LONG TERM AUTOMOBILE OWNERSHIP AND MILEAGE TRENDS BY INCOME CLASS IN FRANCE, 1975-2008

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ABSTRACT

For each quartile of income per consumption unit, annual time-series have been estimated from panel surveys, with annual waves of observations since 1974:
- INSEE[2] Households' "Conjoncture" survey from 1974 to 1994,
- panel “Parc-Auto”[3] Sofres[4] since mid-80's.

In these data sources, household behaviour is described through:
- car ownership (percentage of households with at least one car, of which percentage of multi-car households, average number of cars per adult over 18, which is the minimum age for driving license in France),
- car use (annual mileage per household or per car).

The repeated sample structure of data has been used for improving the accuracy of time-series of variables highly correlated for subsequent years [Cochran, 1977].
In mid-70's, car ownership and use were quite low for the poorest income quartile, but the difference has much decreased with all the three higher income groups, which are more homogeneous. Thus, multi-car ownership, which is mainly structured by geographic and demographic determinants, has slowed down -but not reversed- the social diffusion of automobile.
As the curves representing car ownership (number of cars per adult) and car use (annual mileage per household) seem to become quite horizontal during the most recent period, logistic curves have been estimated according to time, then to real income. For each quartile

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[3] “Car fleet” panel.
[4] TNS-Sofres : Taylor-Nelson, *Société Française d’Etudes par Sondages*, a French private polling institute.

of the distribution of households by income per consumption unit, saturation thresholds are estimated, as well as the date of the point of inflection. The relationship between temporal elasticities (for each quartile) and cross-sectional income elasticities, which can be considered as a measurement of inequality at each point in time, will be discussed [Gardes and Madre, 2005].

Keywords: panel, automobile, car ownership, car use, income inequalities, saturation, France.

1. INTRODUCTION

In many countries like in France, most taxes on automobile were progressive, when they had been established. They have become neutral or even regressive because of the social diffusion of car ownership and use ([Madre, 1985], [Purwanto et al., 2002]). Has multi-car ownership made this evolution slower? The answer to this question is probably different in low density areas, where there is no alternative to automobile, and in large conurbations, where several destinations can be reached by foot or by bicycle and where public transport are available. Expenditure for car purchase are still concentrated in high income groups, as well as for toll motorways or parking, because cheaper (e.g. second hand cars) or free alternatives exist ([Madre, 1991], [Berri, 2005], [Berri et al., 2009]).

First, the data from two panel surveys, on which rely the calculation of annual time-series since the waves of year 1974 for each quartile of income distribution, will be presented in section 2. Then, the methodologies used for the calculation of these time-series (interpolated quartiles, optimised estimate of time-series from panel surveys) and the inequality indicators will be described in section 3. A descriptive overview will give the first results (section 4). Finally, modelling in terms of logistic curves ([Røed-Larsen, 2006]) will be implemented in section 5: do poor/medium/rich households follow the same trajectories for car ownership and use according to the evolution of their income? What results can be derived in terms of relationship between cross-sectional and longitudinal income-elasticities [Madre and Gardes, 2005]?

2. MORE THAN 30 YEARS OF ROTATING PANEL SURVEY DATA

This research is based on two annual nationwide household surveys describing both car ownership and use:
- the "*Enquête de Conjoncture Auprès des Ménages*" (ECAM) conducted by the National Institutes of Statistics (INSEE) among a sample of dwellings drawn from the French census: 10,000 to 13,000 households responding by interview each year, of which about one third had been also interviewed one year before ; the period from 1974 to 1994 (year of end of this survey) is covered by the data files available at INRETS;

- the "*Parc-Auto*" (Car Fleet) survey is a postal survey conducted by the private marketing research company TNS-Sofres; each annual wave sample includes 6,000 to 7,000 volunteer respondent households, of which about 3/4 have already responded the year before (even if having moved, contrary to ECAM survey); data files are available at INRETS for all waves since 1984 and this survey is still on-going ([Hivert, Pean de Ponfilly, 2000], [Hivert et al.,2006]). For a short description of data, see also [Kalinowska, 2005] and [Papon, Hivert, 2007, 2008].

Despite these differences in survey methodology, we have checked that these data source show consistent results for the period 1984-94, when both datasets are available at INRETS.

Both questionnaires contain:
- the annual income of the household in about 10 brackets,
- a description of the household (socio-economics, demographic structure, place of residence, etc.),
- a description of cars (age, type of fuel, main driver, etc.) at permanent disposal of the household (up to 2 cars in ECAM, to 3 cars in Parc-Auto),
- an estimate of the annual mileage for each car described (rounded and heaped ([Hivert, 2001], [Yamamoto, 2009], but unbiased according to odometer reading), as well as an information on main purposes of vehicle use (used/non used).

Thus, this information has to be homogenised mainly for the income, which has been coded in brackets using different grids of nominal income over time (see below).

3. CALCULATION OF TIME-SERIES FOR EACH QUANTILE OF INCOME, METHODOLOGICAL ASPECTS

For the ECAM surveys conducted by the National Institute of Statistics, about 70% of households give for each person detailed information on their resources, including different sources of income (wages, retirement pensions, social benefits, etc.). About 25% give global information on a pre-coded grid, and 5 to 10% refuse. Thus, we chose to use these grids, particularly because the rate of non-response is much lower when using this pre-coded information.

Most of models rely on quantitative variables, but responses given by households are often rounded for income as well as for annual mileage. Moreover inflation, which was important before mid-80's, make comparisons difficult over time. That is why income grids have been revised in 1977, 1983, 1987 and 1997. The grids have been also typically revised in 2002 in order to be converted from Franc to Euro.

Rather than conventional methods ([Bhat, 1994]) like simulated residuals ([Lollivier and Verger, 1989]), we preferred a more robust method: interpolated quantiles from the middle of each bracket ([Madre and Purwanto, 2003]). It could be any quantiles (e.g. terciles or quintiles) but we have first to check that the number of brackets is much larger than the number of quantiles.

Let us consider the distribution of a variable of interest (e.g. the number of cars in the household) by income bracket. In order to locate the limits of each income quantile, the distribution is interpolated, and the average number of cars per household is calculated in each quantile with the rather strong hypothesis, that car ownership is constant inside each bracket containing a limit between two quantiles (e.g. first quartile Q1, median or third quartile Q3).

This method has been tested on the respondents of the 1993-94 French National Travel Survey, which gave precise information in terms of income. The result is obviously better, when the upper and lower limits of a quantile are nearer to the thresholds of brackets on the grid. But surprisingly enough, splitting the sample into a larger number of brackets when dividing the middle of each class by the number of consumption units does not improve the quality of the interpolation, because even inside a bracket the income level is correlated with the composition of the household. Thus the interpolation is more precise for total household income than for the income per consumption unit, which is a more adequate measurement of the standard of living.

After obtaining homogenized income groups through quantiles, how to estimate time-series accurately enough despite of the small sample size of our panel survey data? Referring to [Cochran, 1977], we have implemented the method optimising the accuracy of the time-series for the most recent periods. This optimisation is crucial for the estimation of models using variables affected with small annual changes (often 1 or 2%). However we had to smooth several time-series by moving averages over three consecutive years at national level and over five years for Paris region. In order to improve the accuracy of time-series for income, data have been corrected proportionaly according to the general average given each year by National or Regional Accounts. Because we could not access again roar data from ECAM surveys, we have adopted Oxford scale for the calculation of consumption units, which was generaly used in the 80's.

For the measurement of inequalities, we have adopted three indicators (see also [Bureau et al., 2009]):
- the Gini index [Gini, 1921],
- the ratio "Q4/Q1", i.e. between the means of the variable of interest for the extreme quartiles (Q1 representing the poorest and Q4 the richest),
- the cross-sectional income-elasticity, with usual references (1 when the variable of interest increases proportionally with income and 0 when it is not influenced by income).

More sophisticated indicators could be considered, for example those proposed by [Atkinson, 1970], [Atkinson et al., 1980, 1982] (also cited in [Madre, 1985], [Berri, 2005]). In order to avoid heterogeneity over time due to different income grids, these indicators have been calculated from only four points, which are the mean values for each quartile.

4. DESCRIPTIVE ANALYSIS

For each quartile of the distribution of income per consumption unit, time-series have been estimated since 1974 for :
- income per household (income per consumption unit would have been homogeneous with the criteria used to define the quartiles, but this variable, which presents a quite similar trend, was not available in the database kept from ECAM surveys,
- the average number of cars per adult (i.e. aged > 18, which is the minimum for driving license in France). The number of cars per household (or per capita) would have been more homogeneous with the other variables, but isolating the population concerned gives generaly better estimates in modelling (see section 5),
- the proportion of equipped households,
- the proportion of multi-car households among equipped households,
- the average annual mileage per household or per car,

separately nationwide, and for the Metropolitan Area of Paris (Paris region) in order to show the specificity of a high population density area, where the diffusion of automobile has started earlier than elsewhere in France. Generally, the figures for intermediate quartiles Q2 and Q3 are quite close, thus they have been represented by a single curve.

Nationwide (figure 1), the inequalities of income per household have decreased between mid-70's and mid-80's, then have remained almost constant till 2000 except a temporary increase during the 1993-94 recession. Since 2001, high incomes are growing faster than those of medium or low income groups.

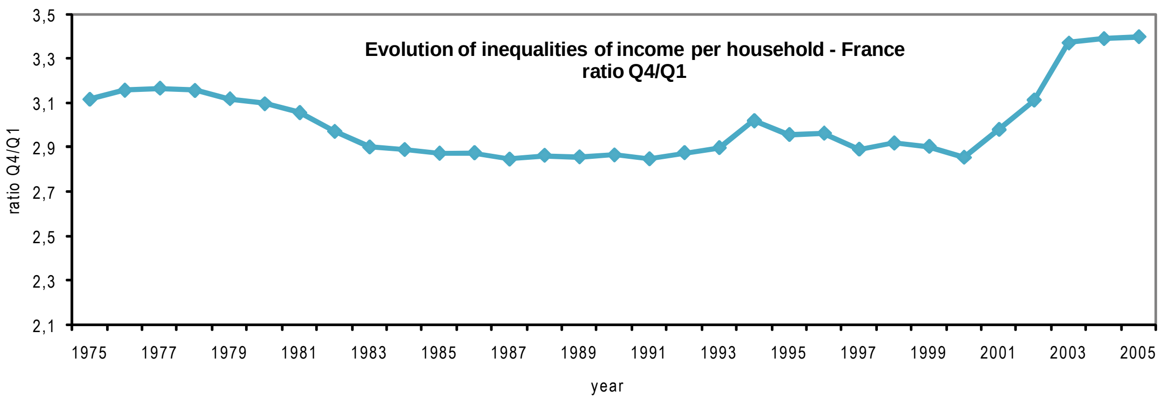

Figure 1: Evolution of inequalities for income per household (ratio of extreme quartiles Q4/Q1) - France

In Paris region (figure 2), inequalities have decreased more rapidly during the first period, then have remained constant only from mid-80's to early 90's, and increase since the 1993 recession. Because of the relative stability of household structures, the evolutions of income per consumption unit follow the same patterns, as shown since 1994 on Parc-Auto data.

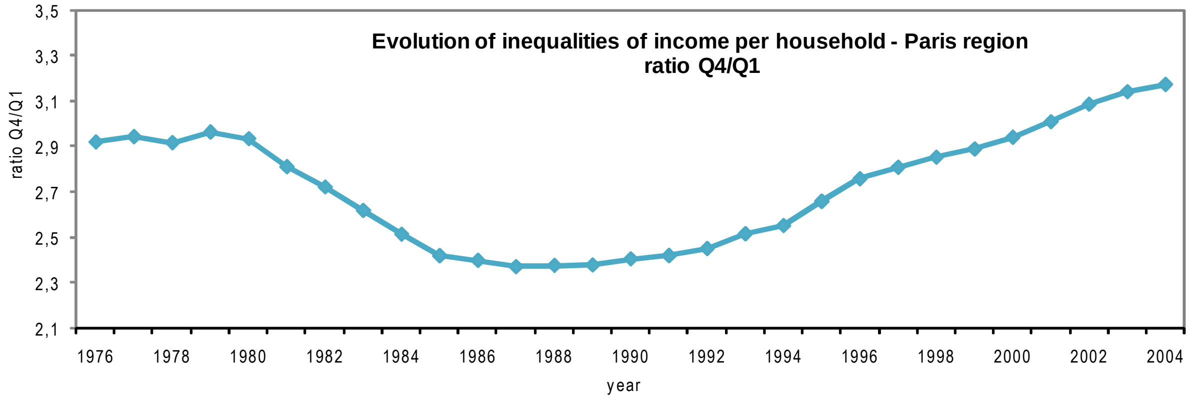

Figure 2: Evolution of inequalities for income per household (ratio of extreme quartiles Q4/Q1) - Paris region

For the whole country, the ratio Q4/Q1 was of 2.1 for the average number of cars per adult in 1974 (figure 3). It has remained almost constant around 1.7 between 1982 and 1993, then it has decreased to 1.4 in 2005. The cross-sectional income-elasticity of the number of cars per adult has followed the same pattern, from 0.6 in mid-70's to 0.2 around 2005, questioning the hypothesis that cross-sectional elasticities represent long term elasticities.

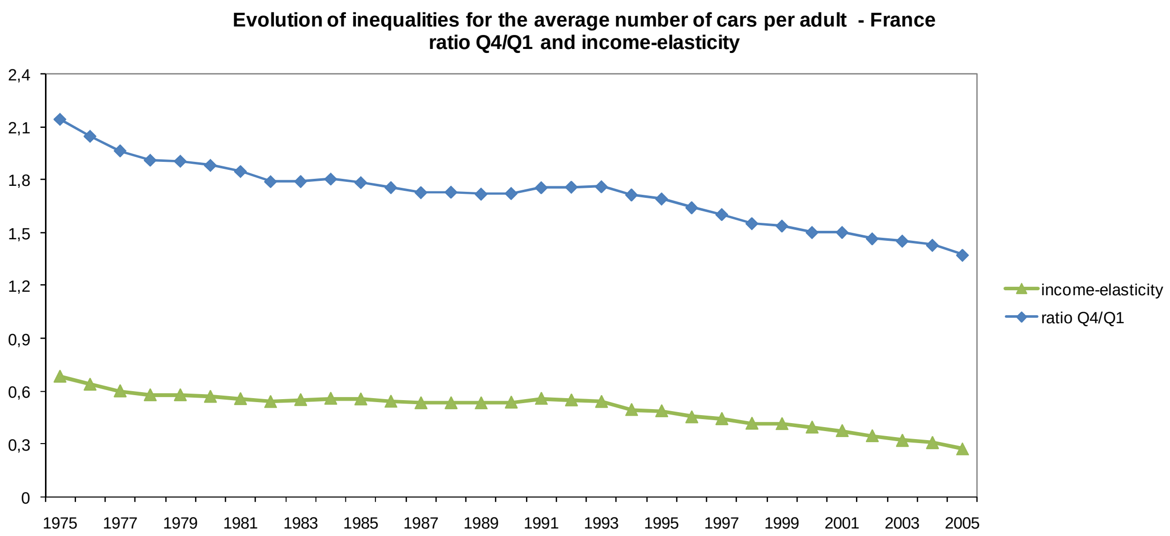

Figure 3: Evolution of inequalities for the average number of cars per adult - France

In the special case of Paris region, the ratio Q4/Q1 was only 1.8 in the mid-70's and has remained almost constant at 1.5 since 1982. Indeed, car ownership has been higher in the conurbation of Paris than in the rest of France since the mid-60's, but high population density with good public transports limits the expansion of car ownership.
Thus, multi-car ownership has not reversed the social diffusion of automobile, but it has stopped it in Paris region since the early 80's and nationwide between mid-80's and mid-90's.

As seen on figure 4, the decrease in inequality for car ownership during the first period is mainly due to the poorest quartile (Q1) catching up with the upper ones: the proportion of households without car has dropped from 55% in mid-70's to 35% in mid-90's. During the same decades, the proportion of multi-car households among equipped households has developed more slowly in Q1 than in richer quartiles, especially Q2 and Q3 catching up with Q4.

Then, figure 4bis presents the evolution of ownership in terms of average number of cars per adult. Taking into account that the average number of adults per household remains higher in lower quartiles (e.g. 1.85 for Q1 vs. 1.75 for Q4 in 2006), there is less difference between poor and rich households in terms of number of cars per household than in terms of number of cars per adult.

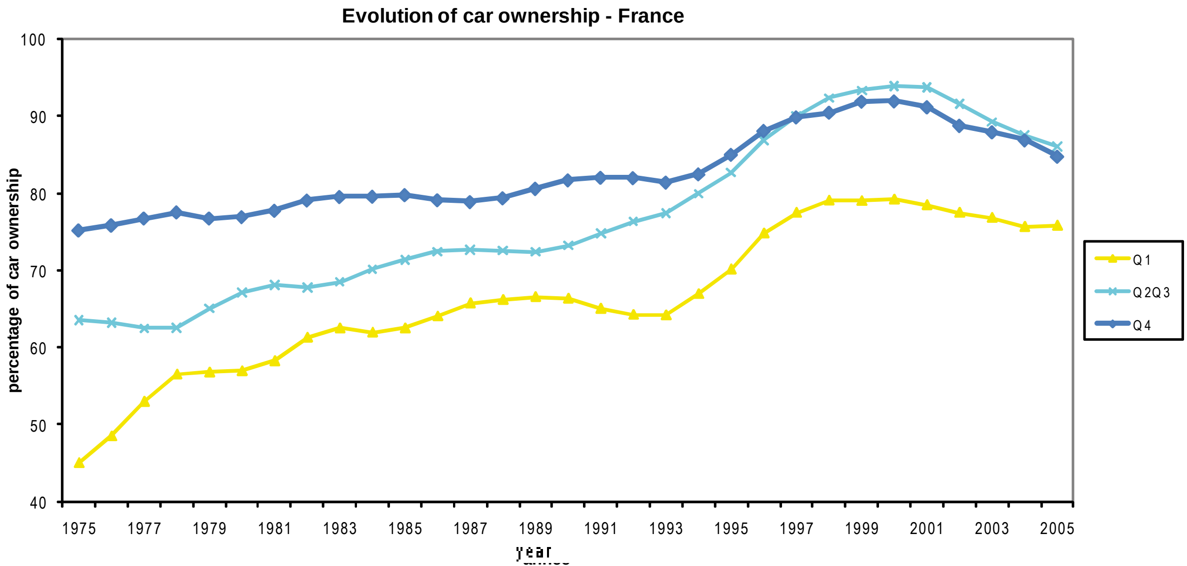

Figure 4: Evolution of car ownership with time: share of equipped households by quartile of income per consumption unit (Q2 and Q3 together, smoothed by mobile averages MA3) – France

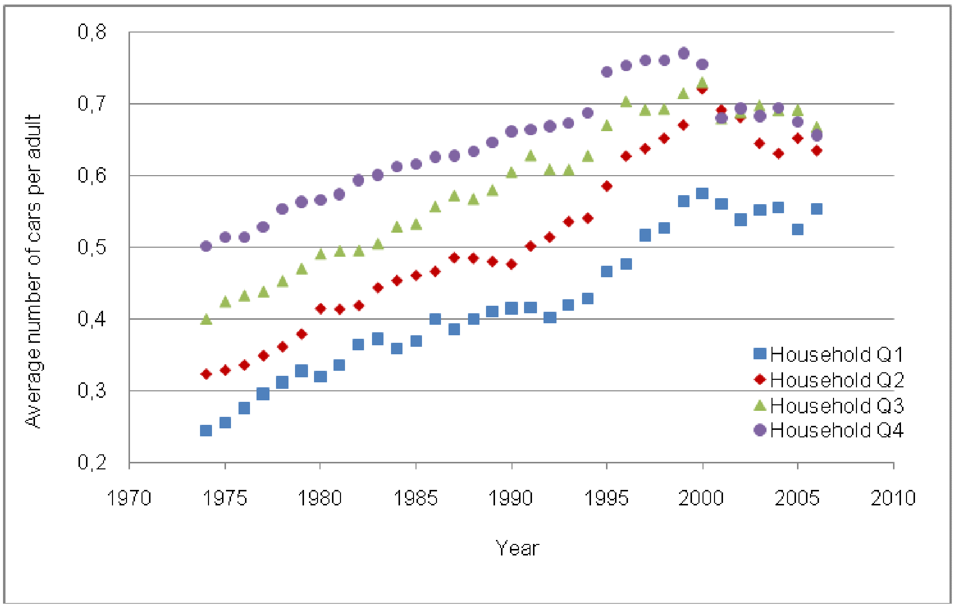

Figure 4bis: Evolution of car ownership with time: average number of cars per adult by quartile of income per consumption unit - France

From mid-90's, different zones can be identified. In the most densely populated areas, the income-elasticity of multi-car ownership dropped from 0.7 during the late 90's to 0.1 in 2005:

Q1 curve is increasing, while those for Q2 to Q4 are decreasing. In Paris region at least since 1995, there is almost no differentiation of multi-car ownership according to income. In low density areas the elasticity decreases more continuously, as well as the ratio Q4/Q1.

Mid-90's, the increase of ownership in terms of cars per adult (especially visible for Q4) can be explained by incentives for replacing an old car by a new one introduced by two successive Governments in France (see below).

A new grant for scrappage ("*prime à la casse*") has been recently introduced in France (early 2009). It has succeeded to previous incentives for scrapping old cars implemented in the middle of the nineties :

- decided by the Balladur Government, a scrap bonus of 5,000 francs (762 euros) was implemented from February 1994 to June 1995 to purchase a new car, when scrapping a vehicle more than ten years old. This "balladurette" measure aimed to help a depressed market and boost consumption, but also cleaned up somehow the French car fleet.

- under the next Juppé Government, from October 1995 to October 1996, another measure allowed any owner to benefit a bonus when scrapping a vehicle more than 8 years old and under 3.5 tonnes This premium amounted to 5,000 francs to buy a new car of economic or low range, and to 7,000 francs (1,067 euros) for higher-end vehicles. This premium, known as "Juppette" was also intended to support the Government decision of toughening automobile technical inspections (originally introduced in 1992).

The annual mileage per household (figure 5) has increased till 2000, then decreased, due to a lower mileage per vehicle induced by a more expensive fuel (peak of fuel price in 2000, then a more continuous increase from 2004 to mid-2008. This inflection is described in detail for example in [Hivert et al., 2008] and in [Kemel et al., 2009]. This decline is more important in urban areas than in low density areas, especially for medium and high income groups (Q2 to Q4).

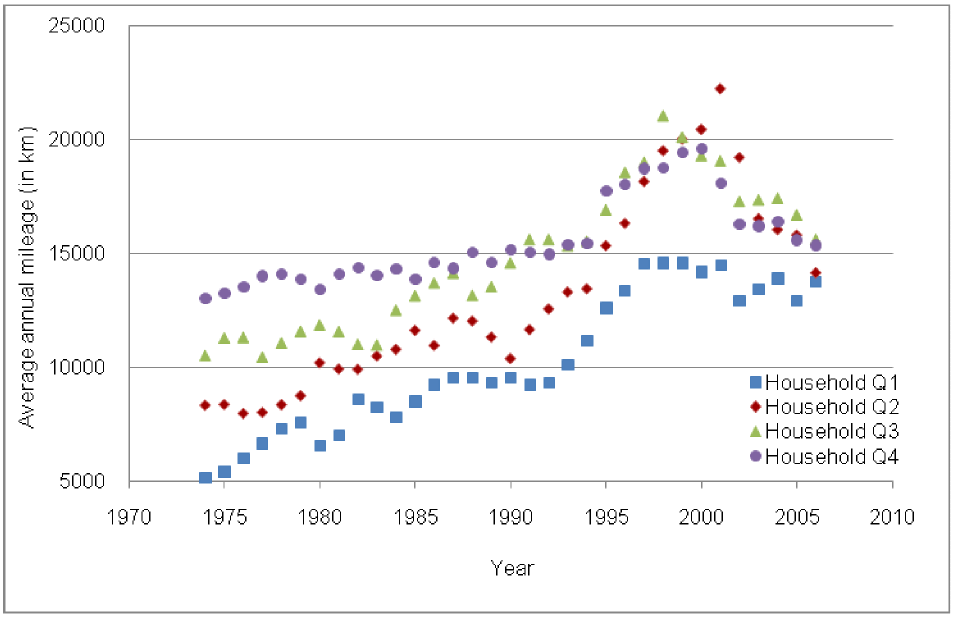

Figure 5: Evolution of average annual mileage per household by quartile of income per consumption unit – France

In terms of annual mileage per vehicle, the ratio Q4/Q1 has declined from 1.8 in 1984 to 1.1 in 1995, because of a slower increase of car use in high than in low income groups. This period corresponds to decreasing fuel price: sharp decline of oil price between mid-1985 and mid-1986, followed by an increasing proportion of diesel vehicles using a 30% cheaper fuel. Between mid-90's and 2005, the ratio Q4/Q1 has decreased in low density areas, while it has increased in urban areas, because car use can be reduced by low income households only where an alternative exists (public transport or slow modes).

Thus, after a period of status quo between mid-80's and mid-90's, the social diffusion of automobile continues like during the 70's, especially in low density areas, whose inhabitants are more car dependant even if their income is low.

The two next figures present, for each quartile by consumption unit, the evolution of car ownership (per adult) and car use by household income, in constant 2006 Euros (considering all the annual waves together).

Globally, the scatter of points on figure 6 shows that, as expected, household car ownership has increased with their income. Indeed, the number of cars per adult has been about 0.45 for a real annual income of €20,000 while it is about 0.7 for incomes over €65,000 (constant 2006 Euros). The shape of the scatter of points suggests a concave augmentation of car equipment with income. However, the slope seems different when comparing each of the four quartiles. Indeed, it is decreasing when the household has a higher social position. Particularly, car ownership is increasing faster with real income for the household Q1 than for the household Q4. Over the years, this has induced a reduction of social inequalities concerning car ownership, as it is shown on figure 3.

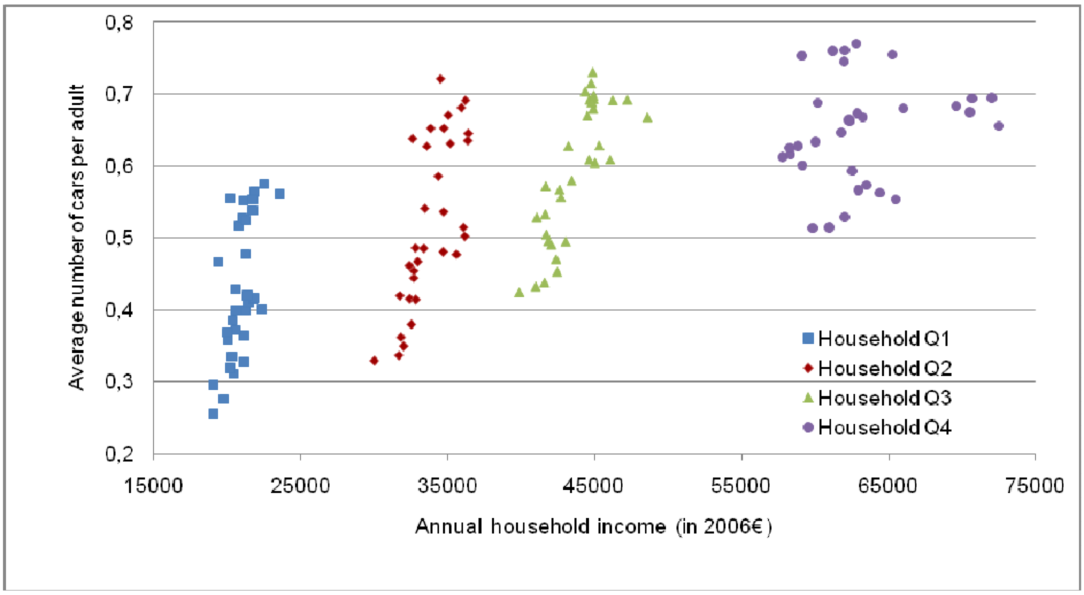

Figure 6: Evolution of car ownership (average number of cars per adult) with household income - France

Considering car use on figure 7, analog conclusions roughly emerge. The average mileage of households has been about 10,000 km/year for an annual income of €20,000. Over €65,000, it has globally ranged between 15,000 and 17,000 km/year. As on figure 6, the scatter of points on figure 7 could also suggest a concave growth of household car use with their real income. Regarding the quartile specific households, the slope of the annual mileage over real income also seems to decrease with their position in the standard of living scale.

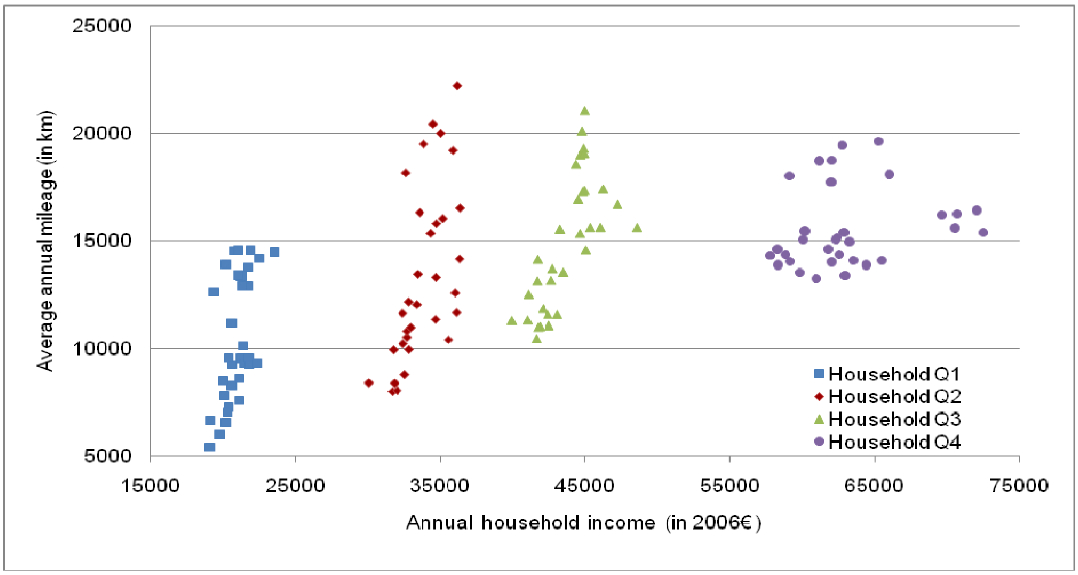

Figure 7: Evolution of car use (annual mileage per household) with household income - France

The apparently concave relations of figures 6 and 7 suggest that the diffusion of automobile can reach saturation thresholds for both car ownership and use when the households are getting wealthy. Theoretically, the social diffusion of a good (either in time or in the income scale) can be represented using a sigmoid curve, ended by a saturation level. It is modelled in the following section for car ownership and use (dependent variables), using time and income as explanatory variables.

5. ESTIMATION OF LOGISTIC CURVES TO MODEL CAR OWNERSHIP AND USE

The average households for each of the four quartiles of annual income per consumption unit are observed annually, during 33 years from 1974 to 2006. Let Q1, Q2, Q3 and Q4 refer to these households by increasing order of resource. In this section, we assume that the household behaviours of car ownership and use can be represented by logistic functions. The logistic model, which is exposed below, is applied on the data of each quartile specific household.

5.1. The model

Let Y_{it} refer either to the number of cars per adult or to the annual mileage in 10^4 kilometres for the household Qi at period t. Both these variables are modelled separately assuming a logistic specification. The explanatory variable is denoted X_{it} and stands successively for the time (section 5.2) and the real income (section 5.3). Thus, the model is given by:

$$Y_{it} = Y_{it}^{*} + \varepsilon_{it} = \frac{\exp(\gamma)}{1+\exp(-\alpha X_{it} - \beta)} + \varepsilon_{it}, \tag{1}$$

where ε_{it} is assumed to be i.i.d. along a $N\big(0, \exp(\sigma)\big)$, and where $\{\alpha, \beta, \gamma, \sigma\}$ are the parameters to be estimated. For α positive, the formulation (1) implies that Y_{it}^{*} is increasing with X_{it} along a symmetrical sigmoid, bounded by two horizontal asymptotes: the lower plateau is fixed at $Y_{it}^{*} = 0$ while the upper plateau, corresponding to a saturation level, is located at $Y_{it}^{*} = \exp(\gamma)$. The inflection point, for which the second derivative of Y_{it}^{*} with respect to X_{it} is zero, is located at ($X_{it} = -\beta/\alpha$; $Y_{it}^{*} = \exp(\gamma)/2$).

5.2. Time as explanatory variable

In this section, the explanatory variable of model (1) is the time. Precisely, X_{it} is given by the index t, with t=0 for the year 1974, t=1 for 1975... and t=32 for 2006. Tables 1 and 2 report the estimates for car ownership and use respectively.

Table 1: Estimates for the car ownership model as a function of time

Parameters	Hh.Q1	Hh.Q2	Hh.Q3	Hh.Q4
α	0.06	0.06	0.08	0.10
β	-0.66	-0.52	0.04*	0.66
γ	-0.27	-0.17	-0.26	-0.31
σ	-7.58	-7.03	-7.84	-6.98
Mean log-likelihood	2.37	2.09	2.40	2.07
Nb. of observations	33	33	33	33
Saturation threshold (# of cars per adult) [90% conf. interval]	0.76 [0.61, 0.96]	0.84 [0.72; 0.98]	0.77 [0.73, 0.81]	0.74 [0.71, 0.77]
Date of inflexion	1986	1982	1973	1967

Note: the dependant variable is the number of cars per adult in households. The explanatory variable is time. All the parameters are significant at the 90% level, except those indicated by *.

As expected, the results show that car ownership and use have increased along time, despite a slight decrease in the mileages after 2001 caused by an increasing fuel price[5]. Indeed, the parameter α is found to be positive and significant in every case on tables 1 and 2. For both car ownership and use, the inflection has occurred in the mid 80's for the two lower quartiles (Q1 and Q2), in the 70's for Q3 and in the 60's for the higher income quartile Q4. Although confidence intervals overlap, the highest saturation level seems to be for Q2, then it decreases till Q4 because higher income groups live in more densely populated areas. Saturation thresholds are quite low for Q1.

Considering the car ownership model, the confidence intervals for saturation level overlap around 0.74 cars per adult (table 1). For car use, the confidence intervals for the saturation level in table 2 overlap around an annual mileage of 20,000 km per household (table 2). Thus, a pooling data model should fit better assuming quartile-specific inflection points, that is, quartile fixed effects.

Table 2: Estimates for the car use model as a function of time

Parameters	Hh.Q1	Hh.Q2	Hh.Q3	Hh.Q4
α	0.07	0.07	0.07	0.05
β	-0.83	-0.79	-0.19*	0.66
γ	0.56	0.81	0.74	0.65
σ	-4.75	-3.27	-3.94	-4.27
Mean log-likelihood	0.95	0.21	0.55	0.71
Nb. of observations	33	33	33	33
Saturation threshold (km/year) [90% conf. interval]	17500 [14600, 21100]	22600 [16800, 30200]	21100 [17800, 24900]	19300 [15600, 24000]
Date of inflexion	1985	1985	1977	1961

Note: the dependant variable is the annual mileage of households in kilometres. The explanatory variable is time. All the parameters are significant at the 90% level, except those indicated by *.

However, the resources of households are a more robust factor than time to explain the diffusion of automobile. Let's now consider income growth as determinant in model (1).

5.3. Real income as explanatory variable

In this section, household car ownership and use are modelled using real income as explanatory variable. Particularly, X_{it} in model (1) refers here to the real annual income of the household Qi at period t, expressed in 10^4 constant 2006 Euros.

The saturation levels obtained from the income model do not differ significantly from those obtained from the time model, even if they seem lower for car use. Confidence intervals are widder for low income groups. Indeed, the estimation of the saturation threshold is much more accurate for higher income groups, which are currently near to their estimated asymptote. The poor fit for car ownership in Q4 is an exception: for this group with a quite high standard of living, changes in income seem to have less influence on the number of cars per adult.

[5] This factor has not yet been taken into account in the model.

Here again, confidence intervals for saturation levels overlap. Concerning income level at the inflection point, it is higher at higher standards of living (except for Q4 in the car ownership model). Pooling the data in a fixed effect model could show if each quartile follow the same trajectory of car ownership and use, but for specific levels of income of inflection.

Table 3 : Estimates for the car ownership model as a function of real income

Parameters	Quartile Q1	Quartile Q2	Quartile Q3	Quartile Q4
α	4,29*	5,61	3,88	0,33*
β	-8,28*	-17,41	-15,45	-0,53*
γ	-0,44*	-0,42	-0,30	-0,24*
σ	-5,20	-5,17	-6,00	-5,28
Mean log-likelihood	1,18	1,17	1,58	1,22
Nb. of observations	32	32	32	32
Saturation threshold (# of cars per adult) [90% conf. interval]	0,64 [0,31; 1,30]	0,65 [0,57; 0,75]	0,74 [0,66; 0,82]	0,78 [0,00; 2,54]
Income of inflexion (in 2006 Euros)	19300	31000	39700	16100

Note: the dependant variable is the number of cars per adult in households. The explanatory variable is their income expressed in 10^4 constant 2006 Euros. All the parameters are significant at the 90% level, except those indicated by *.

Table 4: Estimates for the car use model as a function of real income

Parameters	Quartile Q1	Quartile Q2	Quartile Q3	Quartile Q4
α	4,59*	6,36	4,35	3,61*
β	-8,99*	-19,96	-17,53	-18,82*
γ	0,48*	0,53	0,64	0,48
σ	-2,82	-2,36	-3,25	-3,48
Mean log-likelihood	-0,01	-0,24	0,21	0,32
Nb. of observations	32	32	32	32
Saturation threshold (km/year) [90% conf. interval]	16100 [6500; 39600]	17000 [14200; 20400]	18900 [16700; 21400]	16100 [14800; 17400]
Income of inflexion (in 2006 Euros)	19500	31300	40300	52000

Note: the dependant variable is the annual mileage of households in kilometres. The explanatory variable is their income expressed in 10^4 constant 2006 Euros. All the parameters are significant at the 90% level, except those indicated by *.

Let us discuss now the constraints implied by fitting logistic curves, which are symetric around the point of inflection, and defined on R (i.e. for positive and negative values of the explanatory variable). Negative values can be admitted for time, but is more questionable for income. For a better representation in the left side of the logistic curves, the model (1) has also been fitted using the log of real income, $\ln(X_{it})$, instead of real income in level. The logistic adjustment does not seem to perform better using this alternative specification.

The model (1) assumes the symmetry of the adjusted logistic curves with respect to the inflection point. This can be viewed as a strong hypothesis and asymmetric curves might be more relevant in our context (for an example of application, see [Ricketts and Head, 1999]). However, the assumption of symmetry is made necessary when considering our data. As shown on figures 6 and 7, the data do not cover the lower part of an assumed sigmoid, at the left side of the inflection point and near to the lower asymptote (in zero). As there is no empirical information about this part, its representation has to rely on some assumptions. A solution would have been to extend the observation period farther in the past, back to the end of World War II. Unfortunately, detailed data about car use and equipment between 1945 and 1973 are not available.

6. CONCLUSIONS

The social diffusion of car is a major feature of economic growth in Occidental Europe after World War II. This paper describes this phenomenon in France for four income groups from 1974 to 2006. Multi-car ownership has interrupted but not reversed this long term trend : after a period of status quo between mid-80's and mid-90's, the social diffusion of automobile continues like during the 70's, especially in low density areas, whose inhabitants are more car dependant even if their income is low.

However, the growth of car ownership becomes slower and slower, which shows that saturation levels are not far from already reached levels. In order to determine these thresholds, we have adjusted logistic curves separately for each income quartile. Geographic factors (as density, distance to city-centre, size of conurbation) probably explain why it is not for Q4 that saturation levels are the highest, which could be checked by estimating the same models only for the inhabitants of the Metropolitan Area of Paris.

For both car ownership and use, the confidence intervals of saturation level for each quartile overlap. However, these thresholds should differ across household quartiles because of their heterogeneity, as the geographic factors mentioned above It is only through more narrow confidence intervals obtained from longer time-series or more adequate functional forms that we could get a real proof of this heterogeneity.

However, the curves do not show monoteneous changes towards saturation. Figures 4 and 5 indicate that car owneship and mileage peaked about the year 2001 and have since declined significantly, The main factor that contributed to these trends is certainly fuel price, which could be introduced as explanatory variable. Additional factors could also include rising vehicle prices, tax policies, demographics (aging population and declining employment rates), improvements in alternative modes (walking, cycling and public transport), and changing consumer preferences.

This heterogeneity opens theoretical discussions about cross-sectional versus longitudinal estimates. Another example is an important change over time of cross-sectional income elasticities, which makes impossible to consider them as a proxy for long term longitudinal elasticities. There is still much to do with these data. The first point is estimating fixed quartile effect models using pooled data. This should yield a better estimation of the inflection points according to time and income, and to check whether each quartile follow the same trajectory. Moreover, introducing fuel price as explanatory factor for car use should allow to derive saturation thresholds for the annual mileage at different fuel price levels, which could give an important information for building scenarios for sustainable development. However we should take into account that even fuel price elasticity depends on income level [Kemel et al., 2009].

Differences in vehicle ownership and mileage rates between different income classes are often presented as an inequity, with the implication that, as lower-income households own more vehicles and drive more annual miles, they are better off overall. Yet, these trends could be not as much positive as that. Indeed, lower-income households may have to spend an excessive portion of their budgets for transportation, due to a lack of more affordable alternatives. Lower-income households might be better off, for example, if there were more affordable housing in urban neighborhoods with good walking, cycling and public transit, which would reduce their vehicle ownership. These assumptions about what is considered equitable and desirable are still to be discussed.

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