Demographic composition and projections of car use in Austria

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1. Introduction

Understanding the factors driving demand for transportation in industrialized countries is important to addressing a range of environmental issues including local air pollution and climate change (NRC, 1997). It is also an aid to planners who must anticipate infrastructure needs and address concerns with congestion. Research on travel demand and transportation fuel use has shown that demand generally rises with income (e.g., Dahl and Sterner, 1991). Non-economic factors have received less attention but have been found to be important. Links between indicators of lifestyle and energy use have been identified (Schipper et al., 1989), and analyses of household survey data in the U.S. have shown differences in travel demand across households that differ in the age and gender of the householder, household size and composition, and family type (Pucher et al., 1998; O'Neill and Chen, submitted). Carlsson-Kanyama and Linden (1999) find similar relationships in Sweden; they show that women, the elderly, and those with low incomes generally travel less than men, the middle-aged, and those with higher incomes. In addition to the consideration of separate demographic variables, the lifecycle concept has been demonstrated to provide a useful framework for capturing variation in travel demand and associated greenhouse gas emissions across households that differ by some combination of family size, family type, age of the householder, and marital status (Greening and Jeng, 1994; Greening et al., 1997). Other studies have shown that household characteristics are not only important to explaining variation in travel demand, but also to anticipating the response of households to price changes or other policies (Kayser, 2000).

Little work has been focused on the role demographic characteristics of households might play in explaining past changes in aggregate demand, or to predict future changes. O'Neill and Chen (submitted) use a standardization procedure to conclude that changes in household size, age, and composition in the U.S. over the past several decades have likely had a substantial influence on aggregate demand for direct energy use by households. Buettner and Grubler (1995) point out that sex-specific cohort effects on car ownership in Germany are likely quite significant and will influence future travel demand as populations age. Spain (1997) finds a similar pattern in the U.S., where baby boom women hold driver's licenses at a much higher rate than the current generation of elderly women, portending an increase in travel demand in elderly age groups in the future.

However these studies either simply suggested particular demographic variables that may be important in projections, or made transportation projections in the absence of household projections. Here we go beyond previous work by combining cross-sectional analysis of car use in Austria with detailed household projections. This step raises additional methodological questions, because it may be that some characteristics that are important to explaining cross-sectional variation in travel behavior are not important to projecting future demand. This can result if the population composition is not going to shift across demographic categories that may be important to explaining variation in transportation behavior (e.g., even if small households travel much less than large ones, projections that ignore this difference will not be subject to aggregation error if the proportion of large to small households will remain constant in the future).

Our study is divided into three steps. We start with a descriptive analysis of the demographic composition of car use in Austria in 1997. In a second step we perform a detailed household projection for Austria up to the year 2046. We apply these projections to study the change in demographic compositions across time. In the third step we combine car use patterns in 1997 (as decomposed by selected demographic characteristics) with future changes in these demographic compositions.

By applying this three-step procedure to combine demographic compositions and projections of private car use we aim to explore the following questions: (a) what is the best level of demographic composition for understanding the effect of demographic characteristics on private car use in a cross-sectional analysis, (b) which level of demographic composition will change the most in the future; and (c) in light of results for (a) and (b), what level of demographic composition is best for projecting future car use?

2. Data

The present study is based on the Austrian micro-census (a representative household survey of 1% of all Austrian dwellings, which is conducted quarterly) from June 1996 and June 1997. Each survey provides a core questionnaire on household demographic characteristics as for instance total household size, number of children, age, gender, marital status, education and working status of the household head and housing conditions of the household. The sample size is in the order of about 30,000 dwellings, but each quarter an eighth of all addresses is replaced by new ones. In the particular case of the microcensus of June 1996 and June 1997 the survey contained 23,174 and respectively 22,648 unweighted valid cases (for a more detailed description of the June 1997 survey see Statistic Austria, 1998; a summary of the June 1996 survey is given in Hanika, 1999). The June 1996 survey includes an additional questionnaire on birth biographies. For this reason it was chosen as the base population for conducting a detailed household projection using the ProFamy model (Zeng et al., 1997). In addition, part of the input necessary to run Profamy was derived from the Austrian Family and Fertility Survey conducted in 1995/96 (Doblhammer et al., 1997). For the demographic composition analysis of private car use we use the June 1997 microcensus which includes information on ‘Energy Use in Households’ and in particular also information on private car use. Based on these data it is possible to reconstruct in part the travel behaviour of private households with their first two cars. In particular, the following characteristics can be defined: (1) car ownership and (2) how many kilometres households drove with their first and, if present, their second car in the course of the year before the interview. The fact that information is only available for the first two cars is not really problematic since among all those who record to have a car, only 6% own more as one car while 70% own only one car and 24% own two cars. More problematic may be the total distance driven since it is self reported.

3. Demographic composition of car use

We derive the demographic composition of car use patterns from the Austrian microcensus of June 1997. In a first step we calculate the characteristic form of a household across five dimensions: (1) age of household head, (2) age and sex of household head, (3) size of household, (4) number of adults and children in the household, and (5) age of household head and size of household. For each of those five compositions we next calculate the mean distance driven by households within each category of the compositional variable. These calculations are based only on those households that have recorded a positive distance traveled during the year preceding June 1997. For instance, in case of composition (1) we calculate the mean distance driven for households whose head is aged 16 to 24, 25 to 29, etc. years old, and who report a non-zero distance traveled in the past year. Since the number of households that recorded a positive distance is a subset (of about 90%) of those households that own a car, we calculate the car ownership across the various levels of each composition in a third step. The results of these calculations are summarized in Figure 1a. - 1e.

To verify the sensitivity of travel demand patterns to alternative compositions Table 1 summarizes the results of a simple ANOVA analysis applied to the variable that measures the distance driven with the first two cars for each compositional variable. The F-statistics verify that for all compositional variables the average distances across the categories differ significantly. A comparison across the proportions of total variance accounted for by each model shows that age and size considered independently do about as well in explaining total variance, while age and size together provide the best combination of variables among the models tested.

Figure 1a shows a distinct age pattern of car ownership and car use. Car ownership increases with the age of the household head reaching its peak of almost 90% of all households owning a car for the age group 40 to 44 years old. Thereafter car ownership starts to decline and falls below the 50% mark beginning from the 70-74 years age group onwards. The pattern of car use is very similar to the car ownership pattern. It first increases up to the late middle ages and starts to decline thereafter. The age pattern of private transportation demand obviously reflects the compositional change of household size across various ages. Generally, household size first increases with the age of the household head and starts to decline again at older ages. While 51% and respectively

56% and 71% of all households in the lowest age group (16-24 years of age) and upper two age groups (75-79, 80+ years of age) are of size one, households of size four are predominant (with 30% of all households) for the middle age group of 40 to 44 years old household heads. Beside household size, labor force participation and consequently the necessity to commute but also the means to travel, will change with the age of the household head. While the labor force participation increases from about 70% to 93% for household heads aged 16-24 and 40-44, only 52% of all household heads aged 55-59 are employed. These numbers rapidly fall to 10% and 3% for the age groups 60-64 and 65-69. Beside the strong decrease in labor force participation at older ages, the age pattern may also partly reflect a cohort effect. Today's middle and young aged generation has grown up in times where car ownership has been the norm rather than the exception. As these cohorts age we may expect to see an increase in car ownership and car use patterns also among the older generation.

Table 1: ANOVA analysis for compositional variables

	Sum of squares	Df	Mean Square	F-statisic	Significance	% of Total Variance
Age of household head						
Between groups	1.30E+13	12	1.10E+12	7531.628	0	4.2
Within groups	3.00E+14	2027985	1.50E+08			
Total	3.10E+14	2027997				
Age and sex of household head						
Between groups	1.80E+13	25	7.30E+11	5003.61	0	5.8
Within groups	2.90E+14	2027972	1.50E+08			
Total	3.10E+14	2027997				
Size of household						
Between groups	1.40E+13	6	2.40E+12	16424.32	0	4.5
Within groups	3.00E+14	2027991	1.50E+08			
Total	3.10E+14	2027997				
Number of adults and children in the household						
Between groups	1.90E+13	28	6.90E+11	4773.032	0	6.1
Within groups	2.90E+14	2027969	1.40E+08			
Total	3.10E+14	2027997				
Age of household head and size of household						
Between groups	2.80E+13	68	4.10E+11	2948.789	0	9.0
Within groups	2.80E+14	2027929	1.40E+08			
Total	3.10E+14	2027997				

A distinction between male and female headed households (Figure 1b) evidences the gender difference in car ownership and car use patterns that persists across all ages. While the car ownership is about 20% lower for female as compared to male headed households up to age 50, this difference increases up to 45% for older households. E.g. while only 15% of all female headed households at age 75-79 own a car, 60% of male headed households in the same age group own a car. While the gender difference in car ownership increases with age, car use patterns of female and male headed households become more similar with the age of the household head. The increasing gap across age of car ownership between male and female headed households may partly be caused by a cohort effect. On the other hand we also observe a clear difference in the composition of labor force participation and household size across age between male and female headed households. While among male headed households aged 55-59 years of age about 61% of all household heads are in the labor force, only 26% of all female household heads in the same age category are employed. Moreover, the share of single person households is higher among female headed households across all ages and in particular so for the older age groups. Among all female headed households in the age category 70-74 (75-79) years of age 82% (85%) of all households are single person households. The corresponding number of male headed households are 13% and 15%. In the oldest age group (80+) this difference is slightly lower, 91% of all female and 32% of all male headed households are single person households. Both trends, the lower female labor force participation rate and the higher prevalence of single person households, may partly explain the gender gap in car ownership. Since both trends increase with age, this may also explain the increasing gender gap across age. Not only are female headed households on average of smaller size but they are also more likely to be single adult households. Among all female headed households in the age categories 25-29, 30-34, 35-39 and 40-44 the percentage of single adult households with at least one child is 14%, 27%, 30% and 19%. The corresponding numbers among male headed households are 1%, 0%, 2% and 0%. Obviously the prevalence of single mother households accounts for part of the gender gap in car use patterns and in particular so for middle aged categories where this difference is most pronounced. One may suspect that the fact that we see a closing gender gap in car use patterns by age (as opposed to the widening gender gap in car ownership by age) may indicate that those female headed households that own cars and use them actually have similar labor force participation, size and number of adults compared to male-headed households that own and use cars (they are after all a small subset of female-headed households, at least at older ages). However this conclusion is only valid for the household size. Among all female headed households that own a car in the age category 70-74 (75-79) years of age 53% (54%) of all households are single person households. The corresponding number of male headed households are 7% and 11%. In the oldest age group (80+) this difference further declines, 44% of all female and 17% of all male headed households are single person households. From these numbers it becomes evident that the gender difference in household size at older ages declines if we restrict our sample to households that own a car.

Household size (Figure 1c) positively effects car ownership and car distance. Part of the household size effect reflects an age effect. I.e. smaller households are more likely to be headed by younger and older people and these are the age groups for which we have found the lowest shares of car ownership and car use (Figure 1a). On the other hand households headed by middle aged heads, for which the highest shares of car ownership and car use could be observed, are more likely to be composed of two or more generations and hence their household size is the highest. While car ownership increases most between households of size one and two, the strongest increase in mean distance driven is between households of size two and three. The former result may be explained by an age effect. Among all households of size one 19% and respectively 34% are contributed by young (25-34 age) and old (70-80+) households. Households of size two are composed by 45% of middle aged households (55-74 years old). Together with Figure

1.a. these compositional changes explain the increase in car ownership between one and two person households. On the other hand, the sharp increase in mean distance driven between households of size two and three may be contributed to a compositional change in age as well as the adult/children ratio. 73% of all three person households are headed by persons aged 30-59 (for which group the highest mean distance was observed in Figure 1.a.). Moreover, adult only households account for 92% among households of size two and for 46% among households of size 3. For the latter household type 47% are contributed by households composed of two adults and one child. The difference between no and one child therefore explains part of the steep increase in mean distance driven between households of size two and three. Moreover, the fact that car ownership and mean distance driven increase at a decreasing rate with the size of the household head may be explained by the change in the composition of adult and children living in the household. While 98% and 92% among all households of size one and two respectively are adult only households, these shares decrease to 46%, 21%, 14%, 12% and 4% for households of size 3, 4, 5, 6 and 7. That is, households with children become more prevalent among larger households and therefore car ownership and car use may not necessarily increase proportional to the size of the household, or at least not so for larger sized households.

As becomes obvious from the discussion of Figure 1c, household size may however be too crude a measure since it aggregates households of the same size, independent of the age of household members. E.g. a three person household may either consist of three adults, two adults and one child or one adult and two children. (We use the age 18, which is also the age at which a driving license can be obtained in Austria, as the age that distinguishes between adults and children.) Obviously a three adult household may have a different transportation demand as compared to a one adult, two children household. Figure 1d represents such a composition of car ownership and car use that distinguishes between adults and children. From these figures we may draw the following conclusions. First, adult only households have the highest rates of car use and car ownership across all household sizes. Secondly, within a given household size the presence of one or more children reduces car ownership only for single adult households. I.e. for households of size two, three and four we observe a marked decrease in car ownership pattern only if there are one, two or respectively three children present. In summary, single parent households have the second lowest car ownership after single adult households. Since the latter group of households is composed of old and young aged households (compare our discussion to Figure 1.a and 1.c) it is not surprising that single adult households have the lowest car ownership. Thirdly, single parent households have also the lowest car use within each household size. However while for households of size 3+, the presence of two or more children does not essentially effect the car ownership pattern it markedly reduces car use.

Our results so far indicate a strong correlation between age of the household head and household size. Figure 1e. therefore presents the compositional change of car use and car ownership patterns across age and household size. From these results we may conclude that the age pattern of transportation demand aggregated over all household sizes mainly reflects the age patterns observed for households of size one and two. Larger sized households generally show a more stable age pattern. This may be explained by the fact that firstly, larger sized households are less likely to be headed by persons of very young and alternatively very old age and secondly, that these households are more likely composed of two generation households. In case of more generation households, the age pattern of car ownership and car use reflects the mix of the lifecycle transportation demand of several generations. In case of single adult households (that are more prevalent among smaller household sizes) the age pattern of car use and car ownership is tied to the life cycle demand pattern of only one generation. Viewed differently, Figure 1e. also shows that the difference of transportation demand between household sizes varies across the age of the household head. For middle and in particular for older age groups the difference of transportation demand between households sizes is most pronounced. In light of the fact that we will observe a tendency towards smaller sized households and an ageing of population (see section 4) in the future, a composition by age as well as household size seems to be appropriate for long run projections of transportation demand.

For comparison, Table 2 summarises aggregate car ownership and car use patterns without applying a more detailed demographic composition. We shall use these numbers in Section 5 to project transportation demand and compare the results with projections where we apply a more detailed household composition of demand patterns.

Table 2: Mean distance driven and car ownership per capita, per adult, per household

	Mean distance driven	**car ownership**
per capita	5,776	83%
per adult	7,538	80%
per household	16,652	72%

4. Household projections

To understand the influence of key demographic factors on car use in the long run, it is important to apply population and household projections that can provide detailed information on changes of demographic determinants in the future. However, conducting a consistently and simultaneously dynamic population and household projection has remained difficult for a rather long time. As stated by Lutz et al. (1994, p. 225), “there is no feasible way to convert information based on individuals … directly into information on households. Even if these two different aspects could be matched for the starting year there is no way to guarantee consistent changes in both when patterns are projected into the future”. Therefore, previous studies on population-environment interactions and in particular on the development of population and energy use limit their analysis to separately treating population at the individual level and household information. Those who try to combine household and individual level information apply a static approach, mostly utilising the well known household headship rate method. However, the linkage between the headship-rate and the underlying demographic parameters are unclear, i.e. it is very difficult to incorporate assumptions about future changes in demographic events. Moreover, this approach lumps all other household members into the very heterogeneous category "non-head". Therefore, it can not provide detailed information on changes of demographic factors that may be important for future energy use projection. Therefore, a dynamic population and household projection is desired. The advancement in theories and methods of family demography have been improving our capacity to do such a job.

Dynamic micro and macro household models (e.g. Hammel et al., 1976; van Imhoff and Keilman, 1991; Zeng et al., 1997, 1999) have been developed. Benefiting from methodological advances in multi-state demography, Zeng (1991) constructed a family status life table by extending Bongaarts (1987) nuclear status life table model. Building on this family status life table, a dynamic projection model ProFamy is developed to simultaneously and consistently project future household and population changes which can match our research purposes.

By applying ProFamy model, we conducted a dynamic household and population projection for Austria for the period of 1996-2046. From the 1996 micro-census data we derive the baseline population for running ProFamy. Based on the data from the 1995/6 Austrian Fertility and Family Survey (FFS) and the 1996 micro-census we constructed standard schedules that determine the transitional patterns by age, sex, and sometimes by marital status for the future. Some of the standard schedules which cannot be derived from the two sources are obtained from alternative data sources of Statistic Austria. From the 1996 microcensus, FFS and Statistic Austria, we also derive summary measures of the base year which provide information on the amount of transitions in the starting year. For the summary measures of the future years, we apply the assumptions of the medium variant as suggested in the latest projections of Statistic Austria (Hanika 2000) for the mean age of giving birth, life expectancy, total fertility by parity, and external migration (cf. table 3). Other parameters, such as marriage, remarriage, cohabiting, divorce, leaving parental home and sex ratio at birth we keep constant over the whole projection period. For a detailed introduction to the methodological issue of the household projection see Appendix A.

Table 3: Assumptions on future changes of summary measures

		1996	2020	2046
Fertility	TFR	1.34	1.50	1.50
	1st birth	0.5482	0.6137	0.6137
	2nd birth	0.3858	0.4319	0.4319
	3rd birth	0.2085	0.2334	0.2334
	4th birth	0.1079	0.1208	0.1208
	5th birth	0.0867	0.0970	0.0970
Life expectancy	Female	80.90	84.0	86.7
	Male	74.70	78.3	81.6
Mean age at child bearing		28.14	30.00	30.00
Immigration	Female	33793	37174	37174
	Male	38930	42826	42826
Emigration	Female	27736	26667	24729
	Male	36536	35128	32574

Our projection results indicate a moderate increase in population size and number of households between 1996 and 2035 (Figure 2a) that is followed by a decrease in both numbers after 2035. Moreover, changes in the number of household are more pronounced than changes in the population size. From Figure 2b, we observe a process of population aging for Austria in the next five decades. The proportion of children will continuously decline so that the number of adults grow faster than total population in 1996-2035 and decreases slower than total population later on. However, among the adults, the share of the elderly is increasing. In particular, the elderly aged 75-84 and above 85 are the group whose share in the population increases the most.

Since the number of households increases faster in 1996-2035 and decrease slower in 2035-2046 than total population, the average household size becomes smaller (Figure 2c). The average household size declines from 2.4 in 1996 to 1.95 in 2035 and 1.94 in 2046. Numbers of smaller households (one-person and two-person households) will continuously increase while numbers of larger households (four- and more person households) will decrease. The number of three-person households will increase in the early years of 1996-2010 before they decrease afterwards. This change mainly reflects our assumption that the total fertility rate will increase from 1.42 to 1.5 in the period of 1996-2020, and stay constant at a level of 1.5 after 2020. Even though the fertility rate will increase up to 2020, changes in age structure will drive the number of three-person household down already starting around 2010.

Population aging also implies that households will age[1], i.e. the age of the household head shifts towards higher ages. In particular Figure 2d clearly shows that the peak of households by age of household heads moves from age 30 in 1996 to age 40 in 2000, age 50 in 2010, age 60 in 2020, age 70 in 2030 and around age 80 in 2046. This is mainly due to aging of the baby boomers who were born in the 1960s.

If we separately look at male and female headed households by age of the household head (Figure 2e and Figure 2f), we in general observe the same trend towards higher ages of the household head. However, we also notice that the peak age of household heads becomes less visible for the future years among male headed households, due to higher male mortality. By 2046, the number of male headed households is almost evenly distributed among the age groups of the late 20s to the early 80s. Regarding female headed households, we observe a fluctuating pattern of the peak age of household heads across time. In general there are two peaks across age for all projection periods; one peak is around age 20 and the other one is around age 70. This pattern reflects the fact that women leave parental home earlier and marry earlier than men which makes the first peak at around age 20. Women also have a longer life expectancy which forms the second peak in the advanced age group. However, there is a third peak in the middle periods and this peak shifts towards older ages. This is mainly due to the effect of aging of the baby boomers. Moreover, for female headed households the peak in the early ages is almost constant across the projection period while the peak in the old age shifts towards older ages. Moreover, except in the very young age group (15-19 years) and the advanced older age group (70+), the number of male headed households is always bigger than the corresponding number of female headed households.

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[1] In some developing countries, where extended family is common, population aging does not necessarily lead to "aging" of household heads. Since most of the parents transfer household title to their son while they get old which keeps the age pattern of household headship rates unchanged. In Austria, transition of household heads between generations is not common, therefore, population aging means "aging" of household heads.

Figure 2g presents a projection of households by household size and distinguishing between the number of adults and children for each household size category. The projections evidence that one and two adult households will experience significant and continuous growth in the future five decades, with all of the growth attributable to households without children. Three adult households increase firstly in 1996-2015 but decrease afterwards. Looking at changes of households by size and by age of the household heads, one can see that the increasing one and two adult households are mainly elderly people. Furthermore, the number of households with children are all in the process of decline except single parents with one or two children for the period of 1996-2005.

5. Projections of transportation demand

A combination of household projections and the cross section composition of transportation demand for 1997 yields the projection of future transportation demand if we neglect any behavioral changes in transportation demand patterns across various demographic compositions. To put it differently, such an exercise highlights the role of changing demographic structures[2] but neglects any changes in transportation demand across various demographic groups.

Our cross-sectional analysis showed that household car ownership and use varies substantially with the age and sex of the householder, with size (particularly for the 1-3 person households), and with some aspects of household type – in particular, one adult households (and among those in particular single parent households) differ from households with two or more adults. Moreover we found that the size effect is partly caused by changes in the age composition across households of various size and the other way around. More specifically, while the difference in car ownership and car use across age is most pronounced among households of size one and two, household size matters most for middle and old aged households.

The household projections demonstrate that the age distribution of householders will become significantly older, household size is likely to shift decisively toward 1 and 2 person households at the expense of large households, and that households without children will account for essentially all of the growth in total numbers of households, i.e. all households with children, except single parent households, will decrease.

To arrive at a projection of car use by various demographic decompositions we combine the results of the household projections with the corresponding cross sectional decomposition of car ownership and car use patterns (Figure 3). For each category of a demographic decomposition we multiply the projected number of households with the car ownership rate and the mean distance driven. We then plot the change in car use patterns for each projection step in comparison to our base period 1996.

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[2] Actually in this study we take into account only a few but not all possible changes in behavior of household formation and dissolution.

As Figure 3 shows, the highest projected car use[3] is obtained if we apply the value of car use per household. On the other hand the lowest projected car use up to 2026 is observed if we base our projections on per capita car use patterns. Obviously the constant per capita projection ignores any compositional changes in the population and may therefore be regarded as the benchmark case with which to compare the alternative projections that take into account changes in various demographic compositions. For instance, if we apply the value of car use per adult we obtain a projection that is located between the per capita and per household projections. These three projection results (that refer to per household, per adult and per capita variables) reflect the trend of the demographic projections (Figure 2.a) together with the car use patterns reported in Table 2. Up to 2046 the number of households will increase the most and the number of adults increases faster than the total population. On the other hand car use is highest if measured per household and lowest if measured on a per capita basis.

If we take into account the age structure of household heads we obtain a projected car use pattern that first increases up to 2020 and decreases thereafter reaching a level of car use in 2046 that lies between the projection results for per capita and per adult car use patterns. This pattern can be explained by the aging of the baby boom (cf. Figure 2.d) which implies a movement along the hump shaped car use pattern by age as depicted in Figure 1.a. A projection that distinguishes between the gender of the household head yields slightly higher values on car use as compared to a projection that considers both genders together. The effect of accounting for sex is to increase projected car use because male-headed households have higher car use then female-headed households (Figure 1b), and the increase in male-headed households is projected to be larger than the increase in female-headed households (Figures 2e and 2f). I.e. male headed households are projected to increase from 2,213,542 households in 1996 up to 2,770,336 households in 2046. The corresponding numbers for female headed households are 1,140,038 for 1996 and 1,448,265 for 2046.

Applying the car use pattern by household size we arrive at a projection of car use in 2046 that is close to the projections that applied a compositional change by the age of the household head. However, during the transitional period from 1996 to 2046 projections based on household size are much lower. This pattern may be explained as follows: According to the demographic projections households of size one and two will gain in the future and those are the households for which we observed the lowest car use variables in our cross-section comparison (cf. Figure 1.c). However, Figure 1.e clearly evidences that there is a pronounced age effect across these smaller households which is neglected if we only aggregate across size and ignore age. Obviously there is not much difference whether we apply a simply household size composition or a more detailed composition that also distinguishes between the number of adults and number of children. In fact, what we may observe is the tradeoff between more adult only households and an increasing share of single parent households. While the former shows a car use pattern that is above those observed for total household size, the latter group's car use pattern is much lower (cf. Figure 1.d). As both of these groups are projected to increase in the

[3] In Figure 3 actual car use, henceforth termed car use only, is measured as the product of the mean distance driven times the car ownership rate.

future their effect might cancel each other and in the end we will arrive at a projected car use pattern that resembles the one for total household size.

We conclude by applying a composition that differentiates between household size and age of household head (cf. Figure 1.e). Up to about 2018 the projected car use lies between the projection results applying a composition by household head and respectively a composition by household size. Thereafter the combined decomposition by age and size falls below each of those both projections. From 2025 onwards the projected car use is even below the numbers obtained for per capita car use patterns and from 2033 onwards the projected value of car use is below the one observed in the starting year 1996. This pattern may be explained by referring to Figure 1.e. The demographic projections imply that the car use pattern in the future can best be described by a vertical movement towards smaller household sizes and a subsequent rightward movement towards older aged households in Figure 1.e. Obviously the combination of both trends works in favor of a decline in total car use that is much more pronounced as compared to only referring to size or age compositional changes separately. Of course these trends may be reversed once we include projections for changing transportation demand across demographic groups. E.g. if elderly households are more likely to own and use their car in the future and given that smaller sized households are more likely to rely on cars as well, the projected car use pattern may stay constant or even increase in the future.

6. Conclusions

Demand patterns for transportation with private vehicles are closely connected to demographic variables, including those reflective of life-cycle stages. We find, as have previous studies, that demand for household transportation varies significantly by different subgroups of the population defined by household characteristics such as age and gender of the householder, size, and age composition. By combining cross-sectional variations in travel behavior by demographic characteristics with a new projection of households in Austria, we illustrate that future compositional changes in the population by living arrangements could substantially influence demand for transportation.

Furthermore, we show that projections are sensitive to the particular type of demographic disaggregation employed. These results suggest that demographic disaggregation has the potential to improve forecasts of future travel demand, but also emphasize the importance of careful choice of variables by which to disaggregate the population.

Demographic changes could be important for at least two reasons in addition to those analyzed here. First, we assume that category-specific car ownership and use rates remain constant. If, however, these rates changed differentially across categories, the effect of compositional changes on aggregate demand could be either exacerbated or dampened. Second, one of the reasons category-specific rates might be expected to change is the likely existence of cohort effects (a demographic variable). For example, as baby boom women age, they are likely to increase the rate of car ownership in the elderly age groups.

Whether our results indicate that compositional changes could have a substantial influence on future travel behavior, relative to the influence of other factors, depends in part on the application. Taking the projection by household age and size as an example, differences from the projection which ignores composition (the constant per capita projection) do not exceed 7%. For an application forecasting aggregate transportation energy use 50 years into the future, a 7% adjustment is inconsequential relative to the large uncertainties driven by income or technological changes. On the other hand, the projection with composition shows a different dynamic which may be important, with demand peaking earlier and then declining, in sharp contrast to the constant per capita projection. In addition, the difference between the two projections is also 4% in the short term (2010). Over this shorter time horizon, a 4% absolute difference in projected demand is likely much more important, for example to judging the difficulty of meeting greenhouse gas emission reduction targets, or for planning for changes in demand for road capacity.

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Tables & Figures

Figure 1a: Mean distance driven and car ownership by age of household head

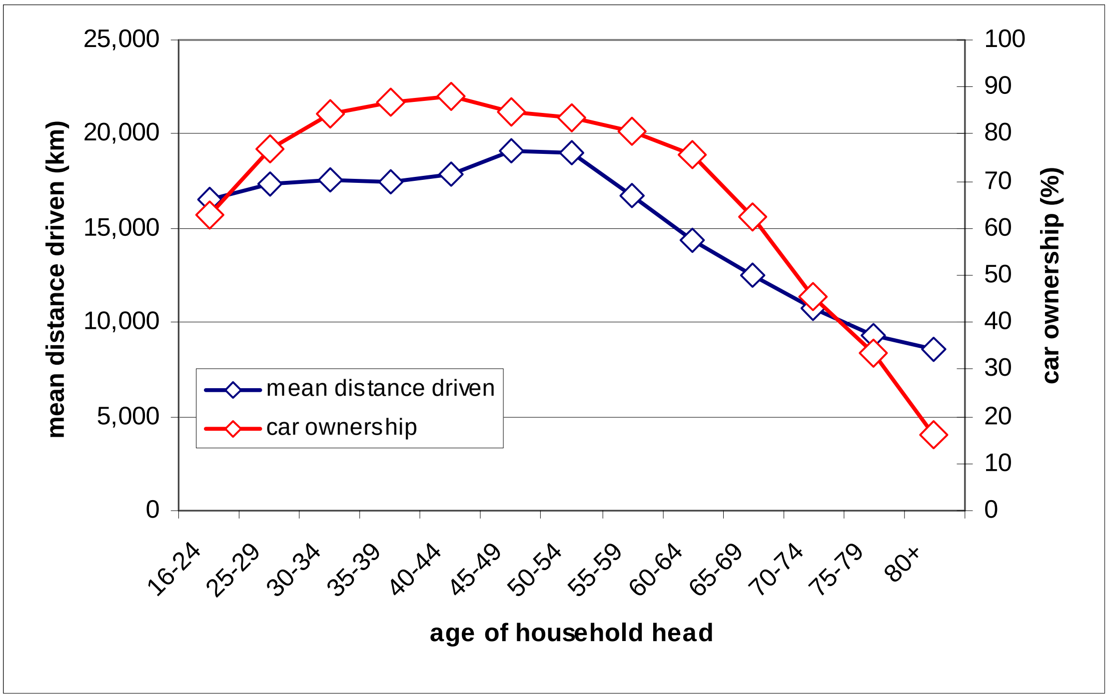


Figure 1b: Mean distance driven and car ownership by age and sex of household head

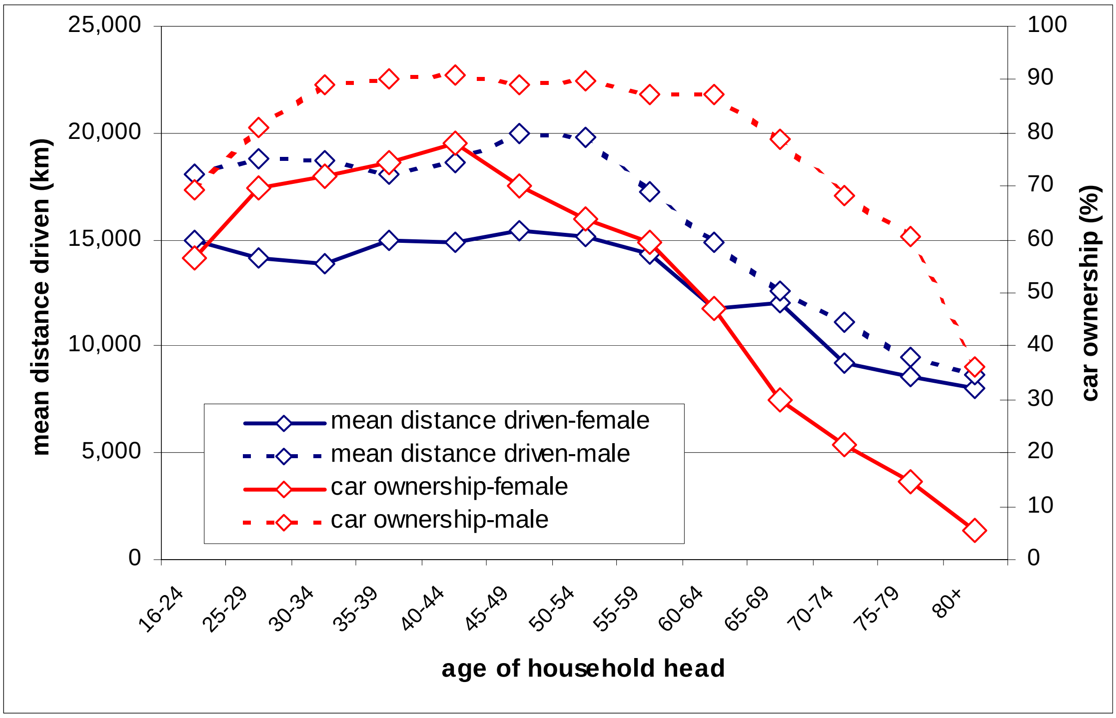


Figure 1c: Mean distance driven and car ownership by household size

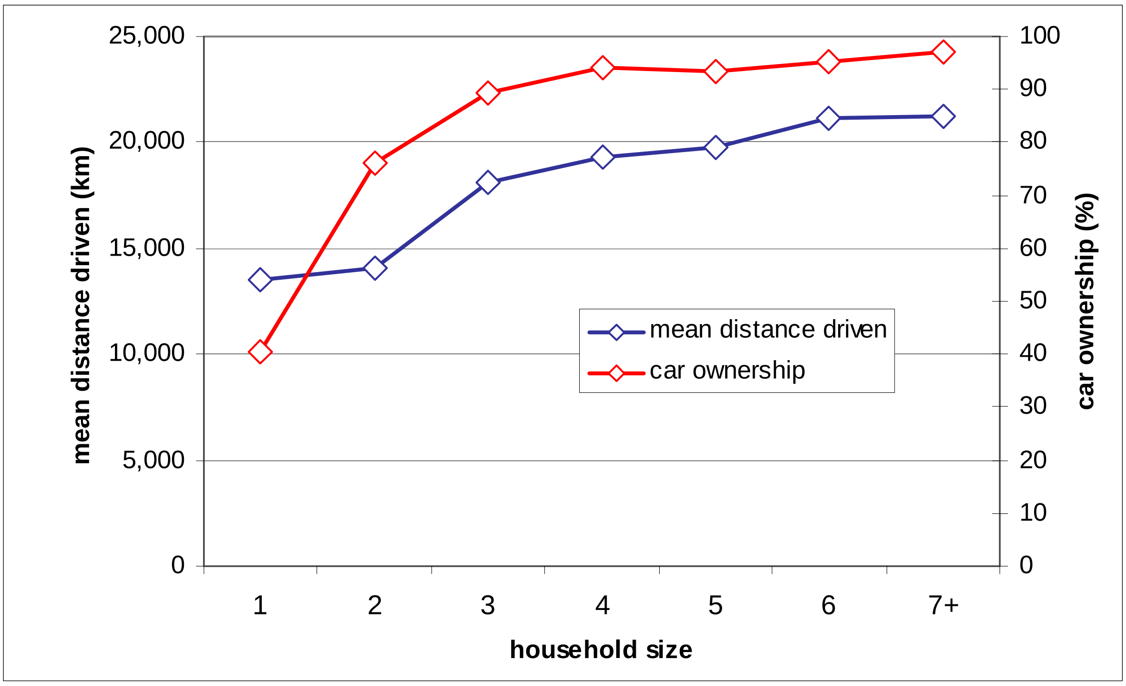


Figure 1d: Mean distance driven and car ownership by household size and number of children

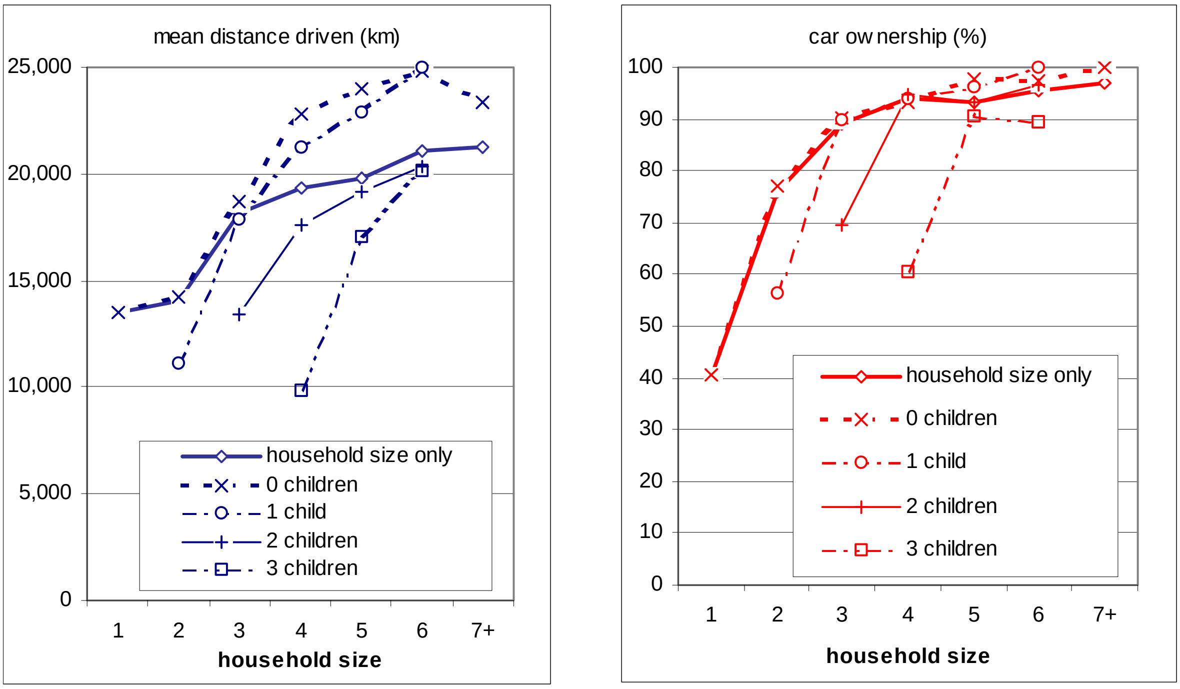
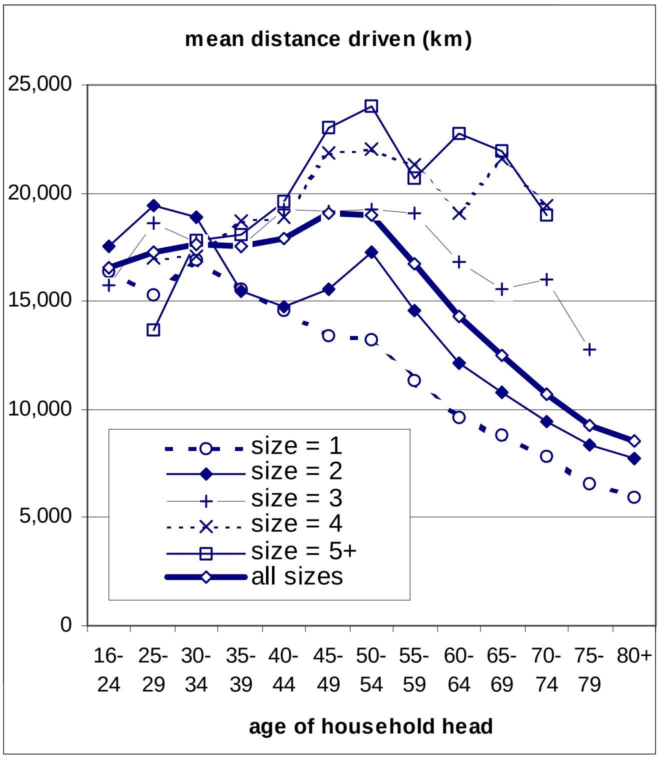


Figure 1e: Mean distance driven and car ownership by age of household head and household size



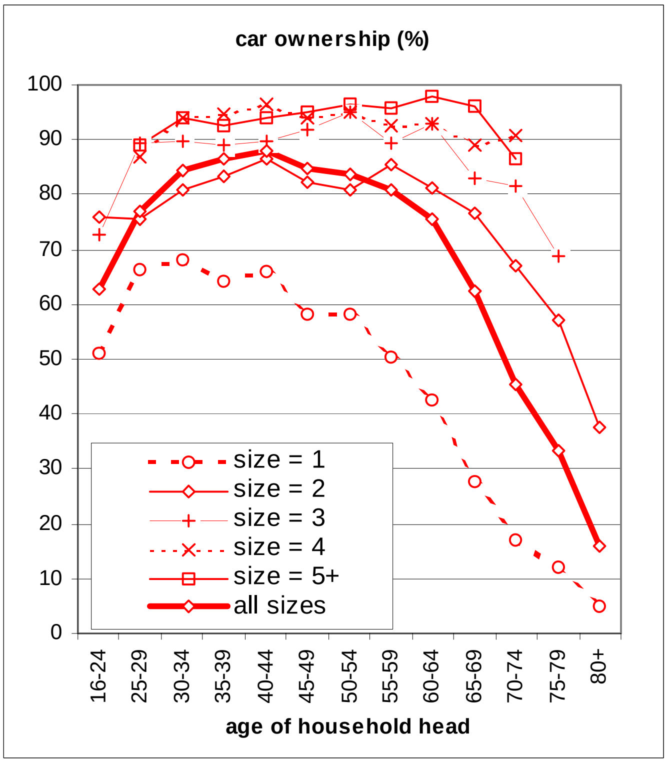


Figure 2a: Population size, number of adults and number of households

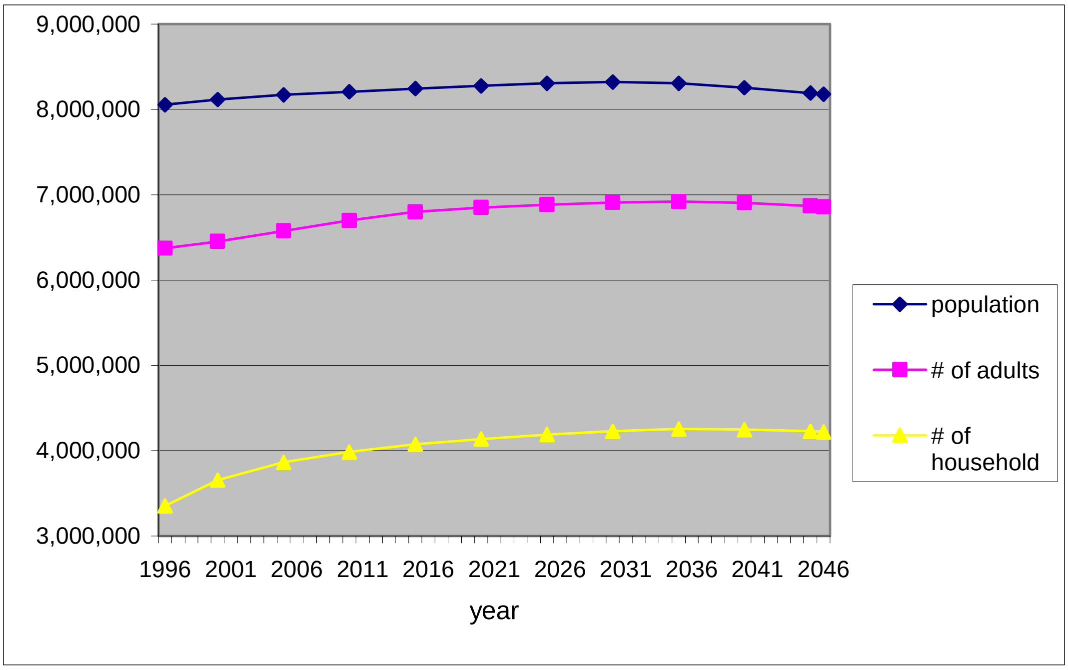


Figure 2b: Changes in the population age structure

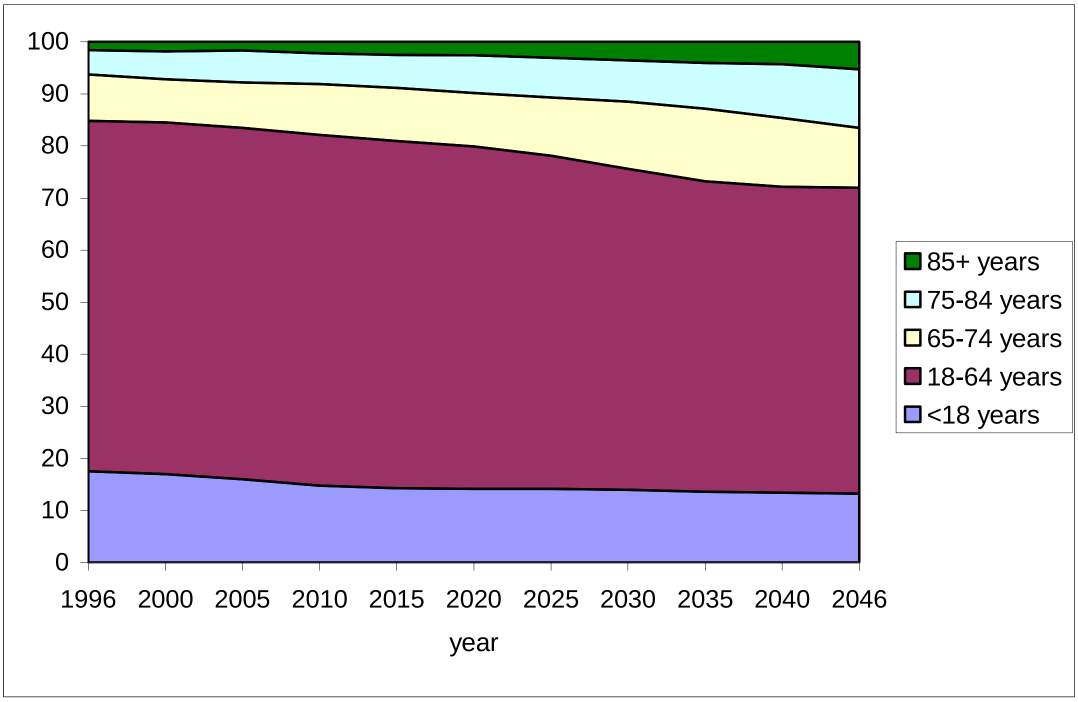
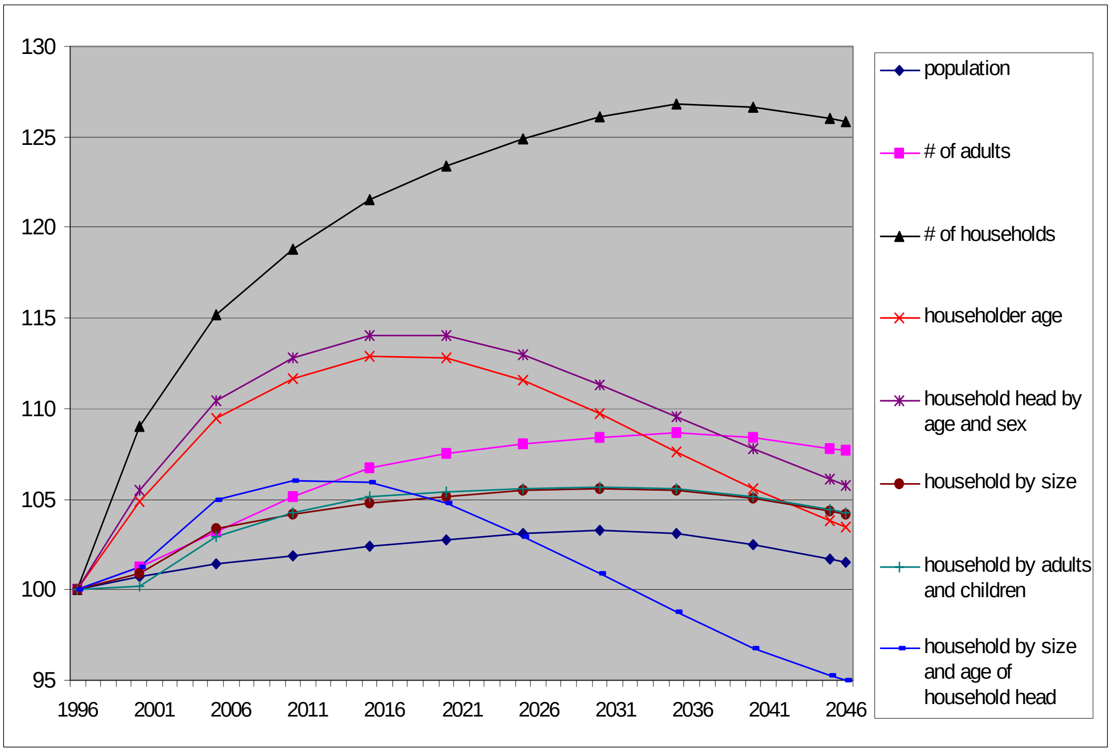


Figure 3: Changes in car use under different population and household decompositions



Appendix A: Methodology of household projection

ProFamy is a software package for a multi-dimensional macro-dynamic model for projecting households and population. In the ProFamy model, the individual is chosen as the basic unit of the projection. The individuals in the starting population are derived from a census or survey. Individuals in the projected population are classified according to 8 dimensions of demographic status: age, sex, marital status, parity, number of children living at home, co-residence with parents, household type (private or collective), and area of residence (rural or urban). Characteristics of the reference person (or household "markers") are applied to derive the distributions by household type and size. Because the model deals with two sexes, children and parents, a harmonic-mean procedure is used to ensure consistency between females and males, and consistency between children and parents. At the end of the projection, the numbers of non-familial members who co-reside with the reference persons is estimated indirectly (Zeng et al., 1997).

<u>Baseline population and status identification</u>

The 1996 Austrian micro-census, which includes a sample of the Austrian population of the order of 64,183 individuals[4], provides the baseline population for our household and population projection. In order to adjust this sample to get the correct total population size by age, sex, and marital status, we need to provide ProFamy with information on the total population in the starting year. The 100% tabulation of the total population (8,054,423) classified by single year of age, sex and marital status is derived by applying the population weights provided in the 1996 microcensus. Table A.1 summarises the individual's statuses as used in our projections.

Table A.1: Individual demographic status identification[5]

Demographic status	**Definition**
Age x	by single year of age, 0 to 95 (the highest age)
Sex s	1 female; 2 male
Marital status m	1 single; 2 married; 3 widowed; 4 divorced; 5 cohabiting[6]
Co-residence with parents k	1 with two parents; 2 with one parent; 3 with no parents; 4 living in collective household
Parity p	0 to 5 (the highest parity)
Co-residence with children c	0 to 5 (the highest parity)
Household type	1 private household; 2 collective household

[4] It should be noted that, there are some individual cases in the micro-census data set containing no information required. Those cases with missing value are excluded from the baseline population. Consequently, 57,030 out of 64,183 are used in the final sample for Profamy. For an accurate household and population projection, an imputation of those cases with missing values would be necessary.
[5] Residence area (rural/urban) could be used as a further individual status identification variable.
[6] Given that the status of cohabiting is not coded in the micro-census statistics of June 1996, we had to determine this status ourselves (see Appendix B).

These informations, as derived from the 1996 microcensus, serve as the input for the sub-program of ProFamy, called BasePop, in order to produce the base population for projections in ProFamy.

Standard schedules

The basic structure of the demographic accounting equation in Profamy is as follows:

number of persons of age $x+1$ with status i at time $t+1$ =
(number of persons of age x with status i at time t) +
(number of entries into status i which occur in the year (t, $t+1$) among persons of age $x+1$ at time $t+1$) –
(number of exits out of status i which occur in the year (t, $t+1$) among persons of age x at time t).

The number of demographic events in year (t, $t+1$) and at ages x or $x+1$ is calculated as the number of persons aged x and at risk of occurrence of the event in the year, multiplied by the projective probability of occurrence of an event that leads to a status transition in the year (t, $t+1$) and at age x or $x+1$ in completed years, fitting in a period-cohort observational plan for analysis and projection[7]. It is obvious that the standard schedules defined by age-, sex-, (sometimes parity-, and marital-status-) specific probabilities (or rates)[8] are extremely important for the projection results.

To derive the standard schedules for the various events we use three sources:

The 1996-1997 Austrian Fertility and Family Survey (FFS) contains detailed information on partnership formation and dissolution, childbearing, leaving parental home, migration, and other events, based on a retrospective investigation of 6120 individuals aged 20-54 during the period December 1995 up to May 1996. Applying the method of survival analysis, we derive the following standard schedules from the FFS data:

(1) Probability of leaving parental home
(2) Transition probability from single to married
(3) Transition probability from single to cohabiting
(4) Transition probability from cohabiting to married
(5) Transition probability from cohabiting to single

[7] Below, when we use the term probability, we always mean probability according to this definition. In this approach, the demographic transitions under study are assumed to depend on some (but not all) of the other statuses at the beginning or the middle of a one-year interval (e.g., giving birth depends on age, parity and marital status of the mother, but does not depend on co-residence with parents). The adoption of the computational strategy in the model, which assumes that births occur throughout the first half and the second half of a year, but other events occur at the middle of the year, will significantly decrease the biases caused by not considering the interfering events while projecting the occurrences of an event.

[8] With regard to the input data, the ProFamy software package allows the standard schedules to be either occurrence/exposure rates or probabilities. If one chooses to use occurrence/exposure rates, the ProFamy model will automatically transform all rates into probabilities. In our case, we transformed all standard schedules, except those for the frequencies of migration, from occurrence/exposure rates into probabilities, before we used them as input into the model.

(6) Transition probability from married to divorced
(7) Transition probability from divorced to cohabiting

Given the small sample size, the FFS data do not allow to construct standard schedules for the transition probability from widowed to cohabiting. For the latter transition probability we therefore assume that it is equal to the transition probability from divorced to cohabiting. A further shortcoming of the FFS data set is the fact that it only includes individuals up to age 54. It is not reasonable to assume that no divorces happen to those aged above 54. To solve this problem we used 1996 age- and sex-specific numbers of divorces from Statistic Austria. Combining these numbers with the number of married couples derived from the 1996 micro-census data set, we calculated the age- and sex-specific divorce rate, and used it in constructing the standard schedule of divorce rates. ProFamy software will automatically calculate the standard schedule for the transition from married to widowed based on the sex-specific mortality schedules and differences of age at marriage between men and women.

Although the FFS data set contains information on fertility, the small sample size again did not permit to use these data to derive standard schedules for fertility. We use the *1996 micro-census data set*, which provides detailed information on births biographies, to construct standard schedules for parity- and age specific fertility schedules.

(1) Single women fertility
(2) Cohabiting women fertility
(3) Divorced women fertility
(4) Married women fertility

It is noteworthy that we set 15 as the starting age of giving birth, and parity 5 as the highest parity. Since the number of births by widowed women is too small in the micro-census we assumed widowed women will not give any birth in our projection. Similarly, the number of births of parity 4 and 5 by single and cohabiting women, and of parity 5 by divorced women are very small and we neglect these births for our projections.

The following standard schedules are provided by *Statistic Austria*:

(1) Probability of survival
(2) Transition probability from divorced to married
(3) Transition probability from widowed to married
(4) Frequency distribution of immigration by age and sex
(5) Frequency distribution of emigration by age and sex

<u>Summary measure</u>

Base year

While standard schedules offer the information on the status transition of the future population characterised by age, sex, and marital status, summary measures provide the assumption of the total amount of all transitions in the future years. All these assumptions should be based on the information from the base year and also start from the base year.

Basically, we obtain information for the summary measures of the base year from the three sources of deriving standard schedules mentioned above.

(1) From the FFS we calculate the proportion of those who eventually leave parental home, the propensity of first marriages, the mean age at 1st marriage, the propensity from married to divorced, the propensity from single to cohabiting, the propensity from cohabiting to married, the propensity from cohabiting to single, and the propensity from divorced to cohabiting.
(2) From the 1996 micro-census data we derive the ratio of the non-married women fertility to the married women fertility.
(3) From Statistics Austria we obtain life expectancy at birth, total fertility rate, number of emigrants and immigrants, sex ratio at birth, propensity of remarriage by the widowed, and propensity of remarriage by the divorced. Since we lack proper data to estimate the propensity of widowed to cohabiting, we assume that it is the same as the propensity of widowed to marrying.

The total fertility rate by parity derived from the micro-census data are the results of the combination of different cohorts. It is not adequate to use it to represent the distribution of total fertility rate by parities. Therefore, we obtained data on total fertility by parities of the latest cohorts of Austrian women born in 1946-1950 who have mostly experienced the events of childbearing (Hanika, 1996), and use it to represent the distribution of the total fertility rate by parities. Moreover, we assume no births given by widowed women.

Numbers for external migrants are obtained from Statistic Austria for the year 1998. We assume that there is no significant change in terms of external migrants between 1996 and 1998 and apply these numbers to our base population of 1996.

From the base population ProFamy automatically calculates the proportion of persons living in collective household by age and sex among those who are not living with children or parents, and the average number of other relatives and non-relatives of different households by size.

Future changes

For the women's mean age at giving birth, the total fertility rate, the life expectancy at birth and the number of external migration we apply the assumptions of the medium variant as suggested in the latest projections of Statistic Austria.

The mean age at giving birth is assumed to increase - following a logistic curve - from 28.14 years in 1996 to 30 years in 2030 and it is kept constant at 30 years from 2030 onwards till 2046.

For total fertility rate three assumptions are stated:

(1) The medium variant assumption assumes total fertility rate will increase - following a logistic curve - from 1.42 in 1996 to 1.5 by year 2020, and will keep at a level of 1.5 till the year 2046.
(2) The low variant assumption assumes total fertility rate will linearly decrease to 1.2 by the year 2020 and keep constant thereafter.
(3) The high variant assumption assumes total fertility rate will linearly increase to 1.8 by the year 2020, and keep constant thereafter.

For life expectancy at birth, also three assumptions are stated:
(1) The medium variant assumes an increase - that follows a logistic curve - in the period between 1996 and 2030 from 74.7 to 80 years for males and from 80.9 to 85.5 years for females. For the period between 2030 and 2050, life expectancy is assumed to increase from 80 to 82.5 years for males and from 85.5 to 87 years for females.
(2) The low variant assumes a linear increase from 74.7 to 78.0 years for males and 80.9 to 84 years for females in the period between 1996 to 2030. From 2030 onwards, life expectancy is assumed to stay constant for both sexes.
(3) The high variant assumes that life expectancy at birth between 1996 and 2030 will increase linearly to 82 years for males and 87 years for females and further linearly increases up to 86 years for males and 90 years for females until 2050.

The external migration is derived from the population projections by Statistic Austria.

Table A.2: Immigration and Emigration numbers for 1998-2050

Year	Immigrants	Emigrants	Year	immigrants	emigrants	Year	immigrants	emigrants
1998	72,723	64,272	2016	79,716	62,894	2034	80,000	58,858
1999	86,710	66,923	2017	79,818	62,638	2035	80,000	58,717
2000	77,242	65,510	2018	79,895	62,363	2036	80,000	58,555
2001	77,280	65,311	2019	79,956	62,071	2037	80,000	58,427
2002	77,327	65,136	2020	80,000	61,795	2038	80,000	58,283
2003	77,388	64,915	2021	80,000	61,533	2039	80,000	58,156
2004	77,468	64,741	2022	80,000	61,286	2040	80,000	58,043
2005	77,572	64,551	2023	80,000	61,039	2041	80,000	57,913
2006	77,705	64,385	2024	80,000	60,797	2042	80,000	57,803
2007	77,867	64,220	2025	80,000	60,561	2043	80,000	57,669
2008	78,063	64,078	2026	80,000	60,327	2044	80,000	57,549
2009	78,289	63,949	2027	80,000	60,109	2045	80,000	57,420
2010	78,531	63,839	2028	80,000	59,887	2046	80,000	57,303
2011	78,779	63,714	2029	80,000	59,719	2047	80,000	57,156
2012	79,019	63,590	2030	80,000	59,508	2048	80,000	57,035
2013	79,240	63,469	2031	80,000	59,349	2049	80,000	56,899
2014	79,430	63,305	2032	80,000	59,168	2050	80,000	56,767
2015	79,590	63,108	2033	80,000	59,018			

All other summary measures are assumed to be constant in the future. By applying this set of assumptions, we actually assume little changes in the behaviour of household formation and dissolution except that changes in women's mean age at giving birth and total fertility rate will to a certain degree affect the timing and volume of household expansion by childbearing.

Appendix B: Determination of cohabiting status

We use information on the marital status variable together with the following information to determine the cohabiting status:

(1) household number -- people cohabiting are coded in the same household
(2) age -- only adults (aged above 15) are considered for cohabiting. The age difference of those cohabiting is put within a 10 years range, which may underestimate the prevalence of cohabiting to a certain extent.
(3) the marital status
(4) gender -- only opposite gender cohabiting is considered
(5) position in the household -- household head or respectively the relationships to the household head
(6) a variable (b5kz1) which indicates partnership relationship of household members while cohabiting partners are stated as other persons of household heads

Consequently, 8 types of cohabitation of two adults that live in the same household, and have different gender are derived:

(1) one is head, one is spouse; one is married, one is non-married
(2) one is head, one is spouse; both are non-married
(3) one is head, one is other person who states to be a partner of the household head; no spouse is present in the household
(4) one is coded as child, one is coded as "other person"; one is married, one is non-married; age difference within a range of 10 years; with or without information on the variable "b5kz1", given that "b5kz1" is not completely coded
(5) one is coded as child, one is "other person"; both are non-married; age difference within a range of 10 years; with or without information on the variable "b5kz1"
(6) both are coded as "parents", and at least one is non-married
(7) one is parent, one is other person, at least one is non-married, with information provided by "b5kz1"
(8) two other persons, at least one is non-married, with information on the variable b5kz1.