# Demographic composition and projections



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## Abstract

Understanding the factors driving demand for transportation in industrialised countries is important in addressing a range of environmental issues. Previous work has identified demographic factors as important influences on demand, in addition to economic factors. While some studies applied a detailed demographic composition to analyse past developments of transportation demand, or estimated parameters based on models that include demographic variables, projections for the future have never accounted for future compositional changes in the population. In this paper, we combine cross-sectional analysis of car use in Austria with detailed household projections to explore the sensitivity of projections of car use to the specific type of demographic disaggregation employed. We find that particular demographic characteristics of households can have important effects on aggregate demand through the combined effect of differences in demand across different types of households, and changes in the future composition of the population by household type. For example, the highest projected car use—an increase of about 20 per cent between 1996 and 2046—is obtained if we apply the value of car use per household to the projected numbers of households. However, if we apply a composition that differentiates households by size, age and sex of the household head, car use is projected to increase by less than 3 per cent during the same time period. These findings suggest that the inclusion of demographic factors in transportation demand modelling should extend beyond their use in historical decompositions and as controls in model parameter estimation to explicit consideration of future demographic changes.

1 This paper was partly written while Jiang Leiwen and Brian C. O'Neill were visiting the Max Planck Institute for Demographic Research in autumn 2000 and in winter 2002. The authors are grateful for the help provided by Zeng Yi and Wang Zhenglian in applying the household projection program ProFamy and for comments and suggestions by participants and in particular by the discussant Anna Babette Wils at the session on 'Population-Environment in Urban Settings' at the PAA 2002 meeting in Atlanta. For language editing, we would like to thank Michael Garrett, Susann Backer and Werner Richter. We are especially grateful to three anonymous referees who essentially contributed to improving both the contents and the exposition of the paper.

2 A large part of this work was undertaken while the first author was working at the Max Planck Institute for Demographic Research, Rostock. The views expressed in this paper are the authors' views and do not necessarily reflect those of the Max Planck Institute for Demographic Research.

## 1 Introduction

The economic model for car ownership and car use underlies most of the empirical specifications in research on travel demand (deJong 1990). Non-economic factors, including demographic characteristics of individuals and households, have received less attention but have been found to be important. Several studies have shown that, even after correcting for economic variables such as income, demographic variables such as sex and age of the householder[3], household size, and number of adults vs. children are significant determinants of travel behaviour (see Johansson-Stenman 2002 and Carlsson-Kanyama and Linden 1999 for the case of Sweden; Pucher et al. 1998 and O'Neill and Chen 2002 for the U.S.; Karlaftis and Golias 2002 for the case of Greece).

In addition to the consideration of separate demographic variables, the life cycle concept has been used to capture 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, Bjorner 1999).

Despite this attention at the household level, little work has focused on quantifying the role that shifts in population composition over time might play in explaining past changes in aggregate demand, or in predicting future changes. O'Neill and Chen (2002) use a standardisation procedure to conclude that changes in household size, age, and composition in the U.S. over the past several decades have probably had a substantial influence on aggregate demand for direct energy use by households. They also project the effect on future travel demand of shifts in population distribution by household size and age, based on a simple household projection. Buettner and Grubler (1995) point out that sex-specific cohort effects on car ownership in Germany are likely to be quite significant and will influence future travel demand as populations age. Spain (1997) finds a similar pattern in the U.S., where far more baby boom women hold driver's licences than the current generation of elderly women, indicating an increasing travel demand in elderly age groups for the future.

However, these studies either simply suggest particular demographic variables that may be important in projections, or make transportation projections in the absence of detailed household projections. In this paper, we go beyond previous work by combining cross-sectional analysis of car use in Austria with detailed household projections. This approach raises additional methodological questions, because it may be that some characteristics that are important in explaining

3 Hereafter, we use "household age" to mean the age of the household head. Note that cohorts of households defined using this definition of age do not necessarily constitute an identical group of households over time, since reorganisations of membership can add or subtract households from a cohort.

cross-sectional variation in travel behaviour are not important in projecting future demand.[4]

We are aware that our analysis only presents a partial view on expected travel demand since we ignore possible behavioural and economic changes. However since demographic composition is an important aspect of travel demand our paper should be regarded as a first attempt to test the importance of future demographic changes to travel demand using a sophisticated household projection. Hence, our focus is on the need to go beyond simple household and population based projections.

Our study is divided into three steps. We start with a descriptive analysis of the demographic composition of car use in Austria in 1997. We then 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. Finally, we combine car use patterns in 1997 (as decomposed by selected demographic characteristics) with future changes in these demographic compositions.

## 2 Data

The present study is based on the Austrian micro-census (a quarterly and representative household survey of 1% of all Austrian dwellings) from June 1996 and June 1997. Each survey provides a core questionnaire on household demographic characteristics such as total household size, number of children, age, gender, marital status, education and working status of the household head plus housing conditions of the household. The sample size is in the order of approximately 30,000 dwellings, but each quarter an eighth of all addresses is replaced.

In the particular case of the micro-census of June 1996 and that of June 1997, the survey consisted of 23,174 and 22,648 unweighted valid cases; respectively.[5] The June 1996 survey includes an additional questionnaire on birth biographies. For this reason it was chosen as the base population for conducting the household projection described below. In addition, part of the input necessary for the projection was derived from the Austrian Family and Fertility Survey conducted in 1995–96 (Doblhammer et al. 1997). For the analysis of private car use, we use the June 1997 micro-census, which included information on energy use in households and private car use. Based on these data it is possible to reconstruct, in part, the travel behaviour of private households concerning their first two cars. In particular, the following characteristics can be defined: (1) car ownership and (2) how many kilometres

4 This could result if the population composition is not going to shift across demographic categories that may be important in explaining variation in transportation behaviour (e. g., even if small households travel much less than large ones, projections ignoring this difference will not be subject to aggregation error if the proportion of large to small households remains constant in the future).

5 A summary of the June 1996 survey is given in Hanika (1999); for a more detailed description of the June 1997 survey, see Statistik Austria (1998).

households drove with their first and, if applicable, 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 relatively unproblematic as only 6% of car owners reported owning more than two cars.[6] What may be more problematic is total distance driven since this was only self-assessed.

## 3 Demographic composition of car use

To analyse the cross-sectional patterns of car use, we categorise households according to five compositional variables, or combinations of variables[7]: (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 these five compositions, we next calculate the mean distance driven by households within each category of the compositional variable. Calculations are based only on those households that recorded a positive travel distance 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 18–24, 25–29, etc. and who report a non-zero distance travelled in the past year. Since the number of households that recorded a positive distance is a subset (about 90%) of those households owning a car, we calculate car ownership across the various levels of each composition in a second step. The results of these calculations are documented in Prskawetz et al. (2002). In the following we only summarise the most important effects.[8]

Car ownership and car use show a very similar pattern by age *of household head*: increasing up to the late middle ages and declining thereafter. These age patterns are driven by several factors, including income, labour force participation, and household size, all of which show a similar pattern. In addition, cohort effects may be involved. Today's middle-aged and young generations have grown up in times when car ownership was the norm rather than the exception. As these cohorts age, we may expect to see a disproportionate increase in car ownership and car use patterns among the older generation. Gender differences in car ownership and car use patterns persist across all ages.

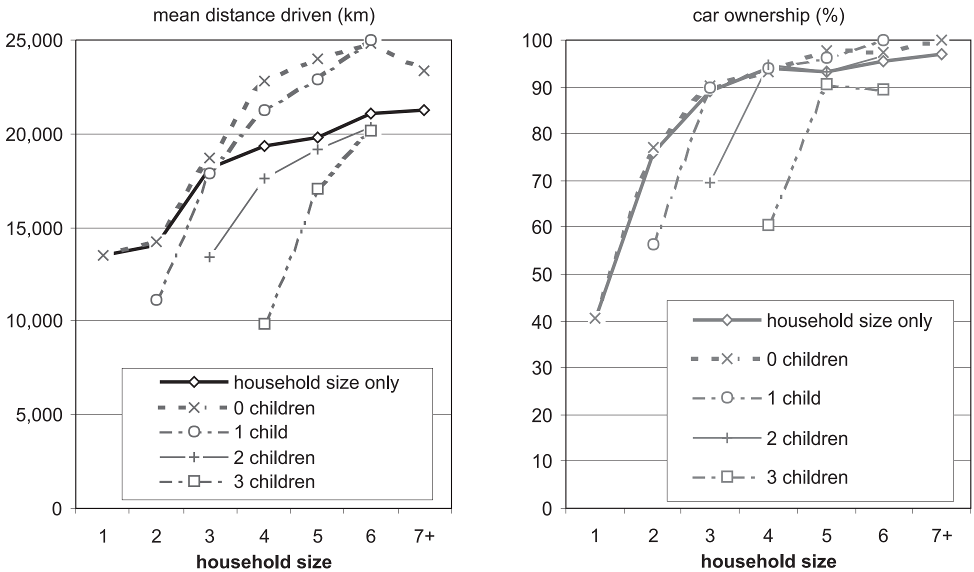
6 As noted by one of the referees, the fact that information is only available for the first two cars may cause a problem if the proportion of households with more than two cars will increase in the future. However, as also noted by the referee we rather argue that the decrease in household size may possibly lessen this problem.

7 The selection of demographic variables is based on findings in the literature and our previous work (Ewert and Prskawetz 2001, Borgoni et al. 2002) which identifies a set of variables to be most significant in explaining car ownership and car use.

8 A comparison across the proportions of total variance accounted for by each decomposition shows that age and size considered independently are almost equally effective in explaining total variance, while age and size together provide the best combination of variables among the models tested (see Appendix, Table A1).

*Household size* positively affects car ownership and car use. Part of the household size effect reflects an age effect. Smaller households are more likely to be headed by younger and older people (rather than by middle-aged ones) and these are the age groups for which both car ownership and use are the lowest.

**Figure 1a:**
**Mean distance driven and car ownership by household size and number of children, 1997**




Household size may be too crude a measure since it aggregates households of the same size, independent of the age of household members. A three-person household may either consist of three adults, two adults and one child, or one adult and two children, and each of these combinations might be expected to have very different transportation demands.[9] Figure 1a represents a composition of car ownership and car use that distinguishes between *adults and children*. From these figures we may draw the following conclusions: Firstly, adult-only households show the highest rates of car use and ownership across all household sizes. Secondly, within a given household size, car ownership is insensitive to the composition of the household except for the difference between 1-adult and 2+-adult households (i. e., for households of size two, three and four, car ownership is substantially lower if there is only one adult in the household). Thirdly, car use—in contrast to car ownership—is sensitive to household composition. Single parent households have the lowest car use within each household size, but car use is clearly affected by shifting the composition within a given household away from children and toward more adults.

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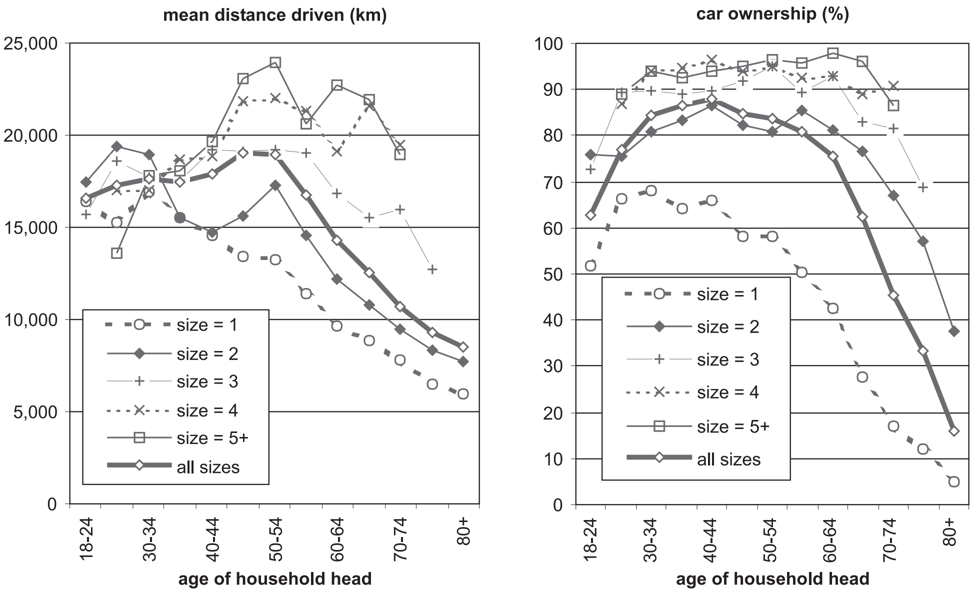
9 We use age 18, when individuals can obtain a driving licence in Austria, as the age that distinguishes between adults and children.

**Figure 1b:**
**Mean distance driven and car ownership by age of household head and household size, 1997**




Our results indicate a strong correlation between age of the household head and household size. Considering car use and car ownership patterns across *age and household size* (Figure 1b) we find 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 or alternatively very old age and secondly, that these households are more likely to be composed of two generations. In the case of multi-generation households, the age pattern of car ownership and car use reflects the mix of the transportation demand of several generations. In case of single-adult households (more prevalent among smaller household sizes), the age pattern of car use and car ownership is tied to the demand pattern of only one generation. Seen from an alternative perspective, Figure 1b also shows that the difference in transportation demand between household sizes varies across the age of the household head. For middle and particularly older age groups, the difference in transportation demand between household sizes is most pronounced.

Summing up our descriptive findings, given that we are likely to observe a tendency towards smaller sized households and an ageing population in the future (see section 4), a composition by age as well as household size seems to be appropriate for long term projections of transportation demand.

## 4 Household projections

To understand the influence of key demographic factors on car use in the long term, it is important to apply population and household projections that can provide detailed information on changes in demographic determinants in the future. Previous projections of energy use incorporating demographic factors have focused mainly on population size. In those cases in which household characteristics were considered, the household projections have been produced using the well-known "household headship rate method". The headship rate method involves extrapolating proportions of household heads in population categories defined by certain combinations of age, sex, and possibly marital status. The headship rate projections are combined with an independent projection of the population by age and sex to produce a projection of households broken down by demographic characteristics of the head of the household. Because it is easy to apply and its data demands are modest, household projection models over the past few decades have been predominantly of the headship rate type (e. g., US Bureau of the Census 1996). However, headship rate models suffer from several important limitations (see Prskawetz et al. 2002, section 4).

We therefore apply a dynamic population and household projection methodology developed by Zeng et al. (1997a, 1997b). Their "proFamy" model extends Bongaarts's nuclear status life table model (Bongaarts 1987) to produce consistent projections of population and households. This approach is attractive in that it allows for direct specification of demographic rates, requires data only from conventional sources, and produces a wealth of detailed output on projected household types.

We conducted a dynamic household and population projection for Austria for the period 1996–2046 (for a detailed description of the data and methodology, see Prskawetz et al. 2002 Appendix A). We derived the baseline population for running ProFamy from the 1996 micro-census data, and, based primarily on data from the 1995–96 Austrian Fertility and Family Survey (FFS) and the 1996 micro-census, constructed standard schedules that determine future transitional patterns between various living arrangements by age, sex, and marital status. Our assumptions about changes in future demographic rates such as total fertility by birth order, life expectancy, mean age at childbearing and external migration (cf. Table 1) were adopted from the projections of Statistics Austria (Hanika 2000). Other parameters, such as rates of marriage, remarriage, cohabiting, divorce, leaving the parental home and sex ratio at birth were maintained at current levels over the whole projection period since we lack any information on possible future scenarios of those parameters. The results of the household projection are documented in Prskawetz et al. 2002. In the following we only summarise the most important effects.

**Table 1:**
**Assumptions on future changes of summary measures**

| | | 1996 | 2020 | 2046 |
|---|---|---|---|---|
| **Fertility** | TFR | 1.34 | 1.50 | 1.50 |
| | 1st birth | 0.55 | 0.61 | 0.61 |
| | 2nd birth | 0.39 | 0.43 | 0.43 |
| | 3rd birth | 0.21 | 0.23 | 0.23 |
| | 4th birth | 0.11 | 0.12 | 0.12 |
| | 5th birth | 0.09 | 0.10 | 0.10 |
| **Life expectancy** | Female | 80.90 | 84.0 | 86.7 |
| | Male | 74.70 | 78.3 | 81.6 |
| **Mean age at childbearing** | | 28.14 | 30.00 | 30.00 |
| **Immigration** | Female | 33,793 | 37,174 | 37,174 |
| | Male | 38,930 | 42,826 | 42,826 |
| **Emigration** | Female | 27,736 | 26,667 | 24,729 |
| | Male | 36,536 | 35,128 | 32,574 |

**Figure 2a:**
**Projected population size, number of adults and number of households**

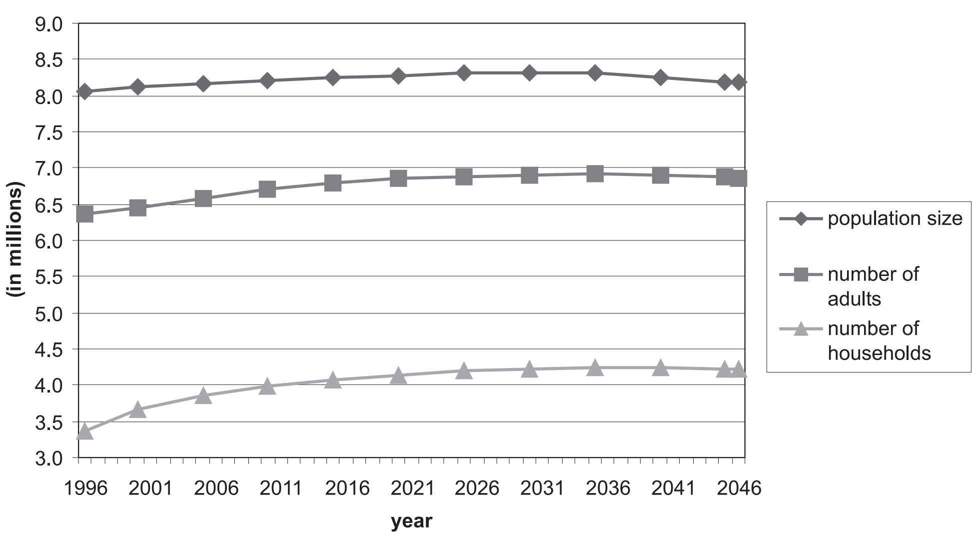


**Figure 2b:**
**Projected age structure of the population**

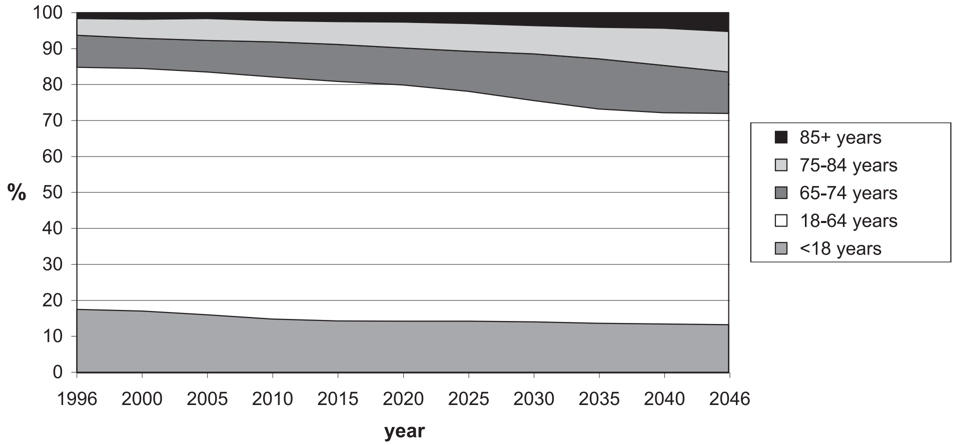
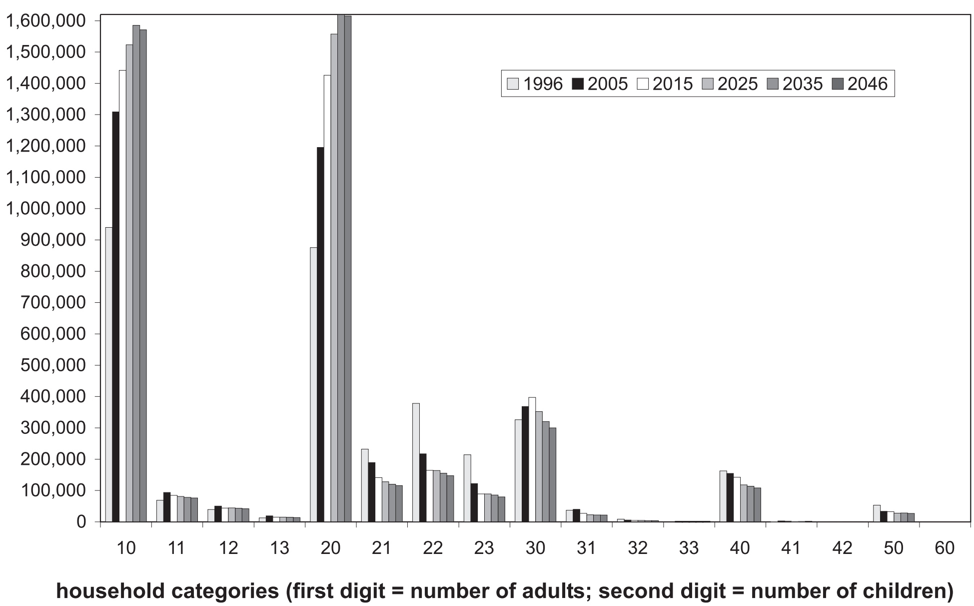



**Figure 2c:**
**Projected number of households by number of adults and children**




Our projection results indicate a moderate increase in population size and number of households between 1996 and 2035 (Figure 2.a), followed by a decrease for both after 2035. Moreover, changes in the number of households will be more pronounced than changes in the population size. In addition to population shrinkage, we observe a process of population ageing for Austria over the next five decades (Figure 2.b). The proportion of children will continuously decline and the number of adults will grow faster than the total population in 1996–2035 and decrease slower than the total population later on. However, among adults, the percentage of the elderly will increase. In particular, it is the 75–84 and > 85 age groups whose population share will increase the most. Population ageing also implies that households will age[10] (i. e. the age of the household head will increase).

Given that the number of households is projected to increase faster than the total population in 1996–2035 and to decrease more slowly in 2035–2046, the average household size is expected to decrease. The figure will decline 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 persons) will decrease.

Figure 2c presents a projection of households by household size and distinguishes between the number of adults and children for each household size category. The projections show that one- and two-adult households will experience significant and continuous growth over the next five decades, with all of the growth attributable to households without children. Three-adult households will increase initially in 1996–2015 but decrease afterwards.

Taking into account the uncertainty of future demographic parameters, we also present household projections for alternative developments of mortality, fertility and union dissolution patterns (see Appendix). From these alternative household projections we may conclude that alternative fertility scenarios will primarily affect the total population size and the share of households of size two and more. Alternative mortality scenarios will have a strong impact on the projected number of adults. Compared to the fertility scenarios, the impact of mortality changes on the distribution of households by age of household head and size of household will be less pronounced. Changes in the dissolution patterns will mainly influence the projected number of households and will have a pronounced impact on the distribution of households by size. Overall, alternative demographic scenarios will not reverse the trends towards older and smaller-sized households. However, a composition of households by size is more sensitive to demographic scenarios as compared to a composition of households by age of the household head.

[10] In some developing countries, where the extended family is common, population ageing does not necessarily lead to “ageing” of household heads. Since most parents transfer household titles to their sons when they get old, the age pattern of household headship rates stays unchanged. In Austria, transition of household heads between generations is not common, therefore, population ageing means “ageing” of household heads.

## 5 Projections of transportation demand

Our cross-sectional analysis shows that household car ownership and use varies substantially with the age and sex of the householder as well as with household size (particularly for the one- to three-person households), and also with some aspects of household composition. One-adult households, especially single parent households, differ from households with two or more adults. Moreover, we found that the size effect is partly caused by changes in age composition across households of various sizes and vice versa. 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 is most significant for middle and old aged households.

The household projections demonstrate that concerning age distribution, households will become significantly older, household size is likely to shift decisively toward one- and two-person households at the expense of large households. Households without children will account for essentially all of the growth in total numbers of households.

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. 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 neglect any behavioural changes in transportation demand patterns across various demographic compositions. In other words, this exercise highlights the role of changing demographic structures[11] but neglects any changes in transportation demand across various demographic groups.

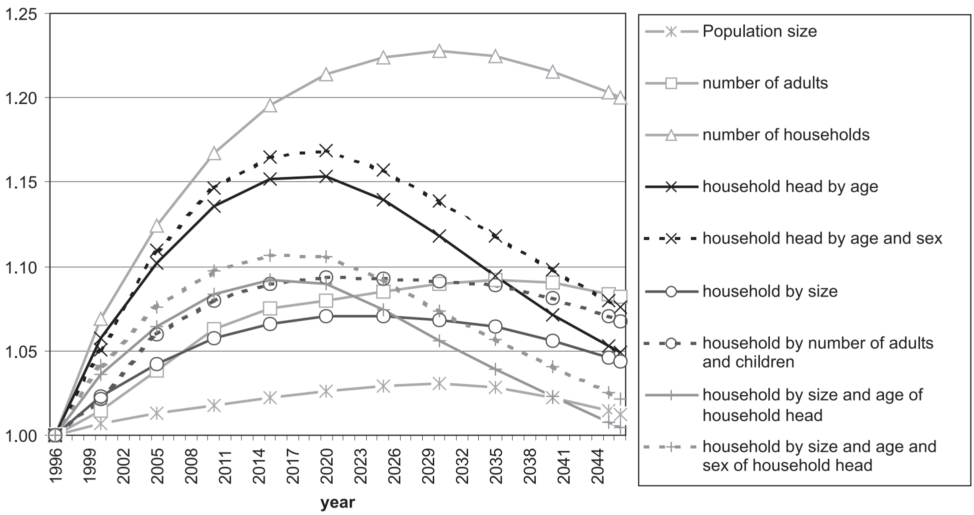
### 5.1 Change in car use under different demographic compositions; medium variant of the household projections

In our first step, we apply the medium variant of the household projections and plot the change in car use patterns relative to 1996 for each projection step and each demographic composition (Figure 3). To interpret these results, it is helpful to begin with the projection based on constant per capita car use multiplied by projected population size. This projection ignores any compositional changes in the population and may therefore be regarded as the benchmark for comparison of alternative projections that take into account a compositional change of some kind (e. g., household size or age of household head). The degree to which these alternative projections differ from the benchmark can be taken as an indicator of the importance of accounting for the compositional variable used in the alternative projection. The effect of adding additional compositional variables (such as adding gender to age) can be measured

11 Actually in this study we take into account only a few but not all possible changes in the behaviour of household formation and dissolution.

by examining whether projections incorporating both variables differ substantially from projections with just the primary variable.

**Figure 3:**
**Change in car use under different demographic compositions; medium variant of the household projections**




We examine two general groups of alternative projections: (a) those that take age composition (and additional variables) into account, and (b) those that take household size (and additional variables) into account. Accounting for the age structure of household heads, we obtain a projected car use pattern that is substantially different in level and pattern from the benchmark projection, namely that car use will increase until 2020 to a level about 12% higher than the benchmark and then decrease to end up about 4% higher in 2046. This pattern can be explained by the ageing of the baby boom generation which implies a movement along the "hump-shaped" car use pattern by age—an effect that is missed by the constant per capita benchmark projection. Note that a simpler means of capturing age effects—(a projection based on number of adults multiplied by per adult car use) is not able to fully capture this age effect. While it projects greater car use than the benchmark scenario, due to the faster growth of numbers of adults as compared to total population, it treats all adults as a homogenous group and misses the fact that most of the growth in adults before 2020 will be in age categories with relatively high car use, while growth thereafter will increasingly shift to older age categories with relatively low car use.

Considering the gender of the household head in addition to age yields a slightly higher projected car use compared to the projection based on age alone. This increase is due to the fact that male-headed households have a higher car use than female-headed households. However the effect is small: car use is never more than 3% higher when gender is taken into account in addition to age.

Accounting for household size alone yields a projection that follows the general trend of the benchmark case but peaks about 4% higher in 2025. This result is driven by the shift toward smaller household sizes: while smaller households have lower car use than larger households, the increase in the number of smaller households is greater than the decrease in the number of larger households, more than compensating for this effect and leading to a net increase in aggregate car use.[12] A simpler means of accounting for household size applied in previous studies is to multiply the projected number of households by the average per household car use. The projected number of households implicitly takes into account changes in average household size, since it is equal to the population size divided by average household size. Figure 3 shows that this approach yields the highest of all the projections, peaking about 20% higher than the benchmark case in 2030. The result is driven by the fact that this method accounts for shifts in household size in the demographic projection, but does not account for the fact that smaller households have lower car use; it applies constant car use per household throughout the projection.

When household composition, defined as number of adults versus children, is added to household size, projected car use increases by just a few percent. This relatively weak influence may be the result of two offsetting effects: more adult-only households, exerting upward pressure on car use rates, and an increasing share of single-parent households, exerting downward pressure on car use.

We conclude by applying a composition that differentiates between household size and age of household head combined . This projection yields results that are substantially different in both pattern and level from the projections accounting for each variable alone. Relative to the projection incorporating age alone, car use is lower by up to 7%. The age-only projection does not account for the fact that the shift toward older households will also involve a shift toward smaller households with lower car use. Relative to the projection incorporating size alone, the projection incorporating age + size is higher through 2026 and lower thereafter. The size-only projection does not account for the baby-boom driven age effect which drives car use first higher, and then lower, than it otherwise would be. Adding gender of the household head in addition to the age of the household head and the size of the household yields slightly higher car use but does not affect the general shape of the projected car use pattern.

Taken together, these results imply that accounting for both age and size of households is warranted in projecting future car use. Adding gender of the householder and the adult/children composition of households has less effect. In addition, simple means of accounting for age and size such as using number of adults and number of households are insufficient to capture these demographic effects.

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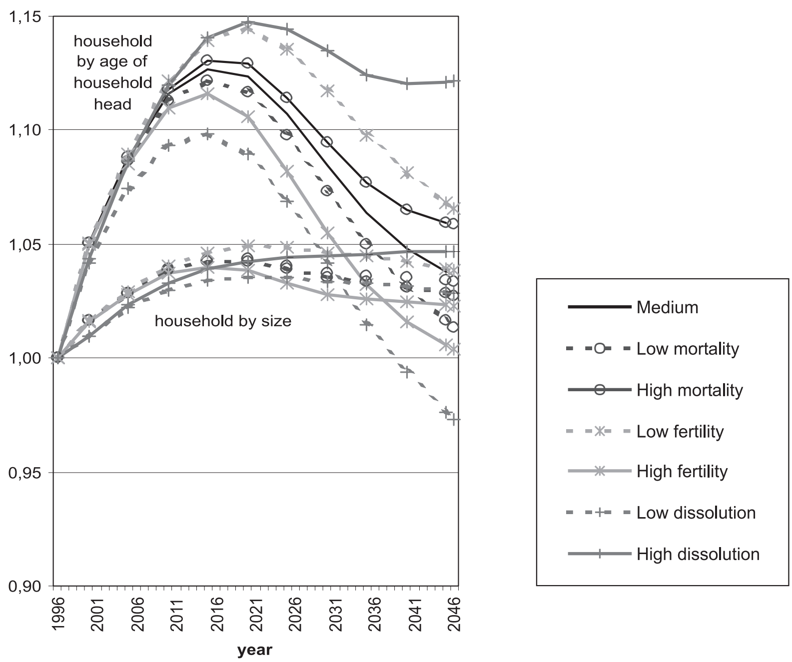
12 Alternatively, the effect can be explained by the fact that smaller households have larger per capita car use and therefore a compositional shift in the population toward smaller households leads to greater aggregate car use.

## 5.2 Change in car use under different demographic compositions and alternative future demographic scenarios

The extent to which a particular compositional variable affects future car use depends on the household projection employed. Under alternative assumptions about fertility, mortality or union dissolution, the projected distribution of households by age, size, gender, and composition will change. As a result, the conclusions regarding the most important compositional variables to include in projected car use could also change.

To explore this possibility, we extend our analysis by investigating the sensitivity of projected car use to the alternative household projections presented in the Appendix and summarised in section 4.[13]

**Figure 4a:**
**Change in car use for alternative demographic scenarios by size of household and age of household head relative to a projection by population size**




13 Of course, changes in the cross-sectional pattern of car ownership and mean distance driven may have an equally important influence on projected car use. However, since we lack information on changes in car use patterns across cohorts we restrict our analysis to the sensitivity of car use with respect to alternative household projection scenarios which can be constructed straightforwardly by assuming alternative future time paths of demographic parameters.

**Figure 4b:**
**Change in car use for alternative demographic scenarios by age and sex of household head and by household size and age of household head relative to a projection by age of household head**

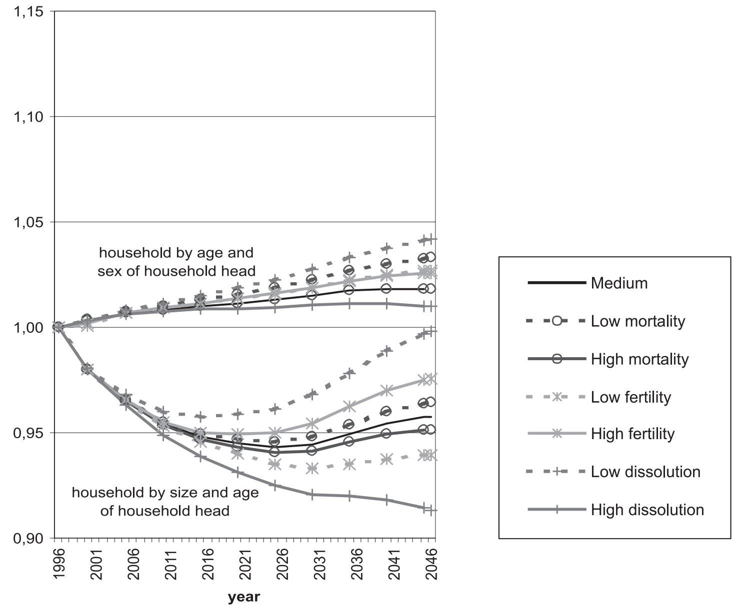



**Figure 4c:**
**Change in car use for alternative demographic scenarios by household size and age of household head and by household size and number of children relative to a projection by household size**

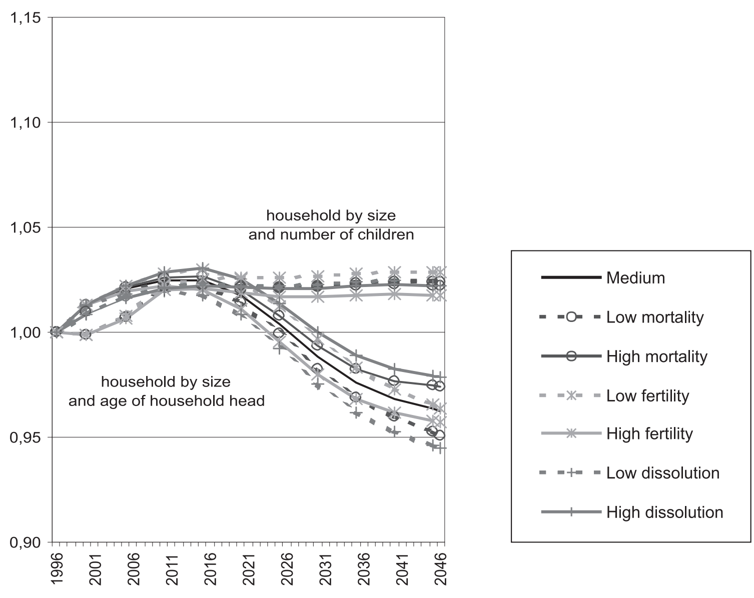


**Figure 4d:**
**Change in car use for alternative demographic scenarios by household size and age and sex of household head relative to a projection by household size and age of household head**

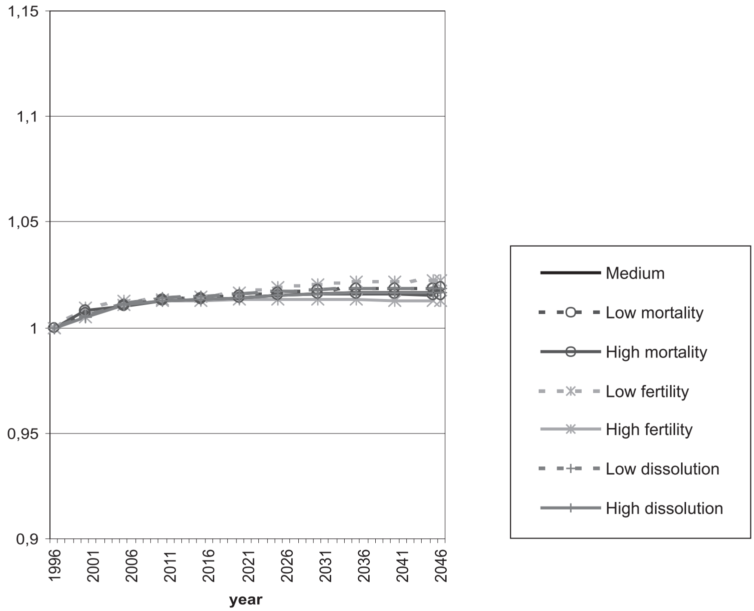
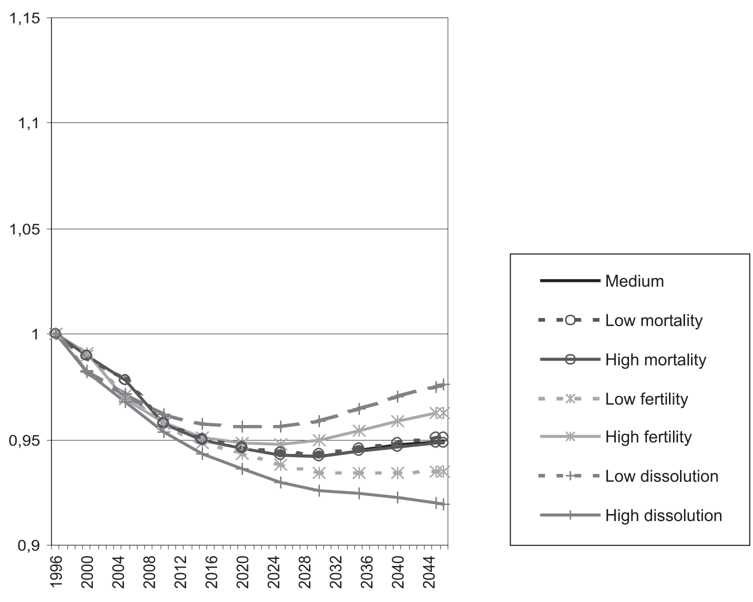



**Figure 4e:**
**Change in car use for alternative demographic scenarios by household size and age and sex of household head relative to a projection by age and sex of household head**



We present our findings as follows. In the case of only one compositional variable we plot the change in projected car use relative to a projection based on population size alone (Figure 4a). If we have two or three compositional variables, we plot the ratio of the projection including both or all three variables to the projection including just one or two variables (Figure 4b, 4c, 4d and 4e). This approach controls for the differences in population size across scenarios with different demographic assumptions. Results can then be interpreted directly in terms of the importance of the compositional effect being tested, independently of the effect of differences in population size.

The results of Figure 4a imply that household age and size will be significant in all of the future demographic scenarios, since in all cases projected car use differs as compared to a projection based on population size alone. The effect of household size is smaller and not as sensitive to demographic conditions, leading to a 3–5% increase in projected car use depending on the household scenario. The effect of household age is more pronounced, and more sensitive to the household scenario, peaking at 10–15% above the benchmark projection and ending at –3% to +12% in 2046, depending on the demographic assumptions.

The results can also be used to examine the main causes of the sensitivity of car use to alternative assumptions. For example, the differences in car use between the high- and low-mortality scenario, after controlling for population size, are not very pronounced over the time period of the projection. Changes in mortality shift the distribution of households between middle- and older-aged categories. For example, lower mortality leads to a greater proportion in older households and a smaller proportion in middle-aged households, reducing overall car use since older households drive less. The differences in projected car use are initially small, since the increase in older households is concentrated in those households with driving patterns the most similar to the middle-aged (i. e., the youngest households within the old-age group). Continued low mortality eventually leads to greater concentrations in the oldest households with the lowest level of driving. As a result, near the end of the projection period lower mortality is leading to an increasingly strong effect on total car use.

Differences in car use (controlled for population size) among the high- and low-fertility scenario are much more pronounced. Alternative fertility scenarios change the share of middle-aged households, and total car use is sensitive to this change. Lower fertility, for example, leads to a smaller share of young households, and a larger share of households in both the middle- and old-aged groups. The effect of the increase in middle-aged households (with high car use) dominates, and total car use increases. Projected changes in car use are even more pronounced if we assume alternative dissolution patterns, since these alternative scenarios lead to the largest shifts in the distribution of households by age (Figure 2b). For example, higher dissolution rates shift the distribution of households toward the middle-aged group, which has relatively high car use, leading to an increase in overall car use.

In Figure 4b and 4c we consider the effect of adding a second compositional variable to either the age of the household head or the size of the household. We plot projected car use relative to projections that account for age of household head or household size only. Results confirm conclusions reached in the previous section regarding the relative importance of different compositional variables. Adding sex to age (Figure 4b) results in relatively small changes in car use, although in the low-dissolution case the effect is the largest, reaching 4% by the end of the projection period. Lower dissolution rates lead to a larger share of male-headed households, which have higher car use than female-headed households. However, this result does not include the size effects associated with changing dissolution rates, which would act in the opposite direction. Adding size to age has a pronounced effect in all scenarios, although it is considerably lessened in the low dissolution scenario (and considerably increased in the high dissolution scenario).

Adding composition (by adults vs. children) to size (Figure 4c) has a relatively small effect in all scenarios while adding age to size has a substantial effect in all cases.

We conclude by considering three compositional variables: age and sex of household head together with household size (Figure 4d and 4e). Adding gender of the household head (in addition to age and size of the household) does not change the pattern of future car use and this is independent of the future demographic scenario we assume (Figure 4d). Compared to Figure 4b, part of the gender-specific effect has already been taken up by the compositional variable household size so that adding gender leads to very small changes in car use across alternative future demographic scenarios. The importance to distinguish by household size (in addition to age and sex) is confirmed again in Figure 4e. However, compared to Figure 4b, the effect of adding size across alternative future demographic scenarios is smaller if gender has already been considered in addition to age.

Our results confirm the robustness of our initial conclusion that household age and size are important compositional variables to include in projections of future car use. By adding gender to a composition by age and size (Figure 4d), not much additional change in car use can be observed. We may therefore conclude that age and size are indeed the most appropriate compositional variables within the set of household characteristics we consider. With respect to the alternative future demographic scenarios our results indicate that the quantitative relevance to a specific demographic composition may change under alternative demographic future scenarios while the qualitative shape persists.

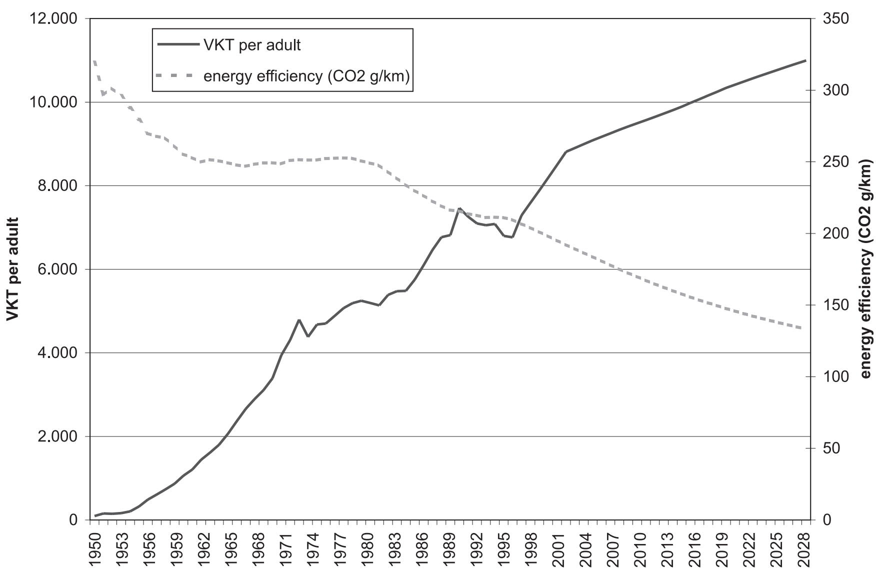
## 6 Conclusions

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 behaviour 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 not only has the potential to improve forecasts of future travel demand, but also to emphasise the importance of carefully choosing the variables by which to disaggregate the population.

Demographic changes could be important for at least two reasons in addition to those analysed 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 why 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 elderly age groups.

**Figure 5:**
**Change in VKT per adult and energy efficiency**




Whether our results indicate that compositional changes could have a substantial influence on future travel behaviour needs to be judged relative to the influence of other factors, including behavioural and technological changes. Referring to data provided by the Austrian environmental ministry (Figure 5), vehicle kilometres travelled (VKT) per adult is forecast to increase by about 62% during the period 1996 to

2030 compared to an increase of 155% over a historical period of similar length from 1967 to 1996.[14] At the same time, changes in energy efficiency and transportation fuels could lead to an improvement in $CO_2$ emissions per vehicle kilometre of 40% over the period 1996 to 2030, compared to an improvement of only 15% for the historical period 1967 to 1996.

Compared to these projected changes in VKT and technological factors, our predicted changes in car use resulting from compositional changes are modest. Taking the projection by household age, sex and size as an example and considering the medium variant of the household projections, differences from the projection which ignore composition (the constant per capita projection) do not exceed 8%. For an application forecasting aggregate transportation energy use 50 years into the future, an 8% adjustment is relatively small given the scope for changes driven by behavioural or technological change. 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 and the projections presented in Figure 5. In addition, the difference between the two projections is nearly 8% in the short term (2010–2015). Over this shorter time horizon, an 8% absolute difference in projected demand is likely to be much more important in judging the difficulty of meeting greenhouse gas emission reduction targets, or for planning for changes in demand for road capacity, for example.

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[14] We would like to thank Günther Lichtblau (Austrian Environmental Ministry) and Alexander Hanika (Statistics Austria) who provided the data on VKT, energy efficiency and the Austrian adult population.

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## Appendix

**Table A1:**
**ANOVA analysis applied to distance traveled for alternative compositional variables**

| | | | | | | % of Total |
|---|---|---|---|---|---|---|
| | **Sum of squares** | **Df** | **Mean Square** | **F-statistic** | **Significance** | **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 | | | |
| **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 | | | |
| **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 | | | |
| **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 | | | |
| **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 | | | | |

## Household projections under alternative future demographic scenarios

In the case of fertility and mortality, we apply the low and high variant as given by Statistics Austria (see Table A2 and Appendix A in Prskawetz et al. 2002, summary measure) in addition to the medium level of fertility and mortality applied in Figure 2a–2c. For the alternative union dissolution scenarios we cannot refer to any prevailing scenarios. We therefore construct a low and high union dissolution scenario, assuming that Austria follows the Italian (low union dissolution scenario) or the Swedish pattern (high union dissolution scenario) of union dissolution by the year 2046. Between 1996 and 2046 we apply a linear interpolation. Out of 19 European countries (cf. Prskawetz et al. 2003) Swedish women of birth cohort 1952–59 have the highest union dissolution rate by age 35  about 1.5 times that of their Austrian counterparts. At the other end of the scale, Italian women of the same birth cohort have the lowest union dissolution rate by age 35—about 0.26 times of that of their Austrian counterparts.

**Table A2:**
**Assumptions on future changes in fertility, mortality and union dissolution levels by year 2046**

| | TFR | $e_0$ | | Married to divorced | | Cohabiting to single | |
|---|---|---|---|---|---|---|---|
| | | male | female | male | female | male | female |
| Low | 1.2 | 78 | 84 | 0.09 | 0.09 | 0.07 | 0.05 |
| Medium | 1.5 | 81.6 | 86.7 | 0.38 | 0.37 | 0.30 | 0.20 |
| High | 1.8 | 86 | 90 | 0.58 | 0.56 | 0.45 | 0.31 |

In Figure A1a–A1c we have assembled selected results of household projections based on alternative fertility, mortality and dissolution scenarios. A comparison across projections by population size, number of adults and number of households (Figure A1a) show that predicted population size will be most sensitive to the assumed fertility development. This can be explained by the fact that a change in fertility today has a multiplier effect since children born today will have children themselves in the future. The projected number of adults will initially be sensitive to changes in mortality patterns and only around 2025, when the changes in fertility will have worked their way through the age groups, can we observe the impact of fertility changes on the number of adults as well. Changes in the rate of union dissolution only have an impact on the projected number of households.[15]

[15] This result mainly follows from our assumptions of future levels of TFR and life expectancy at birth which are the same as for the medium scenarios. We are aware that changes in union dissolution rate may induce important effects on TFR and life expectancy. However since we lack appropriate data we had to pose this assumption.

**Figure A1a:**
**Projection of population size, number of adults and number of households under alternative future demographic scenarios**

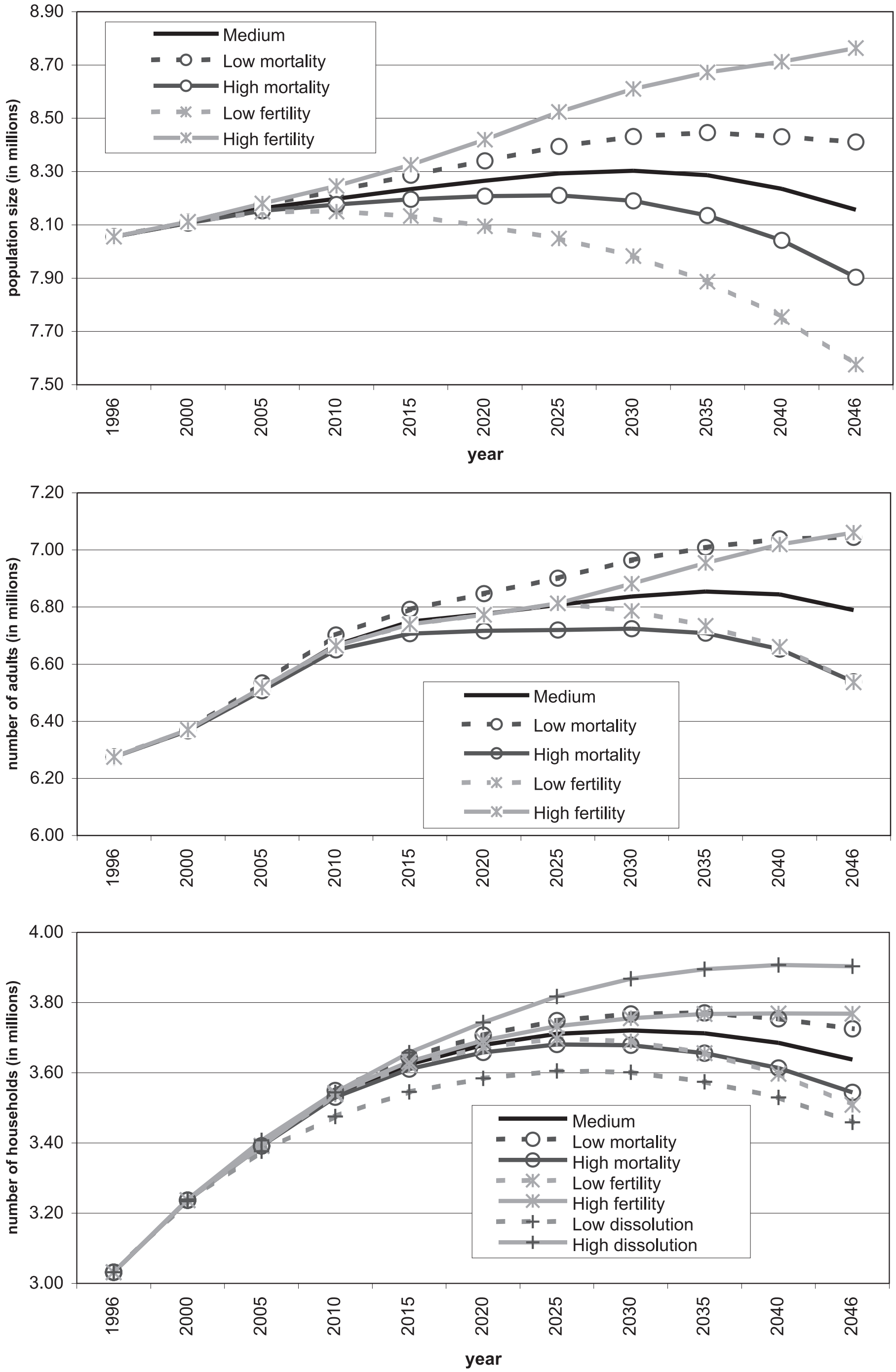


**Figure A1b:**
**Projection of the share of 15–29, 30–59 and 60+ years old household heads under alternative future demographic scenarios**

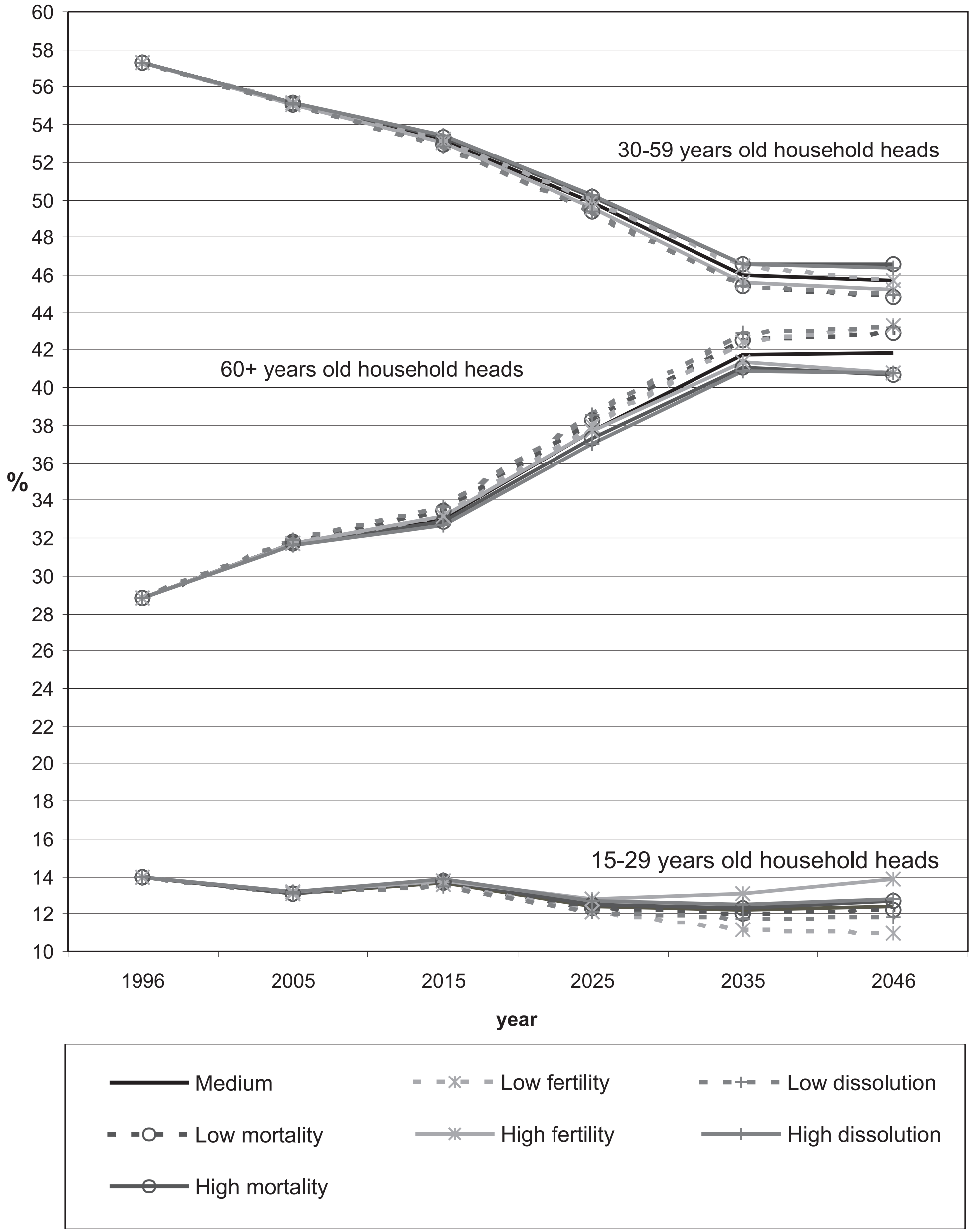
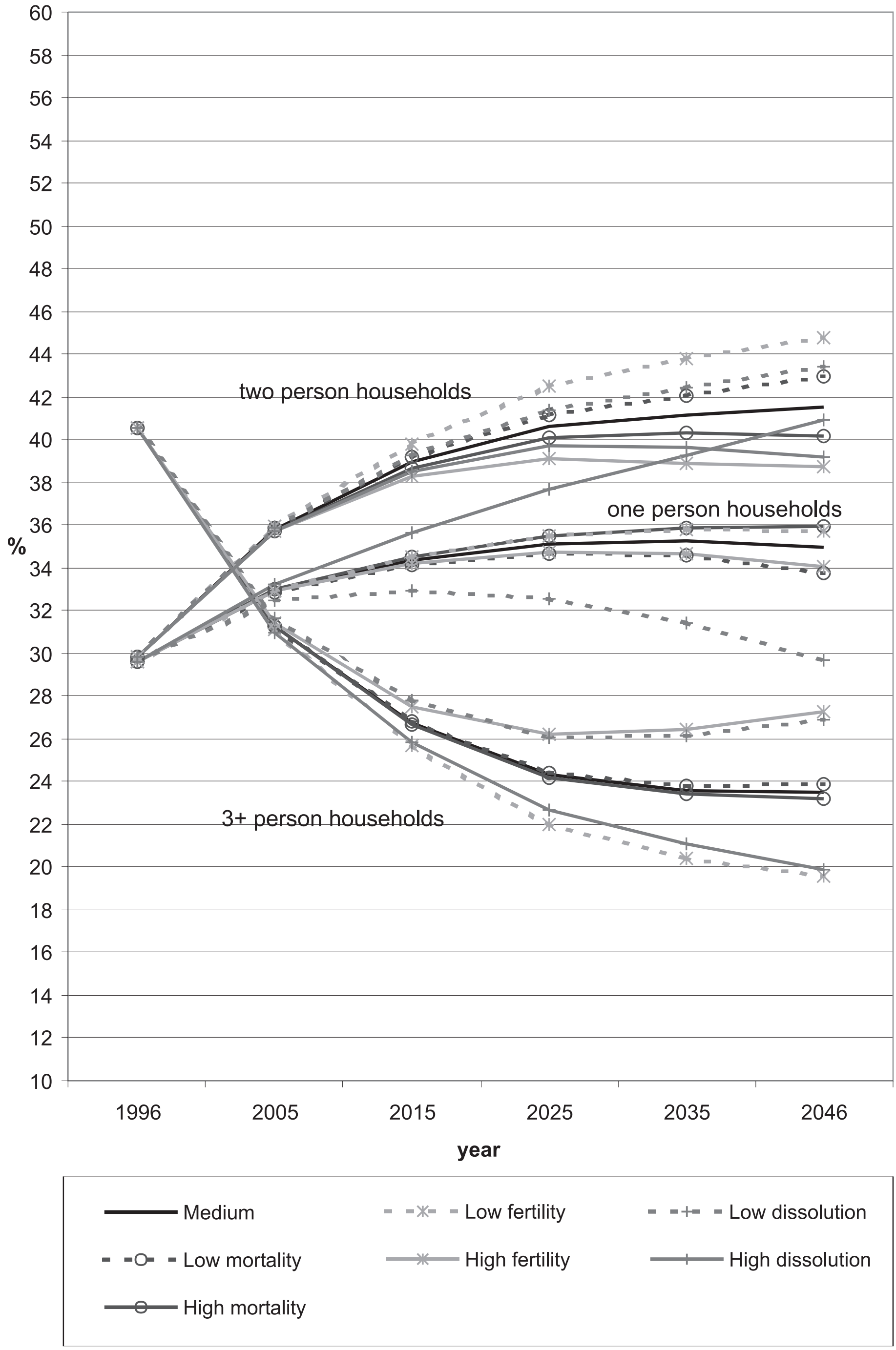


**Figure A1c:**
**Projection of the share of one, two and 3+ person households under alternative future demographic scenarios**



In Figure A1b we plot the projected share of households for three age groups of the household head. The share of household heads in each of three broad age groups is not overly influenced by alternative demographic scenarios. We observe a pronounced decrease in the percentage of middle-aged household heads, and an increase in the percentage of old-aged household heads, for each demographic future scenario (i. e., the ageing process in households will not be overly affected even under alternative fertility and mortality assumptions in the future).

However, projected changes in household size are more sensitive to alternative scenarios. Figure A1c illustrates a general increase in one- and two-person households while households of size three or more are declining over time. By definition, the share of one-person households is most sensitive to alternative dissolution scenarios. This result is a combination of higher dissolution rates among couples without children and the fact that after a dissolution, at least for one partner, the new household form will be most likely a one-person household. Households of size two and more are most sensitive to fertility and dissolution scenarios.