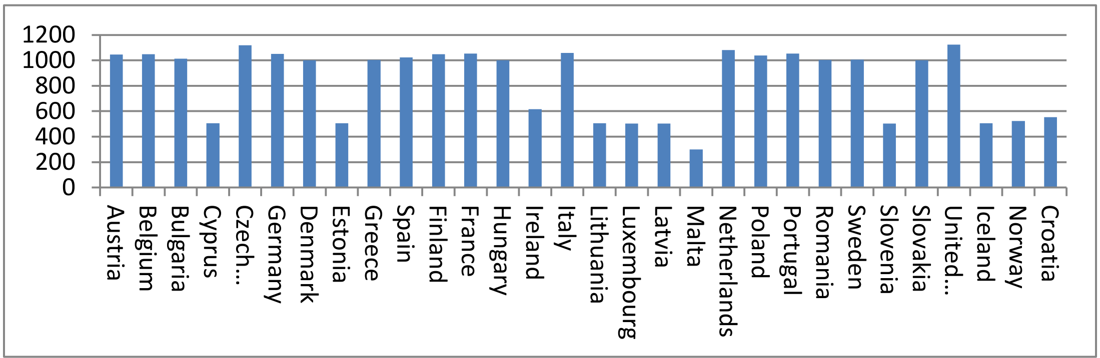
In this chapter, we go into the relation between (used) vehicle ownership and social profile of the owner. The goal is to understand how used car ownership differs from car ownership in general. The intuitive expectation is that low-income social groups spends less on transport equipment and will be forced to buy more in the used car market compared to the high-income groups. We first elaborate on the data we used for the analysis, interpret the pure data to come to first conclusions and finally link the data to other sources to gain further understanding.

4.2 Data collection

4.2.1 Used car survey

The primary data source for this task builds upon a survey done by GFK and TML for DG SANCO[12]. It includes detailed feedback from consumers. The dataset consists of 25,287 data points. The samples size is evenly distributed among all (at the time) EU-27 Member States plus HR, NO and IS. The aim was 1,000 respondents for bigger countries and 500 for smaller. Below an overview of the sample size per member state:

Figure 15: available sample size



On the vehicle side, the following data is gathered (list is limited to key parameters):

- Make/type
- Age (i.e. year of first registration)
- Year purchased
- Mileage upon purchase
- Annual mileage since purchase
- Fuel type
- Price paid
- Country of origin

[12] (GfK, 2014): Consumer market study on the functioning of the market for second-hand cars from a consumer perspective. http://ec.europa.eu/consumers/consumer_evidence/market_studies/second_hand_cars/index_en.htm

On the consumer side we have information on:

- Sex
- Age
- Education level
- Employment
- Household income

4.2.2 SILC

A second source is the EU-Statistics on Income and Living Conditions database (EU-SILC), which is based on an extensive survey and holds data on car ownership from one specific question on car ownership.

EU-SILC, is the reference source for comparative statistics on income distribution and social inclusion in the European Union (EU). It is used for policy monitoring within the 'Open method of coordination (OMC)'. EU-SILC provides two types of annual data:

1. cross-sectional data pertaining to a given time or a certain time period with variables on income, poverty, social exclusion and other living conditions;
2. longitudinal data pertaining to individual-level changes over time, observed periodically over a four-year period.

EU-SILC is a multi-purpose instrument which focuses mainly on income. Detailed data are collected on income components, mostly on personal income, although a few household income components are included. However, information on social exclusion, housing conditions, labour, education and health information is also obtained.

EU-SILC is based on the idea of a common "framework" and no longer a common "survey". The common framework defines the harmonized lists of target primary (annual) and secondary (every four years or less frequently) variables to be transmitted to Eurostat; common guidelines and procedures; common concepts (household and income) and classifications aimed at maximizing comparability of the information produced.

The reference population in EU-SILC includes all private households and their current members residing in the territory of the countries at the time of data collection. Persons living in collective households and in institutions are generally excluded from the target population. Some small parts of the national territory amounting to no more than 2 % of the national population and the national territories listed below may be excluded from EU-SILC. All household members are surveyed, but only those aged 16 and more are interviewed.[13]

[13] Description from the EU-SILC website: http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:EU_statistics_on_income_and_living_conditions_%28EU-SILC%29

SILC includes a single question on car ownership:

"

…Whether the household have a car or whether the household does not have a car because it cannot afford it (enforced lack) or for other reasons. 'Enforced lack' implies that the item is something that the household would like to have, but cannot afford. Possessing the item does not necessarily imply ownership: the item may be rented, leased, provided on loan, or shared with other households. If the item is shared between households, the answer is "Yes" if there is adequate/easy access (i.e. household can use the durable whenever it wants) and "No" otherwise.

In the case of a car, the household is considered to possess it if any member possesses it. A company car or van which is available to the household for private use counts as possessing the item. A car or van provided ONLY for professional purpose, should not be considered as possessing the item. Motorcycles are excluded…

"

SILC data provides information about households owning a car, in ownership or lease. It does not provide information about how many cars are owned by the household and it excludes professional vehicles and motorcycles.

4.2.3 Additional sources

Several auction websites publish own analysis based using the data from their trading platform. The British Car Association (BCA) publishes an annual used car market review, executed by the University of Buckingham. The report includes data on market volumes, prices, age-structure as well as limited information on the socio-economic properties of used car buyers. The report holds data for several years and some information for other EU countries.

2013 report: http://www.bcamarketplaceplc.com/~/media/Files/B/BCA/documents/bca-2013-used-car-market-report.pdf

2014 report: http://www.buckingham.ac.uk/wp-content/uploads/2014/11/pnc-2014-usedcar.pdf

The evaluation of the car and LCV CO_2 regulations by Ricardo-AEAT (Ricardo-AEA - Gibson et. al., 2015) provides limited information on the social impact of new environmental regulation for new cars:

http://ec.europa.eu/clima/policies/transport/vehicles/docs/evaluation_ldv_co2_regs_en.pdf

Several other papers provide fragmented insight in social aspects of the used car market:

- "A cross-country comparison of household car ownership – A Cohort Analysis –" A. BERRI- INRETS (2009)
- "From Consumer Incomes to Car Ages: How the Distribution of Income Affects the distribution of Vehicle Vintages" A. Yurko (2009)
- "THE DYNAMICS OF CAR OWNERSHIP IN EU COUNTRIES: A COMPARISON BASED ON THE EUROPEAN HOUSEHOLD PANEL SURVEY", J. Dargay (Oxford) & L. Hivert (INRETS) (2005)
- "The Anatomy and Physiology of the Used Car Business" CIRP II & Capgemini (2007)
- "A Dynamic Model of Vehicle Ownership, Type Choice, and Usage" K. Gillingham et. Al. (Yale) (2015)

4.3 Observations

The aim of analysis in this chapter is fairly straight-forward: we want to understand how car-ownership differs for different socio-economic groups and explicitly make the distinction in the ownership of new and used hand cars.

Unless otherwise specified, data refers to the used car survey as explained in section 4.2.1

4.3.1 Income

In this section, we look into the relation of the transaction indicator with income as the key indicator for socio-demographic group.

The income categories are fixed and linked to the options given to respondents in the survey. Because of this, it is not possible to set dynamic limits to the 5 income categories, to distribute the sample more evenly over the different groups. For the remainder of the analysis, in this and following sections, we are bound to the income categories as presented in table below. Of all respondents, 84% supplied information on household income, slightly reducing the useful sample to 21.711 records.

Table 6: Income-brackets considered in this study

	WEEKLY	MONTHLY	YEARLY
1	Less than €79	Less than €349	Less than €4.199
2	€80 to €209	€ 350 to €899	€4.200 to €10.799
3	€210 to €449	€ 900 to €1.949	€10.800 to € 23.399
4	€450 to € 824	€1.950 to €3.599	€23.400 to € 43.199
5	€ 825 or more	€ 3.600 or more	€43.200 or more

The figure below shows the absolute sample size (left) and relative share (right) of used car transactions of different car age cohorts per income category.

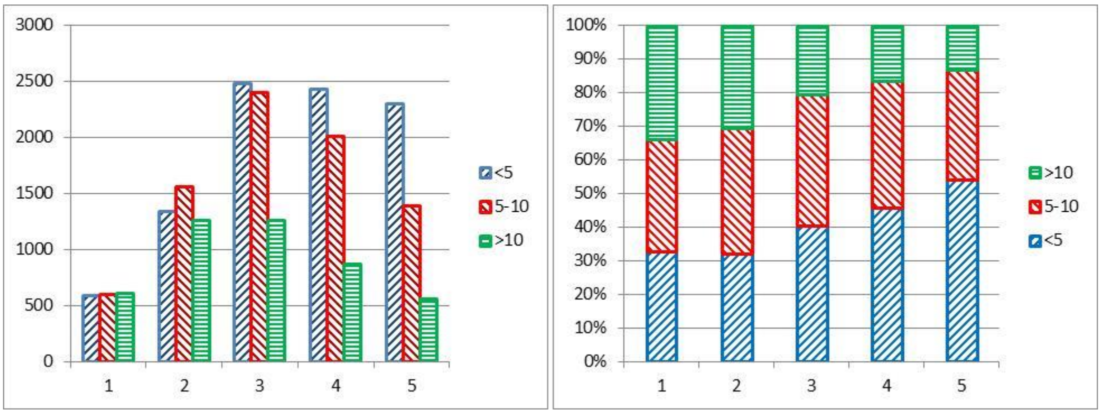


figure 16: used car transactions, per age-group of used cars, per household income category in EU-27. Absolute data (left), relative share (right)

We find a fairly even distribution of the sample, with a higher representation in the higher income categories. The lower income categories tend to buy older cars, in line with the intuition that because of a lower disposable income to buy a car, lower income groups are forced to buy older, cheaper cars. This observation is consistent for different groups of countries.

For this analysis, we have made a distinction between EU-15 countries and EU-10 countries in view of the overall differences in income of the population:

EU-15: AT, BE, DE, DK, EL, ES, FI, FR, IE, IT, LU, NL, PT, SE, UK

EU-10(*): BG, CZ, EE, HU, LT, LV, PL, RO, SI, SK

(*) MT and CY (part of the so-called EU-12 countries) are not included here as they are likely to have an atypical used car market. Therefore, we refer to "EU-10 countries".

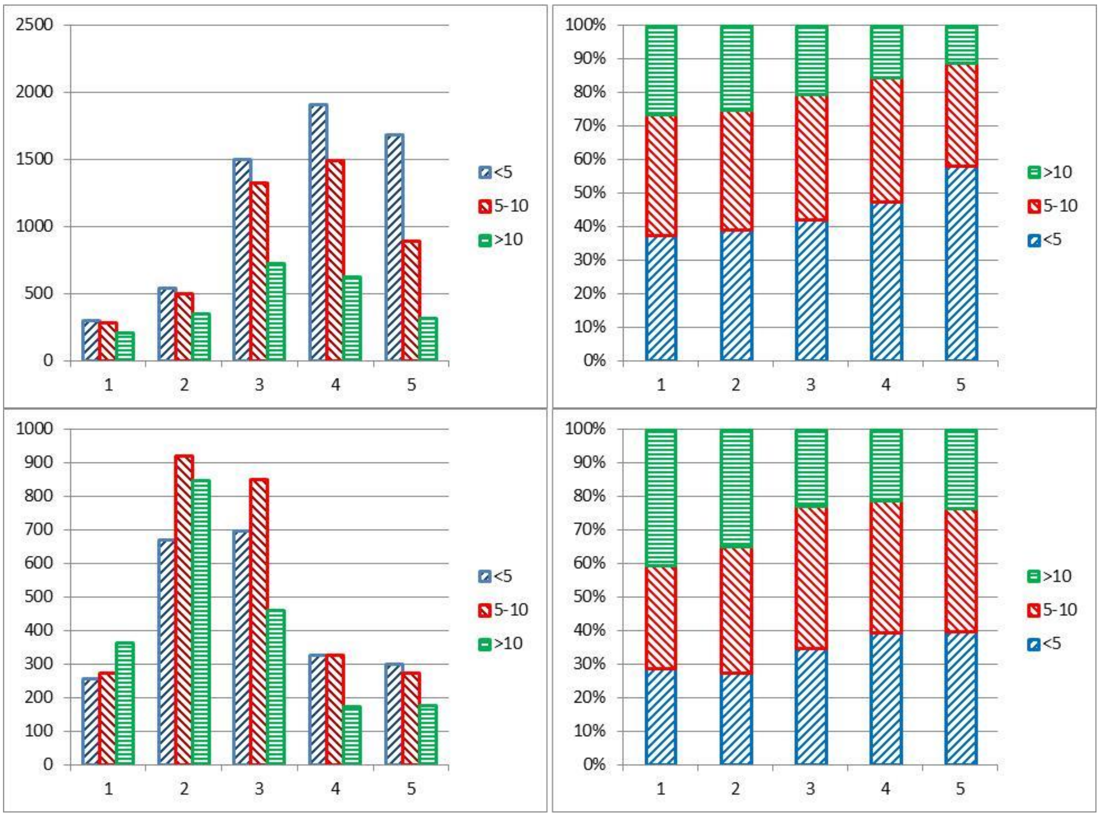


figure 17 used car transactions, per age-group of used cars, per household income category in EU-15 (top) and EU-10 (bot). Absolute data (left), relative share (right)

The sample is distributed less evenly over the income groups, because of the simple reason that household income is higher in EU-15 than in EU-10. The observation that lower income groups tend to buy older cars holds. Older cars are more important in EU-10, with a higher share of used car transactions in the >10y group. In depth observations on income-relations are done later in this chapter.

A similar observation is clear when looking at average mileage:

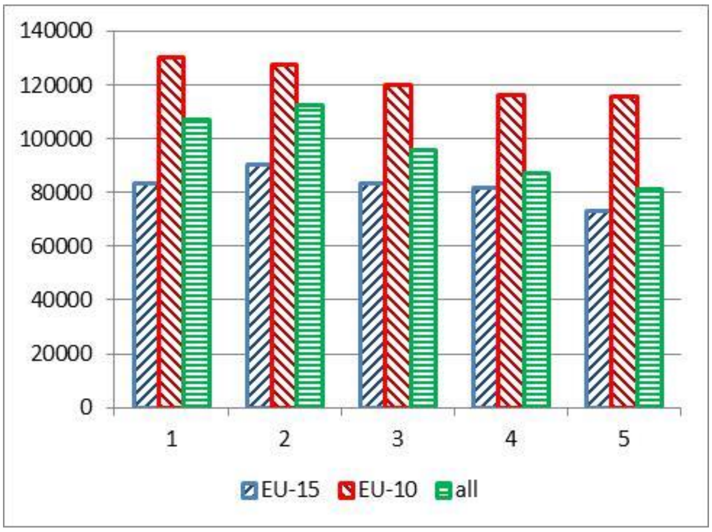


figure 18: average mileage of used cars bought, per income category (km)

The mileage of used cars bought by the lower income groups is higher compared to high income groups. The average mileage of used cars bought in EU-10 is consistently higher than EU-15. It is interesting to note that for EU-15, the average mileage of cars bought by the lowest income group is actually lower than that of the 2nd lowest income group. There is no immediate explanation for this; possibly the used car for the lowest income group is the sole car in the household, while this may be more likely to be an additional car for higher income groups. Willingness to pay for a first car is likely to be higher than for a second car in households and lower income groups could opt for a car with less initial mileage, although it may be more expensive. This hypothesis is also supported when comparing prices of used cars, see figure below.

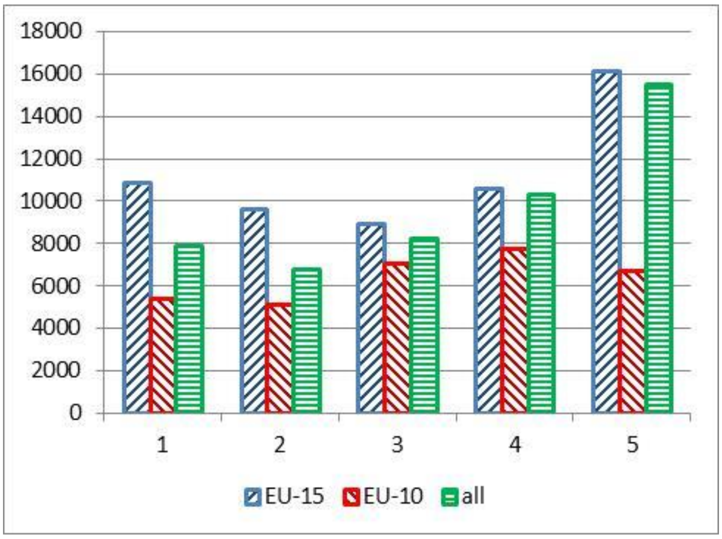


figure 19: average price of used cars bought, per income category (€)

We can make several interesting observations when looking at average prices of used car transactions:

1. For both groups of countries, the average price of used car is higher in the lowest income group compared to the second lowest income group. One possible explanation is that used cars are more likely to be the sole car in the household for the lowest income group (see earlier).

2. Average prices are lower in EU-10 than EU-15, consistently over all income categories. This is logical as disposable income is lower in EU-10 compared to EU-15.
3. The average price of used cars from the highest income category behaves differently in the 2 groups of countries. For EU-15, the used cars of the highest income group are by far more expensive than other income groups, while for EU-10, the average price is actually lower compared to the second highest income group. There is no immediate explanation for this. Possibly the market for young, former leasing cars is more important in Western EU countries (EU-15), driving prices up in the young car market, and therefore more profoundly affecting the highest income group.

Table 7: average and mean prices, per income category, EU-27 (€)

	1	2	3	4	5
average	€ 7 915	€ 6 814	€ 8 273	€ 10 358	€ 15 519
median	€ 3 500	€ 4 000	€ 5 800	€ 7 650	€ 10 720

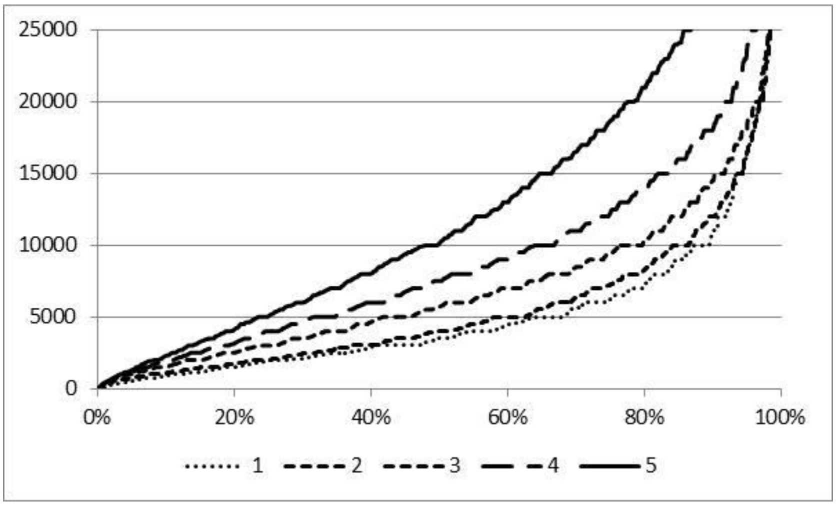


figure 20: Cumulative distribution of used car prices, per income category, EU-27 (€)

When looking in detail into the prices of used cars, we see a similar pattern for the used cars in the different income groups. Mean prices are consistently for all income categories higher than the median value, indicating a long tail in the data. This reflects a marginal, though significant share of high price used cars, in all income groups.

4.3.2 Education level

In this section, we look into the relation of transaction indicator with education level as the key indicator for socio-demographic group. We are again limited to the definition of education level as provided in the survey options given. 5 possible answers are given:

1. Elementary (primary) school or less
2. Some high (secondary) school
3. Graduation from high (secondary) school
4. Graduation from college, university or other third-level institute
5. Post-graduate degree (Masters, PhD) beyond your initial degree

96% of respondents gave feedback on the question related to education level. As such, almost the full dataset was used in this analysis.

The figure below shows the absolute sample size (left) and relative share (right) of used car transactions of different age-intervals per education level.

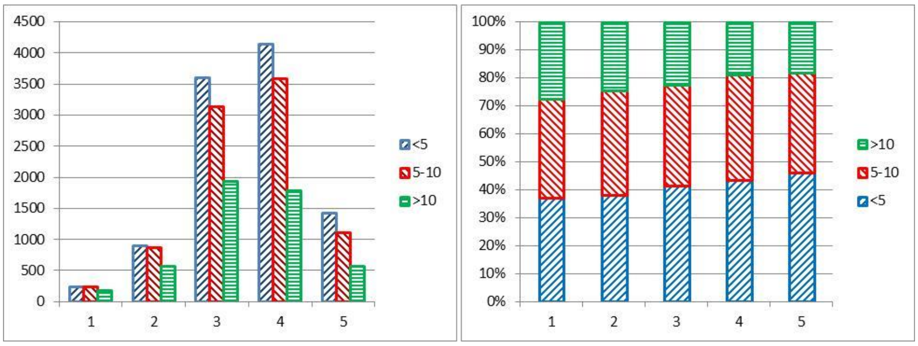


figure 21: used car transactions, per age-group of used cars, per education level in EU-27. Absolute data (left), relative share (right)

The bulk of the sample lies in the 3rd and 4th education group (75%). Only marginal differences between the different levels of education can be observed in terms of age of the vehicles bought. Less educated consumers seem to buy older cars, most likely due to correlation between education level and income.

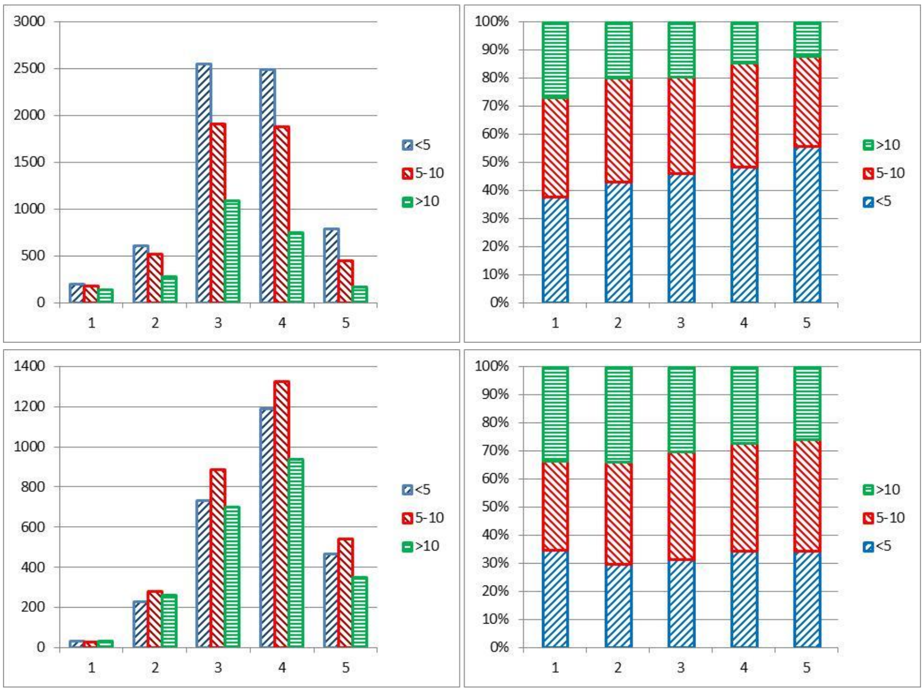


figure 22: used car transactions, per age-group of used cars, per education level in EU-15 (top) and EU-10 (bot). Absolute data (left), relative share (right)

When comparing the 2 groups of countries, no major differences can be observed. The distribution is more even in EU-10; in EU-15, the tendency to young used cars among the higher educated is somewhat more explicit.

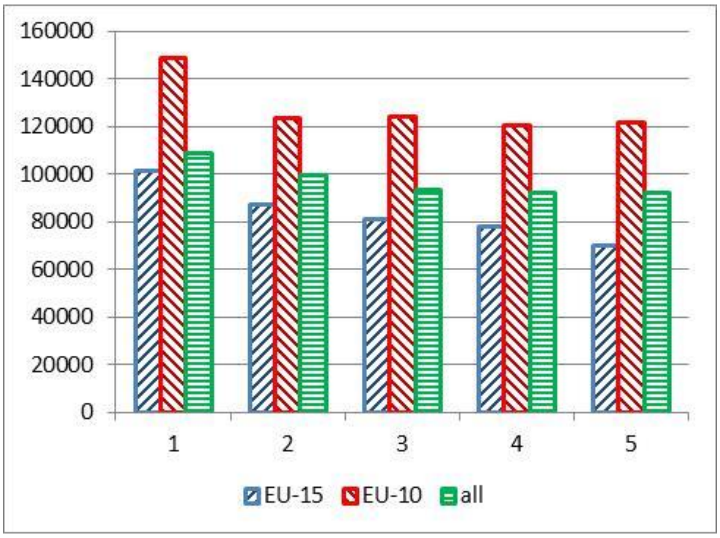


figure 23: average mileage of used cars bought, per education level (km)

Corresponding to the inverse correlation between education level and age of the used car bought, the less educated also tend to buy used cars with higher mileage. As with the age relation discussed in the previous figure, this relation is also more explicit for EU-15,

Finally, when looking at the average purchase price and its link to education level, the following figure emerges:

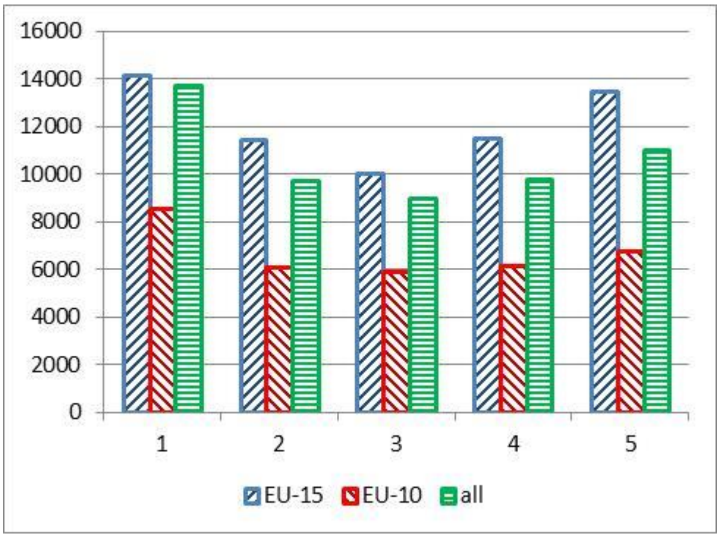


figure 24: average price of used cars bought, per education level (€)

Interestingly, the group with the lowest education level tend on average to buy more expensive vehicles; it is the middle group, "graduation from high (secondary) school", buying the least expensive used cars, on average. The observation holds for both groups of countries.

4.3.3 Employment

1. Self-employed
2. Employed full time
3. Employed part time
4. Unable to work due to long-term illness or disability
5. Unemployed and not looking for a job / looking after the home
6. Unemployed but looking for a job
7. In full time education / student
8. Retired
9. Other

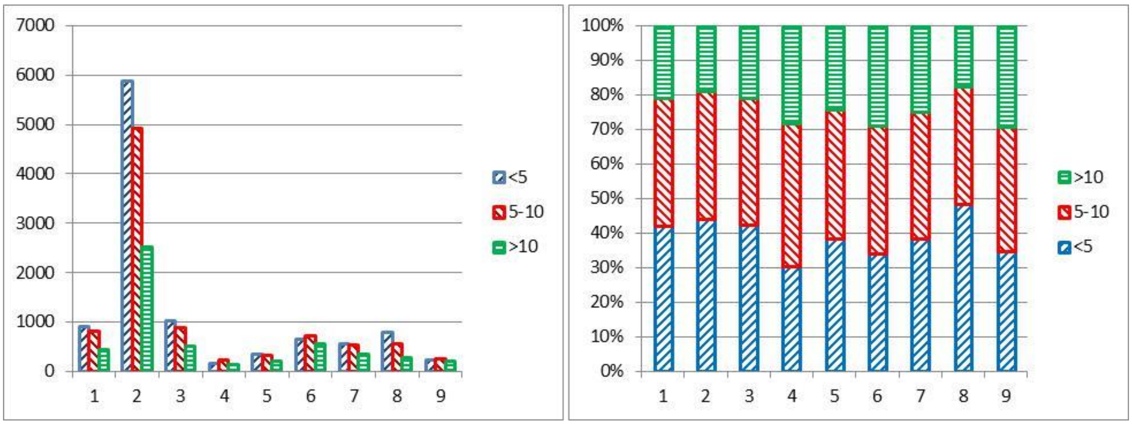


Figure 25: used car transactions, per age-group of used cars, per employment group in EU-27. Absolute data (left), relative share (right)

The employment situation does not provide any significant information on the distribution of the used car sale. Obviously, the category of the full time employed takes the largest share of the sales, as they represent the largest share of the population. The share taken by the other groups therefore is so small that the limited statistical relevance of the data makes interpretation more difficult.

4.3.4 Age

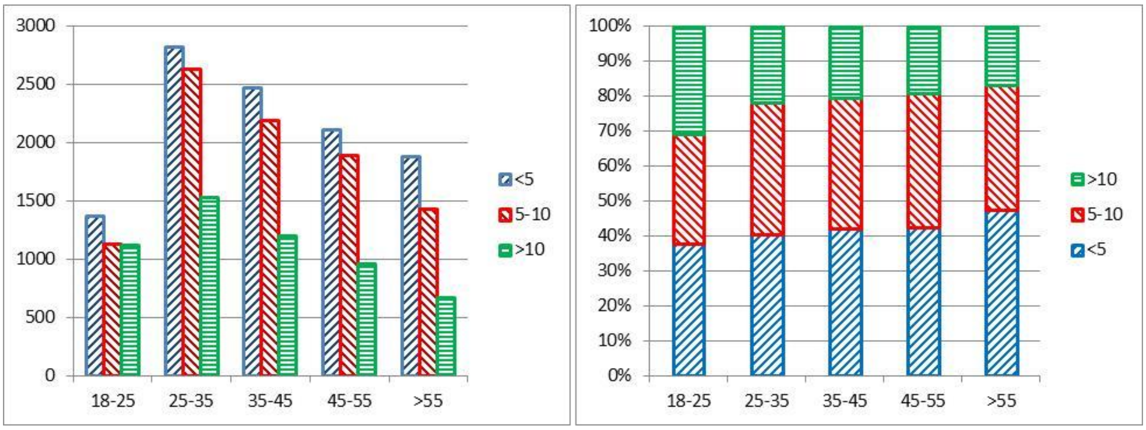


figure 26: used car transactions, per age-group of used cars, per age of the owner in EU27. Absolute data (left), relative share (right)

For distinction by age, we only see a small trend toward buying younger vehicles with increasing age of the buyer. This most likely is linked to increasing income with age.

4.3.5 Income relations – link with SILC

We focus on household income as the indicator to distinguish between socio-economic groups as this correlates with education level and employment situation. Household income is the most logical indicator to focus on.

Our approach is to compare car ownership and transaction data from the 2 sources described in the previous section:

1. SILC: total population with and without a passenger car, per member state and per household income category.
2. TML-GfK data (GfK, 2014): prevalence of used car transactions in the last 3 years, per member state and per income categories as a proxy for car ownership of used cars.

Matching the distributions from both sources gives an indication of the prevalence of used cars in the population, per income category and per member state. More specifically, if the share of the data-points from the TML-GfK data in a given income category is higher than the share of households from the SILC-database estimating total car ownership, this indicates (a subset of) used cars are over-represented in this income category compared to the population average.

Figure below represents the above comparison for EU-27:

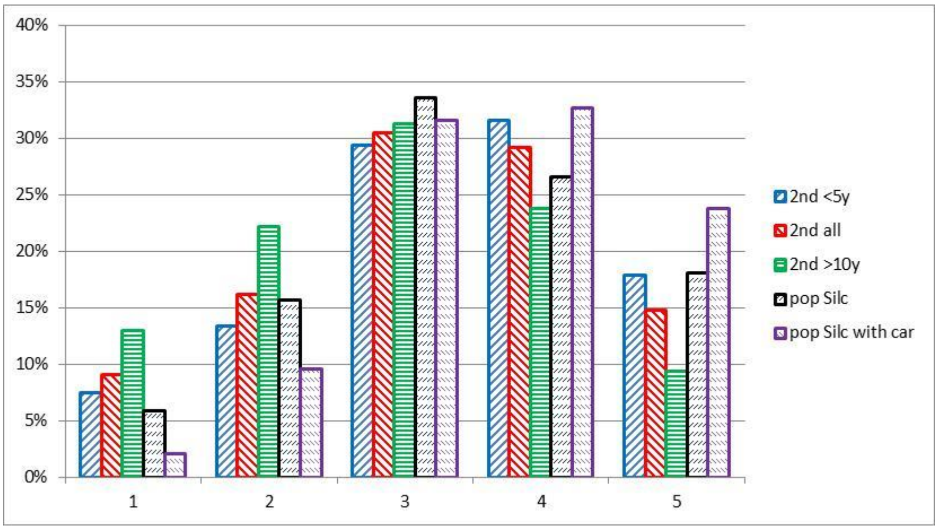


figure 27: comparison of distribution of data-points of different datasets for EU-27

The above figure shows the share of the population (in case of SILC data) or respondents (in case of TML-GfK data) in the different income categories. In the TML-GfK dataset, we make a distinction between all transactions, transactions of vehicles younger than 5 year old and vehicles older than 10 year. We can draw several conclusions:

When comparing SILC-data, the distribution of total households vs. the distribution of household that own a car, the data shows that in the lower income categories the share of households with a car is lower than the share of all households. Conversely, in the higher income category, the share of households with car is higher than the share of all households. This indicates the obvious conclusion that lower income households are less likely to own a car.

When comparing the data for second-hand transactions to the distribution of second hand car transactions per income category, a similar trend emerges: the share of second hand transactions is even higher in lower income categories and lower in the higher income category. This suggests an overrepresentation of used hand car transactions in the lower income categories and thus an overrepresentation of used car ownership in the lower income categories. If a lower income household owns a car, it is more likely to be a used car compared to the population average, again confirming the intuition.

When distinguishing age groups in the used car transactions, we observe it's mainly older cars that are overrepresented in the lower income categories. This is consistent over the income categories, with a decreasing importance of older cars with increasing household income.

This indicates that lower income households are (1) more likely to purchase used cars compared to the population average and (2) tend to buy older used cars.

There are limitations to comparing SILC and the used car transaction survey data:

1. The reliability of data on income in the TML-GfK database is not clear. Though sample size is large, data is never perfect.
2. There is a sample bias in the TML-GfK database in that only dealer transactions are included. Peer-to-peer transactions are excluded.
3. We are comparing transactions (TML-Gfk data) with ownership (SILC). Differences between age groups in terms of transactions (more/less frequent) dilute the comparison. E.g. if a higher turn-over rate occurs for older used cars this would entail more transactions.
4. Uneven distribution of population & transaction over the selected income categories. Care is needed when interpreting (e.g. the top 1% in PL can behave very differently to the top 10% in DE, while this is still the same income category in this analysis).

The observation holds for most individual EU-15 countries:

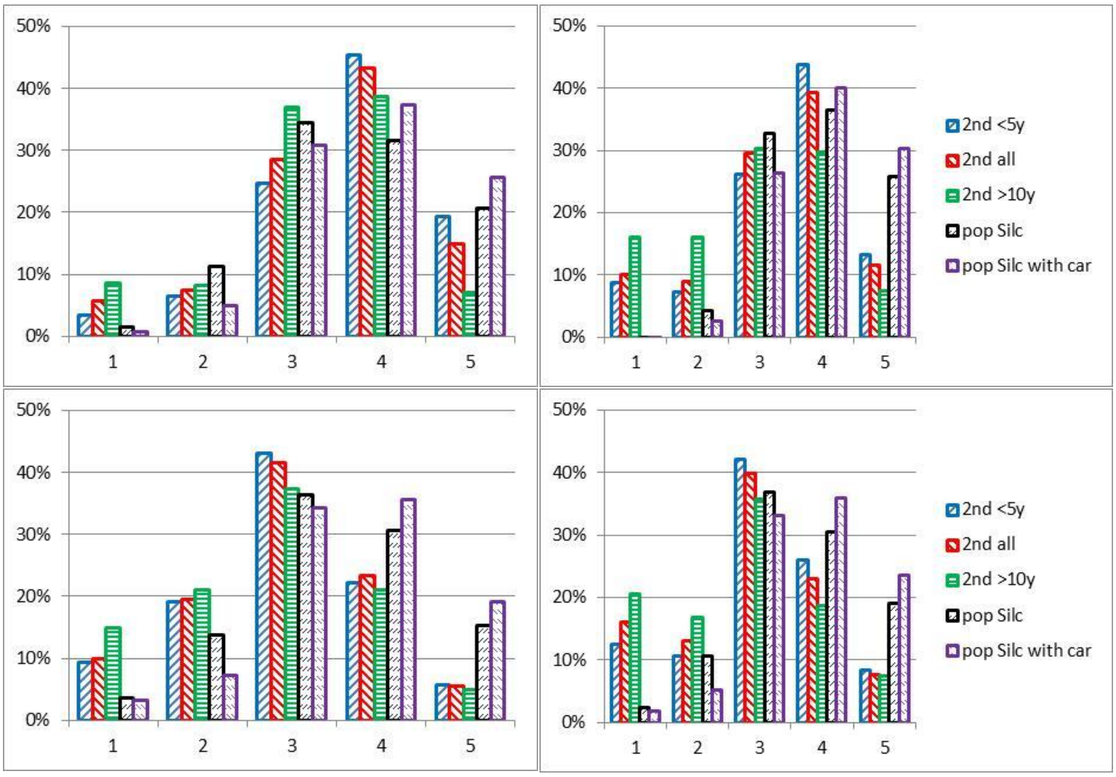


figure 28: comparison of distribution of data-points of different datasets for selected countries (clockwise from top left: DE, FR, IT, ES)

For all countries, the same observation holds: an overrepresention of used cars, mainly older used cars in the lower income group and less used cars compared to total households for the higher income categories. This suggests that lower income groups, more than the population average tend to buy used cars and if they do, the used cars are of older age.

For EU-10, the observations are similar, although there are a few important differences compared to the EU-15 countries.

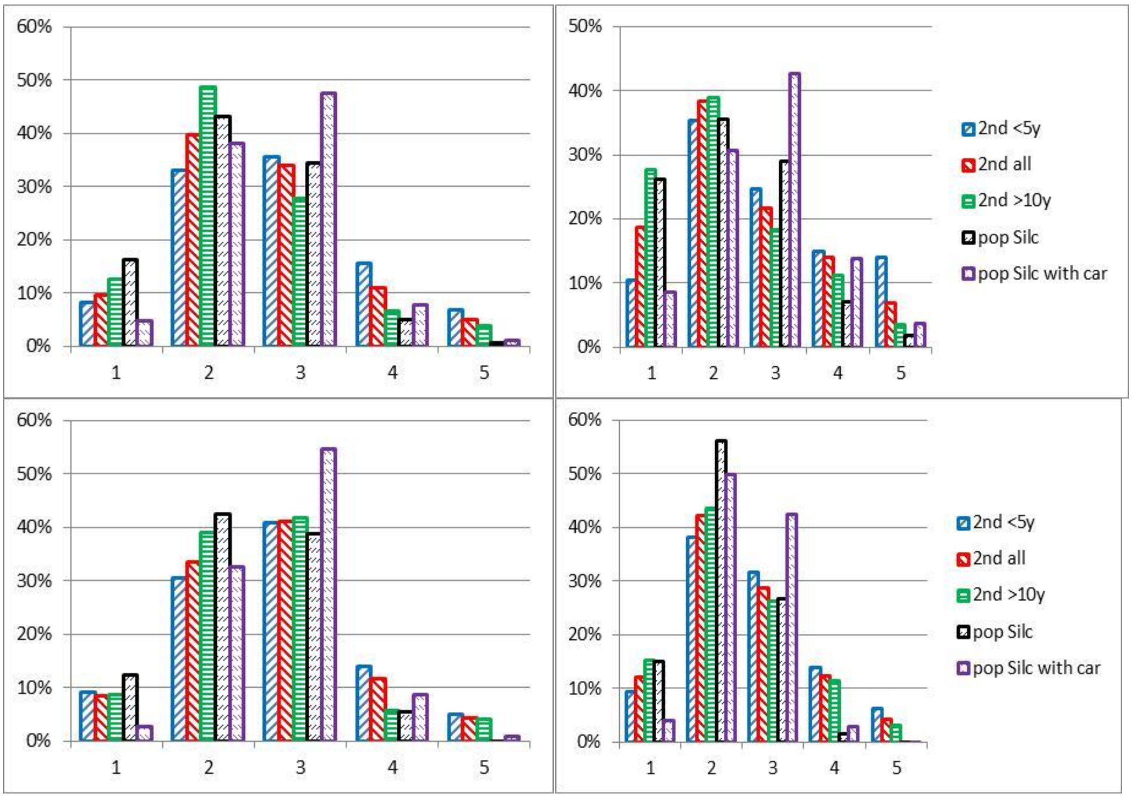


figure 29: comparison of distribution of data-points of different datasets for selected countries (clockwise from top left: PL, LT, HU, SK)

What differs compared to selected EU-15 countries is the higher share of the lower income category. Also, the share of households in the lowest income category without car is much higher compared to selected EU-15 countries. When comparing the importance of used cars for different socio-economic groups, used cars are indeed overrepresented in the lower income category as the share of used car transactions is higher than the share of households with car for that income category. Also, consistently over the countries, older used cars are important in the lower income category.

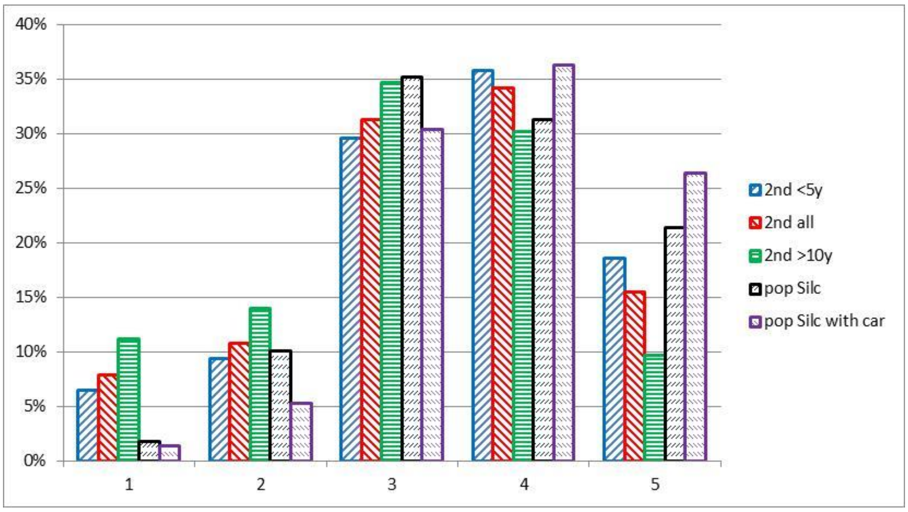
The main difference is the observation that also in the higher income category used car transactions are overrepresented to the population. This would suggest the higher income households buy more used cars instead of new cars compared to the population average. This is counter-intuitive and a straight-forward explanation cannot be found.

If this counter-intuitive observation would hold for only one or two countries, one may attribute this to data-issues. However, the observation is consistent for most EU-10 Member States[14]. Possible explanations:

1. Data issues:
   a. Reliability of data: did the respondents flag the correct household income?, did a higher share of low-income groups not respond to the question related to household income? (84% of respondents gave feedback on income)
   b. Possible respondent bias: although the survey is controlled for the mismatch between the online population and the total population, a respondent bias cannot be ruled out. (e.g. limited access to the questionnaire in lower income groups?)
2. Are there private traders active in the higher income category? There is circumstantial evidence hinting in this direction.
3. Possibly there is a higher turn-over rate of used cars in the higher income category vs. stronger retention in the lower income category. i.e. lower income households could hold on to their (old) used car for much longer while higher income households may afford to change (used) car more frequently. As a result, we would find more transactions in the higher income group compared to the lower income groups. This is a consequence of comparing ownership (SILC) with transactions (TML-GfK)
4. TML-GfK data only includes used car transactions via traders. It is possible the higher income groups tend to buy more via traders and less via direct peer-to-peer purchases.
5. The uneven distribution of selected income categories can cause problems for the methodology. i.e. the highest income category in PL (and most other new Member States) represents only 1% of the population, while this is more evenly distributed for EU-15 MS (e.g. FR: 26%, DE: 15%, IT: 19%.)

[14] All EU-10 Member States except CZ show similar behaviour. In the TML-Gfk database, over 60% of transactions in CZ would fall under the highest income category, while the share of households in this bracket is limited to 1%, according to SILC. We find this specific issue only in data for CZ and conclude the findings for the other countries still stand. CZ is excluded from further analysis when looking into income distribution.

To complete the analysis, we distinguish between EU-10 and EU-15. Because of the data problem, we exclude CZ from further analysis, not to dilute the overall figures.



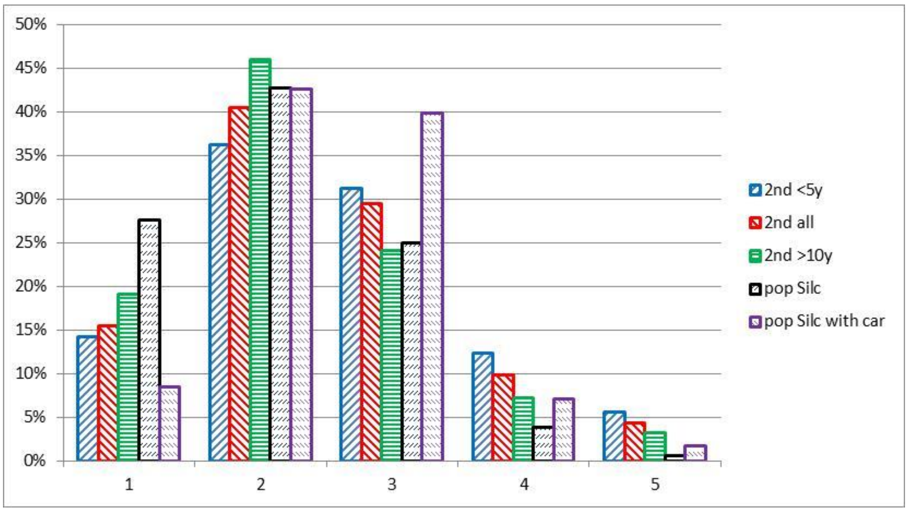


figure 30: comparison of distribution of data-points of different datasets for EU-15 (top) and EU-10-CZ (bottom)

The observation for EU-15 is similar to the EU-27 observations. For EU-10, as discussed earlier, we see an unexpected higher prevalence of used car transactions also in the higher income groups, although in absolute figures this does not account for many transactions.

4.4 Estimation of vehicle stock per income group

In a next step, we use the above sources to estimate the EU vehicle stock, broken down per income group and we make the distinction between new and different age-classes of used cars, in each member state.

We apply the following, step-wise procedure:

1. First, we estimate the total stock per income group per country based on
   a. Car ownership rate per country per income group (SILC)
   b. Numbers of cars owned per household based on additional information on the number of cars owned per income category. This is needed as car ownership rate in SILC as such does not include information how many cars are owned by the household.
2. Secondly, we add the distinction between used and new vehicles in the total stock. For the estimations of size of used car market we rely on various sources.
3. Subsequently, we add further distinction to further break down the share of used cars by using the distributions of used car transactions of different age brackets (TML-GfK data) and total ownership (SILC).
4. Finally, a RAS-procedure is applied to fit totals. This step can also be seen as a quality check to see if the preliminary estimate after the previous step is correct. Initial values for the RAS-procedure should not differ too much from the end result.

4.4.1 Estimation of total stock by income group

SILC provides information on the total number of households per income category, per country, as well as car ownership per household. When combined with the number of cars per household, this allows us to estimate the total stock of vehicles in a given country, per income category.

The number of cars per household is less obvious to estimate. SILC only reports if households own a car, but it does not provide information about how many cars are owned. There is limited anecdotal evidence confirming the intuition that higher income households tend to have more cars.

The "used car market report" (BCA, 2013 and BCA, 2014) includes an annual survey in the UK; including the question how many cars are available in each household, linking the feedback to 'social grade' of the respondent. The distinguishing feature of social grade is that it is based on occupation.

- upper middle class: higher managerial, administrative or professional
- middle class: intermediate managerial, administrative or professional
- skilled working class: Skilled manual workers
- working class: Semi-skilled and unskilled manual workers
- non-working: Casual or lowest grade workers, pensioners, and others who depend on the welfare state for their income

Unfortunately, no data is available at the level of income, so we use the UK NRS[15] social grade segmentation as a proxy for the income group.

[15] United Kingdom National Readership Survey

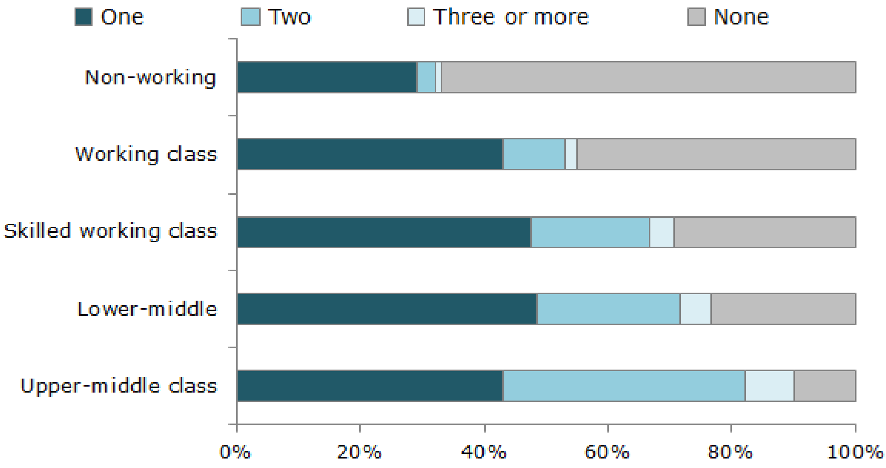


figure 31 Number of cars per UK household by social grade (source: Ricardo-AEAT evaluation, 2015. Original source: BCA, 2013)

A second source holds similar information for Denmark (Gillingham et. al. 2015):

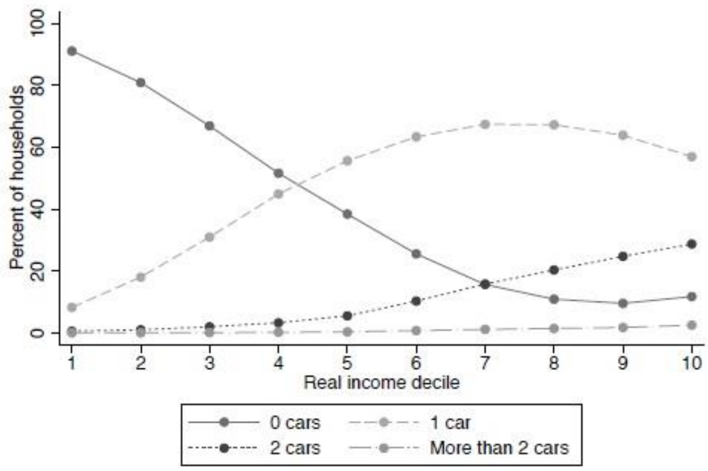


figure 32: Number of cars per DK household by income (source: Gillingham et. al. 2015)

Both sources indicate an increasing amount of cars with increasing income. We use these sources to estimate how many cars are owned by car-owning households. Obviously, this cannot be lower than 1. Building on both sources, thus excluding the households without car and assuming households owning more than 2 cars, on average own 3.5 cars, we can draw the following relationship between social grade (UK)/income quintile (DK) to the number of cars owned per household:

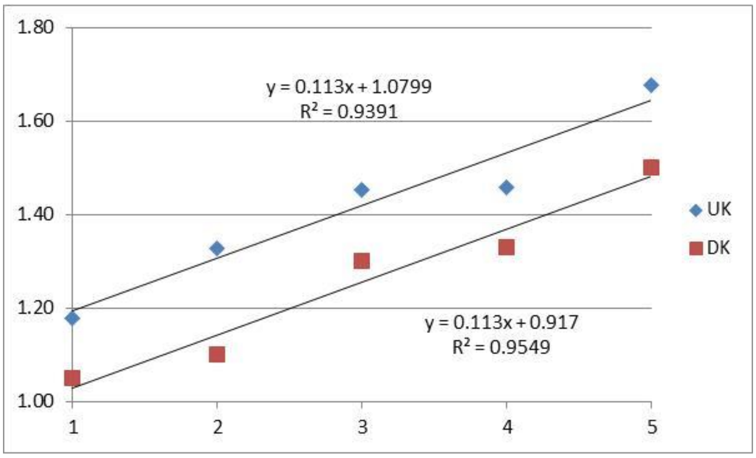


figure 33: estimation of cars per UK household by social grade

We observe a quasi-linear trend and we will assume a similar relation for all EU countries to estimate total number of vehicles per country (confirmed by the Danish data). We then re-estimate the coefficient value (a + b*x, with "x" being the income group, from 1 to 5) so as to match the estimations with the vehicle stock data published in the EU pocketbook "transport in figures" (TiF 2015), for the year 2014.

The table below summarizes the initial estimation, using the coefficient values from the DK-UK analysis. Note that the estimation for the UK gives a reliable estimate, only deviating 4% compared to the statistics. This indicates the assumption to use UK NRS social grade for income group is a good proxy.

Table 8: summary of estimation attempt, breaking down vehicle stock into income groups.[16]

	initial coef		estimate stock	TIF 2013	deviation	adjusted coef		estimate stock
	a	b	pre-calibration			a	b	post calibration
AT	1.15	1.1172	4454358	4641308	96%	1.15	1.1320	4642019
BE	1.15	1.1172	5816874	5504809	106%	1.15	1.0971	5505110
BG	1.15	1.1172	1801163	2910200	62%	1.6	1.2774	2912627
CY	1.15	1.1172	390959	474561	82%	1.15	1.1889	474454
CZ	1.15	1.1172	3824912	4729185	81%	1.15	1.2474	4732292
DE	1.15	1.1172	47955973	43851230	109%	1.15	1.0833	43853183
DK	1.15	1.1172	3141439	2278121	138%	1.05	1.0410	2278016
EE	1.15	1.1172	427784	628500	68%	1.4	1.2405	628515
ES	1.15	1.1172	19983252	22024538	91%	1.15	1.1572	22023055
FI	1.15	1.1172	2976582	3127399	95%	1.15	1.1352	3128476
FR	1.15	1.1172	35400809	32243826	110%	1.15	1.0835	32245437
GR	1.15	1.1172	4490442	5124208	88%	1.15	1.1754	5123156
HU	1.15	1.1172	2553026	3040732	84%	1.15	1.2535	3042781
IE	1.15	1.1172	2148786	1933129	111%	1.15	1.0825	1933278
IT	1.15	1.1172	30477065	36962934	82%	1.15	1.1943	36934766
LT	1.15	1.1172	1037521	1808982	57%	1.6	1.2814	1809326
LU	1.15	1.1172	290266	363247	80%	1.15	1.1879	363244
LV	1.15	1.1172	568368	634603	90%	1.15	1.1854	634525
MT	1.15	1.1172	173918	256096	68%	1.4	1.2108	256102
NL	1.15	1.1172	9138062	7932290	115%	1.15	1.0677	7934142
PL	1.15	1.1172	10735842	19389446	55%	1.8	1.2151	19391585
PT	1.15	1.1172	4148017	4480000	93%	1.15	1.1566	4479866
RO	1.15	1.1172	2738075	4695660	58%	1.8	1.2244	7433739
SE	1.15	1.1172	5442591	4495473	121%	1.15	1.0486	4498511
SI	1.15	1.1172	892170	1063795	84%	1.15	1.1964	1063242
SK	1.15	1.1172	1622129	1879759	86%	1.15	1.2701	3501892
UK	1.15	1.1172	31203773	30074857	104%	1.15	1.1030	30078204
EU-27	**1.15**	**1.1172**	**233700308**	**246548888**	**95%**	**1.15**	**1.1391**	**246679924**
EU-15	**1.15**	**1.1172**	**206026209**	**200387722**	**103%**	**1.15**	**1.1067**	**200384073**
EU-10	**1.15**	**1.1172**	**26067140**	**40780862**	**64%**	**1.6**	**1.2007**	**40821268**

For most EU-15 countries, only minor changes were needed to the coefficient value. We target first the slope ("b") to fit the estimation and only make changes to the constant ("a") if slope adjustments generate more than 4 cars on average for households in the highest income group. The constant reflects how many cars are owned by the lowest income group, if at least one car is owned by the household (households without cars are excluded). A higher constant value is needed mostly for EU-10 countries. This is to be expected as households tend to be larger in those countries.

It is important to understand the limitations of this estimation. Elements to consider:

1. Size of households differs between MS: in order to fit the estimation, the constant need to be higher to account for these differences.
2. The linear estimate, though valid for UK & DK, may not be valid for other MS.
3. The distribution of households among the income groups: The lowest income group may represent >20% of households in one country, it may represent merely 1% for the other. The linear function may not apply for the different countries as the variable "x" is de facto not the same for the countries.

Clearly, there are important limitations to this estimation approach. However, for the purpose of our analysis, the estimation is useful. This step adds nuance to what extent cars are distributed

[16] Graded colour scale: green = closer to perfect fit (100%); yellow increasing to red = increasing relative deviation

between households of different income groups. The main determining factor is the share of households per income group. In this sense, the limitations of the estimation are mitigated, as we only use it to refine the allocation of the vehicle stock not one-on-one to distribution of households, but to take into account the fact that higher income households own more cars.

We come to the following estimate of the distribution of the total stock of cars, per household, for EU countries:

Table 9: Estimated Distribution of passenger cars, per household by income group, for EU member states.

	1	2	3	4	5
AT	0%	2%	21%	38%	39%
BE	0%	2%	27%	36%	35%
BG	15%	57%	26%	2%	0%
CY	0%	3%	21%	37%	39%
CZ	1%	22%	59%	14%	3%
DE	0%	4%	29%	38%	28%
DK	0%	1%	19%	33%	47%
EE	4%	28%	52%	14%	3%
ES	1%	6%	32%	38%	24%
FI	0%	2%	22%	36%	39%
FR	0%	2%	25%	40%	33%
GR	1%	9%	36%	37%	17%
HU	3%	45%	48%	4%	1%
IE	0%	1%	15%	30%	53%
IT	1%	4%	29%	37%	29%
LT	6%	34%	48%	9%	3%
LU	0%	0%	5%	23%	72%
LV	6%	27%	44%	17%	5%
MT	1%	13%	43%	34%	9%
NL	0%	2%	22%	39%	37%
PL	3%	34%	51%	10%	2%
PT	2%	16%	49%	23%	10%
RO	19%	62%	17%	1%	0%
SE	1%	4%	26%	35%	34%
SI	0%	7%	38%	42%	12%
SK	2%	27%	58%	12%	2%
UK	1%	6%	28%	35%	29%
EU-27	1%	8%	29%	34%	28%
EU-15	1%	4%	27%	37%	31%
EU-10	6%	36%	46%	10%	2%

4.4.2 *Distinction between new and used cars*

In the next step, we compare the prevalence of transactions, using the TML-GfK dataset, with the estimated stock per income group. If the prevalence of a given income group is higher than the share of total stock for that group, used cars will be overrepresented for this group.

The table below depicts the share of used car transactions vs. the share of vehicles owned, by household income class for the EU.

Table 10: share of used car transactions and vehicle ownership by income group (source: SILC & TML-GfK database)

	1	2	3	4	5
SILC ownership	1%	8%	29%	34%	28%
TML-GfK used car transactions	9%	16%	30%	29%	15%
ratio	8.07	2.05	1.04	0.86	0.54

While the lowest income class only represents 1% of ownership, it accounts for 9% of used car transactions. This indicates lower income groups proportionally tend to buy more used cars than higher income groups. The trend consistently declines with increasing household income.

The table below adds detail at the level of age of the used car.

Table 11: share of used car transactions, for different age cohorts of used cars and vehicle ownership by income group (source: SILC & TML-GfK database)

	1	2	3	4	5
SILC ownership	1%	8%	29%	34%	28%
transactions <5y	8%	13%	29%	32%	18%
transactions 5-10y	9%	16%	32%	29%	13%
transactions >10y	13%	22%	31%	24%	9%

Older vehicles are more common in the lower income groups and vice versa for the richer income groups. This indicates that low income groups not only tend to buy more used cars than higher income groups, but also that lower income groups also tend to buy older used cars.

To estimate the total fleet by vehicle properties, namely new and different age cohort of used vehicles, as well as by household income group, we apply the following methodology:

From the previous section, we have an estimate of the total fleet by income group. We first distinguish between the total of used cars vs. new cars, using public information about the size of the used car market. This differs by country. (BCA 2013) published ratios for different member states:

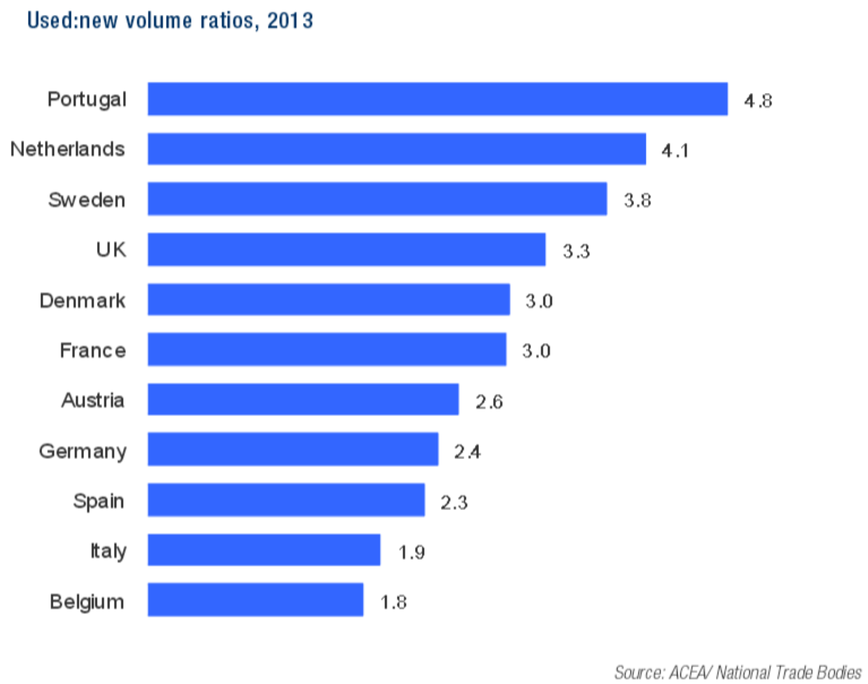


figure 34; ratio used/new passenger cars in 2013, for selected member states (BCA, 2013)

Key fleet indicators from (BCA 2014) for Germany, UK and France are summarized below:

Table 12: fleet dynamics in DE, UK & FR (BCA, 2014)

units (M)	DE	FR	UK
fleet (2012)	43.4	31.6	30.9
sales new (2013)	2.95	1.79	2.26
sales used (2013)	7.1	5.3	7.4
used/new	2.4	3.0	3.3
turn ratio	23%	22%	31%

(CIRP, 2007) comes to a similar ratio for most countries data is presented. Only for Spain, the sources are contradictory:

	UK	U.S.	France	Germany	Italy	Canada	Spain	Japan
New Car Sales	2,567,000	16,995,000	2,070,000	3,320,000	2,262,383	1,583,000	1,517,490	5,852,067
Used Car Sales	7,701,308	44,138,000	5,400,000	6,650,000	4,586,894	2,300,000	2,080,754	5,984,800
Used Car/New Car Ratio	3.0	2.6	2.6	2.0	2.0	1.5	1.4	1.0

Source: CIRP, adapted from various sources, including CNW Marketing Research, Inc. (U.S.), DesRosiers (Canada), Japan Automobile Dealers Association (Japan) and Datamonitor (France, Germany, Italy, Spain, United Kingdom)
Note: All sales in units. All data for CY2005, except Italy, Spain, and UK, which are CY2004.

figure 35: ratio used/new passenger cars in 2013, for selected member states (CIRP, 2007)

There are large differences between countries and this will differ from year to year as market conditions in the new car market can fluctuate significantly. A mix of incentives or disincentives for used car trade and apparent national consumer preferences also explain the large differences. Detailed information is not available for all countries. We thus have to estimate the used car market at EU level with other sources. We use the difference between new registrations from Eurostat and ACEA as a proxy to estimate the importance of the used car market. ACEA data reflects new registrations of new cars, while Eurostat reports total new registrations. This means Eurostat registration includes new registrations of new cars as well as imported used cars (see also in the subsequent chapter). Note that this still excludes the domestic used car market.

Because of the lack of data, we cannot do this analysis at country level, but will stick to analysis for the groups of countries described earlier. Also, the used car market size will still be an estimate, so care is needed when interpreting the final results on the detailed fleet composition, especially with respect to the size of the used car vs. new car share.

As such, conventionally, **we estimate the used car market at factor 3.5 for EU-27, 3 for EU-15 and factor 8 for EU-10 compared to the size of the new car market**.

Secondly, we need to account for differences in used car sales frequency as a function of their age

If younger cars are traded more frequently, this will be reflected in the sample of the used car transactions. A correction factor is needed to derive ratios of the importance of different age cohorts of used cars to the total fleet.

We compare below the age distribution of used car transactions with the age structure of the fleet. For the first, we use the TML-GfK database; for the latter we use TRACCS[17]. The latter is consistent with findings from (Ricardo-AEA - Dun et. al., 2015)

The figure below compares both sources:

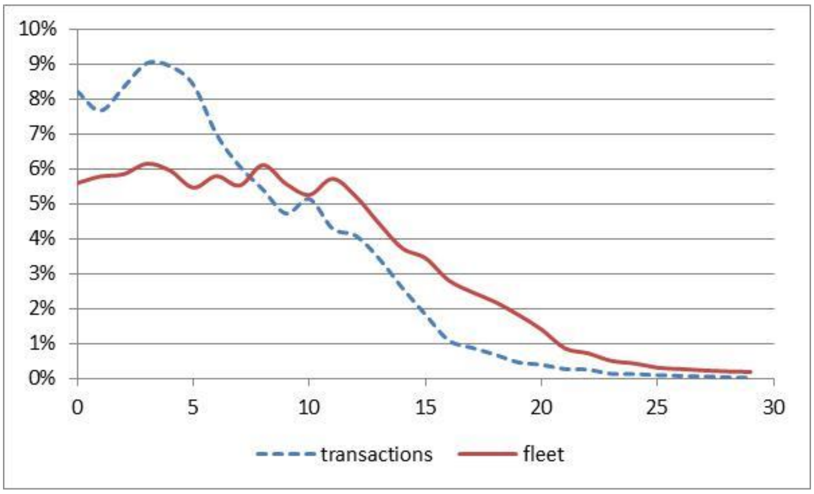


figure 36: share of used car transactions (dashed line) and total fleet (full line) as a function of age.

The figure shows that there are proportionally more used car transactions for younger vehicles compared to their importance in the total fleet. This suggests younger cars are more frequently traded and are as such overrepresented in the sample. This suggests a shorter retention period in a passenger car's early life, changing hands more frequently compared to older cars.

As with the data on the used car market, this information only gives us an indication that the effect is relevant (i.e. younger cars are overrepresented in the sample but cannot be directly used to distribute the stock over different age cohorts of used cars). Various issues complicate the comparison:

[17] http://traccs.emisia.com/index.php

1. The age distribution of the fleet is 2010 data, while the transaction data is mixed 2010-2011-2012-2013
2. Increasing scrappage rates with growing age dilute the relative comparison of the datasets.

Also, data from the UK market suggests dealer transactions are mostly young used cars (BCA, 2013), particularly in the 0-5y segment. The sample of transactions excludes peer-to-peer transactions, suggesting the sample is biased towards young used car transactions.

Based on the available data, comparing sales and fleet, we weigh the transaction sample with the following weighting factors.

Table 13: assumption weighting of used car transaction data

	weight	original distribution	weighted distribution
0 - 5y	0.25	54%	13%
5 - 10y	1.50	24%	40%
>10y	2.00	23%	47%

We have tested different weighting factors and estimated the fleet composition for all income groups over the different vehicle age cohorts and compared the resulting fleet composition by age with Eurostat data. The weighting factors we apply are strong, but the resulting fleet composition supports its use:

Table 14: resulting fleet composition by age cohort, comparing initial estimate with unweighted sample with weighted sample and available data from Eurostat[18]

		Eurostat data	estimate unweighted sample	estimate weighted sample
EU-27	0 - 5y	29%	57%	30%
	5 - 10y	28%	18%	24%
	>10y	44%	26%	46%
EU-15	0 - 5y	32%	58%	32%
	5 - 10y	29%	17%	23%
	>10y	39%	25%	45%
EU-10	0 - 5y	13%	50%	20%
	5 - 10y	23%	20%	27%
	>10y	64%	29%	53%

Both assumptions on the size of the used car market and the correction for comparing transactions with ownership affect the estimation results. The assumptions are a best effort with limited information available but clearly, the estimation of the fleet composition is subject to uncertainty and the reader should be aware about the importance of these assumptions when drawing conclusions from the estimation, in particular about the size of the used car market.

With the above data and assumptions, we can now estimate the fleet size per income group and distinguishing between first owner (hereafter referred to as 'new') and different age cohorts of used cars.

[18] All "new" vehicles in the estimate are allocated to the 0-5y vehicle stock. This will create a minor overestimation in the 0-5y estimate figure.

The share of vehicle ownership per income group, using the SILC data and the (weighted) share of used car transaction enables us to distinguish between used and new cars. The table below summarizes this for the whole EU:

Table 15: allocation of total fleet per household income class to new (first owner) or used car, using the share of used car transactions and total car ownership. (EU-27)

	1	2	3	4	5
total cars owned (SILC)	2 790 472	19 290 866	72 087 805	84 210 716	68 300 064
share	1.13%	7.82%	29.22%	34.14%	27.69%
share of used car transactions	9.13%	16.06%	30.49%	29.38%	14.94%
2nd hand transactions per new sales	28.26	7.19	3.65	3.01	1.89
new	95 370	2 356 608	15 497 182	20 986 582	23 647 617
used	2 695 102	16 934 258	56 590 623	63 224 135	44 652 447

The first row is the estimate of total fleet per income group, using the approach as summarized in Table 8. The second row reflects the relative share per income group, comparing with the share of total used car transactions per income group in the third row. We then estimate the amount of used car transactions for every new car as the share of used car transactions (3rd row) divided by the share of total fleet (2nd row), divided by the correction for the size of the used car market as a whole, in this case 3.5. We then allocated the total fleet (first row) to new and used car fleet, respecting the estimated amount of used car transactions for every new car.

Note that in all income groups, the used car market is still larger in volume than the new car market. We assume a ratio of 3.5 used cars vs. new cars, based on various sources (see earlier).

We add the distinction of the different age cohort of used cars. In this step, the weighting of the transactions according to age is relevant (see earlier about conventional assumptions on sample weighting).

Table 16: allocation of the used cars by income group to different age cohort

	1	2	3	4	5
all	100.00%	100.00%	100.00%	100.00%	100.00%
0 - 5y	8.46%	8.24%	11.10%	14.27%	12.16%
5 - 10y	22.46%	27.99%	37.00%	32.35%	34.60%
>10y	69.08%	63.77%	51.91%	53.38%	53.23%

After applying these shares to the estimates in

Table 15, we come to the following intermediate result:

Table 17: intermediate result: fleet size per income group and new/used car age cohort (EU27)

	1	2	3	4	5	TOTAL		TOTAL*
all	2 790 472	19 290 866	72 087 805	84 210 716	68 300 064	246 679 924		246 679 924
0 - 5y	227 955	1 395 924	6 279 720	9 021 139	5 430 728	22 355 466		19 053 682
5 - 10y	605 420	4 739 188	20 936 193	20 453 045	15 451 757	62 185 603		58 532 866
>10y	1 861 728	10 799 146	29 374 710	33 749 951	23 769 962	99 555 496		114 275 616
NEW	95 370	2 356 608	15 497 182	20 986 582	23 647 617	62 583 358		54 817 761

Note that in table above, there are 2 different figures for totals over the income groups. The totals on the left sum up after the allocation as described above. The totals on the right (*) disregard the distinction per income group, only using the weighted sample on transactions per used car category. The minor differences that persist are a consequence of the proportional allocation per income group, in which we cannot maintain the overall share per category.

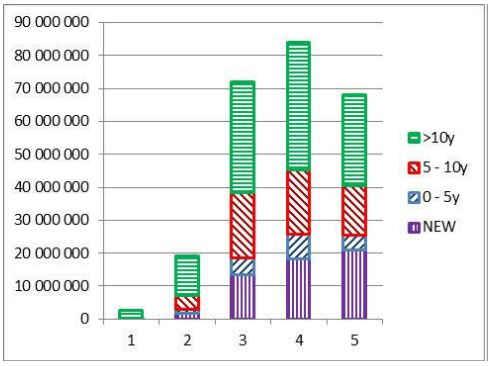
The allocation of the totals, ignoring the distinction per income group is expected to be more reliable (larger sample, less assumptions) and as such we execute a final data conversion to fit row totals, using "Iterative proportional fitting" or RAS-procedure. This procedure is an iterative algorithm for estimating cell values of a contingency table such that the marginal totals remain fixed and the estimated table decomposes into an outer product.[19]

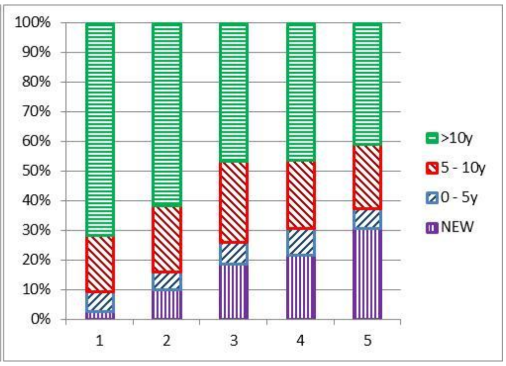
After applying the RAS-algorithm to fit rows and column totals, the final estimation figures are:

Table 18: final estimation of EU-27 passenger car fleet, by income group and used car category

absolute figures	1	2	3	4	5	TOTALS
TOTAL	2 790 472	19 290 866	72 087 805	84 210 716	68 300 064	246 679 924
0 - 5y	181 284	1 139 602	5 328 798	7 697 836	4 706 162	19 053 682
5 - 10y	532 139	4 276 148	19 635 599	19 289 577	14 799 402	58 532 866
>10y	1 999 411	11 905 718	33 661 809	38 891 554	27 817 124	114 275 616
NEW	77 639	1 969 398	13 461 599	18 331 749	20 977 376	54 817 761
TOTAL USED	2 712 834	17 321 468	58 626 206	65 878 967	47 322 688	191 862 163

relative distributions	1	2	3	4	5	TOTALS
TOTAL	1%	8%	29%	34%	28%	100%
0 - 5y	1%	6%	28%	40%	25%	100%
5 - 10y	1%	7%	34%	33%	25%	100%
>10y	2%	10%	29%	34%	24%	100%
NEW	0%	4%	25%	33%	38%	100%
TOTAL USED	1%	9%	31%	34%	25%	100%





The estimation results confirm the intuition. Highlights:

1. Over 70% of cars owned by low income household groups are old used cars (>10 years)
2. New cars only account for 30% even in the highest income group, attributed to the large size of the used car market.
3. The relative share of used cars and the age of the used cars increases with decreasing income.
4. New sales in the EU amount to about 12M unit annually[20]. Our estimate indicates about 54M new cars active. Added up with the youngest used car category, this sums up to about

[19] https://en.wikipedia.org/wiki/Iterative_proportional_fitting

[20] Source: ACEA

73M, suggesting an age of about 4-4.5y for the first transaction new → used (taking into account that a minority cars under the label "NEW" will be retained longer than 5 years).

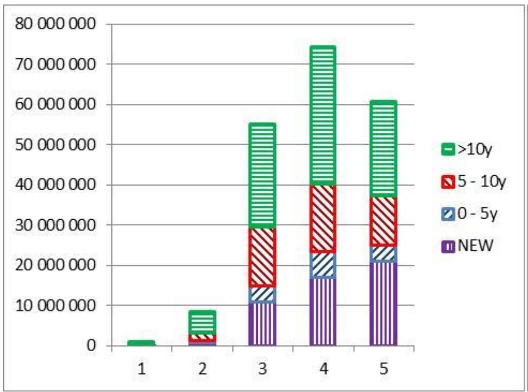
This chapter elaborated in detail the methodology to come to this estimate. At various steps key assumptions were made (size of the used car market, comparing transactions vs. ownership). It's important to acknowledge the above results are an estimate and should not be treated as data.

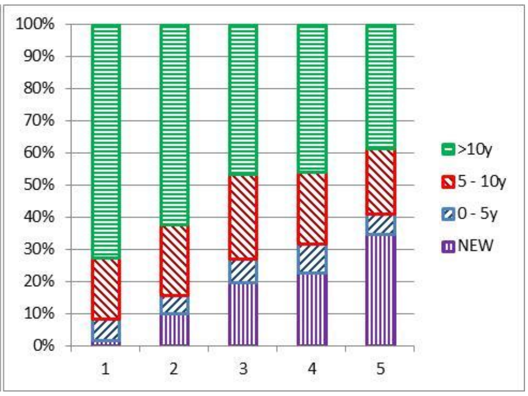
Because of the limited sample size, it is not possible to makes statements at country level. As indicated in the beginning of the chapter, we can distinguish 2 groups of countries: (i) EU-15, with higher average incomes and mainly car exporters, and EU-10 mainly importing cars. To understand if the combination of both groups masks any real differences, we show the results of the analysis for both groups:

Table 19: final estimation of EU-15 passenger car fleet, by income group and used car category

absolute figures	1	2	3	4	5	TOTALS
TOTAL	1 139 582	8 502 730	55 371 998	74 411 038	60 946 432	200 371 780
0 - 5y	72 809	491 404	3 942 753	6 551 946	3 865 162	14 924 074
5 - 10y	216 977	1 871 994	14 749 604	16 668 263	12 339 881	45 846 720
>10y	828 154	5 294 521	25 685 792	34 138 326	23 561 249	89 508 041
NEW	21 642	844 810	10 993 849	17 052 503	21 180 140	50 092 945
TOTAL USED	1 117 940	7 657 919	44 378 149	57 358 534	39 766 292	150 278 835

relative distributions	1	2	3	4	5	TOTALS
TOTAL	1%	4%	28%	37%	30%	100%
0 - 5y	0%	3%	26%	44%	26%	100%
5 - 10y	0%	4%	32%	36%	27%	100%
>10y	1%	6%	29%	38%	26%	100%
NEW	0%	2%	22%	34%	42%	100%
TOTAL USED	1%	5%	30%	38%	26%	100%





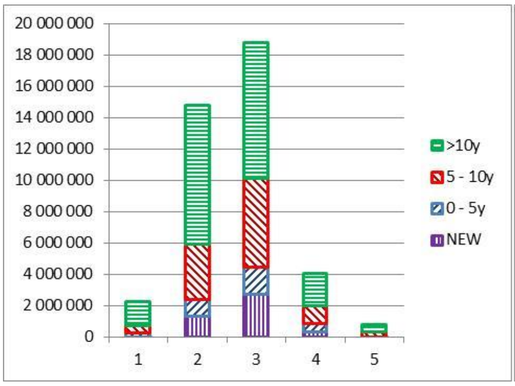
There are no major differences between the total EU-27 estimation and the EU-15 estimation, other than that the lower income groups are smaller. All trends are similar. Note that EU-15 total fleet accounts for over 80% of the total EU-27 fleet, as such it is logical that observations between the 2 outcomes are similar.

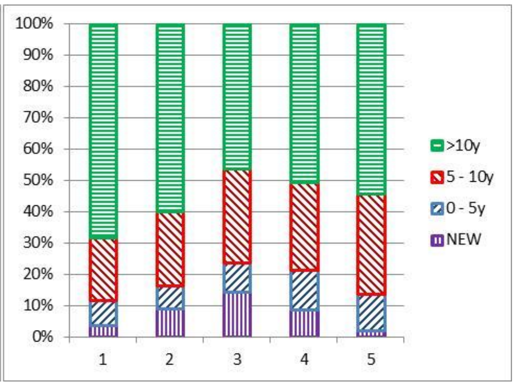
Finally, we discuss the results for EU-10.

Table 20: final estimation of EU-10 passenger car fleet, by income group and used car category

absolute figures	1	2	3	4	5	TOTALS
TOTAL	2 253 623	14 856 273	18 830 507	4 075 718	807 021	40 823 142
0 - 5y	176 199	1 074 867	1 742 264	516 781	93 546	3 603 657
5 - 10y	455 889	3 555 053	5 658 751	1 141 438	259 296	11 070 427
>10y	1 536 122	8 876 437	8 699 688	2 063 834	437 072	21 613 153
NEW	85 414	1 349 917	2 729 804	353 664	17 106	4 535 905
TOTAL USED	2 168 209	13 506 356	16 100 704	3 722 054	789 915	36 287 237

relative distributions	1	2	3	4	5	TOTALS
TOTAL	6%	36%	46%	10%	2%	100%
0 - 5y	5%	30%	48%	14%	3%	100%
5 - 10y	4%	32%	51%	10%	2%	100%
>10y	7%	41%	40%	10%	2%	100%
NEW	2%	30%	60%	8%	0%	100%
TOTAL USED	6%	37%	44%	10%	2%	100%





A different picture for EU-10 emerges. The most striking observation is the reversed trend of increased prevalence of used cars also for the higher income groups. This is not the case for EU-15 and is counter-intuitive.

Possible explanations were already discussed earlier in the chapter. It is not clear if this counter-intuitive observation is the effect of flawed data or if in fact the data holds unidentified behaviour.

Data issues cannot be ruled out, with possible reliability problems of data on the household income, though 84% of respondents gave feedback on income. Secondly, a sample bias on the income classification can distort the result. According to SILC data (considered reliable), only 5% of the households are included in the top 2 income groups, while the survey data on transactions puts 20% of all transactions is the top 2 income groups, reflecting a higher share of used car transactions in the higher income groups. Analysis of the sample used in the survey data revealed no possible cause for sample bias, though this cannot be ruled out.

If the data is indeed correct, the counter-intuitive trends reveals specific behaviour for these aspects of the EU used car market. For example, it is possible there are private traders in the higher income category, causing a higher share of used car transactions. These groups could operate as an importing "gateway" of foreign used cars, reselling foreign used cars quickly in the domestic market.

Secondly, it is possible there is a higher turn-over rate of used cars in higher income category vs. stronger retention in the lower income category. i.e. lower income households, due to limited budget, could hold on to their (old) used car for much longer while higher income households may afford to change (used) car more frequently.

Also the size of the households matters; households tend to be larger in Eastern EU, leading to higher total household income, but also to higher car ownership, of which most may be used cars. (See also earlier in this chapter).

Finally, from a methodological point of view, the uneven distribution of selected income brackets can also cause problems for the RAS-procedure.

In any case, in absolute volumes, the top 2 income groups represent a small share and the 3 lower income groups, accounting for 87% of total used cars, reveal the same trend as the first group of countries, i.e. higher prevalence of used car and older used cars with decreasing household income.

4.5 Conclusion

This chapter looked into the open SILC database and other publications, in combination with our own dataset on used car transaction to gain understanding in the importance of social strata in the used car market.

Scattered data and anecdotal evidence has led to the intuition that there are important socio-economic distribution effects associated with the used car market. This chapter confirms this intuition and supports the rationale with data and estimation. Key conclusions are:

1. The used car market is of substantially larger size than the new car market in terms of volume and this is more explicit for EU-10.
2. There are distinct differences in the size of the used car market between countries
3. Consistently for all EU countries, the used car market is more important for lower income groups.
4. While used cars are more prevalent in lower income groups, the used cars they own also tend to be older.
5. We expect average ownership periods of about 5-7 years, average 3-4 different owners during the lifetime, with potential large differences between member states.
6. **Given the above, we expect important distribution effects between income-groups** for measures focusing on new sales (e.g. environmental legislation, safety, taxation).
7. Some of the findings are not intuitive and important assumptions were needed to come to an estimate of the EU fleet by income group & age cohort (see top income group for EU-10). More empirical evidence is needed to make any definite statements

5 Used car cross-border trade

5.1 Objective

The aim of this task is to update the 2011 study of flows of second hand cars within the EU and export outside the EU (OKO - Mehlhart e.t al., 2011), to construct a time series. Table below summarizes the estimate the findings of that study, estimating used car flows in the EU for 2008:

Table 21: Estimated relevance of imports and exports (M1 & N1) to the composition of the national fleets for 2008 (source European second-hand car market analysis 2011, OKO)

	Import (M1+ N1)		Export (M1 + N1)		Compared to new registrations		
Country	Minimum intra EU-27 (Estimate)	Extra EU-27 (FTS)	Minimum intra EU-27 (Estimate)	Extra EU-27 (FTS)	New registrations (M1 + N1) source (ACEA)	Import (intra + extra EU) / new registrations	Export (intra + extra EU) / new registrations
PL	1 105 615	38 418	6 777	33 127	375 936	304%	11%
BG	151 407	13 059	281	1 140	55 236	298%	3%
LV	40 734	2 790	987	1 634	21 872	199%	12%
GR	397 558	648	427	179	289 500	138%	0%
SK	101 191	2 757	1 023	160	96 940	107%	1%
CZ	203 926	2 530	3 256	5 800	202 823	102%	4%
CY	8 909	15 576	86	65	28 444	86%	1%
MT	887	3 298	112	14	5 666	74%	2%
RO	222 323	984	44 239	86	307 409	73%	14%
EE	14 844	2 210	2 168	2 886	27 555	62%	18%
IE	56 000	3 024	939	119	179 770	33%	1%
FI	24 622	2 630	1 266	618	156 006	17%	1%
HU	28 600	218	1 507	1 691	174 837	16%	2%
DK	42 106	894	51 670	3 330	183 746	23%	30%
LU	16 662	39	28 486	1 044	56 387	30%	52%
BE	168 092	5 277	196 118	221 482	603 493	29%	69%
SI	19 945	304	2 432	47 600	78 857	26%	63%
NL	92 000	8 171	283 636	77 308	584 572	17%	62%
SE	24 000	8 438	16 488	5 754	293 251	11%	8%
AT	31 053	1 481	63 135	8 526	326 460	10%	22%
DE	178 323	54 326	1 557 774	274 621	3 313 565	7%	55%
ES	80 980	8 335	246 959	6 898	1 327 048	7%	19%
FR	97 980	5 632	249 460	29 993	2 509 219	4%	11%
PT	10 750	300	2 562	6 112	268 787	4%	3%
IT	64 236	3 387	388 936	23 976	2 385 564	3%	17%
UK	8 852	22 100	52 062	26 831	2 418 953	1%	3%
LT	252 435	44 543	8 853	249 022	25 217	1178%	1023%
EU 27	3 444 031	251 369	3 211 638	1 030 016	16 297 112	23%	26%
EU 15	1 293 214	124 682	3 139 918	686 791	14 896 321	10%	26%
EU 12	2 150 816	126 687	71 721	343 225	1 400 791	163%	30%
EU 11*	1 898 381	82 144	62 868	94 203	1 375 574	144%	11%

5.2 Methodology

In the 2011 study, national sources were used to compile the above table. COMEXT[21], the European database for intra- and extra-EU trade is the data source of preference. However, due to high reporting threshold values, the bulk of the used car trade is not captured in the trade database. This was a problem for the study in 2011 and still is for this study. We therefore have to focus on national sources.

5.3 Data

5.3.1 Used car survey

Before going over the national data, we look into the survey data from (GfK, 2014). In this survey information about the country of origin was collected and in total, 23.493 transactions include this information (93%). Of these, 1.459 transactions are cross-border trades, 6.2% of all transactions. The table below summarizes the origin and destination of used cars transactions reported in this dataset.

Because the sample size is fixed at 1000 points for big countries and 500 for small countries, while population differs between countries, the data should be weighted to allow for comparison between countries.

The table below shows the weighting factors we apply. Figures represent how many households a data point represents.

Table 22: weighting factors to allow for comparison of transactions between countries

country	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
weight factor	6628	8437	6073	1356	7754	65294	4378	2165	36999	4122	48194	9310	8186	5556	47815	4846	827	3368	1136	12263	30214	8209	17423	7519	3384	4386	44306

In the figure below the number of used car transactions is shown, unweighted (top) and weighted (bottom).

[21] http://ec.europa.eu/eurostat/web/international-trade/data/database

Table 23: origin and destination of used car transactions in the TML-GfK dataset. Unweighted (top – weighted (bottom)

Destination

Origin	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
AT	1010		22		2	1	1				1		13		1						2		11		3	14	
BE	1	1022	4		4	1		1	4		7	4	1		5	5	18	6		3	14	4	9	1	1	7	
BG			827				1					1			2								2				
CY				433																							
CZ					1025																						
DE	23	5	69	1	63	1042	17	28	2	16	5	29	9		5	31	67	44		8	73	4	231	6	10	35	2
DK			2		1		966						1								1		2			11	
EE							1	456		3								1									
ES	1					1			1004						1			1			1	2	4	1			1
FI								5		1017																	
FR	1	4	5	1	5				3		1034	1		1		1	5	2			4	8	13	1		1	1
GR				8								962											1				
HU													965														
IE														562													
IT	4	3	61		9	1			1		1	2	1		1034	1	1				1	1	17	1	4	4	
LT								5		1						444		8						1			
LU		1									4					2	406			1	1						
LV								2		1						2		435									
MT																			218								
NL	1	5	3		3	2										2	4	2		1059	5		8		1	4	
PL					1											2		1			902					2	
PT																						1023					
RO																							682				
SE			3					3					2		1						2	2		990			
SI																									483		
SK			1																							919	
UK			10	39					1				1	53		6		1	66	1	5	1	4	1		1	1114

Destination

Origin	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
AT	285		5.7		0.7	2.8	0.2				2.1		4.5		2.0						2.6		8.2		0.4	2.6	
BE	0.3	367	1.0		1.3	2.8		0.1	6.3		14.4	1.6	0.3		10.2	1.0	0.6	0.9		1.6	18.0	1.4	6.7	0.3	0.1	1.3	
BG			214				0.2					0.4			4.1								1.5				
CY				25																							
CZ					338																						
DE	6.5	1.8	17.8	0.1	20.8	2896	3.2	2.6	3.1	2.8	10.3	11.5	3.1		10.2	6.4	2.4	6.3		4.2	93.9	1.4	171.3	1.9	1.4	6.5	3.8
DK			0.5		0.3		180						0.3								1.3		1.5			2.1	
EE							0.2	42		0.5								0.1									
ES	0.3					2.8			1581						2.0			0.1			1.3	0.7	3.0	0.3			1.9
FI								0.5		178																	
FR	0.3	1.4	1.3	0.1	1.7				4.7		2121	0.4		0.2		0.2	0.2	0.3			5.1	2.8	9.6	0.3		0.2	1.9
GR				0.5								381											0.7				
HU													336														
IE														133													
IT	1.1	1.1	15.8		3.0	2.8			1.6		2.1	0.8	0.3		2104	0.2	0.0				1.3	0.3	12.6	0.3	0.6	0.7	
LT								0.5		0.2						92		1.1						0.3			
LU		0.4									8.2					0.4	14			0.5	1.3						
LV								0.2		0.2						0.4		62									
MT																			11								
NL	0.3	1.8	0.8		1.0	5.6										0.4	0.1	0.3		553	6.4		5.9		0.1	0.7	
PL					0.3											0.4		0.1			1160					0.4	
PT																						357					
RO																							506				
SE			0.8					0.3					0.7		2.0						2.6	0.7		317			
SI																									70		
SK			0.3																							172	
UK			2.6	2.3					1.6				0.3	12.5		1.2		0.1	3.2	0.5	6.4	0.3	3.0	0.3		0.2	2101

For all countries, the country of origin of the used car is most often also the country of destination. Several countries stand out in having a relatively large share of import compared to domestic used cars, though the bulk is still domestic trade:

1. Bulgaria: Large import mainly from Austria, Germany and Italy
2. Luxembourg: Large import mainly from Belgium and Germany. This is due to the fact that domestic supply is limited and to the small size of the country. Neighbouring countries are quite close with shared languages, facilitating cross-border trade
3. Latvia: Large import mainly from Germany
4. Malta: Large import mainly from the UK. Malta and Cyprus are special cases due to left-hand drive and due to their small size. As a consequence, domestic supply is limited leading to high imports from the UK.
5. Poland: Large import mainly from Germany and to lesser extent other Western EU countries.
6. Romania: Large import mainly from Germany and to lesser extent other Western EU countries. At 69%, Romania has the lowest ratio of domestic used car trade according to

the data. The flow from Germany to Romania is the largest in the dataset in absolute figures (231 transactions)

We can use the share of domestic transactions by <u>origin</u> vs total transactions as a proxy to determine to what extent imports are important for a given country. The lower the ratio the more important are imports for this market. Likewise, we use the share of domestic transactions by <u>destination</u> vs total transaction as a proxy to determine to what extent exports are important for a given country. The lower the ratio the more important are exports.

Table 24: share of domestic transactions by origin (left) and destination (right)

country	share domestic origin	share domestic destination
AT	97%	90%
BE	98%	84%
BG	82%	97%
CY	90%	100%
CZ	92%	100%
DE	99%	88%
DK	98%	97%
EE	91%	98%
ES	99%	99%
FI	98%	100%
FR	98%	99%
GR	96%	100%
HU	97%	100%
IE	91%	100%
IT	99%	98%
LT	90%	98%
LU	81%	57%
LV	87%	99%
MT	77%	100%
NL	99%	96%
PL	89%	100%
PT	98%	100%
RO	69%	100%
SE	99%	98%
SI	96%	100%
SK	92%	100%
UK	100%	98%

In general, the 2011 study conclusions on the distinction between importing and exporting countries are supported by this new data.[22] The countries identified as main import countries (green) and main exporters (blue) match the countries in the 2011 study. LT, identified as a somewhat special case in the 2011 study, is also according to this data somewhat different compared to the other member states scoring relatively highly for both import and export.

[22] Note that the ratios presented are not the same ratios from the 2011 study. However, the conclusions that are drawn from the ratios, to identify countries as importer or exporter do match.

Given the relatively small sample-size, we cannot draw general conclusions from this data. For example, even for Poland (the largest importer), we find only 140 import transactions, from various countries. This is not enough to make any robust statement about trends in individual countries of origin.

Also, due to the setup of the survey (which focussed on dealers), it is likely imports are underestimated compared to the domestic trade in the data. Used cars bought via domestic dealers may well be imported by the dealers so should be considered import. To the consumer however, this is perceived as a domestic transaction and it will be reflected as such in the survey feedback. As a consequence, the data is only useful to draw conclusions on the relevance of import and export between countries but not the size of the domestic used car trade vs. import and export.

5.3.2 National sources

The TML-GfK dataset gives an indication of key flows of used cars within the EU, between member states. It is clear, as was concluded in the 2011 study, there is a flow from Western EU countries, particularly Germany, to Eastern EU countries. We cannot derive total trade volumes from the dataset. To this end, we attempt to reconstruct the flows within the EU, using national statistics.

We focus on key countries to understand the main flows. For some countries, data could be found, for other, no data was available.

Table 25: size of the EU vehicle stock (TiF, 2015 – data for 2013) and own assessment of quality of data

country	stock (TiF2013)	share EU stock	data found
DE	43851230	17.79%	++
IT	36962934	14.99%	++
FR	32243826	13.08%	-
UK	30074857	12.20%	excluded
ES	22024538	8.93%	--
PL	19389446	7.86%	++
NL	7932290	3.22%	+
BE	5504809	2.23%	+/-
GR	5124208	2.08%	--
CZ	4729185	1.92%	++
RO	4695660	1.90%	++
AT	4641308	1.88%	--
SE	4495473	1.82%	+
PT	4480000	1.82%	--
FI	3127399	1.27%	+
HU	3040732	1.23%	+
BG	2910200	1.18%	-
DK	2278121	0.92%	+
IE	1933129	0.78%	excluded
SK	1879759	0.76%	--
LT	1808982	0.73%	++
SI	1063795	0.43%	--
LV	634603	0.26%	++
EE	628500	0.25%	++
CY	474561	0.19%	excluded
LU	363247	0.15%	excluded
MT	256096	0.10%	excluded

We first elaborate on the national data for major exporting and importing countries.

5.3.2.1 Main exporting countries

<u>Germany</u>

Germany keeps a detailed record of exports of used cars to other member states. Whenever a car is de-registered in Germany and registered in another EU country, the country of destination reports this to Germany. This enables the German "Kraftfahrt-Bundesamt" to compile detailed export data.

We received data directly from the agency which is not published on their website. This data is considered an estimate and should by no means be considered an official German statistic.

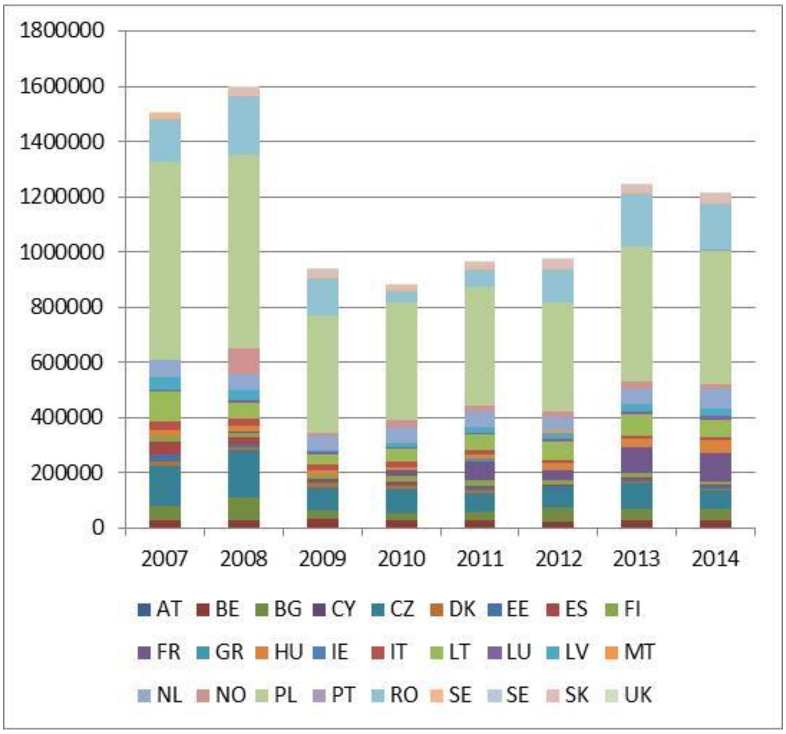


Figure 37: German used car exports, by country, 2007-2014 (source: KBA)

We can observe several interesting findings:

1. The largest export partner is Poland, accounting for almost half of all German used car exports, though the share has declined from 48% in 2007 to 40% in 2014.
2. All Eastern European countries, labelled importing countries in this study, account for 75-85% of German exports.
3. There is a strong decrease of exports in 2009. This is mainly due to the German scrappage scheme to stimulate the car industry. A €5bn scrappage programme, with a subsidy of 2,500€ per scrapped vehicle, led to additional scrappage of 2 million old cars, reducing the supply of used car significantly. We see a decrease of about 660,000 used car exports in 2009, 280,000 to Poland alone. These are old used cars, reports claiming an average age of about 15y[23] which are likely destined for export to Eastern EU. We can thus observe a clear knock-on effect on the used car market and consequently also on the exports.

[23] "*Assessment of the Effectiveness of Scrapping Schemes for Vehicles: Economic, Environmental, and Safety Impacts*"; Global Insight for European Commission DG ENTR; 2010

Exports have only gradually been recovering and have not yet return to peak levels of 2008. It is not clear if this is due to a continuing lack of supply of German used cars in Eastern European importing countries or due to a shift from used cars to new cars in Eastern Europe associated with a (comparative) improvement of economic conditions. Data for Poland further in this chapter will clarify further.

4. German exports to France have increased from nearly non-existent in 2007 to 8.2% of total exports in 2014.

This export matrix is the best data we have found and given the importance of Germany, due to the large size of its used car market, this dataset will be the starting point to reconstruct flows in the EU (see further).

Netherlands

The Netherlands Central Office for Statistics (CBS) publishes official used car export statistics. Data includes export as well as ELV (scrapped vehicles) and distinguishes between cars and LCVs.

Table 26 time series of used car exports and ELV in NL (2000-2014) – source: CBS[24]

	CAR		LCV	
	Export	ELV	Export	ELV
2000	96365	310323	21740	15181
2001	133542	303866	27342	15932
2002	123222	294637	30366	16255
2003	137266	292023	31088	15670
2004	197175	274573	40686	15909
2005	177430	231627	88562	18386
2006	179901	225760	69014	13740
2007	209446	200836	55321	10960
2008	205455	198272	53940	10915
2009	181928	246759	46421	14344
2010	193131	229629	53571	14783
2011	273938	235852	62870	13633
2012	324590	224102	63605	12593
2013	278770	219836	56739	12614
2014	247188	213045	46260	12823

Car exports increased from about 100,000 units to over 300,000 units annually at its peak in 2012, decreasing slightly in 2013 & 2014. The ratio [export]/[ELV] increased from 0.3 in 2000 to 1 in 2007 and up to 1.4 in 2012 to stabilize around 1.2 in 2013-2014. Especially in the period 2000-2008, there is a clear shift from ELV to export, i.e. instead of being scrapped, old vehicles are exported. This is likely due to the gradual opening of the Eastern European markets in the early years of their EU membership.

LCV exports are considerable smaller, on average about one fifth of the passenger car trade. Though smaller, the ratio [export]/[ELV] is considerably higher for LCV's than cars. This indicates that LCVs seem more popular to export. Possible explanations are that LCV's are (almost) always company vehicles and when written off still have a valuable service life remaining. It is expected the bulk of new LCV's in the Netherlands are new purchases so most used LCV's are exported, though we did not find data to support this.

[24] http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=80360ned&D1=1%2c3&D2=1-2&D3=0&D4=a&HDR=G3&STB=G1%2cG2%2cT&VW=D

Belgium

No official statistics exist for Belgian used car exports. Direct contact with the Vehicle Registration Service (DIV: "Dienst InVerkeerstelling": http://www.belgium.be/nl/mobiliteit/Voertuigen/inschrijving/div-kantoren) has resulted in ad hoc analysis to gain some insight in Belgian exports.

As with Germany, Belgium aims to identify partner countries for deregistered vehicles from Belgium, reregistered abroad. This is successful for some countries but less so for others. Officials informally expect an underestimate of 20-50% for countries they receive data from. Also, there is a considerable time-lag of 2 to 7 months (estimate) between deregistration in Belgium and reregistration in other countries. Data is incomplete and not cleaned adding to the underestimation. The table below summarizes exports for 2012-2014, for key export partners

Table 27: time series of used car exports in BE, by partner country (2012-2014) – source: DIV

	2012	2013	2014
BG	1	80	123
CZ	3391	1035	/
DE	2091	116	116
DK	/	71	47
EE	1	130	42
ES	587	2215	476
FR	909	69707	46338
HU	530	481	1249
LT	3401	/	2
LU	810	1500	1623
LV	649	/	1607
NL	3	1525	391
PL	10349	68443	33545
RO	1911	2018	4059
SI	355	250	61
SK	1784	3662	1134
TOTAL	26772	151233	90813

Note the erratic trend pattern in the data. Most likely, in 2012 the system of keeping record of exports by country was setup and was thus incomplete for some countries, while in 2014, the time-lag will lead to further underestimation. It's also possible that in 2013 a "catch-up" operation was done, allocating some of the transactions in 2012 to 2013.

It's clear this data is not reliable, so we will not use the specific figures in the EU flow estimate later on. The data does provide some insight in key partner countries. France and Poland are the key export countries. The total amount of exports is likely to be around 150,000 units annually.

Italy

For Italy, we received data from ANFIA, "*Associazione Nazionale Fra Industrie Automobilistiche*"; the National Association of the Automobile Industry[25]. The data includes both imports and exports by partner country. Holding data both on import and export, by partner country, this is the best data we could find for any EU country.

Figure below summarizes Italian imports and exports from and to other EU countries

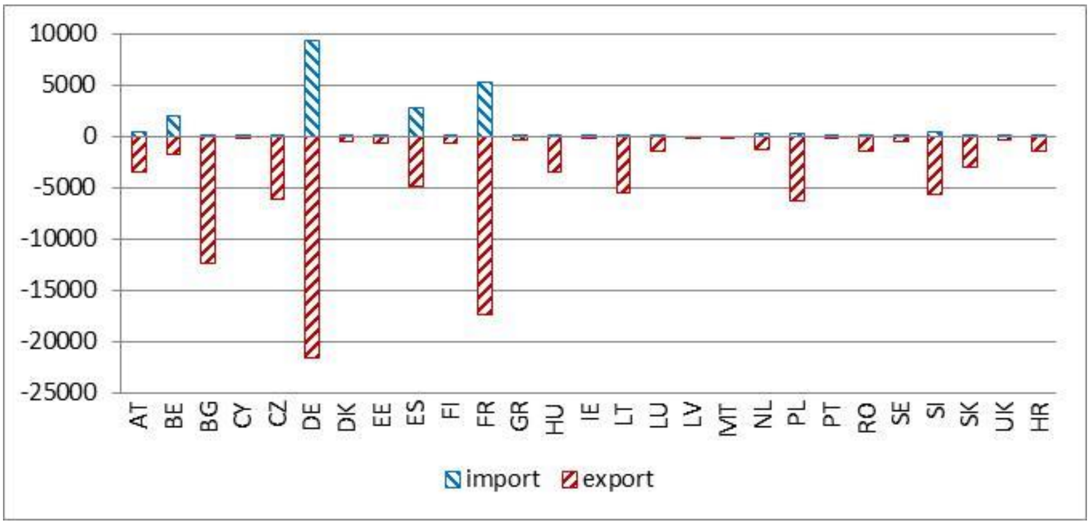


Figure 38: Italian used car imports and exports, by country, 2013 (source: ANFIA)

Total EU imports amount to 21,128 units while total exports are 100,968. The net balance is 79,840 units exported, mainly to Germany, France and Bulgaria. The import from Germany according to this data set (9,222 units) corresponds well to the German data on export to Italy (9,646 units).

Both import and export used car flows are rather low compared to the total fleet in Italy. The Italian fleet is only 15% smaller than Germany's, yet used car exports are a factor 10 smaller than Germany. It is not clear if the data capture all cross-border used car flows, for example the exports to Poland and Romania seem low, compared to German exports to these countries.

The data on volumes also includes the value of the trade. This data allows us to derive average values of the cars traded, per import/export partner country.

[25] http://webmail.anfia.it/autoincifre/indexbis.htm

Table 28: Italian used car trade volumes and value, with derived average price per unit – 2013 (source: ANFIA)

2013	UNITS		VALUE (M€)		Unit price (€)	
	import	export	import	export	import	export
AT	365	3 552	€ 4	€ 37	€ 11 261	€ 10 395
BE	1 949	1 864	€ 17	€ 26	€ 8 883	€ 14 039
BG	139	12 418	€ 1	€ 36	€ 8 886	€ 2 902
CY	9	85	€ 0	€ 1	€ 9 600	€ 9 878
CZ	108	6 141	€ 1	€ 30	€ 11 645	€ 4 910
DE	9 222	21 619	€ 144	€ 256	€ 15 650	€ 11 821
DK	4	516	€ 0	€ 13	€ 18 320	€ 24 339
EE	1	635	€ 0	€ 7	€ 28 000	€ 10 570
ES	2 789	4 942	€ 21	€ 41	€ 7 442	€ 8 336
FI	8	618	€ 0	€ 10	€ 58 784	€ 16 604
FR	5 249	17 436	€ 35	€ 197	€ 6 581	€ 11 291
GR	70	315	€ 0	€ 2	€ 1 950	€ 4 826
HU	9	3 435	€ 0	€ 17	€ 26 802	€ 4 873
IE	16	1	€ 0	€ 0	€ 1 221	€ 80 000
LT	4	5 469	€ 0	€ 33	€ 10 950	€ 6 012
LU	27	1 544	€ 0	€ 19	€ 7 568	€ 11 986
LV	0	160	€ 0	€ 2		€ 10 100
MT	0	6	€ 0	€ 0		€ 59 403
NL	222	1 245	€ 3	€ 18	€ 11 901	€ 14 654
PL	228	6 265	€ 3	€ 22	€ 12 359	€ 3 472
PT	115	128	€ 1	€ 2	€ 7 120	€ 13 468
RO	15	1 469	€ 0	€ 16	€ 15 890	€ 11 120
SE	16	522	€ 0	€ 13	€ 19 229	€ 24 324
SI	407	5 700	€ 5	€ 32	€ 11 859	€ 5 552
SK	13	3 049	€ 0	€ 17	€ 13 147	€ 5 634
UK	122	368	€ 4	€ 5	€ 28 763	€ 12 295
HR	21	1 466	€ 0	€ 5	€ 6 369	€ 3 377
TOTAL	**21 128**	**100 968**	**240**	**854**	**€ 11 374**	**€ 8 458**

Prices implicitly reflect the quality of the used car traded. It's clear that imported cars are of higher value than exported cars. For the main Eastern EU export partners the average prices are low, correlating with comparative socio-economic situation of the country.

The above data is official trade data and suffers the same problem as COMEXT discussed at the beginning of the chapter. As such, the export volumes are expected to be a large underestimate of the real used car flows. In particular, smaller trades are not reported making it most likely the flow to Eastern EU countries is further underreported.

Further inquiry with Italy officials has led to a second source of information, from ACI (Automobile Club d'Italia - http://www.aci.it/). We received a dataset with a similar approach to the German data, i.e. an overview of registered used car per country, of cars deregistered in Italy:

Table 29: Italian used car exports, by country, 2014-2015 (source: ACI)

	2014	2015
AT	5022	5322
BE	6843	6462
BG	106684	116569
CY	85	13
CZ	16243	18729
DE	49172	41983
DK	321	376
EE	799	675
ES	2757	3604
FI	585	620
FR	31279	28934
GR	865	731
HU	15548	16094
IE	46	34
LT	17678	14078
LU	1610	550
LV	500	504
MT	170	157
NL	2260	2463
PL	31109	28821
PT	341	243
RO	23667	15532
SE	1244	858
SI	16180	21863
SK	7798	7962
UK	1442	1282
HR	8148	9242
TOTAL	348396	343701

Exports are a factor 3 higher than reported by ANFIA, confirming the expectation of underreporting. The ACI data also highlights the importance of the trade with Eastern EU countries. For Italy, the key eastern EU export partners of used cars are BG, PL and RO, while LT, HU, CZ and SI are of considerable importance.

This data will be used to estimate EU flows later in this chapter.

Other countries

No data could be found for Austria. For France, official statistics only hold information on the domestic used car market, not on import and export. Direct contacts with statistical offices did not lead to official data, though an estimate was given of about 500.000 exported vehicles over a 6 year period to other EU countries, amounting to 84.000 cars per year.

5.3.2.2 Main importing countries

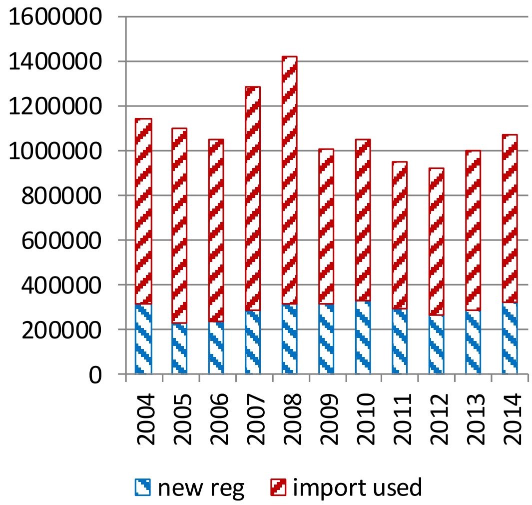
Poland

The German data flagged Poland as the main export destination. Import data from Poland would provide an independent second source to support this observation. As such, Polish data is considered crucial to understanding the flows and assessing the reliability of data found.

Reliable data was found on Poland imports from the Polish automotive association and Ministry of finance. The table below compares total imports to new registrations, to assess the importance of used car imports.

Table 30 Polish imports and new registrations time series (2004-2014) – source http://www.pzpm.org.pl and ACEA

	new reg	import used	% import/ new reg
2004	318111	828142	260%
2005	235522	870777	370%
2006	238993	816789	342%
2007	293305	994564	339%
2008	320040	1103970	345%
2009	320206	693324	217%
2010	333490	718286	215%
2011	297937	655314	220%
2012	270895	657392	243%
2013	288998	711865	246%
2014	327709	748863	229%



The import of used cars exceeds domestic registration of new passengers by a factor of 2 to 3.

There is a slight decrease of the ratio of imported used car to new registrations over time, indicating Polish purchases gradually shift from used to new cars. This shift, however, is still modest and a reversed trend seems visible in the last few years.

Table 31: Polish imports compared to German exports to Poland

	Total PL import	**DE export**	**share DE**
2007	994564	716409	72%
2008	1103970	702030	64%
2009	693324	425686	61%
2010	718286	427736	60%
2011	655314	433349	66%
2012	657392	394311	60%
2013	711865	487585	68%
2014	748863	484429	65%

Polish used car import data is consistent with the German data on exports to Poland. Data on origin is not available in the Polish dataset. Comparing imports from Polish data and exports from German data, the share of Polish imports of German used cars seems stable at about 60-70%. The big drop in imports in 2009 (700,000 units in 2009 vs. 1,100,000 in 2008) is consistent with the German export data and can be linked to the German scrappage scheme. This again proves the important knock-on effects of the German scrappage scheme on the used car market, not only in Germany, but also in Poland and likely other export partners.

It is interesting to note that the dramatic decrease in supply of used cars due to the German scrappage scheme only induced a slight increase in new registrations. It seems in total fewer cars were registered rather than creating a shift from used to new car purchases.

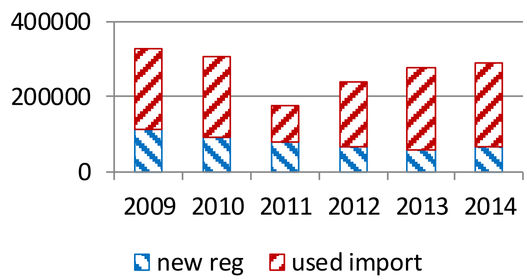
Romania

According to the TML-GfK dataset, Exports from Germany to Romania exceeded even the export from Germany to Poland. This is not supported by the German export dataset but still indicates Romania is a key used car import country.

The largest online used car auction platform as well as official statistics on car registrations from the DRPCIV allows us to summarize the key details of the Romanian used car market in table below

Table 32 Romanian imports and new registrations time series (source www.researchromania.ro[26] and ACEA)

	new reg	used import	used domestic	% import/ new reg
2009	116012	212836	379404	183%
2010	94541	214606	377947	227%
2011	81709	94488	411439	116%
2012	66436	174950	356607	263%
2013	57710	221852	205553	384%
2014	70172	219929	217304	313%



As with Poland, used car imports exceed the domestic registration of new vehicles by factor 2-3. In absolute terms, used car imports into Romania are about 3 times smaller than into Poland.

Table 33: Romanian imports compared to German exports to Romania

	Total RO import	DE export	share DE
2009	212836	131102	62%
2010	214606	41506	19%
2011	94488	62488	66%
2012	174950	117848	67%
2013	221852	191265	86%
2014	219929	169432	77%

[26] http://www.researchromania.ro/2015/01/analiza-pietei-auto-dupa-anul-2014-si-predictii-pentru-2015/

Comparing with German exports, the data shows that also for Romania, Germany is the most important import-partner. Only for 2010 is there a large drop in the market share of Germany as supplier of foreign used cars.

This is consistent with an estimation of the source of foreign used cars by country. Based on the leading Romanian online used car auction platform http://autovit.ro/, by filtering advertisements per country, we were able to estimate the importance of individual import countries

Table 34: importance of used car import countries in Romania, based on used car advertisement by country of origin. (source: http://autovit.ro/)

Country	ads	% import
DE	6568	71%
RO	4370	
FR	631	7%
BE	556	6%
NL	553	6%
IT	273	3%
AT	208	2%
other	450	5%
unknown	2715	

The online trading platform indicates Germany as the most important source of foreign used cars in Romania, with over 70% of all (known) foreign imports. France, Belgium and the Netherlands all supply a small share of about 6-7%

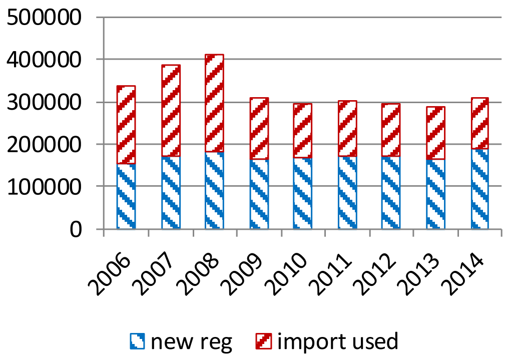
Czech Republic

In terms of fleet size, the Czech Republic resembles the Romanian fleet. According to Eurostat data, Nominal GDP per capita in 2015 in the Czech Republic is 14.7k € while in Romania it is 8k €. The Czech Republic is one of the most prosperous eastern European countries and as has been indicated in the previous task, this would suggest a larger emphasis on the new car market and less dependence on the import of used passenger cars.

Data on used car imports was acquired from public statistics. The table below summarizes used car imports as well as domestic registrations of new passenger cars.

Table 35: Czech imports and new registrations time series (source ACEA & Centrální registr vozidel Ministerstva dopravy ČR)

	new reg	import used	% import/ new reg
2006	156686	183143	117%
2007	174456	212869	122%
2008	182554	230974	127%
2009	167708	144602	86%
2010	169580	127034	75%
2011	173595	131707	76%
2012	173988	124343	71%
2013	164746	126115	77%
2014	192314	120408	63%



Unlike Poland and Romania, in the Czech Republic there is a steady decline of imported used cars. The ratio used vs. new registration is lower than in Poland and Romania.

Table 36: Czech imports compared to German exports to Czech Republic

	Total CZ import	DE export	share DE
2007	212869	144993	68%
2008	230974	171657	74%
2009	144602	82993	57%
2010	127034	88118	69%
2011	131707	66953	51%
2012	124343	60890	49%
2013	126115	88724	70%
2014	120408	66665	55%

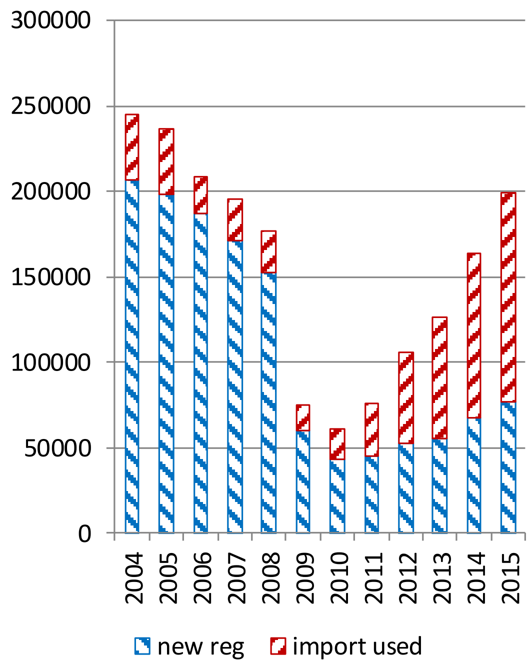
Germany is the most important source of foreign used cars

Hungary

Limited data on used car registrations was found for Hungary. Data was acquired from DATAHOUSE (https://carinfo.hu/) and holds time series data for first used car registrations in HU. As these are first registrations, all are considered as imports. Data by country of origin was not available.

Table 37: Hungarian imports and new registrations time series (source ACEA & DATAHOUSE)

year	new reg	import used	% import/ new reg
2001		43780	
2002		67364	
2003		67550	
2004	207055	38624	19%
2005	198982	37512	19%
2006	187676	20960	11%
2007	171661	24452	14%
2008	153278	23573	15%
2009	60189	15453	26%
2010	43476	17698	41%
2011	45094	31312	69%
2012	53059	53531	101%
2013	56139	70700	126%
2014	67476	96733	143%
2015	77171	122620	159%



Hungary seems to deviate from most Eastern EU countries as the importance of used car imports only emerged later compared to for example in Poland and Romania.

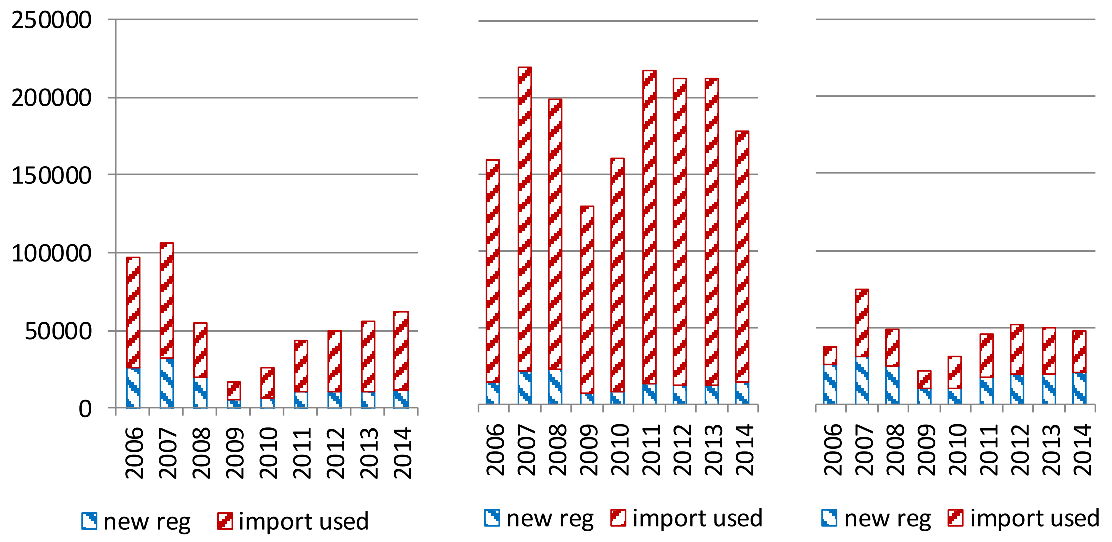
Domestic registrations of new cars exceeded used car imports until 2011. New registrations gradually lost ground to used car imports and after a major decline in 2008 & 2009, the market rebound mainly favoured used car imports while domestic new registrations only slowly recovered.

<u>Baltic countries (LV, LT, EE)</u>

Because of their small market share of the EU market, we combine the Baltic countries in a single section. Though limited in market size, the used car market in the 3 Baltic countries reveals distinctly different characteristics between each other.

Table 38: imports and new registrations in the Baltic countries in time series (source ACEA & various national agencies[27])

	LV			LT			EE		
	new reg	import used	% import/ new reg	new reg	import used	% import/ new reg	new reg	import used	% import/ new reg
2006	26255	71144	271%	14234	145241	1020%	25363	11464	45%
2007	32805	74198	226%	21606	197863	916%	30912	43980	142%
2008	19778	34981	177%	22217	176400	794%	24579	24082	98%
2009	5534	11754	212%	7515	121364	1615%	9946	11574	116%
2010	6588	20068	305%	7970	152422	1912%	10295	20154	196%
2011	11328	32140	284%	13234	204128	1542%	17070	28632	168%
2012	11034	39101	354%	12165	199722	1642%	19424	31691	163%
2013	11070	44738	404%	12163	200129	1645%	19694	29790	151%
2014	12452	50112	402%	14503	163553	1128%	20969	26118	125%



For all 3 countries, used car imports exceed domestic registrations of new vehicles. In Lithuania, new registrations are negligible compared to used car imports. Lithuania is a special case and can be considered a transit country (see earlier).

27 http://www.mnt.ee/?404 http://www.mnt.ee/?404 - http://autotyrimai.lt/ - http://www.bta-kindlustus.ee/en/about/news/the-average-age-of-vehicles-in-latvia-and-estonia-keeps - http://www.csdd.lv/eng/about_csdd/

Latvia and Estonia show a similar pattern to Hungary with declining new registrations in 2008-2009 and a gradual recovery mostly favouring used car imports with limited growth of new registrations. In contrast with Hungary however, used car imports were already large prior to 2008-2009.

5.3.2.3 Other countries

We briefly present data found for other countries. These are smaller countries that can neither be labelled as key exporting or importing in the EU used car market.

Denmark

Direct communication from the Danish statistical office (SKAT) indicated about 32.000 vehicles are exported each year. This information was given in an informal way and cannot by verified. No further information on the source of this claim is available. SKAT could not provide information about imports. On average, there are about 190.000 new registrations per year in DK

Finland

The Finish automobile association publishes information about imports of used passenger cars and LCV's. This data is summarized in the table below

Table 39: Finish imports and new registrations time series (source ACEA & http://www.aut.fi[28])

	car	van	(car new reg)
2000	2229		
2001	1925		
2002	4709		
2003	31944	873	147222
2004	31381	2994	142439
2005	29728	1498	147949
2006	27625	1465	145689
2007	21999	1540	125285
2008	22580	2041	139611
2009	22595	1977	88344
2010	30141	1744	107346
2011	27745	1657	121171
2012	23478	1455	111147
2013	21674	1289	103314
2014	19045	1444	106259

Imports first saw a major increase in 2003, most likely related to the introduction of the Euro, creating helping to open the domestic market to the foreign supply of used cars. Imports have however consistently been low at about 20% of domestic new registrations. In recent years, imports of used car have declined further from 28% in 2010 to 18% in 2014.

Imports of used LCV's are negligible.

Export data was not available. Exports are expected to be low due to a high vehicle registration tax which cannot be recovered when exported.

[28] http://www.aut.fi/en/statistics/other_statistics/used_passenger_cars_imported_one_by_one

Sweden

Public statistics and data from the national Automobile Association allow us to compile a comprehensive picture of used car import and export markets in Sweden.

Table 40: Swedish imports, exports and new registrations time series (source ACEA - https://www.transportstyrelsen.se - http://trafa.se/en/road-traffic/vehicle-statistics/)

	import	export	(car new reg)	import/new reg	export/new reg
2005	36851	14517	311779	12%	5%
2006	29828	19049	313812	10%	6%
2007	29923	21936	338538	9%	6%
2008	20896	30374	276344	8%	11%
2009	13915	39571	228528	6%	17%
2010	17500	29068	308734	6%	9%
2011	20289	24575	326649	6%	8%
2012	20028	27113	301335	7%	9%
2013	19914	23931	292178	7%	8%
2014	16972	26440	324037	5%	8%

As with Finland, the Swedish market appears to be rather isolated, both in terms of imports and exports.

Other countries either lack data or have not been researched due to their limited size (MT, LU, CY). We also excluded IE and the UK from the analysis of flows of used cars as the (separate) market for left-hand drive passenger cars is limited to UK, IE, CY and MT.

5.4 Estimation of flows

The data collected, allows us to estimate the flows of used cars in the EU. We apply a cascade of data manipulations to come to an estimation of the used car flows for the year 2013. We choose 2013 as it is the most recent year we have found data for almost all countries.

The sequence of data manipulations is as follows:

1. The starting point is the German exports. Together with data for Italy, the German data is the most reliable and detailed data we found. Moreover, Germany is the largest car market in Europe and is the key exporting country of used cars to other EU countries.
2. For the main importing countries (BG, CZ, EE, HU, LT, LV, PL, RO, SK), we use the share of export by country, using the imports from Germany as a validation point. For those importing countries lacking detail about the country of origin, we use the total imports as a validation of the approach.
3. Apart from the national data, also the discrepancy between new registration as reported by ACEA and new registration as reported by Eurostat can provide a source for validation. Though not explicitly mentioned in the publications, the new registrations reported by ACEA include only **new** vehicles, while new registration in Eurostat include newly registered vehicles for the first time in a country. This would imply that higher registrations according to Eurostat can only be due to net import of used cars. Indeed, we find the same key importing countries revealing large discrepancy between the two sources.

These steps generate the following preliminary estimate of flows:

Table 41: preliminary estimate of used car flows

	to																										
from	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
AT			13934		2817			0					48324			0		0			13358		9108			1811	
BE			2533		5633			523					3717			12813		3650			93509		7452			906	
BG			0		0			0					0			0		0			0		1656			0	
CY			0		0			0					0			0		0			0		0			0	
CZ			0		0			0					0			0		0			0		0			0	
DE	3281	24771	43701	0	88724		4985	14651	3180	14910	91878	164	33455	34	9646	79438	9123	26769	83	58334	487585	141	191265	9029	4528	15556	714
DK			1267		1408			0					3717			0		0			6679		1656			1423	
EE			0		0			0					0			0		608			0		0			0	
ES			0		0			0					0			0		608			6679		3312			0	
FI			0		0			2616					0			0		0			0		0			0	
FR			3167		7042			0					0			2563		1217			26717		10764			129	
GR			0		0			0					0			0		0			0		828			0	
HU			0		0			0					0			0		0			0		0			0	
IE			0		0			0					0			0		0			0		0			0	
IT			38634		12675			0					3717			2563		0			6679		14076			517	
LT			0		0			2616					0			0		4867			0		0			0	
LU			0		0			0					0			5125		0			6679		0			0	
LV			0		0			1047					0			5125		0			0		0			0	
MT			0		0			0					0			0		0			0		0			0	
NL			1900		4225			0					0			5125		1217			33396		6624			1778	
PL			0		1408			0					0			5125		608			0		0			889	
PT			0		0			0					0			0		0			0		0			0	
RO			0		0			0					0			0		0			0		0			0	
SE			1900		0			1570		6764			7434			0		0			13358		0			0	
SI			0		0			0					0			0		0			0		0			0	
SK			633		0			0					0			0		0			0		0			0	
UK			6333		0			0					3717			15375		608			33396		3312			444	
total import estimate			114003		123932			23023		21674			104082			133251		40154			728038		250052			23454	
total import data					126115			29790		21674			70700			200129		44738			711865		221852				
ratio					98%			77%		100%			147%			67%		90%			102%		113%				
ACEA-EUROSTAT estimate			(175628)										(53612)			((118883))		45172			698811		(169882)			(61550)	

(2012 data)
((2011 data))

For the major flows, it seems this approach generates plausible results. Poland, by far the biggest importer of used cars, sums up to 728.038 units according to the estimation. This matches to 711.865 and 698.811 units according to national data and the ACEA-Eurostat discrepancy, respectively. The close match (2% deviation) suggests the approach is reliable. Also for RO (13%

deviation), CZ (2% deviation), the estimation matches the national data. Only for HU is the estimate 40% higher than the national reported used car import figures. .

LT is a special case and reports higher imports compared to the estimate; however the estimate matches better with the ACEA-Eurostat source.

For Romania, an additional validation check is possible with the data on advertisement of used cars by country of origin (see

Table 34)

Table 42: comparing market share of countries of imported used cars in Romania. Data from online auctions (right) and according to the estimation approach (left)

	share (TML-GfK)	share (adv)
DE	76.49%	71.09%
IT	5.63%	2.95%
FR	4.30%	6.83%
AT	3.64%	2.25%
BE	2.98%	6.02%
NL	2.65%	5.99%
other	4.30%	4.87%

Market shares of countries are of the same order of magnitude. In further steps, we stick to the estimation approach, also for Romania, though the online auction data could be considered superior, for consistency purposes. Italian data provides another source for validation. The table below compares the estimate approach to the reported data by ANFIA & ACI.

Table 43: comparing used car imports from Italy estimates (2013) with data from Italian exports (ANFIA-2013 and ACI-2014).

	estimate		IT data ANFIA	ratio		IT data ACI	ratio
BG	38634		12418	32%		106684	276%
CZ	12675		6141	48%		16243	128%
HU	3717		3435	92%		15548	418%
LT	2563		5469	213%		17678	690%
PL	6679		6265	94%		31109	466%
RO	14076		1469	10%		23667	168%
SK	517		3049	589%		7798	1507%

There are large differences. The estimation approach exceeds the reported Italian data from ANFIA, a consequence of the underreporting discussed earlier. On the other hand, the ACI-data, considered superior, are higher than the original estimate. We attribute this to the limited sample size of the TML-GfK dataset for trans-boundary trade as well as the bias in that sample to transactions via traders only. Private trade is expected to be of larger importance particularly for Eastern EU countries. Therefore we rely on the ACI data in the estimation of flows.

We complement the matrix further with the following elements:

1. Italian import & export (highlighted in blue)
2. Estimates for Scandinavia trades (Swedish import & export figures) – highlighted in orange
3. Missing key data to complete the matrix are highlighted in yellow

This gives the following final picture to complete the matrix of flows of used cars:

Table 44: final estimate of used car flows in EU (2013)

from \ to	AT	BE	BG	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IT	LT	LU	LV	NL	PL	PT	RO	SE	SI	SK	total export estimate	total export data	ratio
AT			13934	2817			0					47110	365	0		0		13358		9108			1811	88503		
BE			2533	5633			523					3717	1949	12813		3650		93509		7452			906	132686	150000	88%
BG			0	0			0					0	139	0		0		0		1656			0	1795		
CZ			0	0			0					0	108	0		0		0		0			0	108		
DE	3281	24771	43701	88724		4985	14651	3180	14910	91878	164	33455	9646	79438	9123	26769	58334	487585	141	191265	9029	4528	15556	1215114	1215114	100%
DK			1267	1408			0					3717	4	0		0		6679		1656	8000		1423	24155	32000	75%
EE			0	0			0					0	1	0		608		0		0			0	609		
ES			0	0			0					0	2789	0		608		6679		3312			0	13389	xxx	
FI			0	0			2616					0	8	0		0		0		0			0	2624		
FR			3167	7042			0					0	5249	2563		1217		26717		10764			129	56847	83333	68%
GR			0	0			0					0	70	0		0		0		828			0	898		
HU			0	0			0					0	9	0		0		0		0			0	9		
IT	5022	6843	106684	16243	49172	321	799	2757	585	31279	865	15548		17678	1610	500	2260	31109	341	23667	1244	16180	7798	338505	338505	100%
LT			0	0			2616					0	4	0		4867		0		0			0	7487		
LU			0	0			0					0	27	5125		0		6679		0			0	11831		
LV			0	0			1047					0	0	5125		0		0		0			0	6172		
NL			1900	4225			0					0	222	5125		1217		33396		6624			1778	54487	278770	20%
PL			0	1408			0					0	228	5125		608		0		0			889	8259		
PT			0	0			0					0	115	0		0		0		0			0	115		
RO			0	0			0					0	15	0		0		0		0			0	15		
SE			1900	0			1570		5000			7434	16	0		0		13358		0			0	29279	26440	111%
SI			0	0			0					0	407	0		0		0		0			0	407		
SK			633	0			0					0	13	0		0		0		0			0	646		
total import estimate			182052	127500			23822		20495			114699	21531	148366		40654		752468		259643	18273		30734			
total import data			xxx	126115			29790		21674			70700	21128	200129		44738		711865		221852	16972		xxx			
ratio				101%			80%		95%			162%		74%		91%		106%		117%						

This table captures keys flows of used cars, mainly based on German export data as well as import by country of origin, as estimated from the international transactions in the TML-GfK dataset. Validation to total import and export figures seem to confirm the initial estimate. Large uncertainties remain for Spanish, French and Dutch exports. For Spanish exports, no data was found; for French exports, the 84.000 units annually are likely to be a conservative estimate. On Dutch exports, the estimation generates only 20% of the reported exports. Dutch statistics are expected to be reliable. Possibly the TML-GfK dataset, with limited figures for cross-border trade are not sufficiently representative. Another possibility is that Dutch exports also include export outside the EU.

On the import side, no validation data was found for Bulgaria and Slovakia. These countries are likely to behave in a similar way as Poland, Romania. However there is no data to confirm this hypothesis.

5.5 Conclusions

We draw the following key conclusions from the above analysis

1. There are large flows of used cars from Western EU countries to Eastern EU countries. The import of used cars exceeds the number of domestic new registrations in almost all Eastern EU countries.
2. The largest exporting countries are Germany, Italy, Netherlands, Belgium and possibly also France though for the latter we did not find data to verify this. Germany is the largest exporter of used cars, likely responsible for 2/3 of all used car exports. The largest importing countries are Romania and Poland.
3. There are no major trend shifts compared to the 2011 study of flows of second hand cars within the EU. The German scrappage scheme did result in significant knock-on effects on the used car market whose consequences clearly impacted used car imports in Eastern Europe for subsequent years.
4. The used car market dynamics are highly influenced by national policy, facilitating or restricting used car trade (import as well as export). Together with the observation of the impact of the German scrappage scheme, policy levers in the used car market are particularly strong. European and/or national authorities can influence the market with targeted regulation.
5. There is no harmonized data available at European level. As a consequence there remain many gaps in the data due to lack of consistent reporting procedure. Informal data sources such as unofficial statistics and used car websites can help to further complete the picture of the used car trade in the EU.

6 Distribution of costs and benefits of CO_2 legislation over social strata and member states

Previous studies have extensively reviewed the impact of costs and benefits of CO_2 legislation, in the case of newly sold vehicles but have not considered the impact of the market for second hand vehicles on the distribution of these costs and benefits among socio-economic groups in great detail. The evaluation of the CO_2 regulations (Ricardo, 2015) briefly discusses the topic. In short, it is expected that lower income groups benefit more from the regulation as the fuel savings are more important compared to the purchase cost of relatively inexpensive new vehicles or used vehicles, primarily bought by low income groups. However, the report does not go in detail to allocate costs and benefits of the regulation quantitatively among socio-economic groups. If the economic benefits or costs of choosing a (second hand) fuel efficient car are priced and thus passed on to consequent owners, this has an impact on the distribution of the costs and benefits over the different owners during the lifetime of a vehicle.

In this chapter, we use findings from the previous 3 chapters to increase understanding of which member states and socio-economic groups are taking the benefits of fuel efficiency and which member states and socio-economic groups are bearing the burden.

6.1 Approach

The main focus is the distribution of costs and benefit at member state level and at level of socio-economic groups by incorporating the second hand market dynamics in the assessment. We use the CO_2 regulation as a test case but in fact the approach applies to any measure affecting prices of newly sold vehicles. (Ricardo, 2015) also gives us recent figures on the different cost components associated with the regulation (increased purchase cost, decreased fuel cost).

The key element is that while costs and benefits are known for the total lifetime of the vehicle, it is unclear to what extent the second hand market influences the allocation of these costs and benefits over the different owners during the lifetime of the vehicle.

These distributional effects by owner, coupled with the dynamics of the second hand market at level of MS and social strata, allow us to estimate the distributional effects at level of EU member state and social strata.

In this chapter, we elaborate on selected cases quantitatively, assessing the costs and benefits first at the vehicle ownership level, secondly how this affects socio-economic groups and finally, what the distribution is between member states.

We add a qualitative discussion, going into possible second order effects ignored in the quantitative analysis.

6.2 Quantitative

6.2.1 *At level of vehicle ownership*

We look into the case of the CO_2 regulation. Cost and benefits of CO_2-regulation on new cars, at vehicle ownership from the perspective of the owner level mainly account to the following 2 elements:

1. Increased purchase cost due to new technology needed to comply with the regulation
2. Decreased fuel cost due to higher fuel efficiency associated with low CO_2-emissions.

These 2 parameters determine the costs and benefits and in the quantitative analysis, we will use a high and low estimate for both, to get a view of the gross order of the impacts.

Cost and benefits of CO_2 regulations have extensively been investigated, most recently by Ricardo-AEAT (2015) in an evaluation study for the EC DG CLIMA. The ex-post evaluation concluded a benefit over the lifetime of the vehicle at 46€/t CO_2, marking a large difference compared to the ex-ante impact assessment which estimated the cost at about 40€/t CO_2 in the central scenario, with variation as wide as a benefit of 3€/t to a cost of 90€/t CO2. The reason for the large difference is twofold. First, the fuel cost trends ex-post were higher than even the pessimistic fuel cost scenario in the ex-ante impact assessment study. Secondly, the cost premium for CO_2 abatement technologies was much lower ex-post compared to the ex-ante estimations: 10€/g ex-post vs. 30-68€/g ex-ante.

In line with these findings, for the first parameter, the increased purchase cost associated with higher fuel economy, we use a low estimate of 10€/gCO_2 and a high estimate of 50€/gCO_2.

For the fuel prices, we use a 1€/L for low and 1.5€/L as high estimate, in line with the ex-ante fuel price scenario's, which also reflect real world prices in the past years.

We assume a maximum of 4 different owners during the lifetime of a passenger car with an average retention of 5-6 years. We assume a shorter ownership period for younger passenger cars as can implicitly be derived from the findings in the second chapter. Leasing cars are almost exclusively new cars and tend to have a contract of maximum 4 years (Ricardo, 2016).

We assume:

- a first life of 4 years: 0-4y,
- a second of 5 years: life 4-9y,
- a third life of 6 years: 9-15y,
- (a possible fourth life of 7 years: >15y)

Taking into account scrappage rates, as reported in Ricardo-AEAT, 2015 (table 8.11), we assume 94% of the cars have a second life, 87% have a third life and for the share of vehicles that live long enough we assume to have a fourth life, as a 27% chance of all new vehicles.

Under these assumptions on timing of ownership transfer, a fourth life is not common given the scrappage rate. Also, for very old used cars, the extra-EU export will become more important. We therefore consider only the first 3 owners for the analysis.

Because we will compare how costs and benefits of fuel efficient vehicles are distributed among the owners, we have to consider 2 types of vehicles and have to make an assumption on the fuel consumption of a fuel efficient and non-fuel efficient vehicle. To this end, we will consider the emission level of the current park average per fuel type a fuel efficient vehicle and the emission level of the counterfactual scenario from the CO_2 policy evaluation report (Ricardo-AEAT, 2015) as the non-fuel efficient vehicle. The regression analysis in chapter 3 included vehicles with CO_2 emissions in this range, so the regression model can be applied for these vehicles. The test cycle (NEDC) emission levels are corrected for real world (RW) levels. We use the same uplift from (Ricardo-AEAT, 2015). Summarized, we are comparing vehicles with the following properties in terms of fuel efficiency:

Table 45: assumptions on CO_2-emissions of fuel efficient and non-fuel efficient passenger cars

	NEDC			*uplift*		RW	
	petrol	diesel				petrol	diesel
fuel efficient	126.7	126.9		*31%*		166	166
non-fuel efficient	159	153.7		*15%*		182.9	177
				delta		**16.87**	**10.5**

Further assumptions include:

1. Discount rate for future fuel cost, set at 8%
2. Premium of resale value on the used car market, as a function of the CO_2-emissions. Chapter 3 concluded a premium of 5€/g for vehicles younger than 5y, 30€/g CO_2 for vehicles of 5-10y and 42€/g CO_2 for vehicles older than 10. As the boundaries do not match exactly the assumed age of transactions (4, 9 and 15), we assume values of 15, 38 and 42€/g CO_2 respectively for the specific transactions, corresponding to a linear relation with g CO_2. Note that 1g/km translates into a fuel saving of about 4 litres per year if you drive 10,000km annually.
3. For the mileage per age, we rely on findings on our own dataset discussed in chapter 3.

We start from the perspective of the **owner**: to compare cost and benefits of choosing a fuel efficient, new or used car. We compare the net (private) costs and benefits of each option at a given time the buyer is considering to buy any of the alternatives available. The buyer will consider:

- The actual purchase cost, with a premium for the fuel efficient car,
- The expected fuel costs, given the expected mileage per year, discounted to the present,
- Expected survival rates, related to the age of the vehicle. Note that the attrition rate will be higher for later owners,
- Expected resale value (if applicable), with a premium for the fuel efficient car, discounted to the present.

In table below, we summarize the calculation approach, for one example case, petrol - 1.5€/l – 50€/gCO_2:

Table 46: summary of the calculation approach for the distribution of costs and benefits for the case [petrol - 1.5€/l – 50€/gCO$_2$]

	years in owernship	retention	fuel savings	purchase premium	resale premium	scrappage	discounted	TOTAL
New (0-4y)	0	100%	€ 0	€ 844		€ 844	€ 844	€ 140
	1	96%	-€ 209			-€ 200	-€ 184	
	2	96%	-€ 159			-€ 153	-€ 129	
	3	95%	-€ 154			-€ 147	-€ 114	
	4	94%	-€ 157		-€ 253	-€ 386	-€ 276	
used (4-9y)	0	100%		€ 253		€ 253	€ 253	-€ 641
	1	98%	-€ 151			-€ 147	-€ 136	
	2	98%	-€ 142			-€ 139	-€ 118	
	3	96%	-€ 140			-€ 134	-€ 104	
	4	93%	-€ 134			-€ 124	-€ 89	
	5	88%	-€ 128		-€ 641	-€ 679	-€ 448	
used (9-15y)	0	100%		€ 641		€ 641	€ 641	€ 108
	1	95%	-€ 127			-€ 121	-€ 111	
	2	90%	-€ 122			-€ 110	-€ 93	
	3	80%	-€ 121			-€ 97	-€ 76	
	4	68%	-€ 118			-€ 80	-€ 57	
	5	55%	-€ 114			-€ 63	-€ 41	
	6	31%	-€ 114		-€ 709	-€ 255	-€ 155	

Table above summarizes by age of the vehicle the potential costs and benefits of a fuel efficient vehicle vs. a non-fuel efficient vehicle.

There are 3 components that influence cost and benefit to the owner:

1. First, the premium in purchase cost for the fuel efficient vehicle. In case of a new car, this is 50€/gCO$_2$ for this specific case. In case of used cars, this is the price premium value as discussed in the 3rd chapter. This value depends on the age of the vehicle. These values are presented in the first column.
2. Secondly, the potential fuel savings for each year. These are calculated as [average mileage per year] x [delta fuel consumption] x [fuel cost], taking into account the attrition rate with increasing age.
3. Thirdly, the premium on the resale value. This value is the inverted value of the purchase premium.

We first calculate each cost component for every year. In a second step, we account for the scrappage. This is done by multiplying the sum of cost and benefits per year by the survival rate related to the age of the vehicle (2nd column). Note that most of the scrappage occurs at the oldest used car. 87% of the 4-9 year old used cars will be resold; for the older used cars ranging 9-15 year old, the probability of resale is only 31%.

Finally, all figures are discounted at a rate of 8% per annum. The total cost (+) or savings (-) are highlighted green if favourable for the fuel efficient car and orange if the fuel efficient car comes at a cost for the specific owner.

We observe that in this example, there is a benefit when buying a fuel economic 2nd hand car 4-9 years old; buying a new car or an older used car with more previous owners, the fuel efficient car is an uneconomical choice.

Considering the purchase cost of a new car is several 10k€, consumers buying a new car are slightly worse off when choosing the fuel efficient options with an extra cost of 140€ for the ownership period compared to the non-fuel efficient option. Keeping in mind the spread between the fuel efficient and non-fuel efficient vehicle is quite large (16g), this means the relative price differential is marginal. However, consumers may overestimate the fuel savings or don't recognize they will not recuperate the value of fuel efficiency in price setting to consequent owners in the used car market.

Consumers buying a relatively young used car (4-9y) are better off with the fuel efficient option. On top of the fuel savings, the owners will be able to pass on the benefit of fuel efficiency more profoundly to the consequent owner in the resale value. Keeping in mind the considerations made in chapter 3 on the interpretation of the increasing premium value with increasing age, caution is needed when drawing conclusions.

Particularly the large cost for the oldest used cars is surprising. The explanation is straight-forward:

1. The 9-15 year old used cars have a high purchase premium value for fuel efficiency, at a rate of 38€/g
2. The older used cars are driven less, thus limiting the benefit of the fuel savings
3. The oldest cars suffer the highest attrition rates, with scrappage rates at least twice as high as younger used cars after equal time in ownership, again reducing benefits from fuel savings over the ownership period.
4. The probability to recuperate some of the premium value of the fuel efficient car, as is done with younger cars, is much lower (31%) as most cars are scrapped.

Under these assumptions (fuel efficiency premium, scrappage rates and usages rates) it would be illogical to purchase an old fuel efficient car. Especially the high purchase premium for older cars is quite surprising; one would expect this to be lower with increasing age, as with increasing age it is less likely the owner can use the car long enough to justify the higher initial purchase price offset by fuel savings. However, the data analysis and the regression model established with the date provide robust results. (See also chapter 3)

For comparison purposes, we add an example for diesel cars: 1.5€/l – 50€/gCO_2:

Table 47: summary of the calculation approach for the distribution of costs and benefits for the case [diesel - 1.5€/l – 50€/gCO_2]

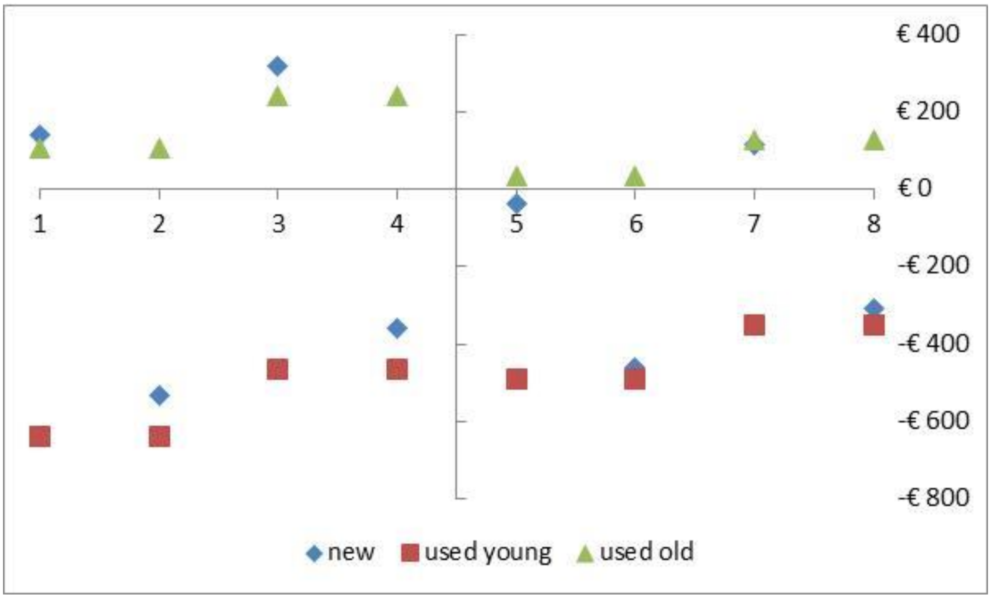
	years in ownership	retention	fuel savings	purchase premium	resale premium	scrappage	discounted	TOTAL
New (0-4y)	0	100%	€ 0	€ 526		€ 526	€ 526	-€ 39
	1	96%	-€ 140			-€ 135	-€ 124	
	2	96%	-€ 149			-€ 143	-€ 121	
	3	95%	-€ 159			-€ 151	-€ 118	
	4	94%	-€ 142		-€ 158	-€ 281	-€ 202	
used (4-9y)	0	100%		€ 158		€ 158	€ 158	-€ 491
	1	98%	-€ 127			-€ 124	-€ 114	
	2	98%	-€ 116			-€ 114	-€ 96	
	3	96%	-€ 109			-€ 105	-€ 81	
	4	93%	-€ 102			-€ 95	-€ 68	
	5	88%	-€ 97		-€ 400	-€ 439	-€ 289	
used (9-15y)	0	100%		€ 400		€ 400	€ 400	€ 35
	1	95%	-€ 92			-€ 88	-€ 81	
	2	90%	-€ 87			-€ 78	-€ 66	
	3	80%	-€ 85			-€ 68	-€ 53	
	4	68%	-€ 79			-€ 53	-€ 38	
	5	55%	-€ 78			-€ 43	-€ 28	
	6	31%	-€ 78		-€ 442	-€ 161	-€ 98	

The result is similar to the petrol case, though there is a slight benefit for new fuel efficient cars and the cost for the 3rd owner is lower. This could indicate that consumers buying a new car or old used car are well informed and can make a (private) cost benefit analysis when considering their options. A hidden bias in the cars owned by the lower households could also be an explanation: we assumed same ownership period for petrol and diesel. The subset of older cars owned by lower income groups could have a higher mileage than the average giving a better benefit to cost ratio.

We summarize the results for all the cases considered

Table 48: summary of the distribution of costs and benefits of fuel efficiency in passenger cars

fuel cost (€/l)	premium (€/gCO2)	fuel type	discount rate	new	used young	used old
1.5	50	petrol	8%	€ 140	-€ 641	€ 108
1.5	10	petrol	8%	-€ 535	-€ 641	€ 108
1	50	petrol	8%	€ 317	-€ 467	€ 241
1	10	petrol	8%	-€ 357	-€ 467	€ 241
1.5	50	diesel	8%	-€ 39	-€ 491	€ 35
1.5	10	diesel	8%	-€ 459	-€ 491	€ 35
1	50	diesel	8%	€ 114	-€ 352	€ 129
1	10	diesel	8%	-€ 306	-€ 352	€ 129



We find that in most cases, when looking at the costs and benefits of a single vehicle, the fuel efficient alternative is the more economical option, with the young used cars (4-9y) benefitting the most. Highlights:

1. Used cars of age 4-9, entering their second life, are more economical with only a minor premium for the fuel efficient car while being able to recuperate a much higher premium in most cases (87%).
2. The fact that the value of higher fuel efficiency is passed on more profoundly to later owners, means that total costs for the later owners (3rd and 4th) exceed the benefits of the fuel savings. Under these assumptions, the fuel efficient option is more expensive when looking at the older used cars aged 9 years and over, though the absolute value in all cases is limited (max 241€ in all cases).
3. The difference between purchased and resale premium value for fuel efficient vehicles primarily determines to what extent owners win or lose. Because of this, the second owner (younger used cars aging 4-9 y) wins the most as fuel efficient vehicles are only priced at

5€/gCO_2 in purchase, while being able to resell at a 30€/gCO_2 premium and this for almost all the vehicles involved (87%)

We see a large variety in the results for new vehicles. This is all down to the assumption on the initial price premium (10-50€/g). We find positive and negative values for the fuel efficient option. Considering the fact that new vehicles are most expensive in purchase, the relative variation of the costs/benefits to the price will be maximum a few percentage. One could argue the consumer accepts minor costs favouring other preferences over the value of future fuel savings. Given that the variety is small compared to the purchase price and varies in sign, we can argue the consumer buying a new car is making a rational and informed purchase decision.

This does not go for the used car market. For the young used cars, there is a clear benefit for the fuel efficient option, in all cases. Also, the benefit is larger in absolute terms while the purchase cost is lower compared to new cars. This mean the relative importance of the fuel savings are large compared to the purchase costs. For the older used cars, all cases considered generate a cost, though smaller in absolute terms. Relative to the purchase price, the lower cost associated with the fuel efficient option is important. Both the observation of the young and older used cars could indicate that buyers of used cars are not fully aware of the cost impacts of choosing of fuel efficient vehicle. There is a case here for better informing the consumer in order to allow them to make a better purchase decision.

6.2.2 At level of socio-economic group

The second step aims to link owner properties to socio-economic groups (chapter 4).

The approach described above quantifies the distributional effects at the level of ownership. To understand the distributional effects at socio-economic groups, we link the distributional effects per owner to properties of the second hand market.

To this end, we allocate the cost or benefits of the different owners proportionally to income groups. We recap the finding in chapter four, more specifically

Table 18, and combine this with the cost and benefits estimated in the previous section of this chapter.

The age cohorts considered in chapter 4 don't match the transaction thresholds used in this chapter. We therefor link the age cohorts 0-5y and 5-10y with the values found for the young used cars (4-9y) and link the age cohort >10y to the old used cars (9-15y).

We also add the relative importance of cost/benefit to disposable income. To this end we make an assumption on the average income per income group. We use 3.000, 7.000, 17.000, 33.000 and 60.000 for the income categories, coming down to the central value in each income category.

Under these additional assumptions, we find the following results for a selected case, petrol - 1.5€/l – 10€/g CO_2

Table 49: summary of distribution effects at income group for the case [petrol - 1.5€/l – 10€/g CO_2]

	1	2	3	4	5
NEW	3%	10%	19%	22%	31%
young used (4-9)	26%	28%	35%	32%	29%
old used (9-15)	72%	62%	47%	46%	41%
TOTAL	100%	100%	100%	100%	100%

	net cost (-benefit)
NEW	-€ 535
young used (4-9)	-€ 641
old used (9-15)	€ 108

	1	2	3	4	5
NEW	-€ 15	-€ 55	-€ 100	-€ 117	-€ 164
young used (4-9)	-€ 164	-€ 180	-€ 222	-€ 205	-€ 183
old used (9-15)	€ 77	€ 67	€ 50	€ 50	€ 44
TOTAL	-€ 102	-€ 168	-€ 272	-€ 272	-€ 304
% annual income	-3.38%	-2.40%	-1.60%	-0.82%	-0.51%

In this particular case, there is a benefit for the fuel efficient option for new cars and young used cars and a cost for the older used cars. The consequence is that the income group with the highest share of older used cars, i.e. the lower income groups, will benefit less. This is indeed what we find, though when looking at the income group as a whole, the benefits from the less prevalent young used and new cars is sufficiently large to also generate a benefit for the income group as a whole.

The benefit increases with increasing income as the share of the oldest used cars decreases, in favour of young used and new cars.

Though lowest in absolute terms, in relative terms compared to annual disposable income, the lower income groups are progressively better off. Relative to annual income, the lowest income groups are best of.

The same case, with a stronger assumption on the new price premium for the fuel efficient car gives the following result:

Table 50: summary of distribution effects at income group for the case [petrol - 1.5€/l – 50€/g CO_2]

	1	2	3	4	5
NEW	3%	10%	19%	22%	31%
young used (4-9)	26%	28%	35%	32%	29%
old used (9-15)	72%	62%	47%	46%	41%
TOTAL	100%	100%	100%	100%	100%

	net cost (-benefit)
NEW	€ 140
young used (4-9)	-€ 641
old used (9-15)	€ 108

	1	2	3	4	5
NEW	€ 4	€ 14	€ 26	€ 30	€ 43
5 - 10y	-€ 164	-€ 180	-€ 222	-€ 205	-€ 183
>10y	€ 77	€ 67	€ 50	€ 50	€ 44
TOTAL	-€ 83	-€ 99	-€ 146	-€ 125	-€ 96
% annual income	-2.76%	-1.42%	-0.86%	-0.38%	-0.16%

In this case, the benefits are lower overall compared to the previous case, but still the fuel efficient options are favourable for all income groups. The income group buying the most new cars (i.e. the higher income groups), suffers more compared to the previous case, while the lower income group, the lowest only buying 3% new cars, suffer less. This results in an overall decrease, and a cost for all income groups for the fuel efficient option. The middle income group, with the highest share of young used cars are the winners in this case. Relative to annual income, again the lowest income groups are best of.

We analyse the results for all other cases, using the same approach as the examples above:

Table 51: summary of distribution effects at income group

fuel cost (€/l)	premium (€/gCO2)	fuel type	discount rate	1	2	3	4	5
1.5	50	petrol	8%	-€ 83	-€ 99	-€ 146	-€ 125	-€ 96
1.5	10	petrol	8%	-€ 102	-€ 168	-€ 272	-€ 272	-€ 304
1	50	petrol	8%	€ 62	€ 50	€ 10	€ 31	€ 62
1	10	petrol	8%	€ 43	-€ 19	-€ 116	-€ 116	-€ 145
1.5	50	diesel	8%	-€ 102	-€ 120	-€ 161	-€ 150	-€ 138
1.5	10	diesel	8%	-€ 113	-€ 163	-€ 239	-€ 241	-€ 267
1	50	diesel	8%	€ 5	-€ 8	-€ 41	-€ 29	-€ 13
1	10	diesel	8%	-€ 6	-€ 51	-€ 119	-€ 120	-€ 142

We find a benefit for most of the cases, for most income groups. Generally, a lower fuel cost diminishes the importance of fuel efficiency; this generates a negative value for the fuel efficient option for all income groups for one case [petrol - 1 €/l – 50€/g CO_2].

Due to the lower fuel savings, the benefits decrease and the importance of the initial price premium has a bigger impact on the result. The case of low fuel price and high price premium for the fuel efficient petrol car generates a cost for all income groups. The equivalent diesel case generates low benefits for most income groups and a cost for the lowest income group. Because the lower income groups are less exposed to the high premium for the new vehicle, there is little difference between the cases of high and low initial purchase premium.

We can conclude the following from the above analysis:

1. The fuel efficient vehicle is favourable for all income groups, in almost all cases.

2. The initial price premium paid by the first owner mainly determines the distribution effects of the costs and benefits of a vehicle over the population of households in different income groups. A higher initial premium is favourable for middle income groups, unfavourable for higher income groups and vice versa for a lower initial premium.

3. Proportional to the household income, the lowest income group win the most. The assumption on the fuel costs is most important for the lower income group, flipping benefits to costs, low in absolute terms, but important compared to disposable income.

6.2.3 At level of EU member state

In the previous section, we have discussed how the distribution of costs and benefits of fuel efficient cars that differ between the different owners during the lifetime of a vehicle affect the distribution of these costs and benefits over different household income groups. We have seen in chapter 4 and 5 that the used car market differs within the EU, with 2 groups of countries: the wealthy, used car exporting West (EU-15) and the less wealthy used car importing East (EU-10).

The previous section only looked at the distribution of costs and benefits at the whole of the EU. We add now the distinction of the 2 groups of countries considered throughout the study, to understand how the distribution effects as discussed in the previous section could change.

To this end, we consider the difference in the vehicle stock distribution between the 2 groups of countries, as estimated in chapter 4. The fact that used cars are more prevalent in EU-10 reflects the West-to-East flows we found in chapter 5.

We look into 2 cases, in the same way as the previous section, adding the distinction between the 2 groups of countries:

Table 52: summary of distribution effects at income group, by member state, for the case [petrol - 1.5€/l – 10€/g CO_2]

	EU-15							EU-10					
	1	2	3	4	5	**TOTAL**	cost (-benefit)	1	2	3	4	5	**TOTAL**
NEW	2%	10%	20%	23%	35%	**25%**	-€ 535	4%	9%	14%	9%	2%	**11%**
young used (4-9)	25%	28%	34%	31%	27%	**30%**	-€ 641	28%	31%	39%	41%	44%	**36%**
old used (9-15)	73%	62%	46%	46%	39%	**45%**	€ 108	68%	60%	46%	51%	54%	**53%**
TOTAL	100%	100%	100%	100%	100%	**100%**		100%	100%	100%	100%	100%	**100%**

	EU-15						EU-10					
	1	2	3	4	5	**5**	1	2	3	4	5	**5**
NEW	-€ 10	-€ 53	-€ 106	-€ 123	-€ 186	**-€ 134**	-€ 20	-€ 49	-€ 78	-€ 46	-€ 11	**-€ 59**
young used (4-9)	-€ 163	-€ 178	-€ 216	-€ 200	-€ 170	**-€ 194**	-€ 180	-€ 200	-€ 252	-€ 261	-€ 280	**-€ 230**
old used (9-15)	€ 78	€ 67	€ 50	€ 49	€ 42	**€ 48**	€ 73	€ 64	€ 50	€ 55	€ 58	**€ 57**
TOTAL	-€ 95	-€ 164	-€ 273	-€ 273	-€ 315	**-€ 280**	-€ 127	-€ 184	-€ 280	-€ 253	-€ 233	**-€ 233**

The first case, with a low estimate for the purchase price premium is favourable for EU-15. The benefit for the fuel efficient car is 280€ for the EU-15 fleet average while 233€ for EU-10. This is because the main difference between the fleet compositions of the 2 groups of countries is the share of the oldest used vehicles, where the fuel efficient option comes at net cost. This share is much higher in EU-10.

Table 53: summary of distribution effects at income group, by member state, for the case [petrol - 1.5€/l – 50€/g CO2]

	EU-15							EU-10					
	1	2	3	4	5	**TOTAL**	cost (-benefit)	1	2	3	4	5	**TOTAL**
NEW	2%	10%	20%	23%	35%	**25%**	€ 140	4%	9%	14%	9%	2%	**11%**
young used (4-9)	25%	28%	34%	31%	27%	**30%**	-€ 641	28%	31%	39%	41%	44%	**36%**
old used (9-15)	73%	62%	46%	46%	39%	**45%**	€ 108	68%	60%	46%	51%	54%	**53%**
TOTAL	100%	100%	100%	100%	100%	**100%**		100%	100%	100%	100%	100%	**100%**

	EU-15						EU-10					
	1	2	3	4	5	**5**	1	2	3	4	5	**5**
NEW	€ 3	€ 14	€ 28	€ 32	€ 49	**€ 35**	€ 5	€ 13	€ 20	€ 12	€ 3	**€ 16**
young used (4-9)	-€ 163	-€ 178	-€ 216	-€ 200	-€ 170	**-€ 194**	-€ 180	-€ 200	-€ 252	-€ 261	-€ 280	**-€ 230**
old used (9-15)	€ 78	€ 67	€ 50	€ 49	€ 42	**€ 48**	€ 73	€ 64	€ 50	€ 55	€ 58	**€ 57**
TOTAL	-€ 82	-€ 97	-€ 139	-€ 119	-€ 80	**-€ 111**	-€ 101	-€ 123	-€ 182	-€ 194	-€ 219	**-€ 158**

The second case is identical to the previous one, except for the assumption on the initial price premium (50€/g). Apart from a general decrease of the benefits for both groups of countries, for all income groups, in this case, the highest benefits are in EU-10. Due to the lower share of new cars, fewer consumers in EU-10 have to carry the initial price premium for new fuel efficient vehicles.

The other cases give similar results. The initial purchase premium determines what group of countries benefits most from fuel efficiency:

If the purchase premium is high, the higher income EU-15 countries, who buy the most new cars, bear the cost of fuel efficiency. The fuel savings during first ownership are insufficient to offset the cost and the purchase premium is only partially passed on to subsequent owners. The subsequent owners are more likely to be EU-10 importers. The EU-10 countries, with a higher share of used cars, import fuel efficient cars with a premium less than the premium paid by the first owner. The net effect is that EU-15 consumers benefit, but less than EU-10 consumers, from car fuel efficiency.

If the initial purchase premium is low, also the first owners have an immediate benefit with fuel savings in the first life easily offsetting the marginally increase purchase cost. At the same time, the oldest used fuel efficient cars, more prevalent in EU-10 countries, come at a cost. In this case both groups of countries benefit more, with EU-15 proportionally benefitting more due to a higher share of new cars/lower share of old used cars.

6.3 Qualitative

There are various other impact pathways possible that affect the way costs and benefits are distributed. We identify the possible impacts on distribution effects not considered in the quantitative analysis. We list a few examples:

- Timing effect: in a trend of improving fuel efficiency over time, fuel efficient vehicles are only available on the used car market with a delay compared to the primary market. This is unfavourable for the used car owner, and thus the lower income groups, if the price premium for a new fuel efficient car is low compared to the fuel savings. It is not clear if this effect is relevant for the quantitative analysis.
- Budget constraints: Consumers with a limited budget are less able to buy a more expensive fuel efficient vehicle in the primary market, even if it would save money over time. The quantitative analysis for example showed that for young used cars the fuel efficient option would generate benefits over the duration of ownership. However, due to higher purchase cost (both fuel efficient and non-fuel efficient option), lower income households may not always be able to buy these cars. As a consequence, lower income classes take less of the direct benefit of fuel efficiency (assuming the lifetime cost of the fuel efficient alternative is indeed lower than the less fuel efficient alternative)
- Spill-over effects of fuel costs: an increase of fuel costs make newer fuel efficient vehicles more competitive compared to less fuel efficient vehicles, incentivising consumers to buy in the primary market (more fuel efficient supply) compared to the second hand market. New car owners will enjoy more from new (very) fuel efficient cars (e.g. under impulse of more stringent CO_2 legislation) compared to owners of older cars, lower income classes being less able to purchase new (more expensive) fuel efficient cars. On the other hand, this can generate a knock-on effect on second hand market prices, mitigating the negative impact for used car owners.
- Difference in retention rate: fuel efficient cars are more likely to be retained by their primary owner compared to less fuel efficient cars, as such limiting the supply of fuel efficient cars on the second hand market. A limited supply of fuel efficient cars in the second hand car market, lower income groups have less access to these vehicles and don't enjoy the benefit of increasing fuel efficiency (assuming the lifetime cost of the fuel efficient alternative is indeed lower than the less fuel efficient alternative). The quantitative analysis could not find any data supporting this hypothesis. This is one of the possible explanations we consider for the increasing purchase price premium associated with fuel efficiency with increasing age.

6.4 Conclusions

In this chapter, we discussed how pricing of fuel efficiency in used cars causes distribution effects at the level of vehicle ownership, socio-economic group and geographically. The key findings are:

- In most cases, higher fuel efficiency generates a benefit during the different stages of the active service life of a vehicle and for the different owners during its lifetime.
- The initial price premium determines the distributional effects. Lower income groups proportionally benefit more from fuel efficiency, if the initial cost for fuel efficiency, borne by higher income groups is larger than initial fuel savings for the first owner.
- Geographically, EU-10 wins more if the initial price premium, borne by EU-15 first owners, is high. The earlier exports happen, the more profound the benefit for the importing partner.

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8 ANNEX

8.1 Underlying data for figures

Fig 2

Endvalue of bin (*1000 €)	Relative frequency
1	0.23%
2	1.62%
3	3.36%
4	4.41%
5	4.94%
6	5.32%
7	5.74%
8	5.68%
9	5.74%
10	5.58%
11	4.69%
12	4.56%
13	4.68%
14	4.46%
15	4.11%
16	3.70%
17	3.50%
18	3.18%
19	3.00%
20	2.91%
21	1.83%
22	2.08%
23	1.97%
24	1.80%
25	1.71%
26	1.32%
27	1.20%

28	1.10%
29	1.01%
30	1.05%
31	0.48%
32	0.61%
33	0.59%
34	0.52%
35	0.50%
36	0.39%
37	0.34%
38	0.12%

Fig3

	0 - 2500	2500 - 5000	5000 - 7500	7500 - 10000	10000 - 12500	15000 - 20000	20000 - 25000	25000 - 30000	30000 - 100000
20-25%	152	116	61	40	29	25	15	5	8
15-20%	381	266	129	140	71	46	23	12	13
10-15%	435	478	236	204	110	93	39	22	25
5-10%	567	857	565	458	211	245	116	69	71
up to 5%	182	417	356	317	196	212	105	49	77
0%	2534	3146	2018	1829	937	853	442	250	285

Fig4

Endvalue of bin (year)	Relative frequency
0.5	4.14%
1	9.45%
1.5	5.77%
2	3.61%
2.5	3.97%
3	4.51%
3.5	8.46%
4	5.91%

4.5	7.24%
5	4.77%
5.5	4.22%
6	3.46%
6.5	4.05%
7	2.96%
7.5	3.16%
8	2.95%
8.5	2.82%
9	2.69%
9.5	2.57%
10	2.22%
10.5	2.19%
11	1.78%
11.5	1.60%
12	1.29%
12.5	1.42%
13	0.98%
13.5	0.95%
14	0.73%
14.5	0.11%

Fig8

	Diesel	Other fuel
1	27203.45	16217.1
2	25705.52	15324.12
3	27544.93	14536.48
4	24300.87	14570.96
5	22061.5	14022.19
6	20470.74	13210.17
7	19564.81	13180.04
8	18540.57	12528.86

9	17929.38	11897.31
10	17432.36	11948.83
11	16715.9	11504.45
12	16397.15	11541.34
13	16221.65	11336.64
14	15469.6	11007.71
15	15775.24	10886.19
16	15184.02	10561.38
17	14832.6	10241.11
18	13758.35	9940.013
19	12362.41	9101.853
20	12487.06	8615.929
21	9562.016	8308.783
22	9454.592	7404.762
23	10624.41	6715.158

Fig10

Endvalue of bin (€)	Relative frequency
1000	0.20%
2000	1.41%
3000	3.10%
4000	4.36%
5000	5.26%
6000	5.81%
7000	6.42%
8000	6.47%
9000	6.55%
10000	6.36%
11000	5.39%
12000	5.19%
13000	5.34%
14000	5.04%

15000	4.45%
16000	3.88%
17000	3.59%
18000	3.20%
19000	2.94%
20000	2.80%
21000	1.73%
22000	1.89%
23000	1.71%
24000	1.59%
25000	1.39%
26000	0.97%
27000	0.88%
28000	0.76%
29000	0.68%
30000	0.62%
31000	0.03%

Fig11

Endvalue of bin (age)	Relative frequency
0.5	4.62%
1	9.83%
1.5	5.88%
2	4.00%
2.5	4.30%
3	4.47%
3.5	8.06%
4	6.05%
4.5	7.75%
5	5.09%
5.5	4.43%
6	3.54%

6.5	4.19%
7	3.00%
7.5	3.10%
8	2.84%
8.5	2.73%
9	2.57%
9.5	2.37%
10	1.96%
10.5	1.97%
11	1.57%
11.5	1.38%
12	1.18%
12.5	1.24%
13	0.87%
13.5	0.78%
14	0.22%

Fig12

Endvalue of bin (g/km)	Relative frequency
80	0.10%
85	0.12%
90	1.42%
95	1.03%
100	4.64%
105	2.83%
110	6.21%
115	5.70%
120	9.46%
125	5.86%
130	7.01%
135	4.39%
140	9.82%

145	5.15%
150	6.54%
155	5.19%
160	6.09%
165	2.96%
170	3.60%
175	2.29%
180	2.21%
185	1.37%
190	1.64%
195	1.68%
200	1.19%
205	0.49%
210	0.50%
215	0.30%
220	0.17%

Fig13

Age	Km		Age	Km/year
1	19.59142		1	21946.22
2	41.52483		2	20461.8
3	68.27356		3	22244.55
4	80.23085		4	20069.48
5	87.64809		5	17781.47
6	95.21741		6	15908.13
7	108.0447		7	15376
8	116.7112		8	14583.09
9	124.9943		9	13906.49
10	132.5536		10	13285.77
11	137.3751		11	12540.94
12	145.221		12	12112.91
13	147.7848		13	11361.36
14	142.1826		14	10452.6

Fig14

	Diesel	Other fuel
1	27203.45	16217.1
2	25705.52	15324.12
3	27544.93	14536.48
4	24300.87	14570.96
5	22061.5	14022.19
6	20470.74	13210.17
7	19564.81	13180.04
8	18540.57	12528.86
9	17929.38	11897.31
10	17432.36	11948.83
11	16715.9	11504.45
12	16397.15	11541.34
13	16221.65	11336.64
14	15469.6	11007.71
15	15775.24	10886.19
16	15184.02	10561.38
17	14832.6	10241.11
18	13758.35	9940.013
19	12362.41	9101.853
20	12487.06	8615.929
21	9562.016	8308.783
22	9454.592	7404.762
23	10624.41	6715.158

Fig16

	1	2	3	4	5
<5	590	1341	2485	2433	2303
5-10	606	1563	2401	2011	1398
>10	608	1268	1268	874	562

Fig17

	1	2	3	4	5
<5	299	548	1502	1909	1683
5-10	286	506	1324	1491	894
>10	212	353	729	627	323
	1	2	3	4	5
<5	257	671	699	327	300
5-10	276	920	852	328	276
>10	363	848	461	175	176

Fig18

	1	2	3	4	5
country group 1	83533	90428	83873	81836	73510
country group 2	130704	127806	120529	116663	115932
All	107458	112532	95783	87590	81439

Fig19

	1	2	3	4	5
country group 1	10887	9664	8973	10583	16187
country group 2	5410	5118	7084	7739	6744
All	7915	6814	8271	10358	15519

Fig21

	1	2	3	4	5
<5	249	899	3610	4142	1434
5-10	239	871	3138	3590	1117
>10	184	580	1944	1797	569

Fig22

	1	2	3	4	5
<5	199	613	2556	2493	789

5-10	187	521	1910	1886	454
>10	141	283	1092	750	173

	1	2	3	4	5
<5	33	228	733	1192	470
5-10	30	280	888	1328	545
>10	32	262	704	938	351

Fig23

	1	2	3	4	5
group1	101711	87553	81675	78192	70531
group2	149166	124129	124282	120718	121908
All	108859	100114	94040	92779	92385

Fig24

	1	2	3	4	5
group1	14155.04	11442.19	10063.72	11555.9	13503.5
group2	8580.531	6098.205	5938.782	6162.441	6793.368
All	13731.73	9726.483	9011.431	9817.029	11019.17

Fig25

	1	2	3	4	5	6	7	8	9
<5	926	5900	1042	169	346	670	566	810	249
5-10	816	4929	900	232	334	720	537	569	259
>10	456	2529	513	157	217	568	366	296	210

Fig26

	18-25	25-35	35-45	45-55	>55
<5	1375	2820	2478	2116	1889
5-10	1133	2639	2196	1899	1429
>10	1120	1538	1201	960	675

8.2 Regression model details + analysis

- Separate document -