Using MicMac to project living arrangements: an illustration of biographic projections[1]

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1. Introduction

How do living arrangements change over the course of life? What are the most common sequences of living arrangements? How many people experience single parenthood in their lifetime and how many experience multiple episodes of single parenthood? How many people live alone at the end of life? What is the expected length of an episode of single parenthood and what proportion of single parents remains a single parent for more than 15 years. At what age on average do parents with children reach the empty-nest stage? What proportion of 55-year old have still children living at home? What proportion of elderly opts for assisted living (institution) and at what age to they leave their home and move to an institution? These are some of the questions demographers receive from policy makers and the general public. To answer these questions, empirical observations must be combined with modeling. This paper shows how the living arrangements of women in The Netherlands change over the life course. We obtain the living arrangement at various ages, determine sequences of living arrangements and estimate the time spent in a given state. The data are from the Population Register and the model is a cohort-survival model that distinguishes multiple states and allows for idiosyncratic behaviour of members of the cohort. The model is MicMac.

This paper shows how MicMac can be used to project the population by living arrangement. The aim is to illustrate how MicMac can provide more information than the traditional demographic projection models by means of combining macro and micro simulations. The model is applied to Dutch data on transitions between six categories of living arrangements. A main advantage of microsimulation over macrosimulation is the level of detail. Whereas macro models project the number of people in certain living arrangements at different ages, micro projections provide

[1] The research is part of the MicMac project, an international (European) project funded by the European Commission in the context of the Sixth Framework Programme. The project started in 2005 and aims at the development of a new demographic projection model that bridges the gap between aggregate projections of cohorts (Mac) and projections of the life courses of individual cohort members (Mic). The model is expected to be used by EUROSTAT, the statistical office of the European Union, and national statistical offices throughout Europe in order to prepare detailed demographic projections for sustainable pension and health care systems. The project is described in Van der Gaag et al. (2005) and is carried out by a consortium of researchers of the Netherlands Interdisciplinary Demographic Institute (NIDI), Vienna Institute of Demography (VID), Institut National d'Etudes Demographiques (INED) (Paris), Bocconi University (Milan), Erasmus Medical Centre (Rotterdam), Max Planck Institute for Demographic Research (Rostock, Germany), the International Institute for Applied System Analysis (IIASA) (Laxenburg, Austria) and the University of Rostock.

information on the number of people that experience a certain succession of living arrangements during their life cycle and the duration in each of these states. For example, the macro model projects the percentages of people at successive ages living alone, whereas the micro model projects the percentage of people that ever live alone during their lifetime, how many times they experience a period of living alone and how many years they are living alone.
The information on life trajectories or lifepaths generated by microsimulation models often differs considerably from the state occupancies at consecutive ages produced by macrosimulation. In MicMac they are consistent. Since the macro and micro projections of MicMac are based on the same set of transition rates or probabilities, the outcomes at the macro and micro level are mutually consistent.

The MicMac project is work in progress. The project will not be finished before 2009. The project will provide an open source software package. As this software is not yet available, the calculations are done with a prototype of MicMac. The results shown in the present paper were based on calculations performed with Microsoft Excel.

The paper consists of 4 sections. Section 2 describes the data and the method. Section 3 presents the results. Section 4 discusses the results. The MicMac model is a generic model of life histories of cohorts and individual cohort members. The study of living arrangements is only one of the many possible applications. Section 5 presents other possible applications.

2. Method and data

MicMac is a multistate model. Different states of existence must be distinguished and transitions between the states must be identified. In this paper, the states are living arrangements. The version of MicMac used in this paper includes six categories of living arrangements:

- living in parental home
- living alone
- living with partner without children
- living with partner with children
- single parent
- living in institution.

Note that marital status is not included. Thus, married couples cannot be distinguished from people living in a consensual union. Moreover, there is a distinction between persons living in families with and without children, but the number of children is not included. Furthermore the category ‘other household position’ is not included in the model (*e.g.* extended families in which grandparents live with the family of their daughter or son).

The population is distinguished by single years of age (up to and including 98 years) and by sex. This paper only shows results for women aged between 15 and 98 years.

The data are based on the Population Register and are provided by the population department of Statistics Netherlands. Since 1995, population statistics are based in The Municipal Population Administration (Population Register – GBA) that keeps track of all individuals residing legally in the country. The analysis in this paper is

based on the living arrangement of residents on 1st January 2004 and the living arrangement on 1st January 2005. The information is by age (1st January 2004) and sex. If a person died in 2004 the dead is recorded. Persons who entered the country in 2004 or who emigrated are excluded from the analysis. Transitions are determined by comparing the living arrangement on 1 January 2004 and 1 January 2005. Transition probabilities are estimated by dividing, for each living arrangement in 2004, the number of individuals in a given living arrangement in 2005 by the number in the selected living arrangement in 2004. The version of MicMac used in this paper is based on these discrete-time transition probabilities. They are period-cohort transition probabilities.
Note that not all transitions during 2004 are measured. For example, if someone living with a partner on 1 January 2004 separates during 2004 and enters a new relationship during the same year, her living arrangement on 1 January 2005 is the same as on 1 January 2004 and consequently no transitions are measured. Thus the number of direct transitions during 2004 is underestimated. Because of the nature of the data, period-cohort transition probabilities are estimated directly from the data and not derived using the more common approach of first estimating transition rates from the data and subsequently deriving transition probabilities from the rates.

In addition to the transitions between the living arrangements the probability of dying is also estimated for women in each living arrangement (distinguished by age). Immigration and emigration are not included in the model.

Table 1 shows the 6 living arrangements and the state of dead, and the transitions. All states except dead are transient states. They can be entered more than once. Some transitions are rare and consequently the associated transition probabilities are very low. They have been omitted from the table. The model includes 25 transitions; the other 11 transitions are not included as the probabilities turned out to be small for all ages.

The following transitions are distinguished:

- from living at parental home to living alone
- from living at parental home to living with partner without children
- from living at parental home to living with partner with children
- from living at parental home to single parent
- from living at parental home to dead
- from living alone to living at parental home
- from living alone to living with partner without children
- from living alone to living with partner with children
- from living alone to sinle parent
- from living alone to living in institution
- from living alone to dead
- from living with partner without children to living at parental home
- from living with partner without children to living with partner with children
- from living with partner without children to living alone
- from living with partner without children to living in institution
- from living with partner without children to dead
- from living with partner with children to living alone
- from living with partner with children to living with partner without children

- from living with partner with children to single parent
- from living with partner with children to dead
- from single parent to living alone
- from single parent to living with partner with children
- from single parent to dead
- from living in institution to living alone
- from living in institution to dead.

Table 1 shows which transitions are not included in the current version of the model.

The model does not include fertility. Even though the transition from living with partner without children to living with partner with children will in most cases involve the birth of the first child, the transition may also occur if a person living with a partner enters into a new relationship with another partner who has already children living in his household. Furthermore the model does not allow women living in the parental home to have children.

The living arrangement 'living with a partner', can be dissolved by separation or death of the partner. The model does not distinguish the end of a relationship due to separation from that due to death of the partner.

The empirical transition probabilities are parameterized using the Rogers-Castro model migration schedule (Rogers and Castro, 1981). The Rogers-Castro model relates the transition probability at an age x to the age x by applying a linear combination of at most three double exponential functions. The double exponential function is:

$$a \exp\{b(x - \mu) - \exp[-c(x - \mu)]\},$$

where x denotes age and a, b, μ and c are parameters to be estimated. The parameter μ determines the location of the curve on the age axis, c determines the steepness of the ascending part of the curve, b the steepness of the descending part and a determines the surface beneath the curve.

For each transition probability a linear combination of maximum three double exponential functions is estimated:

$$f(x) = \sum_{i=1}^{3} a_i \exp\{b_i(x - \mu_i) - \exp[-c_i(x - \mu_i)]\}$$

Graph 1 shows a selection of the fitted age curves. The dotted lines are the curves fitted by the double exponential model.

Graph 1 about here

The transition probabilities are used to make projections on both the macro and micro level. By assuming the probabilities to remain constant the macro model can be used to project the distribution of the number of women by living arrangement at each age between 15 and 98 years.

The macromodel is used to generate cohort biographies that are consistent with the empirical transition probabilities, parameterized by a linear combination of double exponential functions. The cohorts are synthetic cohorts.

The micromodel is used to generate the life course of 10000 women between 15 and 98 years, based on the same transition probabilities that are used for the macro projections by means of Monte Carlo simulation. For each person at each age a random number between 0 and 1 is drawn. If the random number is smaller than the probability of leaving the current state the person will move to another state. If the person can move to different other states, the question to which state the person moves depends on the differences in the level of the probabilities. For example, for a woman aged 22 living at the parental home the probability of leaving the parental home to live alone equals .12 and the probability to live together with a partner equals .18. Thus the probability of leaving the parental home is .3 and given that one leaves the parental home the probability is .6 that one will live with a partner and the probability is .4 that one will live alone. This is modeled as follows: if the random number is below .12 the woman will move to the state living alone and if the random number is between .12 and .30 the woman will move to the state living with a partner.

As the results of the microsimulation depend on drawing random numbers, the results are affected by random fluctuations. Graph 2 shows that 1000 microsimulations provide results that correspond reasonably closely to the distribution of the number of women by age over living arrangements projected by the macromodel. Nevertheless each new microsimulation will provide slightly different results. Thus the results presented below should be interpreted with caution. One should look at the order of magnitude rather than at the precise size of each number.

3. *Results*

Macro: cohort biography

Assuming constant transition probabilities the distribution of the number of women by age (between 15 and 98 years) over living arrangements can be projected. This can be interpreted as a forecast of the biography of the birth cohort that is currently 15 years of age, assuming that the transition probabilities will not change in the future. This is similar to interpreting the total fertility rate as a projection of the average number of children that a young cohort of women will have, assuming age-specific fertility rates to remain constant, or interpreting the life expectancy at birth as the projection of the average duration of life of new-born children, assuming age-specific mortality rates to remain constant.

Table 2 shows the results for five-year age groups. The table shows how in successive age groups different living arrangements are predominant. In the age category 15-24 years children living at the parental home is the largest category, between ages 25 and 29 women living with a partner without children is the largest group, between ages 30 and 54 most women live in a family with children, between 55 and 74 years most women live with a partner but without children, between 75 and 94 years many women live alone, whereas at the oldest ages relatively many women live in an institution, but only few women survive to those high ages. This gives an impression of the successive stages in the life cycle, but it does not show how many people experience which states. For example, the table shows that a quarter of women in their twenties are living alone, but this does not imply that a quarter of women are living alone for some time in their twenties. In order to estimate the number of women living alone for some time, information at the micro level is needed.

Table 2 about here

Micro: individual biographies

On the basis of the same transition probabilities used for the macrosimulation, life courses (i.e. a succession of living arrangements) for a number of individuals can be simulated. The results shown here are based on life courses of 10000 women. Added together they show the same pattern as Table 2. However, the individual life courses contain much more information. The results shown in this section are only a selection of the results that can be obtained, with the purpose of illustrating the type of projections that can be made by MicMac.

Even though the model only includes six types of living arrangements, the variety of life courses turns out to be large. The 10000 microsimulations produce 1911 different life courses (i.e. different successions of living arrangements, not taking into account differences in ages at the different transitions). A total of 1000 simulations resulted in 260 different lifepaths. Table 3 shows the 13 life courses that are experienced by at least one percent of all women.
The life course that is projected to occur most frequently (5%) is living together with a partner after leaving the parental home, then having children, subsequently after the children have left the parental home living in a family without children for some time, followed by a period of living alone, after the death of the partner[2] until the person dies herself. This life course corresponds with the age pattern of the most frequent living arrangements as shown in Table 1. However, as noted, this sequence of living arrangements is experienced by only 5% of all women.
The life course that is the most frequent but one (experienced by 4% of all women) differs from the most frequent one in one respect, *viz.* that one lives alone for some time after leaving the parental home before entering into a relationship. Also the next life course (experienced by 4% of all women) differs in one respect from the most frequent one, but in this case at the end of the life-cycle, *viz.* dying before the partner, implying that there is no period of living alone. In a similar way the life course in the fourth place (experienced by 3% of women) differs from the life course in the second place. The life course in the fifth place (3% of all women) differs from the most frequent one as the last part of life is spent in an institution. In the tenth place is the first life course of women that remain childless (1% of women). Without discussing all other life courses in detail it is interesting to note that in 7th, 8th, 12th and 13th place there are life courses of women who experience the end of a relationship and live as single parent for some time before they start to live alone or enter a new relationship.

[2] The available data do not allow to distinguish between the end of a relationship due to separation and due to the death of the partner. In both cases there is a transition from living with partner without children to living alone or from living with partner with children to single parent.

In place 31 (not included in Table 3) is the first life course of women who do not live together with a partner for some time during their life (127 women, 0.5%).

Table 3 about here

On the basis of the simulated life courses it can be assessed what proportion of women experiences which sequence of states and how long the duration in each state is. Whereas the results of the macro projections show that at young ages maximum 25% of all women are living alone and at older ages less than 40%, a much larger proportion of women live alone for some time during their life. Table 4 shows that as much as 90% of women live alone for some time during their life[3]. More than half of all women even experience two or more periods of living alone during their lifetime, in most cases one period at young ages before entering into a relationship or after a separation and one period at the end of life, in most cases after the death of the partner.

Table 4 also shows that two thirds of all women live together with only one partner in their life[4], whereas one third of women enters into a new relationship after their first one ended either by separation or the death of the partner.

Table 4 about here

As life expectancy of women is some years higher than that of men and moreover women tend to live together with a man that is some years older, most women live longer than their partner. Consequently many women live alone for some time at the end of their life. Table 5 shows that more than 40% of all women are living alone when they die, almost 30% live in an institution and 26% die while living with a partner.

Table 5 about here

Even though most women live alone during a part of their life, only few women live alone during a large part of their life, let alone their whole life after leaving the parental home. Only 2% of all women live alone their whole life until they enter into an institution or die. The vast majority of women lives a considerable part of their life together with a partner. Table 6 shows that two thirds of all women live together with a partner for more than 30 years, whereas only one in five women is living alone for such a long period. The table also shows that even though a majority of couples have children, couples are living together relatively many years without children. One half of women lives for more than 20 years together with their partner without having children in their household.

Table 6 about here

[3] Note that, as remarked in section 2, short periods of living alone are not included.
[4] The actual number may be lower, since if a woman lives together with a partner at the start of the year, then separates and enters a new relationship before the end of the year, this is measured as a relationship with one partner instead of two.

Table 6 shows that 15% of women living with a partner do not have a child. Adding the small number of women who do not live together with a partner for some time, it turns out that 24% of all women will remain childless.

4. Discussion

Section 3 shows some illustrations of the type of projections that can be made by using MicMac. The development of MicMac is as yet only in an early stage. Both the model and the data need further improvement. The results are presented as illustrations of the type of projections that can be done by using MicMac.

The projections presented in this paper have many limitations. To mention the most important ones:

- The version of MicMac used in this paper projects transitions based on a comparison of states at the start and end of a year. This implies that the total number of transitions during that year is underestimated. For example, if someone is living alone at the start of the year, then enters a relationship, but separates before the end of the year, the state at the start and the end of the year is the same and hence no transition is measured. For projecting the distribution of the population over living arrangements this does not have to lead to a bias, if the part of transitions that follow quickly after each other does not change. It does, however, lead to an underestimation of the total number of transitions that people experience during their lifetime. Particularly the number of relatively short periods of living alone and living together with a partner are underestimated.
- Some transitions include several events. For example the transition from living with a partner without children to living alone includes both separation and the death of the partner. The same applies to the transition from living with a partner with children to single parent. Thus the current model is not able to produce information on the number of separations and the number of women becoming widow.
- The transition probabilities are assumed constant. This implies that no cohort effects are taken into account.
- The model does not include marital status. Thus no distinction can be made between married couples and consensual unions. This implies that e.g. differences in the probability of separation of consensual unions and the probability of divorce of married couples cannot be taken into account. Similary, differences in the probability of having a child between non-married and married couples cannot be taken into account.
- The model does not include the number of children.
- The model does not include immigration and emigration.
- The model does not relate persons to each other, e.g. partners or parents and children. Thus if the same projections would be done for men, the number of women living with a partner may not be consistent with the number of men living with a partner. The model does not allow to project the number of households and the size of households.

MicMac is aimed to be an instrument that can be used for two purposes, *viz.* calculation of scenarios and impact assessment. Scenarios are to be distinguished from forecasts. Whereas a forecast is aimed to project the most likely future development, scenarios are aimed to present alternative future developments, that are internally consistent and that show the consequences of different sets of assumptions. MicMac can be used for making scenarios by making separate sets of assumptions about changes in one or more transition rates. For example, MicMac can be used to compare a scenario in which the age at leaving home does not change with a scenario in which children will leave the parental home at a younger age, *e.g.* because of changes in the educational system or because of an increase in the availability of appropriate houses. A comparison of these scenarios will show the effect on the age at entering into a relationship and the age at having the first child.

MicMac may also be used for impact assessment, for example by showing the possible consequences of different policies. This can be done either *ex post* or *ex ante*. *Ex post* analyses can be done by examining whether in the past certain transition rates changed after a given change in policy and comparing the observed development with the development that would have occurred if the transition rates would not have changed. *Ex ante* analyses imply that one compares a scenario in which certain transition rates are assumed to change as a consequence of future policy measures with a scenario in which these changes do not occur.

5. *Other applications*

The results shown in this paper illustrates some features of MicMac. The projection of living arrangements represent only one application.The MicMac project includes also a module for projecting education and a module for projecting health and mortality.

Education will be included in the model as it is assumed to affect both living arrangements and fertility as well as health and mortality.

The MicMac model distinguishes covariates and risk factors. Projections of health and mortality will be based on two indirect and two direct determinants. The indirect determinants are living arrangement and level of educational attainment, the direct determinants are smoking behaviour and body mass index. The effects of the prevalence of these determinants on the transitions between health states and between health states and mortality will be modeled.

In addition to these modules MicMac may also be extended to other fields. For instance, MicMac may be applied to the labour market. For example entry into the labour market can be modeled by specifying transitions from school to the labour market, from being non-employed (e.g. because of raising children) to employed, and from being disabled to re-entry in the labour market. Exits can be modeled by specifying transitions from employed to disabled, from employed to non-employed (e.g. after the birth of a child) and from employed to pensioned.
If MicMac includes a labour market module it may be used for analyzing the impact of various policies. For example the effect of improvements of parental leave or child care on both the age at having children and the ultimate number of children as well as on labour force participation can be analysed by comparing results assuming different levels of transition rates. Another example is an analysis of the impact of policies affecting the age at leaving the labour force. Also the effect of emigration on the size of the labour force may be analysed.

X= transition included in the model; - = not included in the model

Table 1 Transitions included in the model

	Destination						
Origin	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
In parental home (1)	**X**	X	X	X	X	-	X
Alone (2)	X	**X**	X	X	X	X	X
With partner, without child(ren) (3)	X	X	**X**	X	-	X	X
With partner, with child(ren) (4)	-	X	X	**X**	X	-	X
Single parent (5)	-	X	-	X	**X**	-	X
Institution (6)	-	X	-	-	-	**X**	X
Dead (7)							**1**

Table 2. Projection of percentage distribution of women by age and living arrangement (cohort biography), based on transitions measured in 2004

Age	Living in parental home	Living alone	Living with partner without children	Living with partner with children	Single parent	Living in institution	Dead	Total
15-19	89	7	3	0	0	1	0	100
20-24	43	25	26	4	0	2	0	100
25-29	10	25	40	21	2	2	0	100
30-34	3	18	24	49	4	2	0	100
35-39	1	14	15	60	7	2	0	100
40-44	1	13	14	61	9	2	1	100
45-49	1	13	18	55	10	2	1	100
50-54	0	16	35	37	8	2	2	100
55-59	0	20	53	17	5	2	3	100
60-64	0	24	59	8	2	1	6	100
65-69	0	27	55	4	1	1	12	100
70-74	0	32	45	2	1	1	19	100
75-79	0	37	31	1	1	2	28	100
80-84	0	35	16	1	1	6	42	100
85-89	0	23	5	0	1	9	62	100
90-94	0	9	1	0	0	7	83	100
95-98	0	2	0	0	0	3	95	100

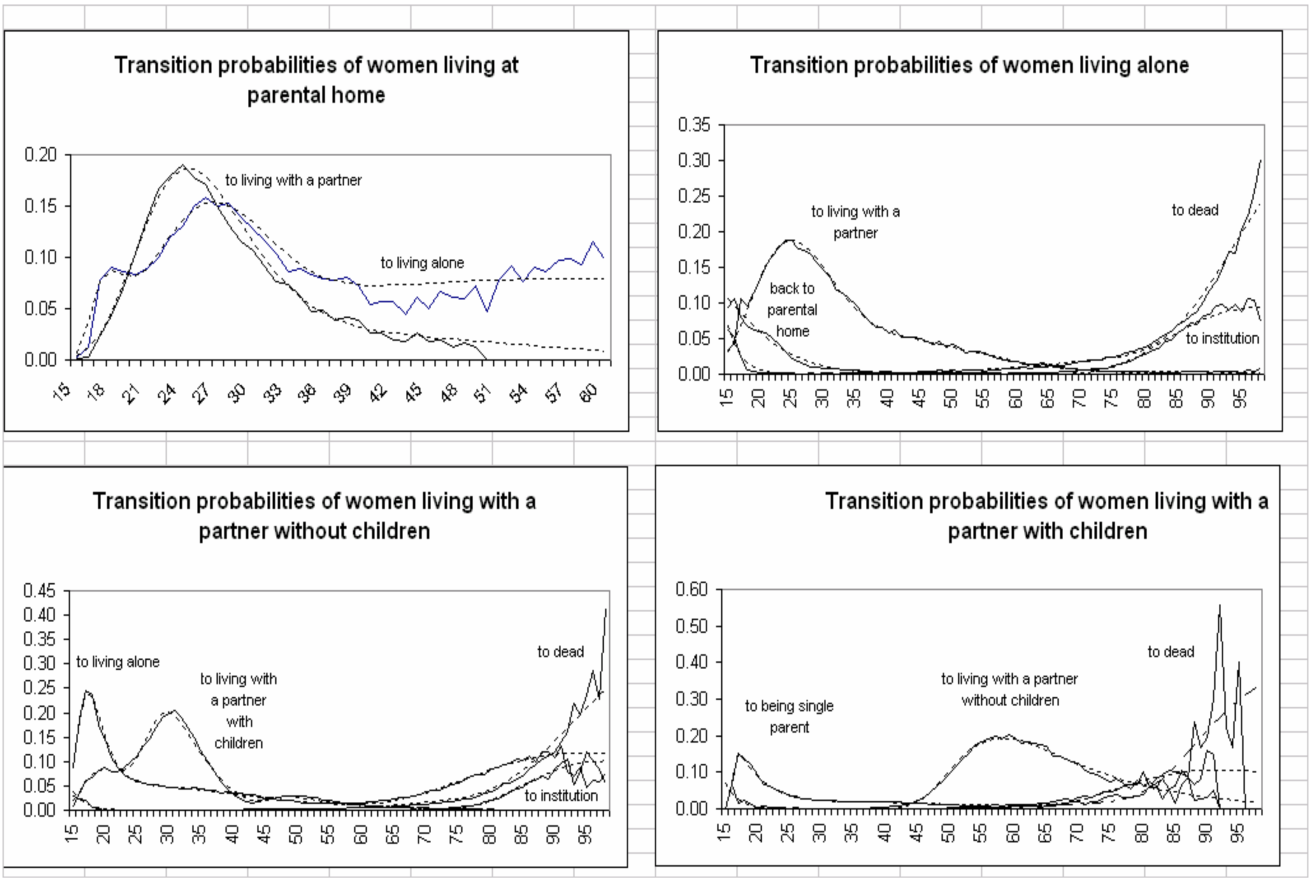
Table 3. Most frequent life courses of women between ages 15 and 98, results of 10000 microsimulations based on transition probabilities measured in 2004		
		%
1	Living at parental home - living with partner without children - living with partner with children - living with partner without children - living alone – dead	4.6
2	Living at parental home - living alone - living with partner without children - living with partner with children - living with partner without children - living alone - dead	4.2
3	Living at parental home - living with partner without children - living with partner with children - living with partner without children - dead	3.8
4	Living at parental home - living alone - living with partner without children - living with partner with children - living with partner without children - dead	3.2
5	Living at parental home - living with partner without children - living with partner with children - living with partner without children - living alone - living in institution - dead	2.6
6	Living at parental home - living alone - living with partner without children - living with partner with children - living with partner without children - living alone - living in institution - dead	2.2
7	Living at parental home - living with partner without children - living with partner with children - single parent - living alone - dead	1.9
8	Living at parental home - living alone - living with partner without children - living with partner with children - single parent - living alone - dead	1.6
9	Living at parental home - living with partner without children - living alone - living with partner without children - living with partner with children - living with partner without children - living alone - dead	1.5
10	Living at parental home – living alone – living with partner without children – living alone - dead	1.1
11	Living at parental home - living with partner without children - living alone - living with partner without children - living with partner with children - living with partner without children - dead	1.1
12	Living at parental home – living with partner without children – living with partner with children – single parent – living with partner with children – living with partner without children - dead	1.1
13	Living at parental home - living with partner without children - living with partner with children - single parent - living with partner with children - living with partner without children - living alone - dead	1.0

Table 4. Percentage distribution of number of times living alone or living with a partner, results of 10000 microsimulations based on transition probabilities measured in 2004		
Number of times	Living alone	Living with a partner
0	9.7	9.1
1	34.5	59.4
2	38.0	26.0
3 or more	17.8	5.6
Total	100.0	100.0

Table 5. Percentage distribution of last living arrangement before dying, results of 10000 microsimulations based on transition probabilities measured in 2004	
Living alone	42.4
In institution	28.5
Living with partner without children	24.1
Single parent	2.5
Living with partner with children	2.1
Living at parental home	0.4
Total	100.0

Table 6. Percentage distribution of number of years living alone or living with a partner, results of 10000 microsimulations based on transition probabilities measured in 2004				
Number of years	Living alone	Living with a partner		
		Total	Without children	With children
0	9.7	2	3.4	14.9
1-10	33.3	6	24.0	14.1
11-20	23.3	10	20.9	28.5
21-30	16.4	13	24.6	32.5
31 or more	17.3	69	27.1	10.0
Total	100.0	100	100.0	100.0

Graph 1. Transition probabilities (the dotted lines show the smoothed age curves)



Graph 2. Comparison of microsimulations, based on 1000 simulations (solid lines) with macro projections (dotted lines)