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Household car use in France: a demographic and economic analysis

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Abstract

This article provides an evaluation of the effects of age and generation on household car-use behavior in France, and sheds some light on household perception of fuel price volatility. Using repeated cross-section data from the French "Car Fleet" survey, a pseudo-panel averaging households in generational cohorts has been built over the 1988-2008 period. The results from the Age-Cohort-Period analysis reveal that younger households, whose heads were born at a time when cars were already very widespread in the French society, have made more intensive use of the car than their parents or grandparents at the same age, who grew up in less car-dependent times. In addition, the negative impact of fuel price volatility on car use is revealed. It can be interpreted as a sign of risk aversion, leading households to reduce their car mileage when there is an increase in uncertainty about fuel prices. Lastly, we demonstrate that failure to consider the volatility effect may result in an overestimation of household car use elasticity with respect to fuel price.

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1. Introduction

At the end of the Second World War, French economic activity was kick-started by substantial public investment programs. In particular, some of these aimed at rebuilding and extending the road infrastructure and network. At the same time, the automobile market was growing rapidly, giving rise to the age of the "people's car". As cars have become more prevalent in the French society, we have seen the birth of new generations. Nowadays, the most recent ones are growing up in an era where the car has become a personal good, as a result of more people now holding a driving license. Obviously, not every generation, at the same age, has had an identical relationship with the automobile, and has used it differently. Besides the effects of age and generation, car use is also sensitive to economic factors, such as fuel price. A lot of studies have shown that household car use is rather inelastic to changes in fuel prices. However, there is very little literature devoted to evaluating the impact of fuel price volatility on car-use behavior.

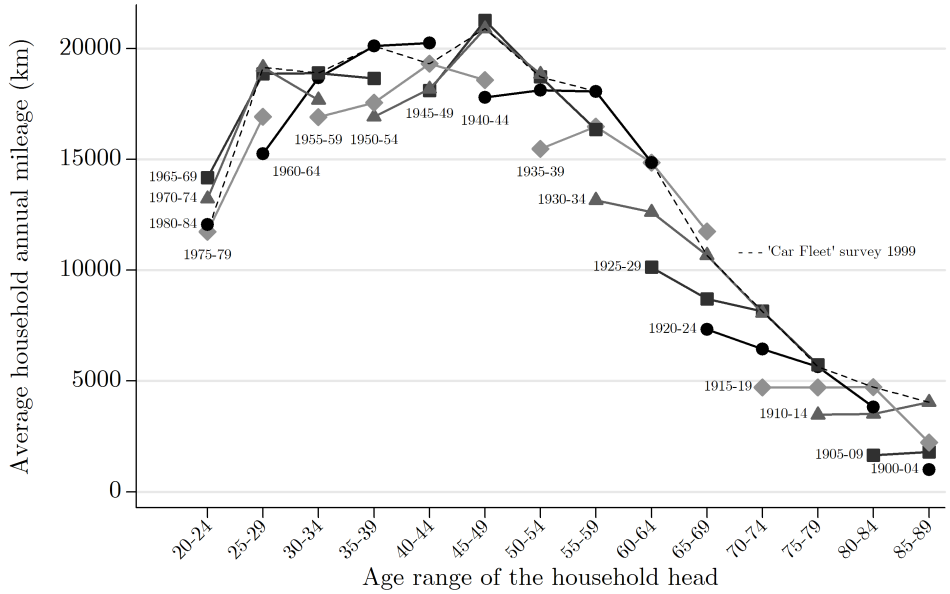
In this article, we set out to evaluate each of these effects with regard to French households. It is structured in the following way. Firstly, we study the importance of considering the effects of age and generation jointly in the analysis of household car mileage behavior. It is illustrated by showing that cohorts of households at the same age generally present a difference in car use, which tends to hold true at nearby age ranges. Next, we discuss the effect of fuel price volatility on household car use. From a theoretical point of view, volatility can be perceived as a source of uncertainty about fuel price, and its increase should entail a decrease in car use with respect to risk-averse households. Subsequently, we briefly present the annual "Car Fleet" survey and its use to establish a pseudo-panel of household generational cohorts over the 1988-2008 period. Then, the Age-Cohort-Period model is applied to analyze the average household car mileage of cohorts, by disentangling the effects of age and generation. The impacts of income, fuel price level and fuel price volatility on car use are also evaluated. The estimation results are provided and commented on the final section.

2. Age and generation effects

Studies about mobility generally show that household car use begins to increase with the age of the household head. This result is often explained by the growth in car use needs during the first stages of the household life cycle, characterized by an increase in its size. This happens initially when a single-person household becomes a couple and then, when a couple becomes a family with children. In France, the peak of household car use generally occurs when the head is aged between 40 and 50. Afterwards, it tends to decrease rapidly. This tail-off in use is usually related to grown-up children leaving the parental home, retirement ending the need to commute to work, and deteriorating driving skills over the last period of the life cycle.

Resorting to econometrics to consider the effect of these aspects on household car use, in addition to usual income and price effects, does not allow the effect of age to be canceled out. Given the household demographic structure, employment, income and location, the age of the household head remains a determining factor in explaining car use. This result is often presented as evidence of a shift in household preferences along the life cycle. However, these age effects become intermingled with the generation effects if the latter are not explicitly

Figure 1: Evolution of car use by household cohort



Sources: waves 1989, 1994, 1999 and 2004 of the French 'Car Fleet' survey.

taken into account. Indeed, at a given period, the car use of older households cannot prejudge that of younger ones some years later. Today's household heads born in the 1930s survived the Second World War and grew up in a near "carless" period; those born in the 1950s lived their childhood in the "thirty-year boom" period after 1945 and have seen the rise of the "people's car" and road network developments; and those born in the 1970s have mainly experienced an era of economic slowdown, while the automobile began to become a personal good. Because of different life experiences, a household with a young head is likely to have made different use of the automobile than his parents, and his grandparents even more so, at the same age. In practice, it is impossible to disentangle age and generation effects using only one cross-sectional dataset. Indeed, all household heads from a same generation, characterized by a given year of birth, have the same age in a one-off survey. To distinguish the effects, the data have to provide a longitudinal perspective, allowing the behavior of households from a same generation to be assessed at different moments in the life cycle. In this study, we use several annual waves of the French "Car Fleet" survey, which is briefly described later.

Defining the household cohorts in terms of five-year ranges of the head generation, Figure 1 presents the average annual mileage for each one in 1989, 1994, 1999 and 2004. The dotted line represents the car-use profiles by age range in 1999. As expected, a bell-shaped curve is observed, with a peak corresponding to the 45-49 year-old category. At the age of 20-24 and 25-29, the households whose heads were born between 1975 and 1984 account for a lower annual mileage in average than cohorts born just earlier, between 1965 and 1974. This result might be explained, at least partially, by the increase in the number

of people remaining single among young households[1], and the decision by the most recent generations to put off having children.[2] With the exception of a few cases when comparing households whose heads were born between 1945 and 1964, the cohorts account for a generally higher mileage than those preceding them at the same age. Nevertheless, the differences remain particularly small when drawn to the scale of annual mileages (between 17,000 and 21,000 km per year on average), since these cohorts can be compared only during the life cycle phase when household car mobility demand is at its highest. Household cohorts whose heads were born before the war are represented for more advanced ages, when automobile needs are more reduced. For each age range between 55 and 74, the differences in mileage between generations are clearer, the former having made lower car use than those succeeding them. Indeed, the comparison of household cohorts at the same age reveals differences in average annual mileage, which tend to hold true at nearby age ranges. They reflect the effect of a differentiation between generations, even if a proportion of these differences also occurs as a result of period effects.[3]

3. Fuel price level and volatility effects

The spread of the automobile in society over time forms the background of an age and cohort analysis of household car mileage, since car motorization and use developed interdependently in industrialized societies (Berri *et al.*, 2005). However, car use is a more flexible behavior than car ownership, and is therefore more sensitive to fuel price variations. In the literature, studies which aim at evaluating the effect of fuel price on car mileage are so numerous that they have served as material for meta-analysis works and reviews (Graham and Glaister 2002 and Goodwin *et al.* 2004). A very large proportion of these agree on the inelastic nature of car use with respect to fuel price. In particular, Goodwin *et al.* (2004, Table 4) have collected seven studies based on a static model, and report an average elasticity of -0.31. However, it is worthy to note that none of them seem to have considered the impact of the fuel price volatility around its average value.

From a microeconomic point of view, price volatility can be related to uncertainty. Let the utility level of a household in a certain environment be denoted $V(p, W)$, where V stands for the indirect utility function, p is the fuel price level and W is the household income. In an uncertain environment, suppose that the fuel price can shift equiprobably by $\pm dp$ around p. These shifts give rise to the "equivalent variations" dW (Varian, 1995, Chap. 10), so that $V(p + dp, W) = V(p, W + dW_1)$ and $V(p - dp, W) = V(p, W + dW_2)$, with $dW_1 < 0 < dW_2$. The certainty equivalent of the expected utility resulting from the lottery on the fuel price is given by the wealth $W + X$. Naturally, X is included in $[dW_1; dW_2]$, but importantly, it is negative if the household presents an aversion to risk.[4] The resulting utility is therefore $V(p, W + X)$, which is equivalent to the utility level given by $V(p + s, W)$, with $s > 0$.

[1] Using the French national transport surveys, the rate of single-person households whose head is aged between 20 and 29 has increased from 36% in 1993 to 42% in 2007.

[2] The average age a woman has her first child has regularly increased between 1985 and 2008, from 25 to 28.5 years-old (Daguet 2002 and Davie and Mazuy 2010).

[3] At the age of 55-59 for example, the household car mileage difference between the 1940-44 cohort and the 1945-49 cohort might also result from the shift in the real fuel price between 1999 and 2004.

[4] That is, if its marginal utility of wealth is decreasing.

Finally, introducing uncertainty leads the risk-averse household to behave as it would under certainty, but considering a fuel price higher than it is really on average. It follows that the household's demand for fuel and car use decreases as fuel price volatility rises around a given average value.

4. An Age-Cohort-Period model applied to the 1988-2008 French Car Fleet pseudo-panel

Our aim is to statistically disentangle age and generation effects, and assess the impacts of fuel price level and volatility on household car use. In this perspective, the French "Car Fleet" survey has been used to establish a pseudo-panel over the 1988-2008 period. The objective of this nationwide and automobile-specific survey is to provide knowledge about household car ownership and use in France. It has been conducted every year since the 1980s, and contains information about car attributes, quality and use, but also about the characteristics of users. Currently, a random sample of 10,000 households is surveyed every year. A more detailed description of the French "Car Fleet" survey can be found in Collet (2007). For each household, car use is defined by the sum of the annual mileage of available cars. Non-motorized households present a zero car use, raising the classic problem of a censored variable. To deal with it statistically, Tobit-type models may be applied. However, we have preferred to stick to a more simple linear method and adapt the data consequently. Pooling households in cells and averaging the data allow the censored variable problem to be circumvented, provided that cells are large enough to contain motorized households, characterized by a positive annual car mileage. In our study, five-year birth ranges of the household head are considered for establishing cohort cells. Thus, our pseudo-panel dataset extends from 1988 to 2008, where the observations are average households for each cohort and each year of the survey.

The Age-Cohort-Period (ACP, hereafter) model is applied to our dataset to characterize household car use. The longitudinal approach of the ACP model allows the disentanglement of the complex effect of time, that combines three dimensions:

- the *Age* of the household head, which reflects the car mobility needs of a household along its life cycle, through family structure or employment status;
- the generational *Cohort* of the head, which captures the behavior of households having evolved in the same general context, and having experienced the same facilities and difficulties of access to car ownership and use;
- the *Period*, which mainly reflects the economic environment of households at a given time, and whose impact on car-use behavior results from income and fuel price.

The ACP model is written:

$$KM_{ct} = \sum_i \alpha_i A_{ict} + \sum_j \beta_j C_{jc} + \sum_k \gamma_k P_{kt} + \epsilon_{ct}, \quad (1)$$

where KM_{ct} is the log of car use for the cohort c at period t, A_{ict} is the dummy variable for age i (whose value is 1 for $i = t - c$, 0 otherwise), C_{jc} is the dummy variable for cohort

j (whose value is 1 for $j = c$, 0 otherwise), P_{kt} is the dummy variable for period k (whose value is 1 for $k = t$, 0 otherwise), and ϵ_{ct} is assumed to be a normal zero-mean error term. Since it results a unity vector from adding the age dummy variables first, the cohort dummy variables next, and the period dummy variables last, the model (1) written above is not identifiable. The identification is usually recovered by replacing the period dummy variables with contemporary economic factors, and taking an age and a cohort as reference in exchange for adding an intercept to the model. It becomes:

$$KM_{ct} = cst + \sum_i \alpha_i A_{ict} + \sum_j \beta_j C_{jc} + \gamma_1 R_{ct} + \gamma_2 P_t + \gamma_3 V_t + \epsilon_{ct}, \tag{2}$$

where R is the log of household annual income expressed in 2008 Euros, P is the log of fuel price, V is an intra-annual indicator of fuel price volatility, and cst is the intercept. Lastly, and for the sake of parsimony regarding the number of parameters to be estimated, the age and cohort variables are grouped into five-year brackets. One can refer to Bodier (1999), Berri *et al.* (2005) or Berri (2009) for an in-depth description of the ACP model and its application.

The fuel price used in this study is the annual average of the petrol and the diesel oil prices expressed in 2008 Euros per liter, weighted by the proportions of petrol and diesel cars in the national fleet. The fuel price volatility indicator is the log of the intra-annual coefficient of variation, based on the monthly fuel price series in France. Since the fuel price has never remained constant within a specific year of our data period, the coefficients of variation are always positive, and their log always defined. In addition, a log-log specification is chosen, so as to interpret the coefficients of economic factors directly as car-use elasticities.

5. Results

The ACP model has been applied to the 1988-2008 French "Car Fleet" pseudo-panel, by weighting each cell by its number of households and removing from the estimation those containing less than 100 households.[5] The estimation results are reported in Table 1, and the following comments and interpretations can be drawn from these.

The model presents an excellent goodness of fit: it strives to explain more than 98% of the total data variance. However, it is a usual property when applying a log-log specification on a semi-aggregated dataset.

All other things being the same (and the generation in particular), the age profiles show that household car use increases with the age of the household head in a first stage. It peaks at the age of 45-49, then it decreases in a second stage. Retirement, which implies an end to commuting mobility, explains why the decrease intensifies after 60 years of age. Thus, results are consistent with the shape of Figure 1, and with its interpretation based on the evolution of car use needs along the household life cycle. Equality tests between the parameters of adjoining age ranges allow the rejection of the null hypothesis that age effects are equal, except when comparing the 50-54 and 55-59 age ranges, and the set of age ranges between 25 and 39. Due to the logarithm of the dependant variable, the exponentials of the age coefficients yield car-use multipliers with respect to the 50-54 age range, chosen as reference.

[5] As recommended by Verbeek and Nijman (1992).

Table 1: Estimation results - ACP model

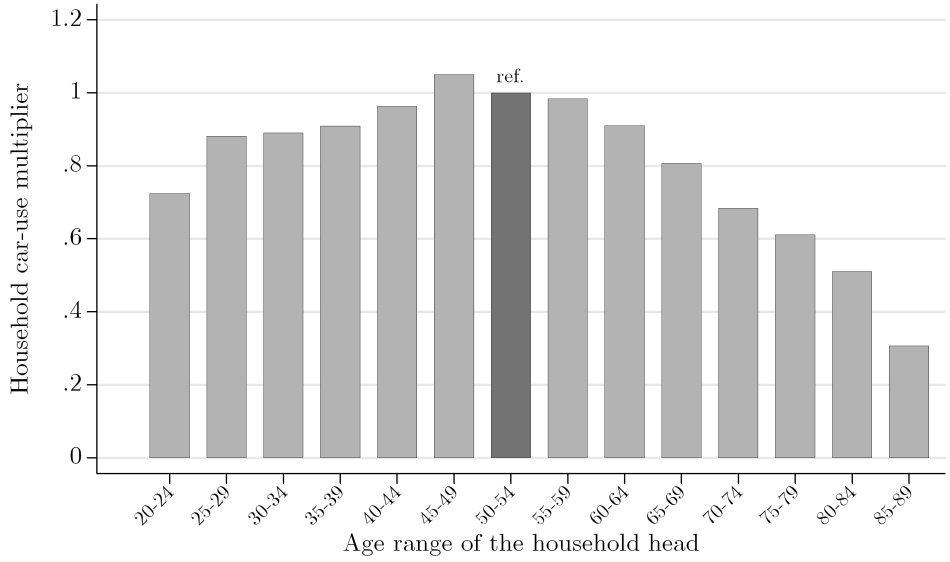
Covariates	Coefficient	Student	[95% C.I.]
Age range variables (ref.: household head aged between 50 and 54)			
20-24	-0.322	-3.74	[-0.491 ; -0.154]
25-29	-0.126	-3.06	[-0.208 ; -0.045]
30-34	-0.116	-3.74	[-0.177 ; -0.055]
35-39	-0.095	-3.53	[-0.148 ; -0.042]
40-44	-0.038	-1.59	[-0.084 ; 0.009]
45-49	0.049	2.08	[0.003 ; 0.095]
55-59	-0.016	-0.59	[-0.068 ; 0.036]
60-64	-0.094	-3.60	[-0.146 ; -0.043]
65-69	-0.215	-6.93	[-0.276 ; -0.154]
70-74	-0.380	-10.21	[-0.453 ; -0.307]
75-79	-0.493	-11.15	[-0.580 ; -0.407]
80-84	-0.672	-11.98	[-0.781 ; -0.562]
85-89	-1.183	-9.52	[-1.426 ; -0.939]
Cohort variables (ref.: household head born between 1950 and 1954)			
1905-1909	-1.621	-22.17	[-1.765 ; -1.478]
1910-1914	-1.134	-23.43	[-1.229 ; -1.039]
1915-1919	-0.816	-18.92	[-0.900 ; -0.731]
1920-1924	-0.645	-18.57	[-0.713 ; -0.577]
1925-1929	-0.458	-14.81	[-0.519 ; -0.398]
1930-1934	-0.289	-10.28	[-0.344 ; -0.233]
1935-1939	-0.147	-6.19	[-0.193 ; -0.100]
1940-1944	-0.086	-4.22	[-0.126 ; -0.046]
1945-1949	-0.043	-2.50	[-0.076 ; -0.009]
1955-1959	0.018	1.08	[-0.015 ; 0.051]
1960-1964	0.095	4.91	[0.057 ; 0.133]
1965-1969	0.134	5.98	[0.090 ; 0.178]
1970-1974	0.168	6.25	[0.115 ; 0.221]
1975-1979	0.122	3.42	[0.052 ; 0.192]
1980-1984	0.189	3.71	[0.089 ; 0.290]
Period variables (economic factors)			
ln(household annual income$^{(a)}$)	0.483	5.22	[0.302 ; 0.665]
ln(fuel price$^{(a)}$)	-0.226	-4.31	[-0.329 ; -0.123]
ln(fuel price CV$^{(b)}$)	-0.029	-5.55	[-0.040 ; -0.019]
Intercept	4.782	4.96	[2.890 ; 6.672]

(a): in 2008 Euros. (b): coefficient of variation. Dependent variable: ln(household annual car use). Generalized least square estimator. Source: 1988-2008 French "Car Fleet" pseudo-panel. 261 observations (cells). Centered R^2: 0.986. $RMSE$: 0.055.

These are represented in Figure 2. All else equal, households from the 20-24 age bracket register a 30% lower car use than at the age of 50-54, that is, almost the same difference as at the age of 70-74. With a multiplier estimated at 0.3, households from the oldest age range (85-89) drive 3.3 times less than when aged 50-54.

Globally, the cohort profiles show that, everything else equal, the earlier the generation of the household head, the lower the car use. Households whose head belongs to the most recent generations, born when the automobile was already very widespread in the society, make greater use of cars than the households of their parents and grandparents at the same age,

Figure 2: Household car-use multipliers by age range of the head
(reference: 50-54)



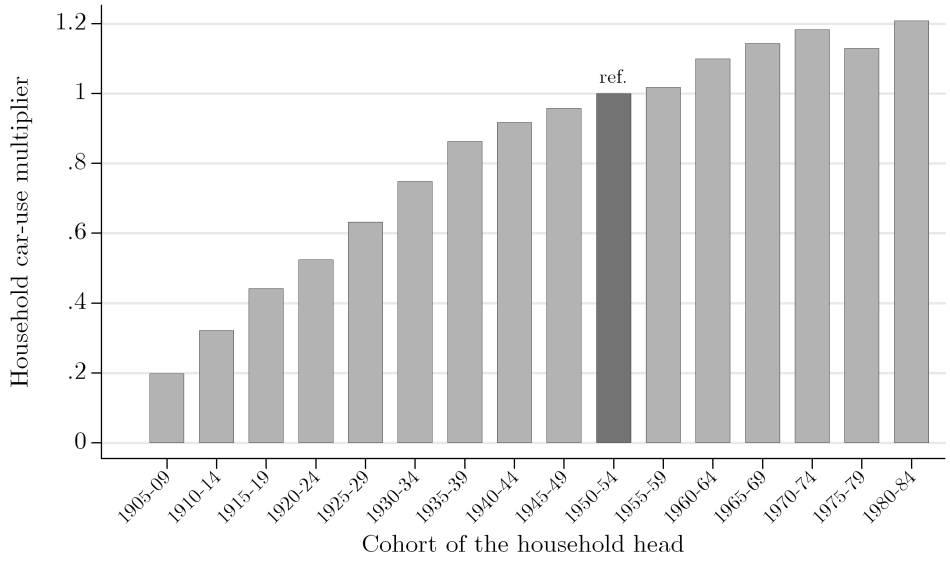
Source : calculations from Table 1.

who grew up in less automobile-dependent times. The comparisons of coefficients between adjacent cohorts from 1905 to 1969 reveal that household mileage is statistically lower in a cohort than in the just succeeding one, except for the 1950-54 cohort. Regarding the group of cohorts whose heads were born between 1970 and 1984, the cohort coefficients are not statistically different two by two. Thus, the hypothesis that these cohorts have the same car-use behavior at a given age cannot be rejected. However, this partly results from the fact that the most recent generations are observed only in the most recent surveys, inducing a relative imprecision regarding their cohort parameter.[6] As with the age coefficients, the exponentials of cohort parameters give car-use multipliers with respect to the cohort of reference (1950-54). These are represented in Figure 3. All else equal, households whose heads were born between 1915 and 1925 drive twice as less as those whose heads were born between 1950 and 1954. At the opposite end, households from the 1970-74 generations register a 20% higher mileage than those from the 1950-54 cohort at the same age. In addition, Figure 3 shows that the increase in car-use multipliers with the recentness of cohorts has slowed down. Therefore, their saturation, or even their decrease, for generations born after 1990 arises as an important question.

The income elasticity of household car use is positive, significant and estimated at +0.48. This result is fully consistent with the literature, as indicated by the meta-analysis study of Goodwin *et al.* (2004, Table 6). Indeed, the authors report an average elasticity value of +0.49 from a set of 15 studies which have applied a static model. The fuel price elasticity is also significant and negative, as expected. It is estimated at −0.23. The elasticity of

[6]Indeed, the standard errors of estimated parameters in Table 1 are higher for the 1980-84 and 1975-79 cohorts than for the 1970-74 cohort.

Figure 3: Household car-use multipliers by cohort of the head
(reference: 1950-54)



Source : calculations from Table 1.

household car use with respect to the fuel price coefficient of variation is also found to be significantly negative, and estimated at -0.03. Thus, households tend to reduce their car use when fuel price volatility increases. From a merely environmental and energy point of view, this result pleads against policy measures which aim at smoothing fuel price fluctuations, such as the floating national tax on oil-based products in France.[7] Indeed, their effect runs counter to reducing GHG emissions and fuel consumption from car use. However, such measures may be considered if the legislator aims at increasing tax revenues from domestic car fuel sales. Regarding taxation tools, given a same increase in the average fuel price, a new fixed tax will have a lower impact on the decrease in household car mileage than a new percentage-tax, thus allowing a larger amount of tax revenues to be raised from car fuel sales.

In addition, if our microeconomic reasoning applies, household car mileage decreases as uncertainty about the fuel price around its average value increases within a period. Households, out of caution, set their car-use plans according to a fuel price higher than it is on average, thus reflecting their aversion to risk. Nevertheless, another explanation of the negative effect of volatility would be that households are more sensitive to fuel price increases than to decreases. In economics, this asymmetry defines the so-called "ratchet effect". Lastly, fuel price level and volatility have evolved correlatively over the data period. Precisely, the fuel price elasticity of the coefficient of variation has been $+3.01$ over the 1988-2008 period. Therefore, the omission of the fuel price volatility effect when analyzing car use may lead to an overestimation of household fuel price sensitivity. In our study, fuel price elasticity would have been -0.31 if the volatility effect had not been taken into account. As mentioned above,

[7]Which ran from October 2000 to July 2002.

this value is exactly the average fuel price elasticity reported by Goodwin *et al.* (2004, Table 4) in their meta-analysis, based on studies that have not considered the fuel price volatility effect. In our case, the estimation bias would have represented 28% of this figure.[8]

6. Conclusion

This paper presents an analysis of household car use in France. It relies on a pseudo-panel of household cohorts, which is established using the annual waves of the French "Car Fleet" survey from 1988 to 2008. The objective of this paper is two-fold: disentangling age and generation effects, and assessing the impact of fuel price volatility on car use. To this end, we have applied the Age-Cohort-Period (ACP) model and considered the intra-annual fuel price coefficient of variation as a volatility indicator. The model parameters allow the household car mileage profiles to be represented by age of the household head, all other things being the same. They show that car use increases during the first stage of the household life cycle, and decreases after having reached a peak at the 45-49 age range. The car mileage profiles by generation show that household cohorts whose heads were born before 1970 make greater use of cars than those preceding them at the same age. Regarding the most recent cohorts, the data do not allow the conclusion of significant differences between them. Therefore, the following question emerges about the cohorts born after 1990: will car-use profiles stabilize or decrease with the arrival of new generations? Future waves of the French "Car Fleet" survey should provide an answer.

In this study, the fuel price elasticity of household car use is estimated at -0.23. In addition, the results highlight the negative effect of fuel price volatility. Indeed, the elasticity of household car mileage with respect to the fuel price coefficient of variation is evaluated at -0.03. We show that this result may be explained by the risk-aversion of households, leading them to decrease their annual mileage when there is an increase in the degree of uncertainty about fuel prices, that is, when price fluctuations amplify around the annual average value. This empirical result is of great importance to policy makers, both from the environmental and the tax revenues perspective. Importantly, fuel price volatility proves to have been highly correlated with fuel price level over the 1988-2008 period. Thus, not controlling for volatility may induce a bias in estimating fuel price elasticity of car use. In this study, it represents 28% of the biased elasticity, which is evaluated at -0.31.

Lastly, the ACP model lends itself to projection exercises. The parameters estimated in our study can support future predictions of traffic and GHG emissions from household car use. It is mainly a question of making the cohorts increase in age and setting hypotheses regarding the evolution of fuel price level and volatility, household income, and car-use multipliers for the most recent cohorts.

[8]Calculation details: $-0.226 + 3.010 \times (-0.029) = -0.313$; $1 - (-0.226)/(-0.313) = 28\%$.

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