Empirical Studies of Nordic household and family structure

How it affects mortality and the environment, and how it has and will change

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Summary

The unifying theme of this thesis is the past, present and future household and family structure in various Nordic countries. It provides a forecast of household structure in Denmark and Finland. An application of household forecasts is to study the implications for energy use – a topical issue in an environmental context. Here the effect of divorce is considered. Another strand of the research on household structure is to examine potential links between selected aspects of family structure and mortality. This thesis studies two such aspects.

A finding from the detailed probabilistic household forecast is that the proportion of households that are one-person households is likely to increase during the coming decades as it has done in the past decades, leading most probably to a further decline in the average household size. On the other hand, the share of households consisting of married couples is likely to fall. Part of the explanation is high divorce and union dissolution rates. Splitting one household into two leads to higher domestic energy use as a result of loss of economies of scale. However, taking into account the depressing effect of divorce on fertility, higher divorce rates may not entail mounting total domestic energy use in the long term; indeed, it may even lead to lower household energy consumption. The results presented here show that in the short run higher dissolution rates lead to higher domestic energy consumption, but in the long run it might drive down energy use due to low fertility.

The thesis also addresses the possible link between mortality and two aspects of the family structure, namely the gender composition of one's children and whether or not one is a grandparent. Neither has so far received much attention. I find only limited support for the hypothesis that having children of only one sex is associated with a mortality disadvantage -

for mothers with two or more children. The link between grandparenthood and mortality is stronger, with grandfathers in general experiencing higher mortality than fathers who are not grandfathers. The association varies with characteristics of the grandparents, especially age, with young grandmothers also displaying a mortality disadvantage, and those who became grandmothers after age 50 having a mortality advantage.

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Introduction

Family and living arrangements are of vital importance for both the individual and society[1]. On the individual level it has an impact on health, mortality and well-being. For public administration household development is crucial for planning housing and use of domestic energy; and public revenue as well as expenditure is affected by family structure.

Many of these factors can work both ways. Health can be *influenced by* the type of household you live in but can also have *implications for* the type of household you live in. For example marriage might have a protective effect through discouraging unhealthy behaviour such as excessive consumption of alcohol, by providing companionship and through household economies of scale. On the other hand good health can make you more attractive as a partner and poor health might lead you to move to an institution or move in with relatives. Household structure can influence public finances, for example the level of child support might depend on whether you are a single parent, but tax and social security rules and public policy can also provide economic incentives to choose a certain type of living arrangement or family. For example generous spending on parental leave and child care might encourage people to have children[2] and if pension rules depend on marital status it can have an impact on marriage decisions (Baker et al. 2004; Brien et al. 2004).

All the studies in this thesis focus on how demographic transition probabilities are linked to household and family in one or more of the Nordic countries. Paper I considers the future Danish and Finnish household structure. Using household register data, we are able to show in

[1] A family is defined as a set of persons who are related either through marriage, birth or adoption, whereas a household can be defined either as those who live together (household-dwelling definition) or as those who live together and share a household budget (housekeeping definition).

[2] See next section for details

more detail than earlier studies, how the fertility, mortality and union dissolution probabilities depend on current household status (not only marital status) and use these probabilities to determine tomorrow's household structure. In addition the uncertainties are quantified. Paper II addresses how the lower fertility outcomes among the divorced can mitigate the negative environmental effect of higher domestic energy use caused by splitting one household into two following a divorce. This paper employs Danish register data.

Decades of research have shown that mortality is associated with the family you are a part of. Not only is mortality lower among those who are currently married compared to the never married and previously married (e.g. Manzoli et al. 2007; Koskinen et al. 2007; Waite and Lehrer 2003), but parents have lower mortality than the childless (at least at low parities) - an effect which is influenced by the spacing of the children (Grundy and Tomassini 2005) as well as whether the children have higher education (Zimmer et al. 2007; Friedman and Mare 2010; Torssander 2013). Paper III and IV build on this tradition by considering, respectively, whether the gender of one's children and whether or not one is a grandparent has an impact on mortality. In both these papers Norwegian register data are utilised.

The rest of this introduction is structured as follows. The next section gives an overview of the Nordic demographic household and family pattern and compares it to the rest of Europe. The last section is the paper, "Household and Family development in the Nordic countries" which gives an historical overview of the past 50 years focusing on the last 30. I then give a summary of each of the papers included in this thesis.

Nordic demographic household and family pattern in a European perspective

Kuijsten (1995) argues that the Nordic countries have the longest tradition for considering demographic behaviour to be totally private. Whether to cohabit or marry; or have a child before or after marrying, is seen to be entirely up to the individual or couple. Indeed, the Nordic countries were forerunners when it comes to trends such as the rise in unmarried cohabitation, the decline in and postponement of marriage as well as the higher proportion of births taking place out of wedlock. Although many of these demographic trends are now witnessed all over Europe, there are still large cross-national differences. This overview aims to place the Nordic demographic pattern in a European context and to discuss the determinants of the differences we observe[3].

Leaving the parental home is for most young people the first demographic event on the way to adulthood, and Nordic youth on average do so earlier than the majority of their counterparts in the rest of Europe (Aassve et al. 2002; Billari et al. 2001; Billari and Wilson 2001; Iacovou 2001; Iacovou and Berthoud 2001; Vogel 2002; Billari 2004; Mandic 2008). In the 1970-1979 cohorts the median age at leaving the parental home was below 20 in all the Nordic countries (Billari and Liefbroer 2010). This is around a year earlier than in most Western European countries, a few years earlier than in Eastern Europe and well below the median age in Southern Europe (Spain 27 years and Italy 28 years in the 1970-1979 cohorts). Furthermore, very few have not left the parental home by the time they turn 30 (Billari et al. 2001).

Buchmann and Kriesi (2011) argue that this is the result of relatively weak family ties, a welfare state geared towards the individual as well as a strong belief in young people's

[3] I will in the following focus on demographic features that are common to all or most of the Nordic countries and to a large extent disregard variation within the Nordic region.

autonomy. Nordic parents also put great emphasis on their children's independence (Chiuri and Del Boca 2008). Furthermore, the Nordic welfare states spend a greater proportion of their expenditure on young adults than the majority of other European countries and offer generous student loans (Chiuri and Del Boca 2008; Sobotka and Toulemon 2008). Levels of youth unemployment and job insecurity are other important factors in explaining cross country variations, as are differences in access to mortgage markets (Becker et al. 2010; Martins and Villanueva 2009).

In addition to being more likely than other Europeans to move out of the parental home before entering their first union, Nordic young adults also enter their first union at the youngest median age in Western Europe - below 22 for Nordic women in the 1970-1979 cohort (Billari and Wilson 2001; Billari and Liefbroer 2010; Buchmann and Kriesi 2011). The first union is much more likely to be a cohabiting union than a marriage (Billari and Wilson 2001; Billari and Liefbroer 2010; Iacovou and Skew 2011) – around 90% of Nordic women born in the 1970s cohabited before tying the knot – and the median duration of premarital cohabitation is longer than in other countries (Kasearu and Kutsar 2011).

The proportion of unions that are cohabiting unions remains high in the Nordic countries into the thirties, especially among those who do not have children (Iacovou and Skew 2010). This is partly the result of having some of the highest average ages at first marriage for both men and women in Europe (Billari and Wilson 2001). For the 1970-1979 cohorts the Nordic countries, together with UK, France and Ireland, were those countries in Europe where median age for women at first marriage exceeded 30 (Billari and Liefbroer 2010). Kalmijin (2007) inquired into possible reasons for these cross-national differences. He found that the level of women's employment is negatively correlated with marriage rates and positively correlated with levels of cohabitation. Cohabiting is also more common in more highly

educated populations, and Catholicism and Orthodox Christianity inhibit cohabitation. Furthermore, the Nordic countries have the highest levels of social approval of cohabitation (Noack et al. 2013), and whereas cohabitation can be viewed negatively in countries where it is rare, in countries where it is common, to marry without going through a trial period of cohabitation is viewed as deviant behaviour (Bernhardt 2001).

Together with the UK and Ireland, the Nordic countries have the highest level of first births outside marriage in Western Europe (Billari and Wilson 2001). Of women born in the 1970s more than half of Nordic women had their first birth outside marriage (Billari and Liefbroer 2010). The majority of these were cohabiting.

The median age at first birth in the Nordic countries is high, nearing 30 for women, but it is even higher in the Netherlands, Germany and the Mediterranean countries (Billari and Liefbroer 2010). The driving forces behind the fertility postponement are likely to be common across countries such as an increased wish for autonomy and freedom; and not least the increase in the number of women taking higher education and aiming for higher degrees than earlier generations, and increased female labour market participation (Ní Bhrolcháin and Beaujouan 2012; Mills et al. 2011; Neels and De Wachter 2010; Gustafsson et al. 2002). However, the fact that we witness a stronger postponement in Southern Europe than in the Nordic countries is likely due to higher economic insecurity such as higher youth unemployment in the South, which means that people delay taking decisions with long term economic implications - such as having children (Adsera 2011a; Mills et al. 2011; Adsera 2005; De la Rica and Iza 2005; Mills et al. 2005, Kohler et al. 2002).

Even though the average age at first birth is high, the Nordic countries have, together with France and the UK, the highest total fertility rates in Europe. The policies put in place to achieve a high degree of gender equality in the labour markets and to make it easier for

women to combine having a career with having a family, probably have a positive impact on fertility. Hoem (2005 p. 569) calls it being "child-friendly by being woman-friendly". The employment rate among mothers is generally very high in the Nordic countries, and whereas it in other countries tends to decline steeply with the number of children a woman has, this is not the case in the Nordic countries[4]. This has been achieved through an extensive provision of subsidised child care and long and generously paid parental leaves (Cosmin 2012; Haan and Wrohlich 2011; Luci and Thévenon 2011; Adsera 2004; Castles 2003). Hoem (2008 p. 251) states that these policies "are pronatalist in effect, but not in stated intention"

In addition, the labour markets in the Nordic countries are more flexible with respect to working part time than in many other countries, and the higher education system is flexible when it comes to taking time out to have a child. These circumstances plus the relatively generous amount of money given to students who have a child mean that childbearing is higher among Nordic students than among students elsewhere in Europe (Kalwij 2010; Adsera 2004; Castles 2003). There is also a higher proportion of public sector jobs than in many other European countries. This has been linked to high fertility (Martín-García and Castro-Martín 2013; Solera and Bettio 2013; Adsera 2004; 2005; 2011a) as has a high level of job security (Adsera 2004; 2011a; 2011b) which is another trait of the Nordic job markets.

The fact that extensive public provision of formal childcare reduces the opportunity cost of childbearing, which is higher for women with higher education, and the fact that the economic returns to education are lower in the Nordic countries than in other European countries, especially for women (OECD 2008), might explain the small differences in fertility by educational attainment in comparison to countries such as the UK, Germany, Austria and Switzerland (Sobotka 2012; Andersson et al. 2009; Ratcliffe and Smith 2006; Spielauer 2004).

[4] UNECE Statistical Database http://w3.unece.org/pxweb/database/STAT/30-GE/03-WorkAndeconomy/?lang=1

Particularly the level of childlessness among the highly educated is much lower in the Nordic countries than in countries such as Austria and Greece (Bagavos 2010; Neyer and Hoem 2008).

Studies considering the effect of a single policy aspect on fertility have often found very small effects (Balbo et al. 2013; Gauthier 2007; Kohler et al. 2006, Sleebos 2003; Gauthier and Hatzius 1997). However, taken together, the public policies and aspects of the Nordic labour markets summarised here constitute a family friendly society. As Hoem (2008 p. 255) puts it "each element may have only an incremental influence, together they may add up to something other than the constituent parts".

Divorce rates are higher in the Nordic countries than in the majority of other European countries. Compared to its Western European counterparts divorce rates in the Nordic countries, which were among the first countries to introduce no-fault divorce laws, were high already in the 1950s and 1960s (Smith 2002). This study mentions two factors that might explain variations in divorce rates across countries - religion and women's economic status. Catholicism has had a more strictly negative attitude against and been more vocal in its condemnation of divorce than the Protestant churches in Europe, especially the Lutheran state churches in the Nordic countries. Women's high levels of employment in the Nordic countries can also have led to high divorce rates as it has given them financial independence making it easier for them to initiate a divorce and lowered the gains from marriage (Becker et al. 1977). Both these theories were confirmed in a cross national study which found that women's employment levels were positively associated with divorce and that levels of religiousness were negatively associated with divorce (Kalmijn 2007). The study also finds that divorce is more prevalent in more highly educated populations, which might be due to more individualistic behaviour in such populations.

As a result of the high divorce rates and high levels of childbearing within cohabiting unions, which are less stable than married unions, the Nordic countries have, together with the Baltic countries, UK and Ireland, some of the highest proportions of single parents in Europe (Sobotka and Toulemon 2008; Iacovou and Skew 2010; 2011). Parents are also more likely to be cohabiting than anywhere else in Europe (Sobotka and Toulemon 2008).

Since fertility is relatively high and childlessness is uncommon, it is not surprising that the percentage of those aged 50 and over who are grandparents is higher in the Nordic countries than in the majority of other European countries (Glaser et al. 2010). Grandparents in the Nordic countries are more likely to provide some form of childcare for their grandchildren than grandparents in the rest of Europe, especially those in Sothern Europe. However, they are the least likely to provide regular childcare (Hank and Buber 2009; Koslowski 2009). Albertini et al. (2007) argue that the reason why more Nordic grandparents than Southern European grandparents offer some child care is that Mediterranean elderly are unlikely to help with childcare if they don't co-reside with their grandchildren. The high female employment in the Nordic countries might also mean that there is a higher need for occasional babysitting due to overtime work or work-related travel. The reasons why grandparents in the Nordic countries are less involved in caring for their grandchildren on a daily basis include the high coverage of formal childcare, generous parental leaves, high labour force participation also among women who are grandmothers, and relatively high retirement ages – in the Nordic countries a higher proportion of grandparents are in paid work than in the rest of Europe (Glaser et al. 2010). In addition, there are very low levels of co-residence between grandparents and their grandchildren (Koslowski 2009), and adult children tend to live further away from their parents than in the rest of Europe (Hank 2007).

As extended family households are extremely rare a larger proportion of elderly people in the Nordic countries live alone or with only a spouse than in the majority of other European countries (Iacovou 2000a; Iacovou and Skew 2011; Tomassini et al. 2004). In addition to a generally more individualistic culture than in Sothern Europe, there is a strong preference for independent living among Nordic elderly and less desire for contact with younger people (Tomassini et al. 2004). Income is also an important factor in explaining cross-national differences in living arrangements among the elderly (Iacovou 2000b ; Gaymu et al. 2006) and helps explain why the Nordic countries with their generous pension systems have such high shares of people living alone. High levels of social spending also means more elderly people with limiting health problems live independently (Iacovou 2000b). Middle aged people in the Nordic countries are those who are most likely to say that their parents should move into a nursing home or receive professional help at home if their health deteriorates instead of receiving help from their children, and the proportion of elderly living in nursing homes are indeed higher than in the rest of Europe (Tomassini et al. 2004).

The Nordic life expectancy is high, which is likely due to favourable socioeconomic conditions such as high GDP per capita, low levels of income inequality as well as highly developed welfare states and generous pension systems (Rodgers 1979: McIsaac and Wilkinson 1997; Wilkinson 1992; Duleep 1995: Lundberg et al. 2008; Esser and Palme 2010). However, life expectancy is lower than in the Mediterranean countries, especially for women. This is probably to a large part due to differences in diet and the protective effect the Mediterranean diet has on the risk of developing cardiovascular disease, cancer, diabetes and Alzheimer's (e.g. Sofi et al. 2008; 2010; Martínez-González et al. 2008; Scarmeas et al. 2006; de Lorgeril et al. 2002; Trichopoulou et al. 2000). There is especially a marked difference in deaths from cardiovascular disease. For example death rates from ischemic heart disease in

the Nordic countries are more than double those of the Mediterranean countries (de Lorgeril et al. 2002).

Life expectancy in Denmark as well as for Finnish men is low compared to the other Nordic countries. This is mainly due to higher mortality among the middle aged and is a result of higher alcohol consumption and a higher prevalence of smoking (Vollset 2013; Juel 2000; Juel et al. 2000; Juel 2008). One study has claimed that the latter characteristic, in Denmark, can be attributed to the smoking habits of Denmark's popular queen Margrethe II (Kesteloot 2001).

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Household and family development in the Nordic Countries: An overview

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Household and family development in the Nordic Countries: An overview

Abstract

There have been major changes to the household and family structure in the Nordic countries during the past 50 years. The number of households has increased much faster than the population, leading to a significant drop in average household size. The reasons are multifaceted including lower fertility, a rise in divorces, more cohabiting relationships - which are less stable than marriages and fewer elderly living with relatives. I will in this article look at the main developments in Nordic household and family structure during the last decades as well as expected future changes, consider different age groups and look at children's living arrangements.

***Keywords*:** *Household structure; living arrangements; Nordic countries.*

JEL clodes: *J10, J11, J12*

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1. Introduction

There is a wide variety of reasons why we are interested in studying the development of household and family structure. The Aging Households and the Nordic Welfare model (AGHON) project, which this article is part of, aims to examine the changes in the Nordic household structure and their economic consequences[1], more specifically how changing household patterns affect public finances both on the income and expenditure side. An example is cash benefits to families which may in many cases be targeted to specific family types such as single parents. The level of support received may also depend on household status, with those living alone receiving more than those who benefit from the economies of scale larger households provide. Changes in household structure influence the housing demand and therefore affect housing prices which again affect public expenditure on housing benefits. For the elderly living arrangements affects the need for home care services, and demand for places in nursing homes as well as the frequency and length of hospital spells (e.g. Iwashyna and Christakis, 2003; Lakdawalla and Philipson, 1999; Lakdawalla et al., 2003; Prior and Hayes, 2003; Grundy and Jital, 2007). Fertility is influenced by changes in family structure such as divorce and determines public expenditure on child care and education. On the income side, tax payments sometimes depend on marital status, or there are tax deductions for example for single parents. Lone parents also often have a lower labour supply and therefore pay less income tax.

In addition to these public finance implications changes in the household structure affects the demand for consumer durables, as well as electricity and car use (e.g. Prskawetz, Leiwen and O'Neill, 2004; O'Neill and Chen, 2002), and therefore plays an important role in determining the levels of CO_2 emissions (e.g. MacKellar et al. 1995; Wier et al. 2001). At the individual level health and mortality are strongly correlated with living arrangements (e.g. Grundy, 2001; Lund et al., 2002; Joutsenniemi, 2007; Koskinen et al., 2007 and Drefahl, 2012), as is well-being (e.g. Stack and Esheman, 1998; Soons and Liefbroer, 2008; Mastekaasa and Næss, 2011).

This article will shed light on some of the main developments in household and family structure in the Nordic countries during the last decades, and put the future expected changes in household structure in a historical context. I start of presenting the data and main developments. After a closer look at particular age groups, I turn to children's living arrangements. The penultimate section presents some results from probabilistic household projections for Denmark and Finland. The final section concludes.

[1] For details see http://www.etla.fi/en/research-projects/aging-households-nordic-welfare-model-aghon/

2. Data

The data I have used are from the Nordic national statistical offices. Denmark and Finland have household registers running back to the 1980s. Data preceding the registers are mainly from censuses. In Norway a household register was put in place using information collected in the 2001 Population and housing census. This means that yearly household statistics are available from 2005 onwards. Earlier data come from censuses as well as sample surveys. The latest Swedish census was held in 1990 and after that household statistics have been compiled using sample surveys. In 2006 it was decided that a Swedish household register will be developed.

According to the UN[2], a family is "those members of the household who are related [...] through blood, adoption or marriage". A household can be defined in one of two ways. In the *housekeeping* definition a household is a group of people who " pool their incomes and have a common budget to a greater or lesser extent; they may be related or unrelated persons or a combination of persons both related and unrelated." In the alternative definition based on *household-dwelling* "a household consists of all persons living together in a housing unit.[3]"For example a group of students who live together but where each provides for himself would be one household according to the second definition but multiple households according to the first definition. In the household registers as well as censuses the household dwelling definition is employed. Since the data in this paper is mainly based on these sources it means that the number of people living alone is lower than had the data been collected using the housekeeping definition.

There are some additional challenges to the Nordic household data. One is the fact that it is not possible to know for sure who are cohabiting unless they have children together. The Nordic standard is that two of opposite sex who live together, with an age gap of 15 years or less, who are not related in any other way and do not live together with other adults are considered cohabiters. A further group that is problematic is students. In Norway, for example, students who live away from home can choose whether they want to be registered with their parents or at the place of residence. In Sweden they are required to register at their actual place of residence but it is estimated that around 100 000 student fail to do so. In Denmark there is also a problem with the nursing home population as the majority are living in nursing apartments where the residents are registered as living alone instead of living in an institution. This inflates the number of elderly living by themselves. In Norway those who have a spouse are registered at the spouse's address instead of at the nursing home, making nursing home statistics unreliable.

In the AGHON project we distinguish 7 household positions[4]: living as a dependent child (up to 25 years of age), living alone, living with a spouse, cohabiting, being a lone parent, living in another type of private household and living in an institution for the elderly. In the probabilistic household forecast for Denmark and Finland that we computed as part of the AGHON project (Christiansen and Keilman,

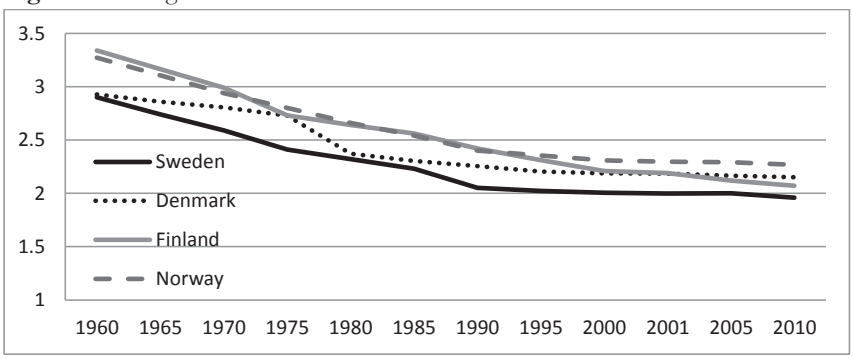
[2] http://unstats.un.org/unsd/demographic/sconcerns/fam/fammethods.htm
[3] http://unstats.un.org/unsd/demographic/sconcerns/fam/fammethods.htm
[4] These categories refer to living arrangement not marital status.

2013), we used data from the Danish and Finnish household registers, respectively. Having these register data made such a distinction of household positions possible. In the current paper I draw on data from many different sources including population censuses and sample surveys. Therefore, using household categories consistent with those employed in the AGHON project, is not feasible throughout.

3. Main developments

During the past 50 years there has been a strong growth in the number of households in the Nordic countries. During the period 1960-2010 the number of households grew by 65% in Denmark, 80% in Sweden and more than doubled in Finland and Norway. During the same period the population grew by 15% in Norway, 10% in Sweden and by 8% in Denmark and Finland. The much stronger growth in the number of households than in the population meant that the average household size fell sharply from around 3 in 1960 to around 2 in 2010. The majority of this decrease took place prior to 1990. Sweden has throughout the period had the lowest average household size, with a starting value of 2.9 falling to 1.96 in 2010. At the other end of the scale, Norway had an average household size of 2.3 in 2010 down from 3.3 in 1960, Figure 1.

Figure 1. Average household size 1960-2010



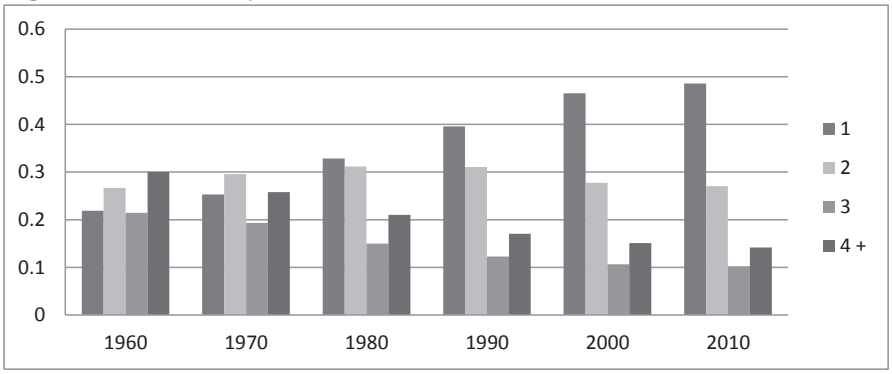
Source: Statistics Denmark, Statistics Finland, Statistics Norway and Statistics Sweden.

An important reason for the observed decrease in the average household size, during the 50 years from 1960 to 2010, is the stark increase in the proportion who live alone. We see that in 2010 they amount to 18% in Norway and Denmark, 19% in Finland and 25% in Sweden. This is, however, a strong increase from 1960 when less than 5% of the population in Norway and Finland and less than 10% of the Danes and Swedes lived alone.

The stark increase in the number of one-person households is mirrored by a sharp decline in the number of households with more than two inhabitants. In Sweden, for example, the share that lives in three person households or households with four or more inhabitants have halved since 1960, Figure 2. The share of two-person households has, on the other hand, been fairly stable during the 50 year period. The same pattern holds true in Norway and Denmark. In Finland, there has in addition to

the strong growth in the share of single person households also been a ten percentage points growth in the number of two-person households during this period. However, starting out from a much higher level there has been a far steeper decline in the share living in households with four or more members.

Figure 2. Households by size Sweden

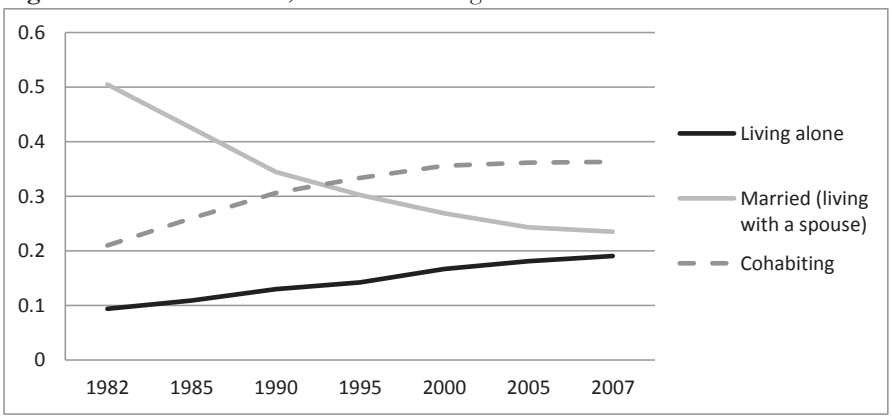


Source: Own calculations using data from Statistics Sweden.

4. A closer look at particular age groups

In order to look more closely at why average household size has fallen, I will consider the young, the middle-aged and the elderly separately. One of the most important trends at young adult ages is the postponement of marriage. During the last four decades the average age of first marriage has risen from around 20 to above 30 for women, being a few years higher for men. This does not mean that couples are not moving in toghether, for example in Norway, we have not observed any increase in the median age at which young adults move in with their first partner across the cohorts born from the 1930s onwards (Billari and Liefbroer, 2010: Noack and Seierstad, 2003; Dommermuth, Noack and Wiik, 2009). However, data from the Danish household register spanning the last three decades show that the decrease in the share of young adults who are married has not been fully offset by the increase in the proportion cohabiting, which mean that the share of young adults living alone has also grown, Figure 3. This growth in the share of young people living alone could also be due to a later age at leaving home, however the median age at leaving the parental home has been stable across cohorts born in all the Nordic since the 1950s (Billari and Liefbroer, 2010) nor has the proportion of young Danes in their 20s living at home (not shown).

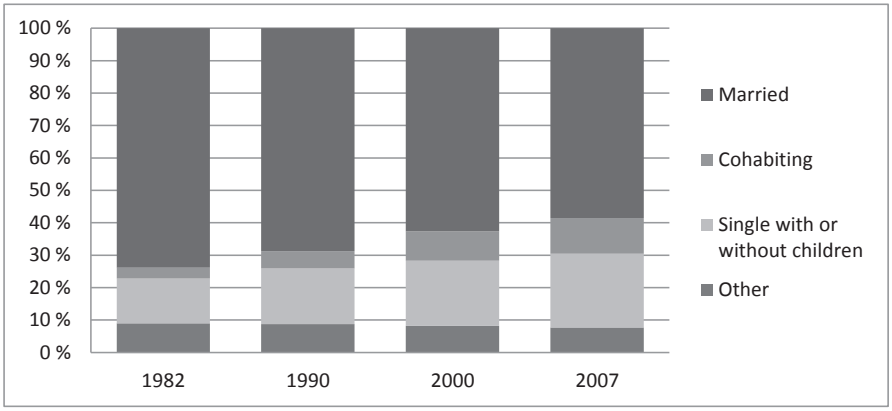
Figure 3. Household shares, Danish women aged 25-29



Source: Own calculations using data from Statistics Denmark.

The vast majority of young couples who decide to move in together nowadays start off living as cohabiting partners and do not marry directly. In Norway, in the cohort born 1980-84 90% of those who have lived with a partner started off cohabiting. The same was true for 60% of those born 1950-54, 24 % of those born in the 1940s and only 9% of those born in the 1930s. This shift happened even earlier in Denmark and Sweden, where around 20% of those born in the 1930s cohabited before marrying rising to more than 80% in the 1950-1959 cohorts (Billari and Liefbroer, 2010; Dommermuth, Noack and Wiik, 2009). It is well known that cohabiting relationships are less stable than married relationships. For example, a Norwegian study found that one in four cohabiters had plans of breaking up with their partner, compared to 12% of the married (Wiik and Noack, 2011). The reason might be both that it is easier to leave a cohabiting partner than to go through a divorce, and that those who choose to marry are those who are most pleased with the quality of the relationship. The fact that cohabiting relationships are more likely to end means that a larger proportion of young adults experience periods living alone following break-ups.

Figure 4. Living arrangements, Danish women aged 45-49 living in different household positions

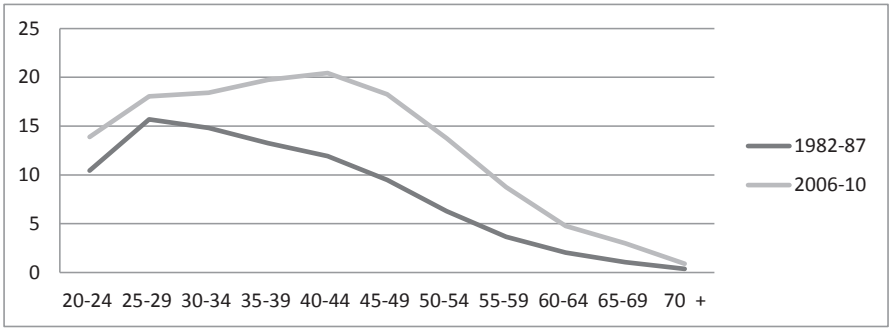


Source: Own calculations using data from Statistics Denmark

For the middle aged there has also been a decline in the proportion married which has not been fully offset by the increase in the share cohabiting, Figure 4. This means that the increase in union dissolutions has led to a rise in the proportion of one-person households and lone parents. The increase in the proportion cohabiting among the middle aged is a result of a growth in the share of people in these age groups who have never married, especially in Sweden (Sobotka and Toulemon 2008), but is mainly due higher divorce rates, as those who repartner following a divorce are more likely to cohabit.

Considering the age specific divorce rates for Norwegian men, we see that the rates are higher for all age groups in 2006-10 than they were in 1982-87, especially for the middle aged, Figure 5. In Finland there has also been an increase at all ages, but there the young couples have seen the starkest increase (not shown).

Figure 5. Age specific divorce rates (number of divorces per 1000 married men)- Norwegian men

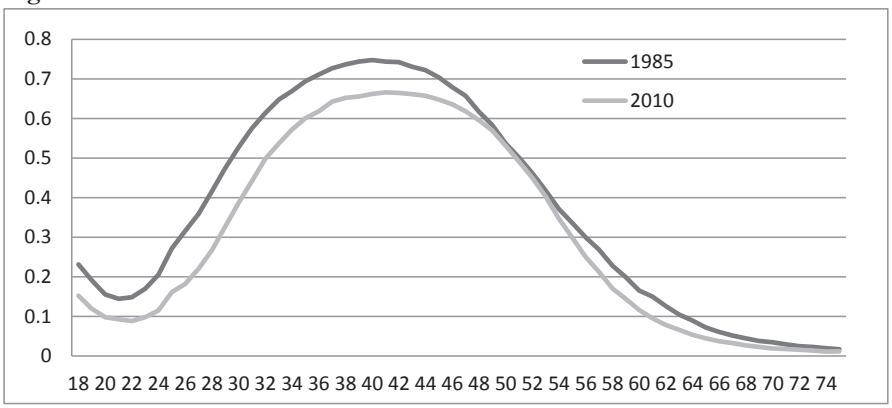


Source: Statistics Norway.

The share of Danish men who live in a household where there are children present has decreaced at all ages compared to the mid 1980s, Figure 6. The decline is especially

marked at the young and middle ages. The curve now peaks at 66% around age 40 compared to 75% in 1985. The smaller proportion of young men who live with children is to a large extent caused by the postponement of childbearing we have seen during the last decades. At higer age an important cause is the increasing break up of couples and the fact that it is still most common for the mother to get custody of the children. There has also been a tendency for the divorces to take place at an earlier stage of marriage than before (Olsen, Larsen and Lange, 2005) Although some of these men do find a new partner and have more children or become step-fathers, in 2008, 65% of Danish fathers who did not live with their children were single (Petersen and Nielsen, 2008). In addition, there has been an incerease in the share of men who remain childless. The same has been observed in Norway were there has been an increse in the proportion of men who are childless at age 40 from about 18% of the 1950 cohort to 26% of the 1960 cohort (Skrede, 2004). Although men can become fathers after this age few become first time fathers after age 40.

Figure 6: Share of Danish men who live with children

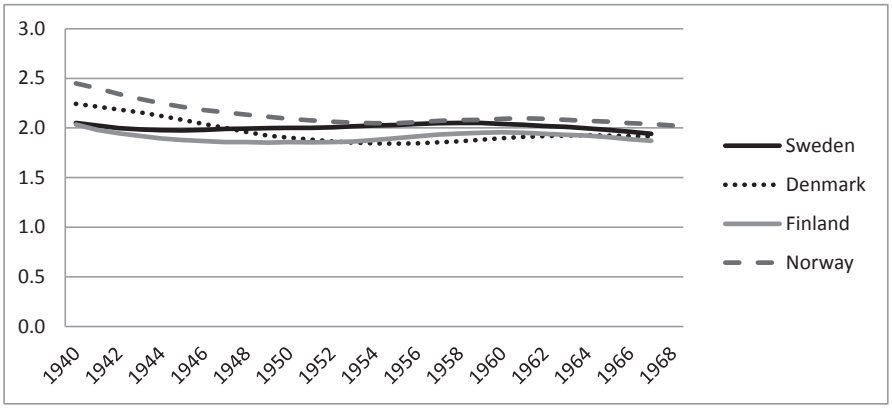


Source: Own calculations using data from Statistics Denmark. Note: The high proportion at young ages is mainly due to living with siblings.

For the cohorts of women born between 1940 to 1968, cohort fertility has been remarkably stable, see Figure 7. Norway has seen the largest fall, from 2.5 for the cohorts born during the second world war to 2 today. In the other countries there has hardly been any change at all during the period - for example in Sweden there has been a decrease in average number of children of 0.1. At the same time there has not been a rise in the share of women who remain childless, except for a slight increase for those born in 1950 and after. For the cohorts born 1955-59 the proportion who had not had a first child at age 40 varied between 12% in Norway and 17% in Finland (Andersson et al., 2008). The age pattern of childbearing has however changed profoundly across cohorts. Among those born in the 1930s and 1940s the median age at first birth was below age 25, rising to nearly 30 among those born in the 1970s (Billari and Liefbroer, 2010).

This means that the majority of women still become mothers, although they do so at a later age, and as noted earlier, a growing proportion spend some of their years with dependent children as single mothers.

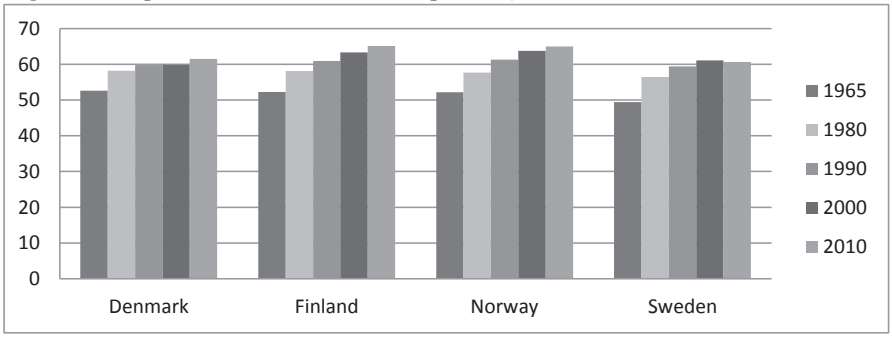
Figure 7: Cohort fertility in the Nordic countries - women (birth cohort on the x-axis)



Source: Data from Statistics Denmark, Statistics Finland, Statistics Norway and Statistics Sweden.

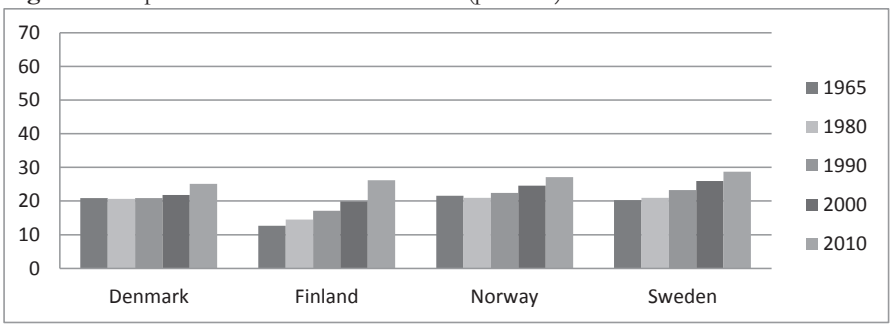
At the highest ages, there has been an increase in the proportion of both men and women who are married (I here consider marital status as cohabiting is still rare among the elderly), Figures 8 and 9. For men the rise has been in the magnitude of ten percentage points in all four countries. Sweden and Finland have witnessed equally large growth for women as for men, whereas in Denmark and Norway it has been about half that of men. Although the proportion married has increased among both women and men, the share in this age group is still much higher for men. Whereas between 60 and 65 percent of men aged 75+ were married, this is true for only around a quarter of women. Among men the increase is first and foremost caused by a falling share of widowers. For women the main driving force is a decrease in the proportion never-married.

Figure 8: Proportion of men75+ married(per cent)- Marital status



Source: Own calculations using data from Statistics Denmark, Statistics Finland, Statistics Norway and Statistics Sweden.

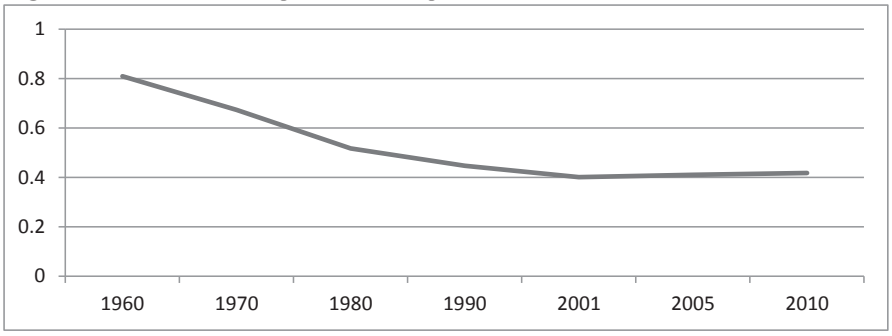
Figure 9: Proportion of women 75+ married (per cent)- Marital status



Source: Own calculations using data from Statistics Denmark, Statistics Finland, Statistics Norway and Statistics Sweden.

The increase in couples will, cet par, lead to larger household sizes among the elderly. However, whereas living with other relatives was common among the elderly in the 1960s and 70s the vast majority now live alone, Figure 10. It is no longer usual for single elderly to move in with relatives. The reasons for this can be both a greater wish for privacy and greater affluence. This trend reinforces the decline in household sizes. All in all more elderly live alone. Of course this is partly caused by an increase in the proportion of those aged 80+ who are in the highest age brackets but there has also been a decline in the proportion living with others than a spouse across the age groups 80-84, 85-89 and 90+. As the elderly now tend to live in rather small households, ageing, per see, has also accelerated the fall in average household size.

Figure 10: Share of Norwegians 80+ living with others

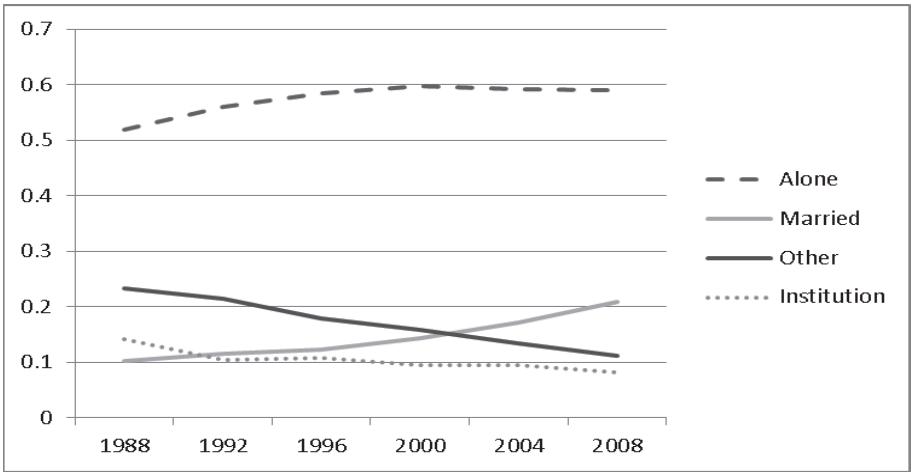


Source: Statistics Norway.

Comparing the development during the last decades for Finnish women in the age groups 80-84 and 90+, respectively, we see that the proportion living alone has been stable among the youngest age group for the last ten years but has been increasing steadily for those aged 90 and over, Figures 11 and 12. The proportion married has increased among those aged 80-84 but has been low and fairly stable among the oldest old. The proportion living with others than their spouse has decreased for both age groups and the share of those aged 90+ living in institutions has decreased. Indeed,

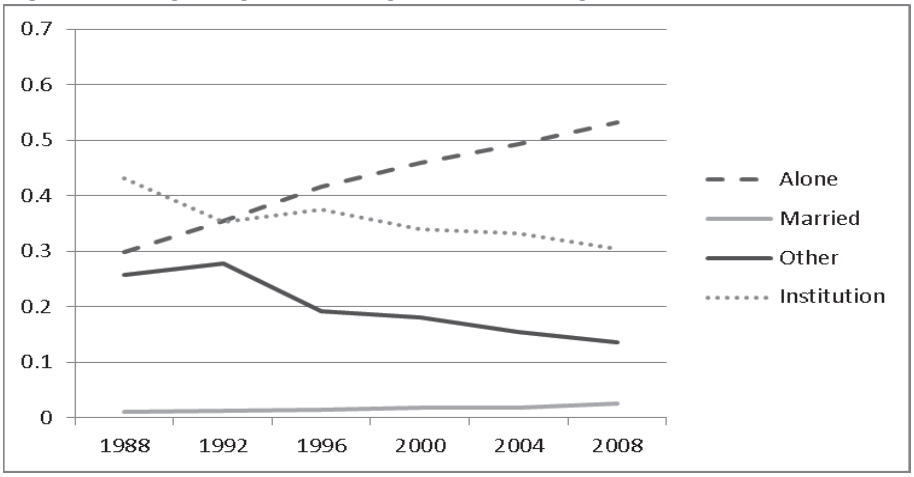
the share in the age group 90+ who live alone is now nearing the share in the age group 80-84.

Figure 11: Living arrangements among Finnish women aged 80-84.



Source: Own calculations using data from Statistics Finland.

Figure 12: Living arrangements among Finnish women aged 90+.

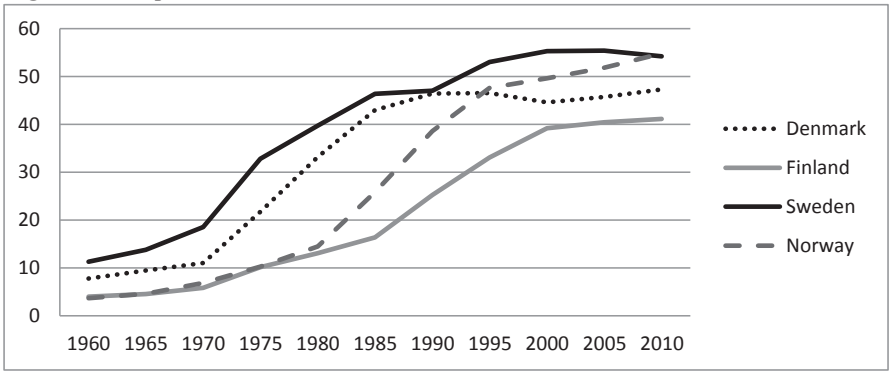


Source: Own calculations using data from Statistics Finland.

5. Children's living arrangements

Beyond affecting adults, these changes in household structure also imply great changes in children's living-arrangements. The family constellations children grow up in have been shown to influence both their well-being and school results (e.g. Jonsson and Gähler, 1997; Cherlin, 1999) as well as a number of adult outcomes (e.g. Amato and Keith, 1991; Reneflot, 2009).

Figure 13: Proportion of children born to unmarried mothers



Source: Statistics Denmark, Statistics Finland, Statistics Norway and Statistics Sweden.

Whereas in 1960 nearly 90% of Swedish children were born to married mothers, the majority now have mothers who were unwed at the time of birth. In Norway in 1960 less than 4% had parents that were not married at the time of birth. In 2010, 56% of children were born out of wedlock - 44% to cohabiting parents and 11% to single mothers. The lowest proportion of children are born out of wedlock in Finland where 59% still have mothers who are married at time of birth, Figure 13. Having cohabiting parents increases the risk that a child will experience a parental break-up.

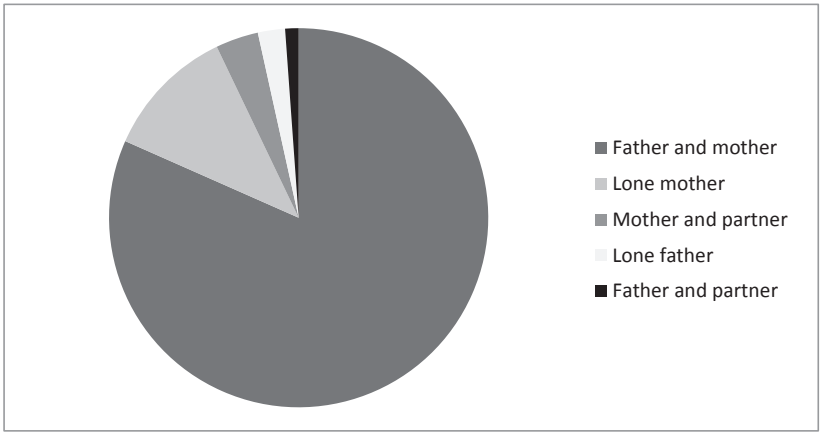
Although the proportion living with both parents has decreased it is still by far the most common living arrangement for children. For example 72% of Danish children lived with both parents in 2010, down from 83% in 1980. For those not living in a nuclear family in 2010 it was most common to live with only the mother (16%), or the mother and a partner (7%). The corresponding numbers in 1980 were 7% and 3%. The proportion that lives with only the father, or the father and a partner, has not increased much and in 2010 still constituted only 3% of children. The proportion that lives in each family type does, however, vary with age. In 2007, 90% of Danish infants lived with both their parents whereas this was only the case for 60% of 17-year olds. Looking in more detail at 15 year olds' living-arrangements, we see that between 1980 and 2010 the large increases have been in the shares living with only their mothers or with the mother and a partner. The first category now constitutes 20%, up from 11%

in 1980. The proportion living with the mother and a stepfather has more than tripled from 3.6% in 1980 to 12% in 2010, Figures 14 and 15.

Statistics on the proportion of children experiencing a parental split-up are hard to find. However a Swedish study of 30 000 couples who had their first child in 2000 found that 27% had separated ten years later (Statistics Sweden, 2012). Of 17 year olds in Denmark in 2008, 53% had lived their whole lives together with both their parents. 41% had at some point in their lives lived with only their mother (Petersen and Nielsen, 2008).

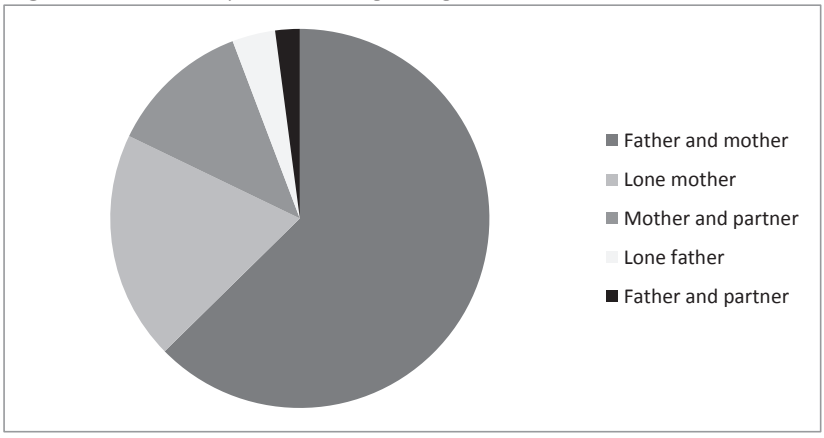
Although it has become more common to experience parental break-ups and to live in single parent and reconstructed families the vast majority of children, 87% in Denmark in 2010, is an only child or has only siblings who share the same biological parents. However, by the age of 17 a quarter of Danish children have either step or half siblings (Petersen and Nielsen, 2008).

Figure 14: Danish 15 year olds' living arrangements 1980



Source: Statistics Denmark

Figure 15: Danish 15 year olds' living arrangements 2010

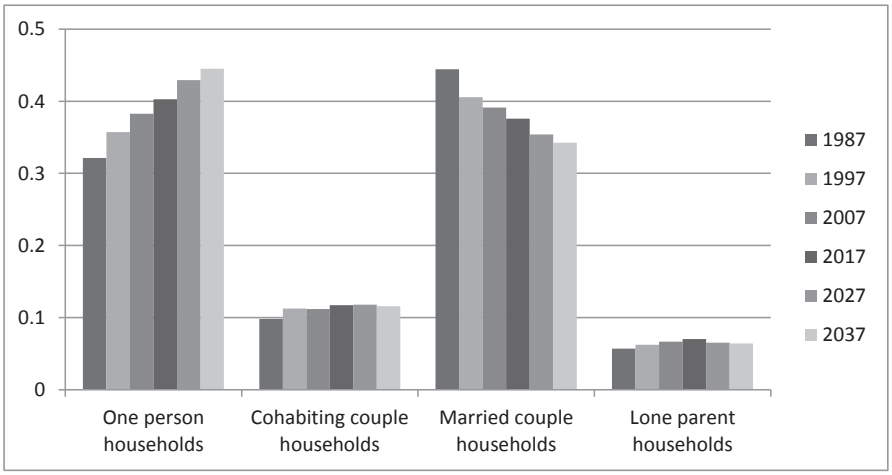


Source: Statistics Denmark

6. Future developments

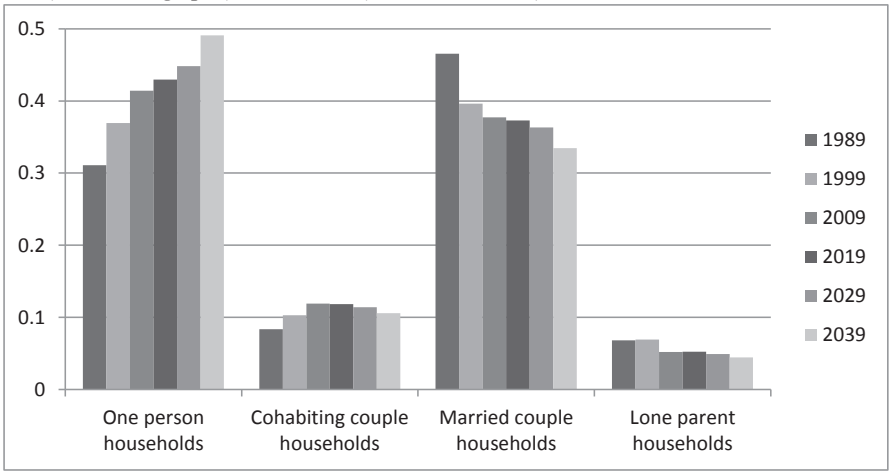
As part of the AGHON project we computed probabilistic household forecasts for Denmark and Finland with a 30 year horizon (up to 2037 in Denmark and 2039 in Finland). Full details of the method used and results are available in Christiansen and Keilman (2013). We assumed constant transition rates during the 30 year period, based on averages over the period 2004-2008 for Finland and 2002-2006 for Denmark. However, in order to achieve consistency with the national population projections, we set the total number of births, deaths, immigrations, and emigrations in each projection interval equal to the numbers from Statistics Denmark's population projection 2010 for Denmark and Statistics Finland's population projection for 2009 for Finland. The results show that the number of private households is expected to grow by 27% in Finland and 13% in Denmark during the 30-year period. This means an increase in the number of private households from 2.5 to 2.8 million (80% prediction interval 2.6-3.0 million) in Denmark, and from 2.5 to 3.1 million (80% prediction interval 3.0-3.3 million) in Finland. Taken together with the expected increase in population size, this leads to a fall in mean household size from 2.16 to 2.07 (80% prediction interval 2.01-2.28) in Denmark and from 2.14 to 1.97 (80% prediction interval 1.79-1.99) in Finland. When considering the growth in the numbers of private households of various types during the 30 year period, the strongest increase is expected for the number of one-person households: 31% and 50% in Denmark and Finland, respectively. However, whereas the number of married couple households is expected to grow by 12% in Finland, a slight fall is expected in Denmark. As a result, married couple households are expected to become less important, numerically speaking: falling from 40% to 34% of all private households in Denmark and from 38% to 33% in Finland. The fraction of single person households is, on the other hand, expected to rise from 38% to 44% in Denmark and from 41% to 49% in Finland. The shares of cohabiting and lone parents are expected to remain remarkably stable during the 30 year period, Figures 16 and 17.

Figure 16. One-person households, cohabiting and married couple households and lone parent households, as a share of all private households. Observed (1987, 1997, 2007) and average[5] projected values (2017, 2027, 2037), Denmark.



Source: Own computations based on data supplied by Statistics Denmark

Figure 17. One-person households, cohabiting and married couple households and lone parent households, as a share of all private households. Observed (1989, 1999, 2009) and average projected values (2019, 2029, 2039), Finland.



Source: Own computations based on data supplied by Statistics Finland

[5] We calculated 3000 sample paths for the number of people in each household position.

7. Uncertainty

Probabilistic household projections, in addition to projecting the development of different household types, also quantify the uncertainty these projections entail. Our results show that the numbers of household consisting of married and one-person households are the most certain, and single parents and other private households are the most uncertain.

The relative uncertainty is generally largest for the youngest age groups. For young adults the greatest uncertainty concerns single parents and least uncertainty regarding the number of cohabiting and those living alone. For the middle aged there is also greatest uncertainty concerns single parents and the married and those living alone are the most certain. For the elderly there is a large amount of uncertainty concerning the cohabiting, the number living in nursing homes and the number living in other private households, whereas the most certain are the married and those living alone. In general, household positions containing a lot of people are easier to predict than the less numerous ones.

8. Summary

The Nordic countries have seen a rise in the number of households during the last decades which has far exceeded the population growth. This has led to a steep decline in the average household size from between 3.3 and 2.9 in 1960 to between 1.96 and 2.3 in 2010. This has been driven by a strong increase in one-person households and a fall in households consisting of three or more members. The reasons for this is to be found in the increase in cohabitation and postponement of marriage and childbearing among the young, increased divorce risks and the fact that the elderly less often live with relatives. Ageing has also played a role as it has increased the proportion of the population who live in small households.

A larger proportion of children are born out of wedlock and experience the breakup of their parents' relationship. However the majority of children still live with both their parents.

Table 1 and 2 give a summary, from multistate life tables[6], of how an "average" Finn and Dane spend their lives, based on data (transition rates) from 2002-2006 in Denmark and 2004-2008 in Finland. Table 1 shows that the Finns spend a little more than a quarter of their lives living as a child, a third living with a spouse, 11% cohabiting and around 20% living alone. The Danes spend a somewhat larger fraction of their lives living as a child and a little less living with a spouse (Table 2). In both countries the majority of children are born by mothers who live with a spouse,

[6] In multistate life tables there are multiple states between which transitions occur subject to specified transition rates. This allows us to estimate the expected proportion of life spent in each state for a representative individual, given that he or she were subjected to the specified transition rates from the moment of birth until the moment of death.

although the difference between births by married and cohabiting women is smaller in Denmark than in Finland.

Table 1: Percentage of life time spent in various household positions, and number of children by mother's household position, Denmark 2002-2006

	Child	**Single**	**Cohabiting**	**Married**	**Lone parent**	**Other**	**Institution**	**All (=100%)**
				%				years
Men	29	19	11	31	1	8	0.3	75.1
Women	26	21	11	30	5	6	0.7	79.9
				children				
	0.02	0.08	0.7	0.83	0.08	0.16	0.00	1.88

Source: Calculations from the AGHON-project

Table 2: Percentage of life time spent in various household positions, and number of children by mother's household position, Finland 2004-2008

	Child	**Single**	**Cohabiting**	**Married**	**Lone parent**	**Other**	**Institution**	**All (=100%)**
				%				years
Men	26	20	11	35	1	6	1	74.8
Women	22	22	11	34	4	5	1	82.3
				children				
	0.00	0.09	0.42	1.27	0.10	0.05	0.00	1.93

Source: Calculations from the AGHON-project

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Summary of the studies

Paper I: Probabilistic household forecasts using register data: The case of Denmark and Finland

The purpose of this paper is to forecast the household structure in Denmark and Finland 30 years into the future. The forecasts are based on data from the Danish and Finnish household registers. Thus far the vast majority of household forecasts have not had access to household register data and have been based on sample surveys. As a consequence, researchers have been restricted to basing their transition probabilities on marital status instead of household position and have made a number of simplifying assumptions. Employing high quality household register data encompassing the entire Danish and Finnish population, respectively, we are able to calculate quite reliable transition probabilities even for infrequent transitions. As the Danish household register has been in operation since the early 1980s, and its Finnish counterpart since the late 1980s, we also had access to household time series data spanning more than two decades. Having detailed time series data meant that we could estimate the uncertainty in the future distribution of the population across household positions in more detail than earlier studies have been able to do. Combining the uncertainty parameters with expected shares computed in a deterministic household forecast, we simulate sample paths for the household shares for each age and sex. These paths are then combined with simulations from a stochastic population forecast covering the same period to obtain the predicted numbers of households (one-person households, cohabiting couple households, married couple household, single person household and other private households) as well as persons in each household position by age and sex.

The results show that the share of households which are one-person households will rise, and the proportion of married couple households will continue to fall. The fractions of cohabiting and single parent households are quite stable over the projection period. In terms of

uncertainty, the number of married couple households and one-person households are the most certain as they are the most numerous, and single parent and other private households the most uncertain. The more detailed uncertainty parameters derived from the time series analysis of household data mean that prediction intervals are narrower than in earlier probabilistic household forecasts based on survey data.

Paper II: Is divorce green? Marital dissolution, demographic dynamics and energy use

This paper addresses the environmental impact of changes in the household structure – more specifically how a change in divorce and union dissolution rates impacts on the demand for domestic energy. In contrast to earlier inquiries into this topic, we consider not only the higher per capita energy use resulting from a loss of economies of scale when one household is split into smaller households, but also the inhibiting effect divorce has on fertility at the individual level. We use household forecasts taking the transition rates observed today as the Benchmark and compare them to scenarios with higher or lower divorce rates, holding other transition rates constant. The birth rates vary with the household position of the mother according to observed patterns. The projected number of households is then combined with data on domestic energy consumption broken down by household size to estimate the total Danish domestic energy use.

In addition to household register data, data from the Danish consumer expenditure survey are utilised. Our finding is that the dominant effect in the short run is the higher per capita domestic energy use resulting from smaller households being less energy efficient, confirming the results of earlier studies. However in the long run, higher divorce rates lead to a lower

energy use than in the Benchmark scenario and lower divorce rates lead to higher energy use than in the Benchmark scenario. Holding the number of births constant across scenarios, there is no such reversal, and the domestic energy use is higher in the scenarios with higher divorce rates than in the Benchmark scenario throughout the projection period. Taking the effect of divorce and union dissolution rates on fertility into account therefore leads to a different conclusion in the long run than do the earlier studies based on cross-sectional data. Although one might argue that large changes in divorce rates in developed countries are unlikely, divorce rates are on the increase in many parts of the world and knowledge about the impact on energy consumption is therefore important.

Paper III: The impact of children's sex composition on parents' mortality

In study III, I examine whether the sex of one's children is associated with one's mortality . Earlier studies have found that those with children have lower mortality than the childless (at least at low parities). However, few studies have inquired into whether there is a link between the children's gender and mortality, and the majority of these studies have been based on small samples and historical populations. This study is novel in that it addresses this question using register data encompassing an entire contemporary western population (the Norwegian).

Gender preferences are generally not very strong in western societies, with the majority of parents having either no preference or preferring having at least one of each sex. Children's sex can still have both biological (for the mother) and social implications for the parents. The likelihood of divorce, time spent with children, number of hours spent working, weight and

alcohol consumption are examples of areas earlier studies have found to be linked to children's sex composition.

I find limited support for the hypothesis that mortality is linked to the sex composition, namely that having only girls, compared to having at least one child of each sex is associated with higher mortality among women with two or more children. This is also the case for mothers who had their first child as a teenager and only have sons. Mothers of two daughters and no sons have a higher mortality than mothers of two sons and no daughter. However, mothers of four daughters and no sons have a lower mortality than mothers of four sons and no daughters. Finally, having children of only one sex is associated with higher mortality for mothers in the 1980s.

This analysis contributes to the field of study inquiring into the link between family and mortality, particularly the growing literature on the association with children, by showing that gender composition can have a mediating effect. It also fits into the tradition of studying how far-reaching effects the gender composition of one's children may have on one's life.

Paper IV: The association between grandparenthood and mortality

Paper IV inquiries further into the link between family and mortality by addressing another aspect of one's children - namely whether they in turn have children. Very few studies have so far looked at whether there is a link between grandparenthood and health, and the majority of these studies have focused on US families where the grandparents have taken over parental responsibility for their grandchildren. No-one has so far studied whether mortality is linked to being a grandparent. In order to address this question I employ Norwegian register data.

The result shows that being a grandfather is associated with higher mortality. The strength of the association is not dependent on number of grandchildren or the number of sets of grandchildren. However, there is a mediating effect of age with young grandfathers having a stronger mortality disadvantage than older grandfathers. Young grandmothers also have higher mortality than mothers who are not grandmothers, as do grandmothers who are married or who have many children. This is also the case when considering age at becoming a grandparent. Those who became grandfathers early display a stronger mortality disadvantage than those who became grandfathers later in life and for women becoming a grandmother after age 50 is associated with a mortality advantage. Controlling for characteristics of the middle generation does not remove the associations. The results are surprising given that the vast majority of the research on grandparenthood emphasises the positive aspects of being a grandparent such as a greater satisfaction with life, less loneliness and more contact with the middle generation.

I have also looked at the association between grandparenthood and self-rated health using data from the Norwegian Gender and Generation Survey. As with mortality, being a grandparent is linked to poorer self-rated health for men, especially for those who became a grandfather early in life. Grandmothers who have many grandchildren or became grandmothers prior to age 45 are also more likely to report poor health.

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Research Article

Probabilistic household forecasts based on register data - the case of Denmark and Finland

Solveig Glestad Christiansen

Nico Keilman

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Research Article

Probabilistic household forecasts based on register data - the case of Denmark and Finland

Solveig Glestad Christiansen[1]

Nico Keilman[2]

Abstract

BACKGROUND
Household forecasts are important for public planning and for predicting consumer demand.

OBJECTIVE
The purpose of this paper is to compute probabilistic household forecasts for Finland and Denmark, taking advantage of unique housing register data covering the whole populations dating back to the 1980s. A major advantage is that we do not have to rely on small population samples, and we can get quite reliable estimates even for infrequent transitions. A further merit is having time series containing the population in different household positions (dependent child, living with a spouse, living in a consensual union, living alone, lone parent, living in other private household and institutional households) by age and sex.

METHODS
These series enable us to estimate the uncertainty in the future distribution of the population across household positions. Combining these uncertainty parameters with expected shares computed in a deterministic household forecast, we simulate 3000 sample paths for the household shares for each age and sex. These paths are then combined with 3000 simulations from a stochastic population forecast covering the same period to obtain the predicted number of households and persons in each household position by age and sex.

RESULTS
According to our forecasts, we expect a strong growth in the number of private households during a 30-year period, of 27% in Finland and 13% in Denmark. The

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number of households consisting of a married couple or a person who lives alone are the most certain, and single parents and other private households are the most uncertain.

1. Introduction

Our aim is to compute probabilistic household forecasts for Denmark and Finland, using register data. Household forecasts are useful for planning housing supply, energy use, and the demand for consumer durables (e.g. King 1999; Muller, Gnanasekaran, and Knapp 1999; O'Neill and Chen 2002). For the elderly, the household position also has an effect on their demand for places in nursing homes (e.g. Lakdawalla and Philipson 1999; Lakdawalla et al. 2003; Grundy and Jital 2007).

Traditionally, household forecasts have been computed by models that, roughly speaking, can be divided in two groups: household headship rate models, and household transition models (Van Imhoff et al. 1995). Compared to headship rate models, which are static in nature, transition models have the advantage that they explicitly describe the dynamics of the household composition of the population.

Both types of models are widely used for computing deterministic forecasts. A projection of the number of households of a certain type in a given year in the future is computed as one number (or just a few numbers: see section 2). Such a deterministic forecast, however, does not give an accurate view of forecast uncertainty. The future is inherently uncertain, and hence probabilistic methods have to be used. Alho and Keilman (2010) have recently developed a method for computing probabilistic household forecasts. They applied their method to Norwegian data. One important drawback of their application is that the uncertainty assessments were based on limited data, and simplifying assumptions had to be made (see section 2).

The purpose of this paper is to improve on the approach of Alho and Keilman by taking advantage of high quality data from the population registers and housing registers of Denmark and Finland. Both countries have register data covering the whole populations dating back to the 1980s. The registers contain information about persons in every dwelling, including all flats in apartment blocks, each having its own unique address (Lind 2008; Niemi 2011). We constructed time series for household parameters and analysed the prediction errors in those time series. This allowed us to assess the expected errors in the household forecasts for the two countries.

We forecast, with a 30 year horizon, the number of people occupying the following household positions: dependent child, living with a spouse, living in a consensual union, living alone, lone mother or father, and living in other private household. In addition, the elderly can live in an institutional household. Our household

forecasts for Denmark and Finland form part of the AGHON project (Ageing Households and the Nordic welfare model (http://www.etla.fi/en/research-projects/aging-households-nordic-welfare-model-aghon/).

The aim of this project is to combine statistical analysis of household types with economic analysis of population ageing in Denmark and Finland. Probabilistic household forecasts, which describe the developments of different household types and quantify the uncertainty in these descriptions, are used jointly with computable general equilibrium models and partial models describing household behaviour under uncertainty.

Following this introduction, the paper is divided into five sections. We give a brief overview of earlier work in the field of household forecasting in section 2. Section 3 describes the methods used to forecast household shares and the population. In section 4 we present the data employed in this paper. Section 5 gives some selected results from our household forecasts. Finally, section 6 summarises and draws some conclusions.

2. Overview of earlier work

As mentioned in the introduction, our model is similar to that used by Alho and Keilman (2010). This random share model can be characterized as a probabilistic and dynamic macro model that projects households of various types, as well as the population broken down by age, sex, and various household positions. Below we will briefly sketch the most important features of our model, as compared with other approaches to household forecasting. Extensive literature reviews of household projection models have been published by Jiang and O'Neill (2004), Bell, Cooper, and Les (1995), and Arminger and Galler (1991). Another useful reference is Van Imhoff et al. (1995).

Probabilistic household projection models are new to the literature, compared to deterministic models. De Beer and Alders were the first to publish a probabilistic household forecast (see Alders 1999, 2001, and De Beer and Alders 1999). They combined a probabilistic population forecast with random shares that distributed the population probabilistically over six household positions: individuals could live as a child with parents, live alone, live with a partner, as a lone parent or in an institution, or belong to another category. For instance, the authors computed the random variable for the number of lone mothers aged 40 years in 2015 as the product of two other random variables: the number of women aged 40 years in 2015 and the share of those women who live as a lone mother. Expected values for population variables and for the shares for specific household positions were obtained from observed time series, but the statistical distributions that were assumed for the shares were based on intuitive

reasoning. Perfect correlations across age and sex were assumed for the mortality rates, fertility rates, and migration numbers in the stochastic population forecasts, as well as for the random shares. In addition the authors assumed perfect correlation in the time dimension for the random shares.

Scherbov and Ediev (2007) combined a probabilistic population forecast for the population broken down by age and sex with random headship rates. In demography a headship rate reflects the proportion of the population that is the head of the household, for a given combination of age and sex (United Nations 1973; Jiang and O'Neill 2004): see below. Like De Beer and Alders, Scherbov and Ediev based a large part of their uncertainty distributions on intuition. In contrast, our contribution is to show how uncertainty in the forecast of the shares that distribute the population over several household positions can be modelled as a stochastic process, the parameters of which can be derived from time series models estimated from population register data.

In our view probabilistic forecast models are more appropriate for computing forecasts than deterministic forecast models. There are many possible future household developments for a given population, but some of these are more likely than others. As opposed to a deterministic forecast, which predicts only one number (or perhaps just a few: see below) for a certain year, a probabilistic forecast tells us how likely it is that future household numbers will be within a certain range. Information of this kind allows policy makers, planners, and other forecast users in the fields of housing, energy, social security etc. to take appropriate decisions, because some household variables are more difficult to predict, and hence more uncertain than others. It also guides them once actual developments start to deviate from the most likely path. New actions or updated plans are unnecessary as long as developments are likely to remain close to the expected future. Deterministic forecasts traditionally deal with forecast uncertainty by formulating alternative scenarios, usually in terms of a high and a low trajectory for some key input parameter, in addition to a most likely trajectory (Jiang and O'Neill 2006). The drawback is that uncertainty is not quantified, and hence the user does not know how likely it is that the high trajectory will materialize, instead of the most likely trajectory. Moreover, the results are not plausible from a statistical point of view, as they implicitly assume perfect correlation across age, time, and type of household (Lee, 1999; Alho et al. 2008).

Our household model is a dynamic one, as opposed to static household models. Dynamic household models (also labelled as household transition models) deal explicitly with household events. A household event is defined as a change in household position that an individual experiences during a brief time interval. For instance, a person who lives as dependent child with his or her parents and starts to live with a cohabitee experiences the event of home leaving. A lone mother whose last child leaves home becomes a one-person household. Dynamic household models were first

developed in the 1980s, when existing multistate demographic models were applied to household analysis (Kuijsten and Vossen 1988). A prominent example of the group of dynamic household models is the LIPRO ("LIfe style PROjections") model (Van Imhoff and Keilman 1991), which is based on the methodology of multistate demography but includes several extensions to solve the particular problems of household modelling. At present it is used by Statistics Netherlands for their official household forecasts (Van Duin and Harmsen 2009) and by The Office of National Statistics for their marital status projections for England & Wales (http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Population+Projections+by+Marital+Status). Other dynamic models, which demand less detailed data, have been employed elsewhere (e.g. ProFamy: see Zeng et al. (2007)). In the current forecasts we have used the computer programme developed for LIPRO (version 4.0: see http://www.nidi.knaw.nl/Pages/NID/24/841.bGFuZz1VSw.html) to compute the expected values for our random household shares.

The advantage of dynamic household models, as opposed to static models, is that they explicitly model household events. At the same time their data demands are relatively high. Most of the static models are of the headship rate type. Headship rate models compute future numbers of households by combining an independent forecast of the population (broken down by age, sex, and often also by marital status) with future values for the proportions of household heads in the population (specific of age, sex, etc.). These models have a long tradition in demography (US National Resources Planning Committee 1938; United Nations 1973; Keilman, Kuijsten, and Vossen1988). Because of their modest data demands they are more often used than dynamic models (e.g. Jiang and O'Neill 2004), in spite of the fact that processes of household change remain a black box.

A final distinction is that between microsimulation models and macrosimulation models. Microsimulation household models (Wachter 1987; Galler 1988; Fredriksen 1998) take the individual as the unit of analysis, and attach a number of characteristics to each person: age, sex, survival status, number of children, household position, etc. Pointers[3] indicate which individuals live together in a given household. The model updates these characteristics (except for those that are fixed, such as sex) for each individual by means of random draws from assumed probability distributions for events such as death, the birth of a(n additional) child, change in household position, etc. In this sense the microsimulation model is a probabilistic model, but it only captures Poisson uncertainty. The Poisson rates that determine the distributions (death rates, birth rates, rates for household events) are non-random. For this reason microsimulation models are less well suited to reflect forecast uncertainty, as in reality the rates tend to

[3] Pointers are identification numbers. Every household is assigned an identification number and this number is then given to all members of that household.

change over time in an often unpredictable way. The advantage of the microsimulation models is that they are very well suited to map complex household, family, and kin structures (Jiang and O'Neill 2004). But the data requirements are large, because the model is applied to a file with information about individual persons. A recent attempt to combine microsimulation and macrosimulation has resulted in the MicMac model (http://www.nidi.nl/smartsite.dws?id=24930&ver=&ch=NID&lang=UK).

The model in this paper extends the work of Alho and Keilman (2010) for Norway, who estimated their household transition rates from panel data from around 5000 households. Mortality rates, however, were estimated based on marital status data from the population register of Norway, together with a number of simplifying assumptions. A few other transition rates had to be borrowed from a deterministic dynamic household forecast for Norway published by Keilman and Brunborg (1995).

A major advantage of having register data is that we do not have to rely on small population samples when calculating household transition rates. Having transition data for the total population and for many years means that we can get quite reliable estimates, even for infrequent transitions. A further merit of the register data we have in this case is the relatively long time series containing the population in different household positions. These series are used to estimate the uncertainty in the future distribution of the population across household positions. This is an improvement on the Alho and Keilman (2010) study in which uncertainty parameters were based on the empirical errors in the predicted household shares from an earlier Norwegian household forecast.

Using register data, it is also clear that all the data are compiled using the same definition. When household data are taken from different sources, different definitions may have been used. For instance, one part of the data may have been based on a household-dwelling definition, where all those who live at the same address are member of the same private household. Other data sources may have used the housekeeping definition, where only those who take meals together and use common household facilities form a household. The first definition includes lodgers as part of the household of the landlord, whereas the second does not. Thus numbers of one-person households will show substantial differences depending on whether one takes the household-dwelling definition or the housekeeping definition of a private household. The same is true for numbers of large households.

3. Methods

3.1 Brief overview of our approach

We begin by computing deterministic household forecasts with a 30-year horizon for Finland and Denmark. We have set jump-off years to 2007 for Denmark and 2009 for Finland, which were the latest years for which we have reliable data. In 2008 there was a change in some definitions in Denmark, which makes the data from the years 2008 and later difficult to compare to earlier data. The results of interest of the latter forecasts are the distributions of the population over several household positions. Each household position corresponds with one share. These shares are different for men and women in different age groups. Also, they change over time. In order to assess the level of uncertainty in the shares, we analyse time series data on the share for each household position broken down by age and sex. The time series models predict, among other things, the likelihood that a share will be different from its expected value by a certain amount. Also, the data enable us to estimate the correlations of the shares across ages and between the sexes. Correlations across household positions are dealt with in a specific manner: see Section 3.4. Using the shares computed in the deterministic population forecast and the estimated standard deviations and correlations, we simulate 3000 sample paths for the household shares for each age and sex: see Section 3.5. These paths are then combined with 3000 simulations from an earlier computed stochastic population forecast that covers the same period. This gives the predicted number of persons in each household position.

We will now explain in further detail each of the steps outlined above.

3.2 Deterministic household forecast

The population is divided into categories defined by sex, 5-year age groups up to 90+, and seven different household positions. Our particular choice for these household positions was governed by the requirements of the economic models developed within the AGHON project: see, for example, Højbjerg Jacobsen et al. (2011). The household positions are:

1. CHLD – dependent child living with one or both parents (up to 25 years of age).
2. SIN0 – person living in a one-person household.
3. SIN+ – single mother or father (aged 15–75).
4. COH – living in a consensual union with or without dependent children.

5. MAR – living with a spouse with or without dependent children.
6. OTHR – living in a private household, but not in any of the positions described above.
7. INST – living in an institution for the elderly (from 70 years of age).

These categories refer to living arrangement and not marital status. For example, the category MAR does not include all those who are married, but only those who are currently living with a spouse. An example of a person belonging to the group OTHR is someone living in a multiple family household. Persons who live in households where they have no parent-child relationship and are not married or cohabiting with any of the other members of the household also belong to this category. In addition, those who in the data were coded as children although they are 25 and older, coded as lone parent and aged 75 and over, and those aged under 70 who are living in institutions were assigned the household position OTHR.

To compute the deterministic household forecast we use the macro simulation model and corresponding computer programme LIPRO. We will here give a rough sketch of the LIPRO model. For a detailed description of the model and the computer programme, see Van Imhoff and Keilman (1991).

We start out with a jump-off population broken down by age, sex, and the seven household positions described above. This population is then projected forward five years at a time by exposing it to household transition rates, death rates, and emigration rates that are dependent on age, sex, and household position. The female part of the population in the age group 15-49 is also exposed to age and household-specific fertility rates. International migration is included in the model as emigration rates and immigration numbers broken down by age, sex, and household position.

The population at time t+1 can then be calculated using the standard demographic bookkeeping equation.

$$V_{t+1}=P_tV_t+Q_tI_t$$

where V_t is a column vector of the population broken down by age, sex, and household position at time t. I_t is a column vector of immigrants who have arrived between time *t* and time *t+1*.

P_t and Q_t are square matrices containing transition probabilities determined by the rate matrix M_t which contains age, sex, and household position-specific rates.

The period (*t*, *t+1*) is five years.

We have applied the exponential version of the model in which intensities are assumed to be constant within the unit time interval. Under this assumption the transition probability matrix P_t equals $\exp(5M_t)$. Transition probabilities for immigrants are given by

$$Q_t=(M_t/5)^{-1}\left[\exp(5M_t)-I\right],$$

where I is the identity matrix. For small values of the rate matrix M_t the latter expression implies that immigrants are exposed to the risks of household events during approximately half the length of the unit time interval, i.e., approximately 2.5 years. The model is a first-order discrete time Markov model. Hence, once the immigrants have entered the country, they are subject to the same transition rates for household events, fertility, mortality, and emigration as the population present at the beginning of the time interval. For more details about the model and its derivation see Van Imhoff and Keilman (1991).

As discussed above, the LIPRO model is based on the projection of individuals, not households. This means that, for example, the number of women who marry during a period will not in general be the same as the number of men who marry during the same period according to the model. To solve this problem LIPRO employs a consistency algorithm. For a thorough discussion of this algorithm see Van Imhoff (1992). In this case the consistency algorithm contains equations that require that equal numbers of men and women marry or enter cohabiting unions in each projection interval. The same applies to the number of men and women experiencing the dissolution of marital and cohabiting unions. We here employ the harmonic mean version of the consistency algorithm. This means that when there is a discrepancy between the modelled number of men and of women experiencing one of these events, the number is adjusted to the harmonic mean of the modelled number of men and the modelled number of women experiencing this event.

The consistency algorithm described above assumes that each new couple consists of one male and one female partner. In reality same sex partnerships are observed as well in the two countries. In Denmark in the years 1999–2011 between 300 and 400 same-sex couples married each year compared to 30,000 to 40,000 marriages of partners of opposite sex. In 2012 there were 4000 married same–sex couples in Denmark compared to more than one million married couples with partners of opposite sex. In Finland 0.2% of households are made up of same-sex married couples. Because same-sex couples make up such a small percentage and because statistics on same-sex cohabiters are not available (as they are difficult to distinguish from friends living together), we have chosen not to include them in this forecast.

In addition to requirements for union formation and dissolution we have also constrained the capacity of institutions to be constant over time. In practice this was achieved by making the number of persons leaving an institution equal to the number entering an institution in each projection period. As the number of places available in institutions is a result of policy decisions we do not find it reasonable to let the future number of people in institutions be determined purely by transition rates. In addition to

the kind of consistency requirements described thus far it is also possible to set the number of births, deaths, immigrations, and emigrations equal to numbers from an external source. In this case we have chosen to set the total number of these events in each projection interval equal to the numbers from Statistics Denmark's population projection 2010 for Denmark, and Statistics Finland's population projection for 2009 for Finland. For the case of mortality this means that, although initially the death rates are held constant during the 30-year projection period, the consistency algorithm reduces them so as to result in the numbers of deaths from the official population forecast. This implies an increase in the life expectancy.

3.3 Stochastic population forecast

The population forecasts are updates of the results from the Uncertain Population of Europe (UPE) project. The aim of that project was to compute stochastic population forecasts for 18 European countries, including Denmark and Finland. For more information about the methodology and assumptions see Alho et al. (2006), Alders, Keilman, and Cruijsen (2007), Alho et al. (2008) and the website http://www.stat.fi/tup/euupe/.

We calculated the stochastic population forecast using the Program for Error Propagation (PEP) developed by Juha Alho. This programme takes as its inputs the jump-off population and predicted mortality rates and fertility rates (for women) as well as net migration, all by one-year age groups for all the forecast years. In addition one must specify uncertainty parameters for these rates and the rates' co-variances across time, age, and between the sexes.[4] The programme then draws sample values from a standard normal distribution, and transforms them to correlated errors. Adding these errors to the specified rates in the logarithmic scale creates a sample path for the vital rates. This sample path together with the jump-off population is then used to calculate a sample path for the future population, using a cohort component model. The process is repeated to create the number of desired sample paths for the population.

We updated the results from the UPE project by changing the jump-off year to 2007 for Denmark and 2009 for Finland, and using age-specific death rates, birth rates, and net migration numbers taken from Statistics Denmark's population projection of 2010 for Denmark and that of 2009 for Finland. The remaining assumptions, that is, the variances and co-variances for the mortality rates, fertility rates, and net migration, were kept unchanged. We simulated 3000 paths for the future population.

[4] Fertility, mortality, and net migration are assumed to be independent of each other.

3.4 Analysis of time series data

In order to assess the level of uncertainty in the household shares we modelled time series for the period 1988–2009 for Finland and 1982-2007 for Denmark. Following earlier work on Norwegian data (see Alho and Keilman, 2010), we have opted for a tree-like structure.

This led us to model six types of fractions (all specific for age, sex, and time):

(1) the total share of MAR and SIN0;

(2) the relative share of MAR out of MAR and SIN0;

(3) the relative share of COH out of the total share of COH, CHLD, SIN+, OTHR, and INST;

(4) the relative share of CHLD out of the total share of CHLD, OTHR, SIN+, and INST;

(5) the relative share of SIN+ out of the total share of SIN+, OTHR, and INST;

(6) the total share of INST out of the total share of INST and OTHR.

We number the household positions as CHLD j=1, SIN0 j=2, COH j=3, MAR j=4, SIN+ j=5, OTHR j=6, INST j=7. Write V(j, x, s, t) for the number of people in household position j=1,2, . . . who are in age x=0,1, . . . and sex s, at time t=0,1,2, ... Aggregating over position, we obtain the population $W(x, s, t)=\Sigma_j V(j, x, s, t)$ of age x and sex s at time t. The share of household position j is $\alpha(j, x, s, t)=V(j, x, s, t)/W(x, s, t) = \alpha_j(x, s, t)$. The six fractions defined above are restricted to the interval [0,1]. Therefore, we applied logit transformations to the above-mentioned fractions. Temporarily suppressing indices for age, sex, and time, this gives:

$$\xi_1=\text{logit}(\alpha_2+\alpha_4)= \log((\alpha_2+\alpha_4)/(1-\alpha_2-\alpha_4))$$

$$\xi_2=\text{logit}(\alpha_4/(\alpha_2+\alpha_4))= \log(\alpha_4/\alpha_2)$$

$$\xi_3=\text{logit}(\alpha_3/(\alpha_1+\alpha_3+\alpha_5+\alpha_6+\alpha_7))= \log(\alpha_3/(\alpha_1+\alpha_5+\alpha_6+\alpha_7))$$

$$\xi_4=\text{logit}(\alpha_1/(\alpha_1+\alpha_5+\alpha_6+\alpha_7))= \log(\alpha_1/(\alpha_5+\alpha_6+\alpha_7))$$

$$\xi_5=\text{logit}(\alpha_5/(\alpha_5+\alpha_6+\alpha_7))= \log(\alpha_5/(\alpha_6+\alpha_7))$$

$$\xi_6=\text{logit}(\alpha_7/(\alpha_6+\alpha_7))= \log(\alpha_7/\alpha_6)$$

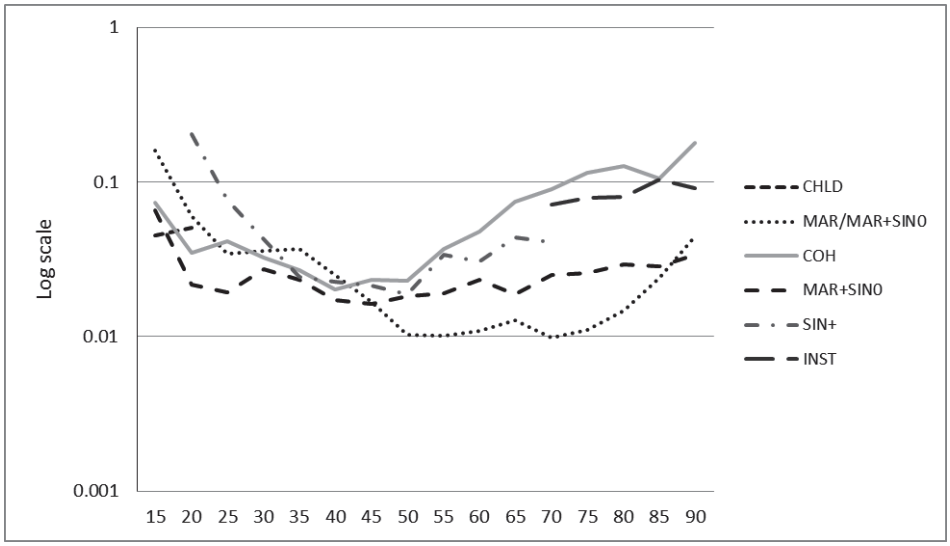
We now have, by construction, six statistically independent time series, all of them specific for age and sex.

We conducted tests to see whether there were signs of autocorrelation in the data. This was indeed the case for quite a few of the time series for the first three fractions in both countries, and also for fraction 5 in Denmark. Therefore we experimented with different versions of ARIMA models. All in all we detected autocorrelation in a little less than half the time series for both Finland and Denmark. In the majority of cases an ARIMA (1,1,0) model $\xi_k(t) = c_k + \xi_k(t-1) + \varphi\big(\xi_k(t-1) + \xi_k(t-2)\big) + e_k(t)$, where c_k is a constant and e_k is an error term, gave a good fit, although in a few cases models including a moving average part fitted even better.

For each of the time series we also estimated a random walk with a drift model (RWD model), $\xi_k(t) = \xi_k(t-1) + D_k + e_k(t)$ where D_k is a deterministic drift and e_k is an error term. In the cases where autocorrelation had been detected we compared the residual standard deviations estimated from the RWD model and the ARIMA model that gave the best fit. Although the RWD model did overestimate the residual standard deviation compared to the more refined model, the differences between the two were generally small. Striving for parsimony, we therefore decided to employ the RWD model throughout. This means that for a few household positions and age groups our prediction intervals for the household shares are wider than strictly necessary. In this sense our assessment of uncertainty is a bit conservative.

The resulting standard deviations are generally larger for the youngest and oldest age groups than for the middle aged. They are also generally smallest for the shares for fractions 1 and 2, although this is not always the case for young adults (see Figure 1).

Figure 1: Residual standard deviation of random walk with drift. Finnish men.



Source: Own computations based on data supplied by Statistics Finland.
Note: The categories refer to the six fractions defined in Section 3.4.

We estimated the correlation between the sexes to be 0.46 for Denmark and 0.53 for Finland, assuming independence of age and household position. Based on the work on Norwegian data by Alho and Keilman (2010), we assumed an AR(1) model, $e_k(x+1,s,t) = \beta e_k(x,s,t) + u_k(x,s,t), |\beta| < 1,$ for the correlation across age groups, assuming independence of sex and household position. Here e refers to the errors from the random walk with drift models; x = age, s =sex, t =time, whereas k=1, …, 6 refers to the six fractions defined above. The first-order autocorrelation β was therefore estimated as the empirical correlation between residuals $\hat{e}_k(x+1,s,t)$ and $\hat{e}_k(x,s,t)$. The estimated median values for the correlations were 0.63 for Denmark and 0.29 for Finland.

3.5 Simulation of household shares

We took 3000 draws, from a t-distribution.[5] We assumed that the errors $\hat{e}_k(t)$ of RWD model for the fractions $\xi_k(t)$, k = 1,...6 have a normal distribution, with expected value zero, and standard deviation estimated from that model. The $1-\alpha$ level prediction interval $[L(h), U(h)]$ for $e_k(T+h)$ is of the form

$$e_k(T) + \widehat{D}_k.h \pm t_{T-2}(1 - {}^1\!/_2\,\alpha)\hat{\sigma}_k \sqrt{\frac{h^2}{T-1} + h},$$

where T is the number of observations in the RWD model, $\widehat{D}_k$ is the estimated drift, $t_{T-2}(1 - {}^1\!/_2\,\alpha)$ is the $(1 - {}^1\!/_2\,\alpha)$ quantile of a *t*-distribution with $T-2$ degrees of freedom, and $\hat{\sigma}_k$ is the estimated residual standard deviation of the RWD model.

The terms h and $h^2/(T-1)$ under the square root account for innovation variance and for estimation error in the drift, respectively, while the t-distribution accounts for estimation error in the innovation variance.

Assuming standard deviation and correlation between the sexes and across age groups as estimated from the time series analysis, these are used to create correlated errors, for each sex and age group. These errors are then added to the point predictions from the deterministic household projection, which have been transformed into the same type of logit fractions as described in the previous section.

We then transformed the predicted shares ξ_k in the logit scale back to shares α_k in the original scale, for each time t and both sexes, according to:

$$\alpha_2 = \exp(\xi_1)/[(1+\exp(\xi_1))(1+\exp(\xi_2))]$$

$$\alpha_4 = \alpha_2 \exp(\xi_2)$$

$$\alpha_3 = (1-\alpha_2-\alpha_4)\exp(\xi_3)/(1+\exp(\xi_3))$$

[5] The number 3000 for our household simulations was chosen for practical reasons only: the probabilistic population forecast contains 3000 sample paths, and each population sample path is to be combined with one sample path for the household shares. Our box plots in Section 5 do not show an unrealistic number of outliers, and we therefore see no reason to increase the number of draws. 3000 has shown to be sufficient, especially when considering 80% prediction intervals. For probabilistic population forecasts, 3000 simulations are more or less standard for populations with sizes comparable to the Danish and Finnish (Alho et al. 2006, 2008).

$$\alpha_1 = (1 - \alpha_2 - \alpha_3 - \alpha_4)\exp(\xi_4)/(1 + \exp(\xi_4))$$

$$\alpha_5 = (1 - \alpha_1 - \alpha_2 - \alpha_3 - \alpha_4)\exp(\xi_5)/(1 + \exp(\xi_5))$$

$$\alpha_7 = (1 - \alpha_1 - \alpha_2 - \alpha_3 - \alpha_4 - \alpha_5)\exp(\xi_6)/(1 + \exp(\xi_6))$$

$$\alpha_6 = 1 - \alpha_1 - \alpha_2 - \alpha_3 - \alpha_4 - \alpha_5 - \alpha_7$$

This way we obtained 3000 sample paths for each of these shares, specific for age and sex. Finally, we multiplied each of these sample paths for the household shares with one of the simulations from the stochastic population forecast. This then results in 3000 sample paths for the number of people in each household position.

Implicit in this multiplication is the assumption that the household shares and the population numbers are independent random variables. This assumption is difficult to check empirically, but we have reasons to believe that it is a reasonable one. A possible dependence is that between the number of elderly persons (which is determined by mortality) and the share of one-person households in that age bracket. Often, when one of two partners in an elderly couple dies, the surviving partner becomes a one-person household. The implied correlation is likely small, because it refers to a second-order effect, namely the difference between mortality of men and women who live in a couple.

Somewhat less straightforward is a possible link between the number of young children and household structure through fertility, as demonstrated by Jiang and O'Neill (2007). The impact on partnered households caused by fertility is not very big, given that COH and MAR represent households both with and without children. But our assumption on stochastic independence will have a small effect on the number of lone parents. Jiang and O'Neill find that increasing or decreasing TFR by 0.5 leads to a change in the number of single parents by 1% 30 years ahead. Because the effect is small we think it is reasonable to ignore the interdependence in this paper.

4. Data and assumptions

As mentioned above, we have used data on the population broken down by five-year age group, sex, and household position from population registers compiled by Statistics Denmark and Statistics Finland for January 1st of the years 1987–2008 and 1982–2007, respectively[6].

We have also used data on transitions between household positions, broken down by sex and five-year age groups. These data show the number of persons who were in household position k (k=1,…,7) on 1 January of a certain year and in household position j (j=1,…7) on 1 January of the previous year. In this case we had Finnish data for the period 2004–2008 and Danish data for the period 2002–2006. The household transition data were used to compute one-year transition probabilities. We decided to use averages over the period 2004–2008 for Finland and 2002–2006 for Denmark so as to avoid erratic patterns for infrequent transitions. The probabilities of entry into single fatherhood in Finland seemed too high, and were therefore set to 20% of the corresponding numbers for women (but this probability was set to zero for men aged 10–14). The Finnish birth rate for single mothers in the age group 15–19 also seemed unrealistically high and was adjusted downwards to the Danish rate. In addition, for both countries the probabilities for entry to single parenthood after age 70 were set to zero, and those for going from single parent to other private households were set to 1. The same applies to dependent children after the age of 25.

Numbers of deaths, emigrants, and immigrants decomposed by age, sex, and household position, as well as births broken down by age and household position of the mother, were available for the same years as the rest of the transition data in the Danish case, whereas in the Finnish case they were only available for the year 2008. To avoid irregular patterns in Finnish age-specific death probabilities, the married, cohabiting, and single parents were combined into one group, and those living alone and those living in other positions in private households were gathered into another group. Similarly, the married, cohabiting, and single parents were grouped together when computing emigration probabilities.

Many of the age patterns for the transition probabilities are qualitatively the same for men and women and also between the two countries, although the magnitudes vary. As an example of the age patterns, Figures 2–5 show some of the one-year transition probabilities for Finnish women for the period 2004–2008[7].

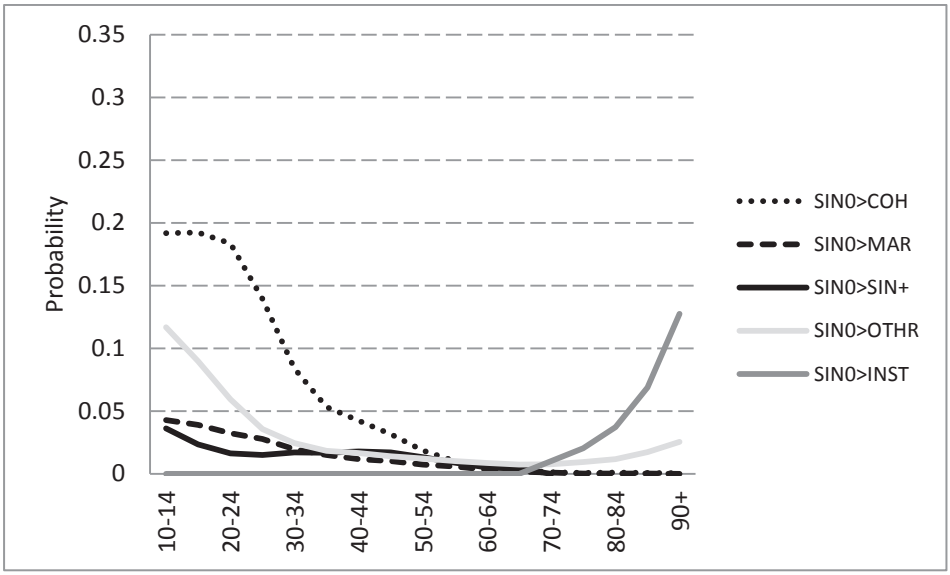
Among the general features observed for both sexes and in both countries are:

[6] For more information on the Danish data see www.dst.dk/declarations/761.
[7] The age groups on the X-axis refer to age as of 1st January 2004.

- young people who live on their own are likely to enter into cohabitation (Figure 2);
- those cohabiting in their 20s and 30s have high marriage probabilities (Figure 3);
- living with a spouse is a stable position except at the end of the life course when experiencing the death of the spouse or entry into an institution is common (Figure 4);
- for all age groups the cohabiting experience higher probabilities of switching to single household position than do those living with a spouse (Figures 3 and 4);
- young single parents often start a cohabiting relationship (Figure 5). When they are in their fifties they have an elevated chance of living alone because their (last) child leaves the household;

Figures 6 and 7 show the probabilities of entering and exiting an institution, respectively, for men and women in Finland. We see that the probability of entering an institution is highest for the cohabiting and lowest for married men and women, and for women living in other private households. The protective effect of marriage is in line with findings in earlier studies (e.g. Nihtilä and Martikainen 2008; Martikainen et al. 2009). Earlier research has not, to our knowledge, included the cohabiting as a separate category; little is known about their excess risk of entering an institution for the elderly. The probability of leaving an institution is highest for those living alone and lowest for the cohabiting. A possible explanation is that persons who live with a partner receive more private care and hence tend to enter an institution later than those who live alone, other things being equal. This means that persons in an institution with a partner who lives elsewhere have more fragile health than persons who do not have a partner. In support of this idea, Martikainen et al. (2009) found that those living alone were in better health when moving to an institution than those living with a spouse or cohabiting.

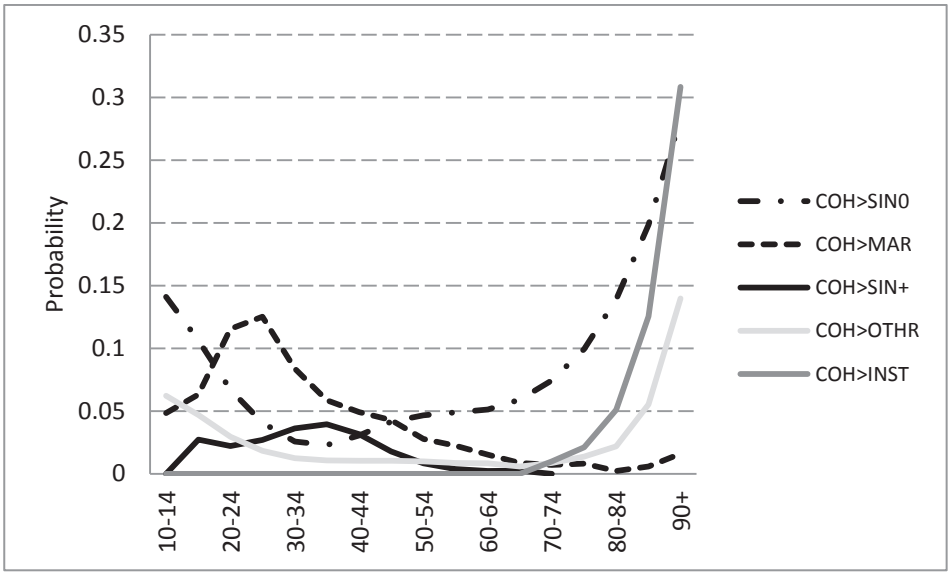
Figure 2: One-year transition probabilities. Women who live alone, 2004-2008, Finland



Source: Own computations based on data supplied by Statistics Finland.

As described above, what we have computed from the transition data are transition probabilities. What we need as input to our household projection model are, however, occurrence-exposure rates. Under a constant intensity assumption, the probability matrix P_t is an exponential function of the rates matrix M_t. Thus to find the occurrence-exposure rates in M_t we need to compute the logarithm of P_t, defined as a power series. The power series, however, does not always converge: see Van Imhoff and Keilman (1991: 77) for details. Hence we assume that the occurrence-exposure rate for a certain household event is equal to the one-year transition probability for the corresponding change in household position. This introduces a small error in the rates. Under the assumption used, a Taylor series expansion shows that the probability matrix P and the rate matrix M are related as $P = I - M + {}^1\!/_2\, M^2 - {}^1\!/_6\, M^3 + \cdots$, where I is the identity matrix. Most rates are in the order of magnitude of a few per cent or less. Mortality at high ages is an exception, where rates up to 30% are found. Thus for mortality we computed rates from numbers of deaths and exposure times assuming that there are no disturbing events in the particular population group defined by age, sex, and household position.

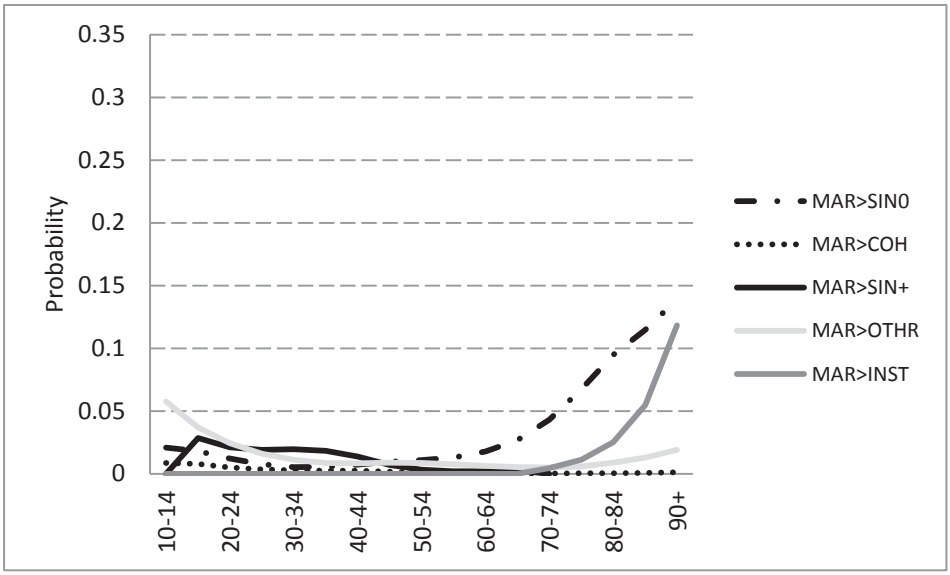
Figure 3: One-year transition probabilities. Cohabiting women, 2004-2008, Finland



Source: Own computations based on data supplied by Statistics Finland.

Getting numbers for the institutional population in Denmark was difficult. A law was passed in 1987 which abolished the building of nursing homes from January 1st 1988. The existing nursing homes were to be phased out gradually. These were then to be replaced by nursing apartments which offer the same level of care, but where the residents all have their own apartment with bathroom and a small kitchen. The nursing apartments are not considered institutions in the legal sense. Although residents of these apartments are needs tested they are considered tenants, which involve a different set of rights and responsibilities compared to persons who live in an institution. As the nursing apartments are not considered institutions, those living there are not registered as living in an institution in the household register. The way the residents are registered can vary between municipalities.

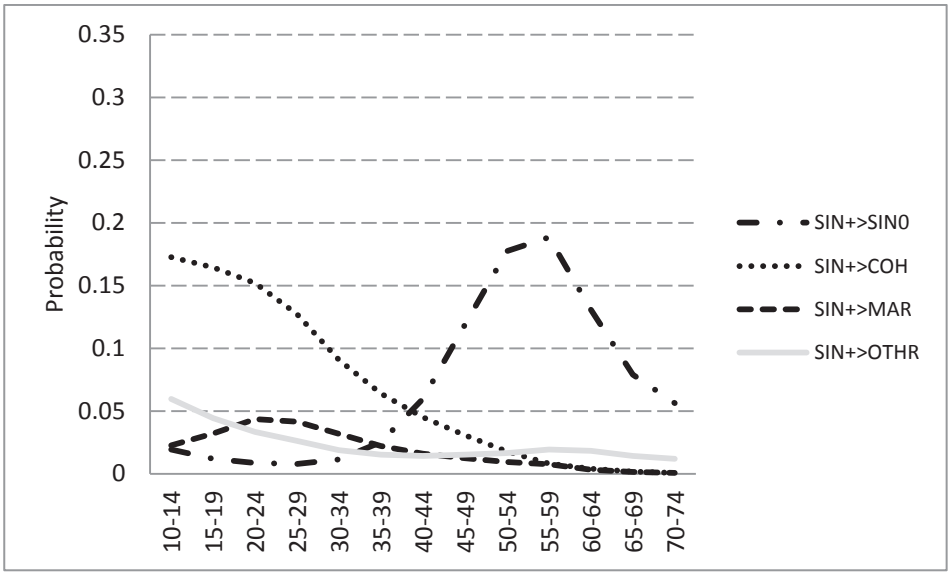
Figure 4: One-year transition probabilities. Married women, 2004-2008, Finland



Source: Own computations based on data supplied by Statistics Finland.

For those living in nursing homes we have detailed information about numbers and transitions, broken down by age and sex. The data we have about the population living in nursing apartments are the numbers in the age groups 67–74, 75–79, 84–89, and 90+. We assume that the distribution across age and sex is the same in the nursing apartment population as in the nursing home population, which numbered about 10,000 and 30,000, respectively, in 2007. In order to get an estimate of the number of persons living in institutions in the jump-off population we therefore adjusted the distribution of residents in nursing apartments to fit into our age group classification and divided the residential population between the sexes using the age and sex distribution of the nursing home population in 2007. To accommodate the increase in the institutional population the numbers of elderly living alone were adjusted downwards. Although, as noted above, the registration of those living in nursing apartments varies between municipalities, we have reason to believe that the majority are registered as living alone. In the years when extra funding was given for the conversion and replacement of nursing homes we witness a steep decrease in the share living in nursing homes. This is mirrored by a sharp increase in the proportion living alone. The same is not the case for the share living with a partner.

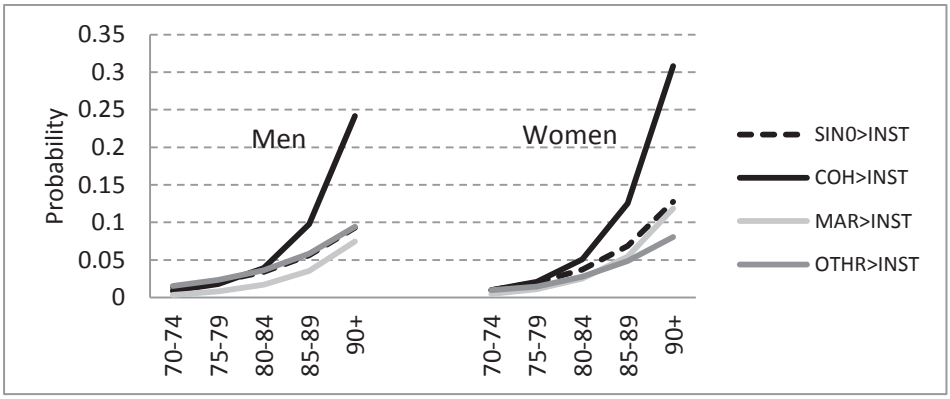
Figure 5: One-year transition probabilities. Lone mothers, 2004–2008, Finland



Source: Own computations based on data supplied by Statistics Finland.

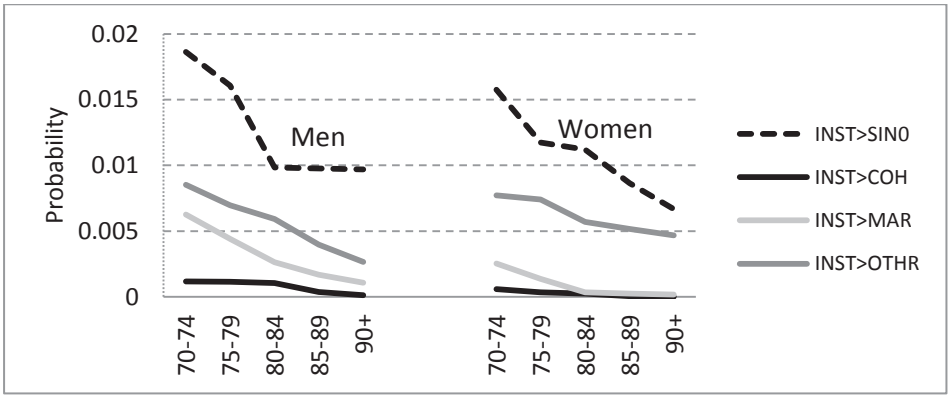
As the Danish transition rates into institutions only reflected those moving to nursing homes, we decided to use the transition rates into institutions from the Finnish data in the Danish forecast.

Figure 6: One-year transition probabilities. People entering an institution, 2004–2008, Finland



Source: Own computations based on data supplied by Statistics Finland.

Figure 7: One-year transition probabilities. People leaving an institution, 2004–2008, Finland



Note: Different scale.
Source: Own computations based on data supplied by Statistics Finland.

Multistate life tables based on the first projection interval, which is 2009–2013 and 2007–2011 for Finland and Denmark, respectively, give a summary view of the input rates for this period (Tables 1 and 2). Table 1 shows that the Fins spend a little more than a quarter of their lives living as a child, a third living with a spouse, 11% cohabiting, and around 20% living alone. The Danes spend a somewhat larger fraction of their lives living as a child and a little less living with a spouse (Table 2). Based on this life table the average Fin is more likely to be married than the average Dane; cf. below. In both countries the majority of children are born to mothers who live with a spouse, although the difference between births by married and cohabiting women is smaller in Denmark than in Finland.

Table 1: Percentage of lifetime spent in various household positions, and number of children by mother's household position, Denmark 2007–2011

	CHLD	SIN0	COH	MAR	SIN+	OTHR	INST	All (=100%)
				%				years
Men	29	19	11	31	1	8	0.3	75.1
Women	26	21	11	30	5	6	0.7	79.9
				children				
	0.02	0.08	0.70	0.83	0.08	0.16	0.00	1.88

The rates are held constant throughout the projection period, except for small changes due to consistency requirements; cf. Section 3.2. In Section 5.2 an alternative to holding the rates constant, based on trend extrapolation of the rates, will be discussed briefly.

Table 2: Percentage of lifetime spent in various household positions, and number of children by mother's household position, Finland 2009–2013

	CHLD	SIN0	COH	MAR	SIN+	OTHR	INST	All (=100%)
				%				years
Men	26	20	11	35	1	6	1	74.8
Women	22	22	11	34	4	5	1	82.3
				children				
	0.00	0.09	0.42	1.27	0.10	0.05	0.00	1.93

5. Results

5.1 Main outcomes[8]

The numbers of persons in each household position are obtained directly from multiplying the sample paths as described in Section 3.5. In addition we have computed sample paths for the number of private households of each type, as this is important for many planning purposes. The numbers of married and cohabiting households equal half the numbers of married and cohabiting persons. The number of other private households is estimated by dividing the population living in such households by 4.65, which was the mean size in Finland at the jump-off point. The same number was used for Denmark. Adding on the numbers of people living alone and single parents gives 3000 paths for the number of private households. Mean household size is then computed as the size of the population in private households divided by the number of private households.

Tables 3 and 4 show the expected development in the number of private households of each type, the lower and upper bounds of the 80% prediction intervals, as well as the coefficients of variation (CV) for Denmark and Finland, respectively.

Table 3: Average value, coefficient of variation, and lower and upper bounds of 80% prediction intervals, for the number of private households, by household type. Denmark

	Married couple	One-person household	Cohabiting Couple	Lone parent household	Other private household	All private households
2007						
Observed	990299	944405	283197	168944	91148	2477992
2017						
Average	968171	1036930	302350	181323	86936	2575710
CV (%)	3.3	4.9	8.9	21.3	12.5	1.8
80% low	926441	972475	268641	135234	72368	2517057
80% high	1009953	1103045	336773	234197	100781	2637122
2027						
Average	962468	1167539	321254	177936	90419	2719616
CV (%)	7.2	9.7	17.7	29.5	19.9	3.5
80% low	873445	1025302	251565	115541	68362	2602674
80% high	1051393	1314627	397698	249010	114750	2839892
2037						
Average	957762	1244238	324567	179700	90555	2796823
CV (%)	7.8	17.8	17.8	29.1	20.2	4.8
80% low	862518	1084466	254229	117327	68352	2626514
80% high	1052869	1413500	402241	250377	114791	2968712

[8] Additional results are available from the webpage of the AGHON-project (http://aghon.etla.fi/) and from the first author upon request.

When we look at the growth in the numbers of private households of various types during the 30 year period, the strongest increase is expected in the number of one-person households: 31% and 50% in Denmark and Finland, respectively. We also notice quite a large increase in the number of households consisting of a cohabiting couple. On the other hand, the number of "Other private household" in both countries and the number of married couple households in Denmark will decrease slightly. Overall, we expect an increase in the number of Danish private households by 13%, from 2.5 to 2.8 million. For Finland we expect a growth of 27%, from 2.5 to 3.1 million. Married couple households become less important, numerically speaking, falling from 40% to 34% of all private households in Denmark and from 38% to 33% in Finland. The fraction of single person households, on the other hand, is expected to increase from 38% to 44% in Denmark and from 41% to 49% in Finland. It is virtually impossible that there will be fewer private households by 2037/2039: looking at the 3000 draws, only 1% of the Danish and none of the Finnish imply a smaller number of households in the final year than in the initial year. The corresponding number for married couple households is a staggering 67% for Denmark but only 0.7% for Finland. The probability of a decrease in single person households is 2% in Denmark, whereas in Finland none of the draws imply a reduction. All in all we expect a decrease in the average household size from 2.16 to 2.13 (80% prediction interval 2.01–2.28) in Denmark and from 2.14 to 1.89 (80% prediction interval 1.79–1.99) in Finland during the period.

Table 4: Average value, coefficient of variation and lower and upper bounds of 80% prediction intervals, for the number of private households, by household type. Finland

	Married couple	One-person household	Cohabiting Couple	Lone parent household	Other private household	All private households
2009						
Observed	924692	1014974	292381	127534	90830	2450410
2019						
Average	1012967	1166789	321919	142903	70801	2715379
CV (%)	1.9	3.0	4.9	8.2	6.5	1.1
80% low	988438	1123281	301699	128596	64752	2677248
80% high	1037475	1211384	342188	158311	76866	2753627
2029						
Average	1037753	1279715	325467	141195	71540	2855671
CV (%)	3.7	5.0	9.4	13.7	12.2	2.6
80% low	988412	1197593	286651	117146	60886	2762293
80% high	1087005	1359412	364671	166342	82429	2947925
2039						
Average	1043100	1530345	330394	139418	74851	3118108
CV (%)	4.8	5.8	10.2	14.3	12.9	4.1
80% low	980039	1415572	288291	115461	63024	2953258
80% high	1108612	1641940	373195	165715	87043	3278831

We see that there is largest relative uncertainty, as reflected in the CVs, concerning the household types "Other private household" and "Lone parents". The number of married couple households is easier to predict, as judged by the CV. The Danish predictions are more uncertain than the Finnish numbers. This is due to two reasons. 1. The Danish RWD models show somewhat larger residual standard deviations than the Finnish models. 2. Danish population numbers are somewhat more uncertain, especially among the elderly. For instance, 30 years ahead the CV for Danish men aged 95–99 is 0.83 compared to 0.62 for Finnish men. Likewise, for women the Danish CV is 0.61 and the Finnish 0.49. Note that forecasts for the total number of private households are more certain (CV-values after 30 years of 4.8% and 4.1% for Denmark and Finland, respectively) than forecasts for each of the specific household types (CV-values ranging from 4.8% to 29.1%). This is due to aggregation: some of the specific household types move in opposite directions. Hence their sum is easier to predict than the elements.

Note also that prediction uncertainty (still judged by the CV) increases more steeply during the first two decades than during the last decade of the forecast period. The reason that uncertainty stabilizes towards the end of the projection period is to be found in the transformation of the shares from the logit scale (with linearly increasing prediction intervals and unbounded predicted values) back to the original scale (with predicted values limited between zero and one).

With a few exceptions[9], the coefficients of variation in Tables 3 and 4 are smaller than corresponding CVs for Norway in the article by Alho and Keilman (2010). Thanks to the high quality register data we were able to fit more realistic times series models (RWD) than Alho and Keilman: due to the paucity of their data they estimated very simple Random Walk models. If the real process is random walk with drift, a random walk model will result in too large estimates of the residual standard deviation.

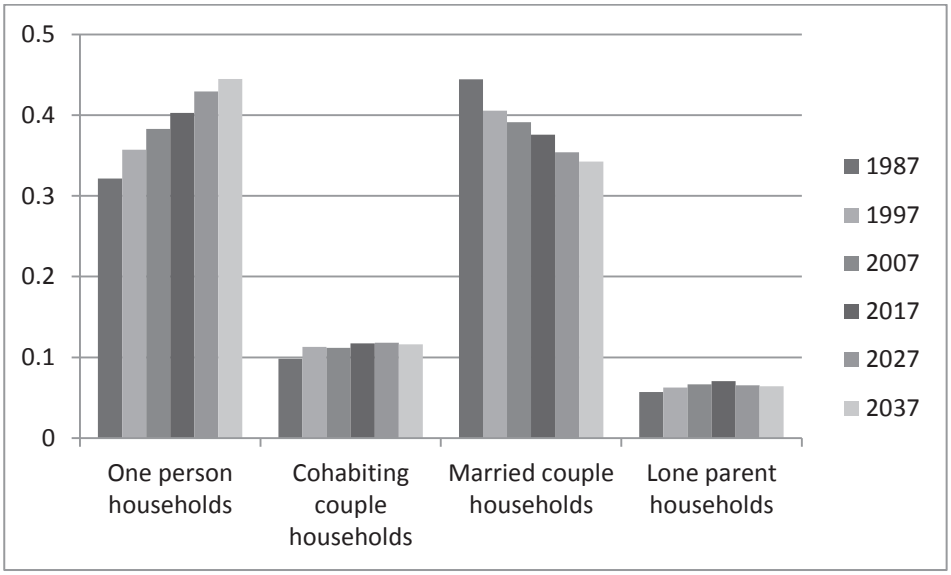
While CVs reflect relative uncertainty, absolute uncertainty can be analysed by inspecting the width of the prediction intervals. The upper and lower bounds of the 80% prediction intervals in Tables 3 and 4 show that there is largest absolute uncertainty regarding the number of single person households in both Denmark and Finland. This reflects the fact that they are the most numerous household type. On the other hand, because of their small numbers, single parents have some of the smallest absolute uncertainties.

Figures 8 and 9 show that predicted household trends are in line with two broad developments that have gone on for a few decades: among all private households married couple households have lost their dominant position, while one-person households have become much more important, numerically speaking. This development, which also is to be found in many other Western countries (e.g.

[9] Exceptions are Danish results for lone parents in the first period of the forecast, lone parents, married and cohabiting couples in the second period, and single person households in the final period of the forecast.

Christiansen 2012), is caused by falling fertility and the increased popularity of consensual unions, combined with an increase in divorce. Since the late 1980s the shares of both cohabiting couple households and lone parent households have been remarkably stable.

Figure 8: One-person households, cohabiting and married couple households, and lone parent households, as a share of all private households. Observed (1987, 1997, 2007) and average projected values (2017, 2027, 2037), Denmark



Tables 5 and 6 contain the CVs for the number of people in different household positions for the age groups 20–24, 50–54, and 80–84, separately for each sex, for Denmark and Finland, respectively. The relative uncertainty is generally largest for the youngest age group. A notable exception is the group of young adults who live in consensual union, those in Denmark in particular. Although residual standard deviations for young adults are higher than those for middle-aged adults (cf. Figure 1 for the example of Finnish men), the large numbers of cohabiting young adults reduce their relative uncertainty. For the youngest two age groups (20–24 and 50–54) the greatest relative uncertainty concerns single parents. For the oldest age group there is a large amount of uncertainty concerning the cohabiting, the number living in nursing homes, and the number living in other private households. For the youngest age group

there is generally least uncertainty regarding the number of cohabiting and those living alone, whereas for the middle aged and elderly the most certain are the married and those living alone. In general, when there are many persons in a particular household position, this category is easier to predict than a less numerous one.

Figure 9: One-person households, cohabiting and married couple households, and lone parent households, as a share of all private households. Observed (1989, 1999, 2009) and average projected values (2019, 2029, 2039), Finland.

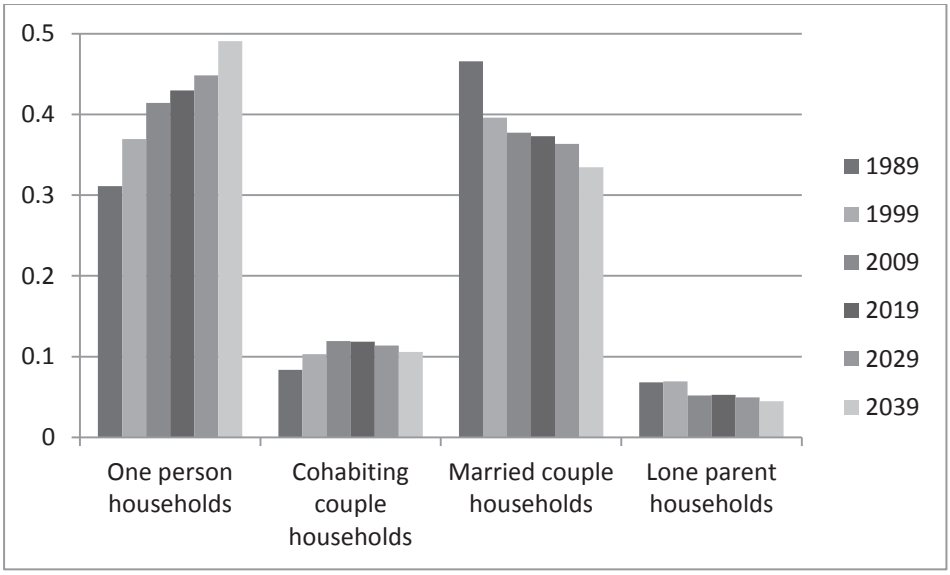


Table 5: Coefficient of variation for the number of people in different household positions for selected age groups, by sex. Denmark

	20-24 years	50-54 years	80-84 years
Men 2017			
MAR	0.390	0.045	0.065
SIN0	0.104	0.084	0.080
COH	0.113	0.179	0.320
SIN+	1.890	0.290	-
OTHR	0.386	0.183	0.530
INST	-	-	0.345
Men 2027			
MAR	0.755	0.098	0.142
SIN0	0.261	0.136	0.171
COH	0.198	0.415	0.618
SIN+	1.963	0.524	-
OTHR	0.490	0.407	0.865
INST	-	-	0.750
Men 2037			
MAR	0.762	0.110	0.177
SIN0	0.273	0.142	0.192
COH	0.212	0.417	0.596
SIN+	1.969	0.525	-
OTHR	0.499	0.405	0.840
INST	-	-	0.822
Women2017			
MAR	0.349	0.042	0.079
SIN0	0.115	0.091	0.050
COH	0.093	0.190	0.346
SIN+	1.170	0.202	-
OTHR	0.626	0.237	0.541
INST	-	-	0.322
Women 2027			
MAR	0.655	0.098	0.175
SIN0	0.275	0.145	0.110
COH	0.166	0.432	0.710
SIN+	1.230	0.414	-
OTHR	0.686	0.447	0.876
INST	-	-	0.680
Women 2037			
MAR	0.660	0.105	0.196
SIN0	0.287	0.150	0.138
COH	0.181	0.431	0.682
SIN+	1.124	0.416	-
OTHR	0.697	0.448	0.839
INST	-		0.744

Table 6: CVs for the number of people in different household positions for selected age groups, by sex. Finland

	20-24 years	50-54 years	80-84 years
Men 2019			
MAR	0.262	0.033	0.051
SIN0	0.142	0.050	0.072
COH	0.149	0.104	0.582
SIN+	-	0.160	-
OTHR	0.214	0.123	0.323
INST		-	0.365
Men 2029			
MAR	0.432	0.066	0.123
SIN0	0.246	0.086	0.157
COH	0.281	0.235	0.829
SIN+	-	0.398	-
OTHR	0.364	0.288	0.618
INST		-	0.783
Men 2039			
MAR	0.439	0.075	0.155
SIN0	0.254	0.093	0.169
COH	0.290	0.240	0.780
SIN+	-	0.400	-
OTHR	0.367	0.289	0.634
INST	-	-	0.866
Women 2019			
MAR	0.244	0.034	0.068
SIN0	0.177	0.055	0.044
COH	0.118	0.112	0.715
SIN+	0.710	0.121	-
OTHR	0.377	0.135	0.297
INST	-	-	0.306
Women 2029			
MAR	0.357	0.071	0.158
SIN0	0.306	0.095	0.094
COH	0.219	0.249	1.060
SIN+	0.817	0.285	-
OTHR	0.493	0.332	0.544
INST	-	-	0.664
Women 2039			
MAR	0.360	0.077	0.166
SIN0	0.332	0.080	0.170
COH	0.228	0.253	0.989
SIN+	0.821	0.287	-
OTHR	0.499	0.335	0.550
INST	-	-	0.726

The box-and-whisker plots in Figures 10 and 11 display the shares in the household types married, cohabiting, and single person households in the age groups 20–24, 50–54, and 80–84, for Denmark in 2037 and Finland in 2039, respectively. These plots give the usual first and third quantiles as well the median, and outliers among the 3000 sample paths.

Figure 10: Box and whisker plots of the shares living in the household positions married, cohabiting, and living alone, men and women in selected age groups in 2037. Denmark

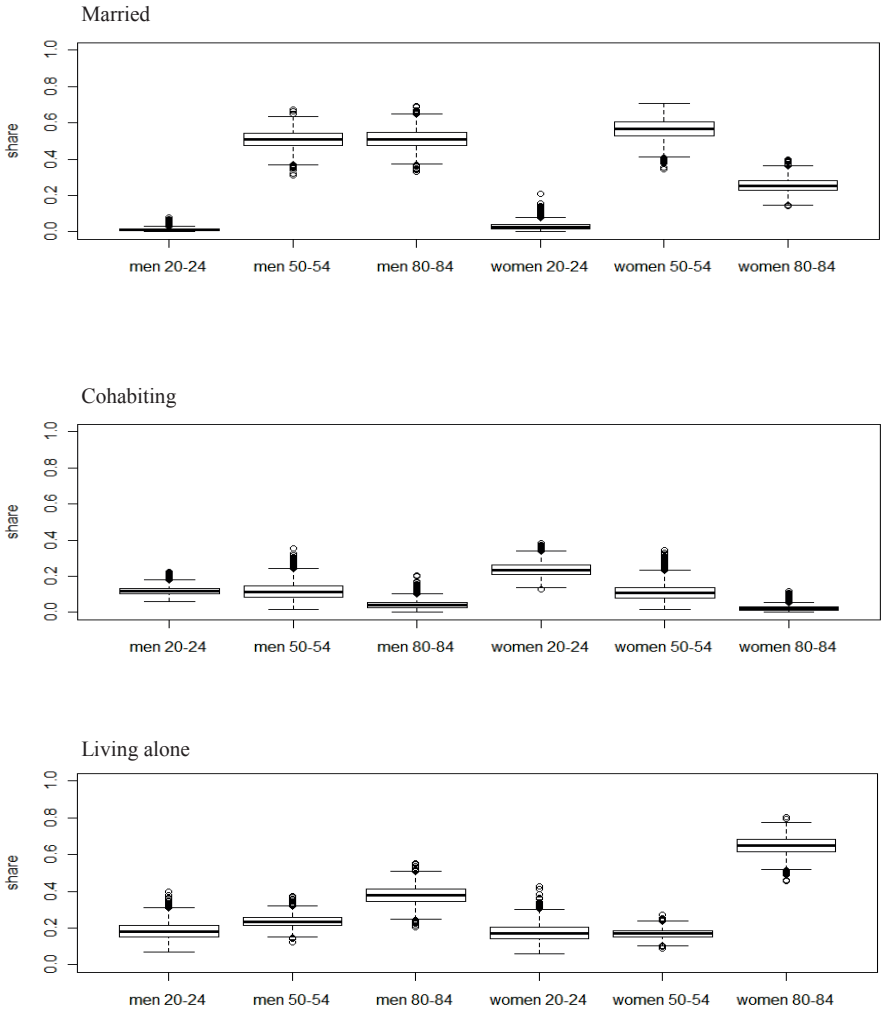
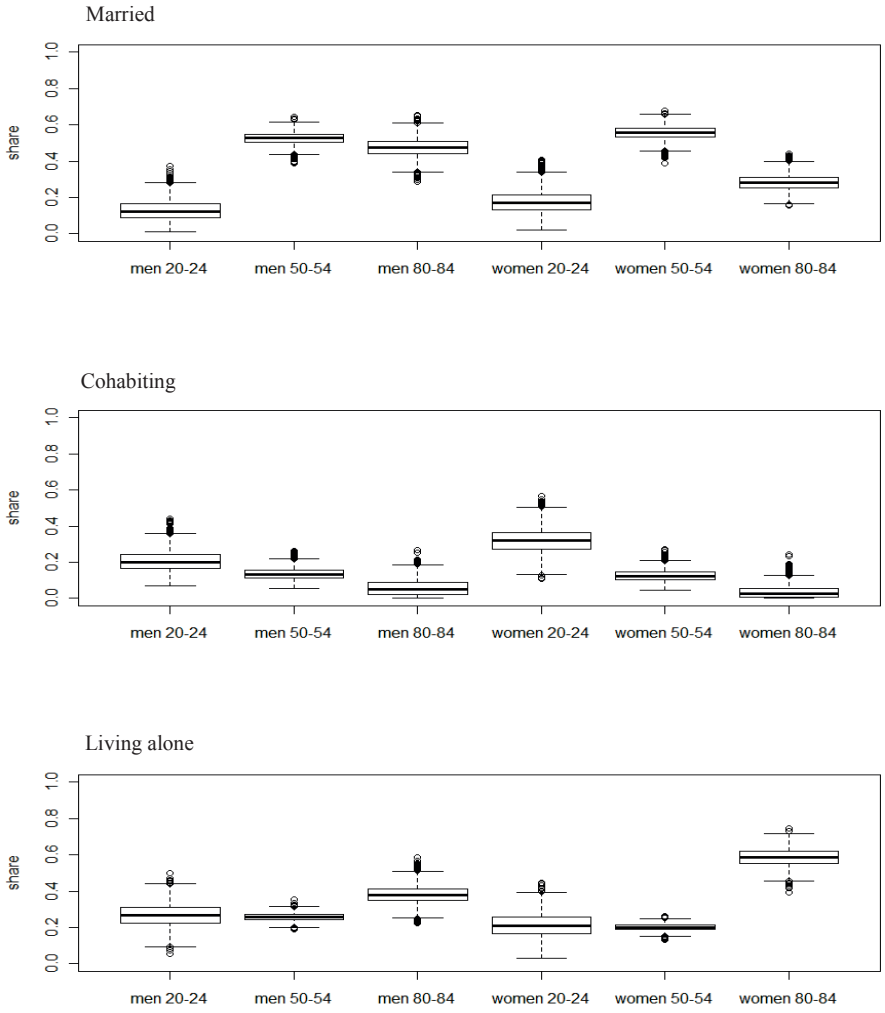


Figure 11: Box and whisker plots of the shares living in the household positions married, cohabiting, and living alone, men and women in selected age groups in 2039. Finland



5.2 Changing rates

As mentioned in Section 4, the input rates for the deterministic household forecast are held constant throughout the projection period, except for adjustments to satisfy internal and external consistency requirements. We tried to improve on this approach detecting a possible time trend in the rates. We assumed a linear trend in (the logit of) the rates and extrapolated these rates linearly. This meant that there were varying rates for each five-year period of the projection. Using these types of rates did, however, in some cases lead to implausible results. An example is the share of cohabiting among young (20–35) women in Denmark. Using varying rates led to a sharp increase in the share of these women from 2009 to 2019. The share then fell quite significantly from 2019 to 2029, and thereafter increased to about the same level as in 2019. In our opinion these results were implausible. For the majority of other household positions using varying rates did not have much effect on the results, and we therefore decided to stick to constant rates throughout the projection period. Loosely speaking, when rates are constant over time, this corresponds to shares that have constant (upward or downward) slopes.

5.3 RWD extrapolations

We also experimented with expected values for the shares computed from direct extrapolations of the random walk with drift models (transformed back from the logit scale to the original scale). This was done in order to directly take account of the trends in the shares. This approach did, however, in some cases lead to implausible results. For example, it gave results for Finland in 2037 where only around 60% in the age group 15–19 lived with their parents, and hardly any in the age group 20–24. In Denmark it all but extinguished the share of elderly living in other private households. Compared to the LIPRO findings, the results from this method suggest a much stronger substitution of marriage for cohabitation for the young and middle aged. An additional methodological drawback of this approach is that we cannot take advantage of the internal and external consistency requirements built into the LIPRO model.

6. Conclusion

Given the need for planning based on household structure, spanning from public income and expenditure to the demand for consumer durables, this article has investigated the future household structure in Denmark and Finland with a 30-year

horizon. Predictive distributions have been computed for households of several types and for persons in various household positions, including the institutionalized. We have used the random share approach developed by Alho and Keilman (2010), and tried to improve on their results by taking advantage of high quality data from Danish and Finnish population and housing registers. As was done in their article, we combined a probabilistic forecast for the share of people in each household position, broken down by age and sex, with simulations from a stochastic population forecast covering the same period. This then gives a probabilistic household forecast for the number of people in each household position.

Our results show an expected further increase in the number of private households, from 2.5 to 2.8 million (80% prediction interval 2.6–3.0 million) in Denmark and from 2.5 to 3.1 million (80% prediction interval 3.0–3.3 million) in Finland. Taken together with an increase in population size, this means a decrease in the mean household size from 2.16 to 2.13 persons per private household in Denmark and from 2.14 to 1.89 p/ph in Finland. We find a further reduction in the share of married couple households and a growing importance of one-person households. The largest coefficients of variation are for lone parent households and "other private household", and smallest for married couple households. The single person household, on the other hand, displays the largest absolute uncertainty, reflecting the fact they are the most numerous household type.

How should users handle a specific forecast result in the form of a probability distribution, rather than one number? In the short term, up to five years, say, forecast uncertainty is not important. In the longer run, however, users should be aware of the costs attached to employing a forecast result that subsequently turns out to be too high or too low ("loss function"). Also, users should ask themselves whether an immediate decision based on the uncertain forecast is necessary, or whether they can wait for a while until a new forecast possibly shows less uncertainty. If an immediate decision is required they should try to determine the most essential features of the loss function, and base their decisions on that. For instance, will an overprediction imply the same loss as an underprediction of the same magnitude? If not, a number higher or lower than the median or the mean of the predictive distribution will be the optimal choice.

In his British Academy Annual Lecture on 1 December 2004, the Bank of England Governor Mervyn King stressed that in a wide range of collective decisions it is vital to think in terms of probabilities (King 2004). We must accept the need to analyse the uncertainty that inevitably surrounds these decisions. In order to frame a public discussion in terms of risk, the public needs to receive accurate and objective information about the risks. Transparency and honesty about risks should be an essential part of both the decision-making process and the explanation of decisions. If demographic projections are to inform policy decisions then the uncertainty of these projections must be assessed. In some areas greater uncertainty might lead to

postponement of action. In other policy arenas greater uncertainty might indicate that the best polices would be those most easily changed as the future unfolds. For example, a planner of public care facilities facing uncertain projections of the number of elderly who need institutional care might decide to rent additional capacity rather than building or buying a new institution. Explicitly estimating the degree of uncertainty in demographic projections encourages consideration of alternative population futures and the full range of implications suggested by these alternatives (Lee and Tuljapurkar 2007).

The fact that we could use register data had several advantages, compared to the data of Alho and Keilman (2010). First, we could estimate all the transition probabilities without making approximations from data based on marital status and small sample surveys. Hence we obtained reliable rate estimates even for household events that occur quite seldom. Second, using register data implies that the same definitions (of households, families, etc.) have been used throughout. Third, the data, spanning more than 20 years in both countries, could be used to construct time series models of household shares. We could then analyse the empirical prediction errors in these time series models to derive estimates for the uncertainty in the predicted household shares. This is a clear improvement on the Alho and Keilman (2010) approach where the "uncertainty parameters were estimated from observed errors of an old household forecast against subsequent censuses". The better data is reflected in the fact that, when it comes to household numbers, compared to the Norwegian results the vast majority of the coefficients of variation are smaller, given household position and number of years into the forecast.

Thus an important new insight based on our analysis is that households become easier to predict when household data from administrative registers are available for at least two decades. One may wonder why there are so few examples of household forecasts (not necessarily probabilistic) based on register data. To our knowledge there are few countries that have household register data reliable enough to employ them as a basis for household projection. Denmark and Finland have the longest running registers in Scandinavia. Norway and Sweden set up their household registers just a few years ago. In addition the Netherlands have a register running back to the mid-1990s. Other countries (Belgium, Italy, Spain) maintain registers, but the household data are not generally available for research purposes, as far as we know. A number of Asian countries have family registers that keep track of blood relations. To use survey data as a basis for household projection has a long history, e.g., see Van Imhoff et al. (1995) and the references therein. Variances and covariances necessary to construct an empirically based probabilistic household forecast may be estimated from the errors of an old household forecast, as exemplified by Alho and Keilman (2010) for the case of

Norway. But reliable estimates of such uncertainty measures require richer data than these authors disposed of.

Finally we want to stress a more general point. There are many reasons why administrative registers should get more emphasis in data collection for statistical purposes. An important one is that a traditional population census, based on questionnaires to be filled out by individuals, has become extremely costly to undertake. As an alternative many countries consider a change away from a traditional census to a register-based census. Countries such as Denmark, Finland, Norway, the Netherlands, and Sweden have shown how those registers can be used. The registers of Finland and the Netherlands have excellent household information, the quality of household data from Danish register is good (information on elderly institutions is not reliable), while Norwegian household data are problematic, due to problems in the dwelling register in that country. Statistical agencies should prioritize improving the quality of existing registers, and developing administrative registers in countries where they do not yet exist.

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II

III

The impact of children's sex composition on parents' mortality

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Abstract

Background: This study explores the relationship between children's sex composition and parents' mortality in a contemporary western society. It improves on earlier research by using a larger and more representative dataset – constructed from registers and encompassing the entire Norwegian population. **Methods:** The analysis is based on discrete-time hazard models, estimated for the years 1980-2008 for women and men born after 1935. **Results:** When operationalising sex composition as the "number of boys", coefficients are insignificant in all specifications. However, when considering the three categories "only boys", "only girls" and "mixed sex", I find a small but significant disadvantage of having only girls, compared to having at least one of each sex, for mothers of two or more children. Having only daughters is associated with a mortality disadvantage compared to having only sons for mothers of two children, but a mortality advantage among mothers with four children. Among women who gave birth to their first child as teenagers, those who have only sons have relatively high mortality. I also find an excess mortality both for mothers of only girls and mothers of only boys in the period 1980-1989. **Conclusion**: These results lend some support to the notion that there is a larger benefit of the first son or daughter than the later children of the same sex, and especially in the earliest decade of the study period.

Keywords: Mortality, children's sex composition, register data, Norway

1. Introduction

Many earlier studies have shown a relationship between an individual's mortality and the number of children he or she has. Generally, the childless have higher mortality than those with children, and those with only one child have higher mortality than those with two. Some authors have also reported an increasing mortality as the number of children exceeds four or five [1,2,3], while other studies, including one from Norway [4], have shown no such disadvantage at high parities. These relationships have been thought to reflect physiological effects of pregnancies (for women) as well as various types of social effects of having children. For example, children may be a source of emotional satisfaction, and above a certain age they may exert control on parents' behaviour and provide care and assistance, which may reduce mortality. On the other hand, parenthood may also lead to stress because of economic worries or concerns about the children's wellbeing. Moreover, there are selective influences: several factors of importance for fertility also affect later health and mortality through other channels. The social effects of parenthood probably vary with the characteristics of the children, such as their personality, education, economic resources, health, and family situation. The children's sex may also have some importance as a conditioning factor.

Few studies have addressed the effect of children's sex composition on parents' mortality, and most of them have considered pre-industrial populations. Using data on Sami women from northern Scandinavia, Helle, Lummaa and Jokela [5] found that having sons increases a woman's mortality, whereas having daughters has the opposite effect. However, later studies have failed to consistently replicate these results and have usually found identical, or almost identical, effects of sons and daughters on women's mortality [e.g. 6,7,8,9]. There has been little research into whether the sex composition of the children affects parents' mortality in western contemporary societies. A study by Jasienska, Nenko and Jasienski [10] concluded that daughters reduce men's mortality whereas both sons and daughters increase women's

mortality, and do so to the same extent. However, this investigation included only 102 women and 163 men born between 1894 and 1937. It also only included people who had already died at the time of study and had at least one son and one daughter, and excluded those who were single or remarried. Studies based on larger and more representative samples are lacking.

One could argue that there might be diminishing marginal returns to having children of a single sex. For example, even if having one son might benefit the parents and their health, having a second or third son might be less important. Perhaps they would be better off having at least one daughter, who might give them other benefits. In fact, many parents seem to have a preference for mixed-sex offspring. An indication of such sex preferences, is that in the Scandinavian countries there is no effect of the sex of the first born on the probability of having a second child and subsequent fertility is slightly higher among those who have two children of the same sex than those who have one boy and one girl. However, a slightly stronger preference for daughters seems to have developed over the last two decades [11]. This means that Scandinavians still prefer to have at least one child of each sex but now consider it to be more important to have at least one girl than at least one boy. The purpose of this study is to explore the relationship between children's sex composition and parents' mortality in a Nordic setting.

The analysis is based on discrete-time hazard models, estimated for the years 1980-2008 for women and men born after 1935 using register data that encompasses the entire Norwegian population. As suggested by earlier studies [10], the effect of a certain sex composition is not necessarily the same for mothers and fathers, so the models are estimated separately for women and men. Furthermore, the effect may vary with certain characteristics of the parents. For example, among those who have support from a spouse, the practical assistance that daughters have often provided may be less crucial. In this study, the conditioning effects of age, education, marital status, age at first birth and period are considered.

Little attention has been devoted to the conceivable underlying mechanisms in the few earlier studies that have addressed the link between children's sex and parents' mortality. This paper therefore includes a quite thorough discussion of potential causal effects and selective influences, as well as the variations in these (section 2).

2. Background

Parenthood influences the well-being[2] and lifestyle as well as economic decisions of the parents. Some of these influences may be contingent on the sex of the child.

A few studies have looked into how the gender composition of children affects lifestyle choices. They have found that having an additional daughter reduces the probability of having an alcohol or drug problem, or smoking [12], and that mothers of first-born daughters weigh less than mothers of first-borns sons. However, fathers whose first-born was a daughter weigh more than a father who's first-born was a son [13].

It can also be hypothesised that it is more stressful to bring up boys. They are more likely to be hyperactive or diagnosed with attention deficit disorder or autism. More importantly, even boys without any disorders are often seen as more boisterous, noisy and less well behaved than girls. At later ages boys have in recent decades been more likely to drop out of school and be unemployed, which may worry the parents. Moreover, bringing up sons may entail a higher level of economic stress. Studies have found that boys receive more pocket money than girls and that boys consumption is considered more important by parents [16,17]. A survey by a British bank [18] showed that boys cost on average 23% more to raise than girls.

[2] A project with the aim of developing measures better reflecting general well-being is being undertaken by Eurostat and the OECD, albeit at a country level. See for example [14,15].

A US study [19] reported that the birth of a son induces a man to increase the number of hours worked more than does the birth of a daughter. Similarly, research employing German data finds that having a first-born son increases fathers' working hours compared to having a first-born daughter [20]. Moreover, both these studies find that fathers of boys have a higher wage rate than fathers of daughters, so the income advantage of the former is even larger than suggested by difference in working hours. Although fathers of sons work longer hours, there is no evidence that this happens at the expense of time spent with their children. On the contrary, fathers have been found to spend more time with their children – also with their daughters – when they have at least one son, and more time with their sons than with their daughters [21,22,23]. Even in a gender equal society like Sweden, fathers take out more parental leave following the birth of a son [24].

A much cited study using US data found that having sons reduces the risk of divorce [25]. Later research has, however, failed to consistently replicate this result. For example, a study employing data from 18 countries [26] reveals no difference between one-child couples with a son and one-child couples with a daughter. They do however find that two-child couples with children of the same sex, whether girls or boys, have higher divorce risks than those with one child of each sex, and that sons slightly lower divorce risks in three children families. A Swedish study reports the lowest divorce risk in mixed-sex two-child families, whereas the divorce risk at parity three rises with increasing number of girls [27].

Old people tend to have more social contact with daughters than sons [28,29] and daughters are more likely than sons to provide care to their elderly parents. However, some studies report that the elderly receive more help from a child of the same sex, and that the reason why women are overrepresented as caregivers is that there are more women than men among the elderly due to men's higher mortality [30].

All of the effects mentioned above probably have implications for the health of the parents and ultimately their mortality. For example, a higher weight (possibly linked to having sons, for mothers) is a risk factor for several potentially fatal diseases. Working long hours, such as fathers of sons are more inclined to do, may affect health adversely. It has been shown to increase the risk of coronary heart disease and depression [31,32,33]. Furthermore, men's possibly stronger involvement in their children if there is a boy in the family may be beneficial for the fathers, as well as for the mothers, in the long run. Even more importantly, divorce – which may also be linked to children's sex – is strongly associated with mortality (e.g. [34]). Finally, the amount of social support, which daughters are particularly likely to supply to their ageing parents, may affect mortality [35]. Studies based on measurements of subjective health have yet to provide a clear picture. Powdthavee, Wu and Oswald [12] conclude that having an additional daughter induces people to report better subjective health, whereas (in a Middle East setting) Engelman, Agree, Yount and Bishai [36] find a negative association between the number of daughters and reported physical functioning, especially for men.

A few studies have looked at the effect of children's sex on parents' well-being. One investigation employing Danish data reports a positive effect on fathers' well-being if the first-born was a boy [37]. Another study finds that mothers of only sons are the happiest, and that those with a majority of boys display higher levels of happiness than those with other sex compositions of children [38]. Yet another study reports that fathers of boys are more likely to be happily married [39], which in turn heightens the protective effect of marriage (e.g. [40,41,42].

In addition to all of these social effects of having children of a given sex, there are physiological implications for the mother of giving birth to sons. Male foetuses have higher intrauterine growth rates and birth weights and therefore require more maternal energy

[43,44,45,46]; and women carrying male foetuses experience higher levels of testosterone, which is an immunosuppressant [47,48].

Possible variations in the importance of children's sex

The potential effect of a given sex composition may be conditional on a variety of other factors. I consider these possible conditioning effects by stratifying according to a few characteristics (of the parent): age, period, marital status, education and age at first birth.

The importance of children as caregivers increases with parents' age, and having at least one daughter may therefore become increasingly advantageous with age. The same is true of the role of a daughter as a source of social contact.

Besides age, marital status may also have an effect on the need for social contact with and help from the children, often daughters, as having a spouse can be a substitute when it comes to practical help and companionship. A wife or husband can also make the partner adopt a healthier lifestyle (e.g. cut down on smoking and drinking) in the same way as children, especially daughters often do.

Education is another possible conditioning factor. The more highly educated have a healthier lifestyle, which means that any pressure concerning life-style changes by children, and especially daughters, will be less important. However, one study [49] found that the highly educated women have a higher preference for girls, which assuming they assess correctly how important a daughter is to them, may mean that having at least one daughter is especially beneficial for this group.

Having a child at an early age is detrimental to health later in life. The effect might be dependent on the sex of the child. Women who become mothers at a very early age, especially

teenage mothers, are less likely to be in a relationship with the child's father or have contact with the father at all. They are also likely to take less education [50]. Having had sons may have been particularly stressful for these women, as sons often require more attention than daughters and are more costly.

Finally, the effect of having a certain sex composition may vary over time. For example, a relevant point might be that sons tended to be more highly educated than daughters a few decades ago. The education of the children has in some studies been shown to have a protective effect on parents' mortality [51,52,53]. The differences between the sexes in these respects are now much smaller.

3. **Data and model**

The study includes all men and women born 1935-1968 who lived in Norway some time between January 1, 1980 and December 31, 2008 and while they had at least one child. The data come from the Norwegian Central Population Register[3], which includes every person resident in Norway for some time after 1960, each of whom has been assigned a unique identification number (at birth or at the time of immigration). The identification number is used in all kinds of contact with the authorities such as applying for education, paying tax or registering at a new address, thus allowing individual-level data from different registers to be linked. In this study, information on education has been added from the National Education Database operated by Statistics Norway, which includes the highest achieved educational

[3] The data were used with the permission of Statistics Norway.

degree based on censuses prior to 1980 and on schools' reporting thereafter. The available data file reports year of death[4] (taken from the exact dates in the primary data).

In the Norwegian Central Population Register, parents' identification numbers are included for all children who were born in Norway after 1964, or if born earlier, lived at home according to the 1970 census. Thus, almost complete birth histories can be established for all men and women in the country born after 1935. Unfortunately, given the available data it is not possible to distinguish between biological and adopted children. However the proportion of children who have been adopted is less than 1%.

Discrete-time hazard regression models are estimated, separately for women and men using the Proc Logistic procedure in SAS version 9.3 [54]. I start by considering a model with the number of sons as the independent variable before considering models which compare having at least one child of each sex to those who have only children of one sex.

For each individual, a series of one-year observations was created, starting in January 1980 or in January of the year he or she turned 40 (if born 1940 or later) or immigrated, and ending with the year of death, emigration, or in 2008, whichever came first. Each one-year observation includes an outcome variable, which is whether the person died within that year or not, and several independent variables characterising the situation at the beginning of the year: age, calendar year, educational level, marital status, number of children, and age at first birth. Those who did not have any children at the beginning of the year were excluded.

[4] By law all deaths must be reported to the authorities based on a doctor's death certificate and will automatically be registered in official statistics.

Mathematically the model is **log (1/(1-p)) = bX** where p is the probability of dying, **X** is a vector of covariates and **b** are the estimates. Since death probabilities are low **(1/(1-p)) ≈ p.** An estimate b can therefore be interpreted as p being b times what it is in the reference category.

Among men there were 54 073 deaths during the 12,816,408 person-years of follow-up, while there were 36 325 deaths during the 13,316,760 person-years for women.

Five categories of education are distinguished: compulsory education (10 years of schooling according to the current school system); some secondary education (11-12 years); completed secondary education (13 years); some higher education (14-17 years); and master's degree or higher (18+ years). When it comes to marital status the categories are: married, divorced, widowed and never married. Using Norwegian register data it is unfortunately not possible to distinguish those living in cohabiting relationships. Age at first birth is divided into the following groups: below 19, 20-22, 23-25, 26-29, 30-34 and above 35 years of age.

The educational level is included in the models because it is an important determinant of fertility as well as mortality (e.g. [55,56]). For the same reasons, calendar year and age are taken into account. Furthermore, age at first birth is controlled for, as giving birth at a very young age is associated with higher mortality [1,57,3] and tends to increase or be positively associated with completed fertility. Marital status affects mortality and is closely linked to reproductive behaviour, though without a clear one-way causality. For example, being unmarried obviously reduces fertility, while the number of children, and perhaps even their sex, are likely to have implications for marital status, which is therefore included in some, but not all, models.

Finally, the association between children's sex and parents' mortality may vary with the parent's age, period, age at first birth marital status and education. I assess this by estimating the model separately for different categories of these variables.

The exposure time and number of deaths in various categories of age, period, education, marital status, number of children and age at first birth are shown in table 1.

Table 1 Descriptive statistics (CDR- crude death rate)

	Men			Women		
	Exposure time	Number of deaths	CDR (per 1000)	Exposure time	Number of deaths	CDR (per thousand)
Education						
Compulsory education	3,094,623	19,618	6.34	3,970,690	15,929	4.01
Some secondary education	3,226,322	15,376	4.77	4,519,491	12,867	2.85
Completed secondary education	2,771,992	9,490	3.42	1,706,506	2,553	1.50
Some higher education	2,582,601	7,073	2.74	2,763,219	4,494	1.63
Master's degree or higher	1,140,870	2,516	2.21	356,854	482	1.35
Marital status						
Married	9,957,835	34,347	3.45	9,813,708	22,275	2.27
Never married	666,561	2,342	3.51	581,631	1,294	2.22
Widowed	157,845	1,805	11.43	621,147	3,984	6.41
Divorced	2,034,167	15,579	7.66	2,300,274	8,808	3.83
Number of children						
1	1,831,685	9,196	5.02	1,820,757	6,312	3.47
2	5,664,702	21,463	3.79	5,828,087	14,430	2.48
3	3,646,831	14,717	4.04	3,853,061	9,825	2.55
4	1,196,454	5,917	4.95	1,295,294	3,909	3.02
5	476,736	2,780	5.83	519,561	1,849	3.56
Age at first birth						
Below 19	319,730	1,866	5.84	1,799,311	6,439	3.58
20-22	2,021,660	10,716	5.30	3,927,521	11,868	3.02
23-25	3,418,994	15,451	4.52	3,390,422	8,667	2.56
26-29	3,799,934	14,775	3.89	2,600,871	5,919	2.28
30-34	2,193,136	7,700	3.51	1,163,814	2,561	2.20
Above 35	1,062,954	3,565	3.35	434,821	872	2.01
Age						
40-49	6,733,908	13,236	1.97	6,971,375	8,755	1.26
50-59	4,302,732	20,007	4.65	4,426,953	13,699	3.09
60-73	1,779,768	20,830	11.70	1,918,432	13,871	7.23
Period						
1980-89	2,059,959	5,608	2.72	2,123,594	3,299	1.55
1990-99	4,575,997	16,628	3.63	4,719,398	10,878	2.30
2000-08	6,180,452	31,837	5.15	6,473,768	22,148	3.42

4. Results

In my first model, sex composition is operationalised as the number of boys. Table 2 displays the results of this regression without controlling for marital status, for men and women, respectively. I control for age, year, education, number of children and age at first birth. Neither for women nor for men is the effect of "Number of boys" statistically significant. The other effects are as expected: mortality is lower and fairly stable when the number of children exceeds one, lower among those who have a higher level of education, and lower for those (especially women) who had their first child later.

Table 2 Relationship between number of boys and parental mortality controlling for parental demographics excluding marital status. (Odds ratios with 95% confidence intervals)

	Men	Women
Year	0.98 (0.97-0.98)	0.99 (0.99-0.99)
Age	1.11 (1.11-1.11)	1.09 (1.09-1.10)
Education		
Compulsory education	1	1
Some secondary education	0.76 (0.74-0.78)	0.75 (0.73-0.77)
Completed secondary education	0.65 (0.64-0.67)	0.50 (0.48-0.52)
Some higher education	0.53 (0.52-0.55)	0.55 (0.53-0.57)
Master's degree or higher	0.42 (0.40-0.44)	0.47 (0.43-0.52)
Number of children		
1	1	1
2	0.69 (0.68-0.71)	0.69 (0.66-0.71)
3	0.65 (0.63-0.67)	0.61 (0.59-0.64)
4	0.67 (0.65-0.70)	0.60 (0.57-0.63)
5	0.68 (0.64-0.71)	0.59 (0.56-0.63)
Age at first birth		
Below 19	1.34 (1.27-1.40)	1.33 (1.29-1.38)
20-22	1.19 (1.16-1.21)	1.10 (1.07-1.14)
23-25	1	1
26-29	0.91 (0.89-0.93)	0.97 (0.94-1.00)
30-34	0.86 (0.84-0.88)	0.94 (0.90-0.99)
Above 35	0.76 (0.73-0.79)	0.80 (0.74-0.86)
Children's sex composition		
Number of boys	1.00 (0.99-1.01)	1.00 (0.99-1.02)

Table 3 shows the estimates from models where marital status has been included. We see that the estimated coefficient for the variable "Number of boys" is hardly affected. The estimates for marital status are as seen in earlier studies: there is an advantage of being married compared to being single, whereas the never-married and the divorced are at a greater disadvantage than the widowed.

Table 3 Relationship between number of boys and parental mortality controlling for parental demographics including marital status. (Odds ratios with 95% confidence intervals)

	Men	Women
Year	0.97 (0.966-0.97)	0.99 (0.99-0.99)
Age	1.11 (1.11-1.12)	1.09 (1.09-1.10)
Education		
Compulsory education	1	1
Some secondary education	0.79 (0.78-0.81)	0.76 (0.75-0.78)
Completed secondary education	0.69 (0.67-0.70)	0.49 (0.47-0.52)
Some higher education	0.57 (0.55-0.58)	0.55 (0.53-0.57)
Master's degree or higher	0.46 (0.44-0.48)	0.46 (0.42-0.51)
Marital status		
Married	1	1
Never married	2.05 (1.95-2.14)	1.48 (1.40- 1.58)
Widowed	1.65 (1.57-1.73)	1.38 (1.33-1.43)
Divorced	2.16 (2.12-2.20)	1.63 (1.59-1.67)
Number of children		
1	1	1
2	0.78 (0.76-0.80)	0.75 (0.73-0.78)
3	0.74 (0.72-0.76)	0.68 (0.66-0.71)
4	0.76 (0.73-0.79)	0.67 (0.64-0.70)
5	0.75 (0.71-0.79)	0.66 (0.64-0.70)
Age at first birth		
Below 19	1.27 (1.13-1.34)	1.26 (1.22-1.31)
20-22	1.15 (1.12-1.18)	1.08 (1.05-1.11)
23-25	1	1
26-29	0.92 (0.90-0.94)	0.98 (0.95-1.01)
30-34	0.87 (0.85-0.90)	0.96 (0.92-1.01)
Above 35	0.76 (0.73-0.79)	0.82 (0.99-0.88)
Children's sex composition		
Number of boys	0.99 (0.99-1.01)	1.00 (0.99-1.02)

I my second model, I replace the number of boys variable with an indicator variable denoting whether all the children are of the same sex. As this variable is always unity for one-child families, tables 4 and 5 show regression results only for those with two or more children. Controlling for age, period, education, marital status, number of children and age at first birth I find no significant effect of having only sons or only daughters rather than having at least one child of each sex for men (Table 4). For women, however, there is a statistically significant, though small, mortality disadvantage associated with having only daughters (3%). Very similar estimates are obtained when marital status is excluded from the models (not shown).

Table 4 Effect of having children of only one sex compared to having at least one of each sex, for those with two or more children (Odds ratios with 95% confidence intervals)

	Men	**Women**
Only boys	1.01 (0.99-1.04)	1.02 (0.99-1.05)
Only girls	1.02 (0.99-1.05)	1.03 (1.00-1.07)

Controlling for age, period, education, marital status, number of children and age at first birth.

Using "having only sons" as the reference category instead of "having at least one of each sex", in order to compare having only sons to having only daughters (and including parents with only one child) I find that mothers of two daughters have a significantly higher mortality than mothers of two sons (odds ratio 1.05; 95% confidence interval (1.00-1.10)). I also find that mothers of four daughters have a significantly lower mortality than mothers of four sons (odds ratio 0.82; 95% confidence interval (0.69-0.98)) (not shown in tables).

When stratifying by level of education, marital status or age, I find no significant effects of children's sex composition, neither when operationalised as number of boys, nor as only boys, only girls and mixed (results not shown). However, estimating the model separately for the

years 1980-1989, 1990-1999 and 2000-2008 I find a disadvantage of having only children of a single sex on the longevity of women for the period 1980-1989 (Table 5).

Table 5 Effect of having children of only one sex in the periods 1980-1989, 1990-1999 and 2000-2008, for those with two or more children. (Odds ratios with 95% confidence intervals)

	Men			Women		
	1980-1989	**1990-1999**	**2000-2008**	**1980-1989**	**1990-1999**	**2000-2008**
Only boys	1.01 (0.93-1.09)	0.99 (0.99-1.06)	1.03 (0.99-1.06)	1.11 (1.00-1.23)	1.00 (0.95-1.06)	1.01 (0.97-1.06)
Only girls	0.99 (0.91-1.07)	1.02 (0.99-1.06)	1.03 (0.99-1.06)	1.15 (1.04-1.24)	1.00 (0.94-1.06)	1.03 (0.99-1.08)

Controlling for age, period, education, marital status, number of children and age at first birth.

The other statistically significant effect appears among women who gave birth to their first child as teenagers. In this group, I find a disadvantage of having only sons compared to at least one of each sex (odds ratio 1.10; 95% confidence interval 1.021-1.177).

5. Discussion

There is almost no knowledge available from contemporary western countries about whether the sex composition – in line with the preferences or not – affects the parents' mortality. Given the lack of earlier research, a study of the association between children's sex composition and parents' mortality based on high-quality data covering an entire national population should be a valuable contribution to the literature. Interestingly, when models are estimated for the period 1980-2008 and using the whole sample, there is only one significant effect: mothers who have only girls have a slightly higher (odds ratio 1.03 95% confidence interval (1.00-1.07)) mortality than those who have at least one child of each sex. These results indicate (weakly) that there is a special value associated with sons. In other words, the benefits

supposed to be derived from having a daughter seem to be somewhat smaller than the positive effects of having a son, such as stronger involvement by the father, which probably also benefits the mother. Such a marginally higher value of having a son would accord with the results from some studies of parents' subjective well-being.

Having only daughters compared to only sons is associated with a mortality disadvantage for mothers with two children, but an advantage for those with four children. The first result again points to a special importance of having sons. The second effect might reflect physiological effects of carrying many male foetuses or that having many sons is in some way burdensome.

According to period-specific models, the high mortality among mothers with only girls was confined to the 1980s (odds ratio 1.11; 95% confidence interval (1.00-1.23)), when there was also a significant, but weaker, adverse effect of having only boys (odds ratio 1.15; 95% confidence interval (1.04-1.24)). This finding may reflect that sons and daughters at that time had more distinct roles, with sons for example being able to offer better advice as a result of having more education on average, while daughters to a larger extent contributed as caregivers, and as a consequence it was more important to have at least one child of each sex.

The most surprising result is perhaps that the patterns differ so much between women and men. Women might need children more because they are more often widowed, however an analysis stratified by marital status did not give support to this interpretation.

One might expect the relationship between children's sex composition and parents' mortality to vary with age and education, but no such pattern appeared. Only a significant conditioning effect of age at first birth was seen: among women who entered motherhood early, those with only sons had a particularly high mortality (odds ratio 1.10; 95% confidence interval 1.021-1.177). The main reason might be that it is more stressful for young girls to raise boys as they

are often more energetic and boisterous and are a greater drain on the mother, especially if she lacks the support of a partner, as many teenage mothers do.

Limitations

One limitation of the study is the somewhat limited age range of parents (40-73) that could be included. It may be that some characteristics typically associated with a child's sex are appreciated by parents primarily at higher ages. An example may be willingness, especially of daughters, to offer social support. The relatively narrow age range also means that the distribution of deaths by cause in the sample differs from the distribution for the population as a whole. It may be that children's sex is more important for causes of death that are more prevalent at higher ages[5]. Furthermore, given the data it is not possible to determine the possible mechanisms through which children's sex composition may affect mortality.

Another major limitation of this study is that factors such as previous health status, earlier life crises and socio-economic status other than education could not be controlled for. It is however possible that such factors affect both the children's sex and the parents' mortality. For instance the male-female sex ratio at birth might not be constant even in settings where sex-specific abortion is very uncommon. It has been found to diminish subsequent to disasters or economic downturns (e.g. [58,59,60]). Furthermore, stressful life events such as having a severely ill partner or child, or bereavement, are associated with a lower sex ratio [61]. Conversely, characteristics indicative of an advantaged situation, economically or otherwise, are associated with high sex ratios: married mothers have been found to give birth to more

[5] Research looking at the association between children's sex and specific causes of death would be an interesting topic for further research. This dataset is also well suited to address other topics such as studying the mortality of those who have lost a child.

boys than mothers not living with the father [62,63], and better educated mothers have more sons [64], as do male billionaires - 60% compared to 51% in the population as a whole [65]. Being married, more highly educated or rich also reduces mortality, while adverse life experiences, such as unemployment or losing a child, has been linked to higher mortality later in life [66]. These factors may therefore in principle give rise to an inverse spurious relationship between the proportion of the children who are sons and parents' mortality.

6. Conclusion

This article finds that there is a small mortality disadvantage among women with two children having only daughters, among women who had their first child as a teenager and only have sons, and among mothers in the 1980s who only have children of one sex. Mothers of two daughters and no sons have a higher mortality than mothers of two sons and no daughter. However, mothers of four daughters and no sons have a lower mortality than mothers of four sons and no daughters. The results lend some support to the notion that there is a larger benefit of the first son or daughter than later children of the same sex. This is more pronounced in the earliest decade of the study period, when men and women had more different roles. The findings also indicate (weakly) that supposed benefits of having a daughter (for example because of their special contributions as caregivers), may be somewhat smaller than the positive effects of having a son, such as stronger involvement by the father, which probably also benefits the mother. However, having many sons may be a burden on the mother. In principle, the observed relationships may also reflect selection processes.

Obviously, one cannot conclude from such estimates that men and women who have only girls or boys should try to have an additional child of the opposite sex to improve their health in the long term. Neither do mortality differentials of this modest size serve as a warning that

groups of parents with a special sex composition deserve extra attention. Rather, the results should be seen as interesting illustrations of how far-reaching consequences the sex composition of one's children might have on one's life.

Competing interests

The author declares that she has no competing interests.

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