Bridging the micro-macro gap in population forecasting
Contract no. SP23-CT-2005-006637

Deliverable D7

Illustrative projections using MicMac: an example in the field of fertility and living arrangements

Work Package 1/2
Multistate Methods and Microsimulation

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October 2009

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Contents

List of Tables

List of Figures

1 Introduction

To illustrate the possibilities and limitations of MicMac and to test the model in different national settings two case studies have been carried out using data for the Netherlands or Italy. The first case study refers to analyses in the field of fertility and living arrangements, whilst the second case study includes analyses in the field of health (morbidity and mortality). This deliverable (D7) describes the case study in the field of fertility and living arrangements; D13 describes the case study in the field of morbidity and mortality.

1.1 Population projections

Population projection models can be used for several purposes: the calculation of population forecasts, scenarios and impact assessments. Population forecasts are aimed to project the most likely future development. Scenarios on the other hand, are aimed to present alternative developments that show the consequences of different sets of assumptions. Impact assessments, finally, show the potential impact of behavioural changes, which may be caused by policy interventions.

The impact of policy interventions can be assessed ex post, by examining whether in the past behavioural changes occurred after a given change in policy, or ex ante, by comparing a scenario in which certain behaviour is assumed to change as a consequence of future policy measures with a scenario in which these changes do not occur.

For assessing the potential impact of behavioural changes it is necessary to have insight in the processes underlying demographic events from a life course perspective. Essential to the life course approach are the notions that 1) experiences earlier in life have an impact on choices made later in life and 2) events in one domain of life (for instance education) are interrelated to events in other domains of life (for instance housing preferences).

By incorporating the life course perspective into demographic projection models we can improve the predictive performance of these models as well as the use of these models for policy assessments, for instance for assessing lifetime financial and other consequences of life events such as marriage, divorce, childbirth, and retirement.

The general methodology for compiling population projections is the cohort-component model. The basic approach is to distinguish birth cohorts, to determine the number of survivors in the base year and to determine for each cohort and for each year in the projection period the number of persons by age and sex that (1) enter the population because of birth or migration and 2) leave the population because of death or emigration. The number of entries and exits are based on rates of birth, death and emigration by age and sex, and the number of immigrants by age and sex.

The basic model by age and sex can be extended to functional/biographic projections including other characterisics, for instance to projections of the population by labour force status, educational status or health status. The distribution of people among functional states is the outcome of transitions people make: people move for instance between different health states. As a consequence of these transitions, the structure of the population changes.

For making population projections assumptions need to be specified on the future values of the transitions involved in the projection model. Depending on the complexity of the model, this may require assumptions on a large number of parameters.

Apart from the distinction between different purposes of projections and the extension to functional or biographic projections, a further distinction can be made between macro models at the aggregate level and micro models at the individual level. Multistate models applied at aggregate level produce cohort biographies that give for each age the distribution of cohort members among the different states. A cohort biography is a collective biography, i.e. a combined biography of a group of individuals, for instance how many persons of age x will become disabled in year y?

Applying the same multistate model to a single individual generates an individual biography. Individual biographies are projections of the way people live their lives. For a given individual, the state occupied at a given age is determined by chance. The chance mechanism is implemented using Monte Carlo simulation (micro simulation).

Introducing the life course approach in population projections corresponds with a move from macro level models that generate cohort biographies to micro level models that generate individual biographies. The link between the two models is the transition rate: cohort transition rates in macro models can be set similar to the expected values of the individual transition rates of micro models.

Both macro and micro level models have advantages and disadvantages (see Table 1). The main advantages of the macro models are the transparency of the models, the fact that they can be applied to large populations and that the results are often rather robust. The main disadvantage is that insight in the (individual) behavioural mechanisms underlying demographic change is missing.

Table 1 Advantages and disadvantages of macro and micro models

	Advantages	Disadvantages
Macro models	Transparency Large populations Robust results	No insight in underlying individual processes
Micro models	Heterogeneity Duration of stay	High data and computer requirements

The main advantages of micro models are the introduction of heterogeneity and the possibility of the calculation of duration of stay. Members of the same (sub)population are often not homogeneous but may differ in many ways. These differences (or heterogeneity) are likely to affect their chances for survival, the number of children they have, and other aspects of demographic behaviour. An approach that focuses on individuals instead of populations facilitates the implementation of various degrees of heterogeneity. Individual life course projections also provide estimates of the expected duration of stay (or sojourn times) in given states. The most important disadvantages of micro models are the high data and computer requirements.

Often, macro and micro models are used independently of each other. In the software tool MicMac, both approaches are combined. MicMac therefore, is a methodology that complements conventional population projections by age and sex by the way people lives their lives.

Looking at a general application of MicMac, in principle, the same input, i.e. a base population and a set of transition rates, can be used to either run a macro simulation or a micro simulation. If we use exactly the same model and same input in Mac and Mic, the outcomes of both simulations will be similar except for Monte Carlo variation. The only restriction is the size of the simulation: running a micro simulation for 50 years for 16.5 million people (the population of the Netherlands), for instance, is simply too much. What we can do, however, is to apply a micro simulation including additional characteristics to a sample of the population to get more information on the underlying processes. In this case, the aggregate outcomes of Mic may differ to more or less extent from the outcomes of Mac. Depending on how much they differ, we can use this information to refine the assumptions for the limited number of characteristics included in the macro simulation to be compiled for the total population. This synergy of Mic and Mac is depicted in Table 2.

Table 2 The synergy of Mic and Mac

	Application	**Outcomes**
Mac	**To compile aggregate projections by age and sex, based on assumptions on fertility, mortality and migration**	**Population projections for “total” populations**
Mic	**To introduce heterogeneity for a sample of the population**	**Detailed information on demographic processes**

1.2 The life course approach

MicMac follows a life course approach. Instead of forecasting numbers of people, MicMac projects characteristics of people over their life course. A life course is defined as a number of states and events. Each event implies that a person enters a new state. Whether or not someone experiences an event is determined by transition rates. For instance, if we look at marital status, we can describe the following life course:

State 1	*Event 1*	State 2	*Event 2*	State 3	*Event 3*
Unmarried	*Marriage*	Married	*Death of spouse*	Widowed	…

The life course approach also applies to fertility. In this case the states refer to the number of children ever born, while the events refer to childbirth:

State 1	*Event 1*	State 2	*Event 2*	State 3	*Event 3*	State 4	*Event 4*
Childless	*First birth*	1 child	*Second birth*	2 children	*Third birth*	3 children	…

As a consequence of this life course approach, to make optimal use of MicMac we need an initial (female) population not only distinguished by age and sex, but also distinguished by children ever born. In addition, the model requires parity-specific fertility rates. Parity-specific fertility rates are not the same as fertility rates by birth order. Age-specific fertility rates by birth order refer to all women of a certain age, for instance rates for first-order births are calculated as the number of first children divided by all women of a certain age. Fertility rates for first parity, on the other hand, are calculated as the number of first children divided by women *without* children. The total fertility rate TFR equals the sum of the fertility rates by birth order, but *not* the sum of the parity-specific rates.

Unfortunately, often the data required to calculate parity-specific fertility rates are missing. For migrants for instance, information on children ever born might not be available. Based on data on cohort fertility, however, parity-specific fertility rates can be estimated.

In case also data on cohort fertility is missing, a more simplified application of MicMac can use fertility rates not taking into account parity. In that case we still have to define the fertility process as a sequence of states and events. The interpretation of the states and events, however, is meaningless as we use identical rates for all childbirths. At macro level, the model will give a reasonable projection of the number of children born, but at micro level information fertility life courses is useless.

Another characteristic of MicMac is that each transition implies a move from one state to another. All possible states and transitions have to be defined in advance. For fertility, this means that we explicitly have to define the maximum number of times a woman can give birth.

1.3 Outline of the report

Section 2 of the report describes how to treat fertility in MicMac, using both a macro and micro model with parity-specific fertility. Section 3 provides a more extended example applying a micro simulation approach taking into account a life course approach for fertility and living arrangement.

2 How to treat fertility in MicMac

The purpose of this case study is to show how MicMac can be used to study developments in the field of fertility and living arrangement. At first we illustrate a general simulation using both a macro and micro model with parity-specific fertility rates. We use data for the Netherlands (source: Statistics Netherlands). As population data by children ever born, as well as parity-specific fertility rates are not available, in a first step we estimate the input for the model. Section 2.1 describes the estimation procedure while section 2.2 reports on the simulation.

2.1 Estimation of parity-specific fertility rates

In order to estimate parity-specific fertility rates, we need to define a population at risk, i.e. a distribution of the population by age of the mother and parity, or in other words by children ever born. Partly due to missing information for migrants, population data by children ever born are not available. Using information on realized cohort fertility for 2006, the distribution by children ever born has been estimated.

In a following step we estimated period parity-specific fertility rates based on 1) number of births by age of mother and parity (first child, second child, third child and fourth + children) for 2006 and 2) the population at risk estimated as average population for 2006.

Based on cohort fertility rates published by Statistics Netherlands for observation year 2006 we calculated for each cohort the proportion of women with zero, one, two or three+ children (see Table 3). Data were available from cohort 1935 until cohort 1991. In 2006, cohort 1991 was 15 year of age; cohort 1990 16 years, etc. From birth cohort 1958 onwards, women did not yet reach the age of 49 and thus cohort fertility for these women refers to cohort fertility reached so far and not to an estimated level of final cohort fertility. For cohort 1935 until 1957 cohort fertility refers to completed fertility.

Table 3 Estimation of number of birth per woman

birth cohort of women	1935	1936	…	1976	…	1990	1991
Age 31 Dec 2006	70	69	…	30	…	16	15
first children	0.883256	0.881056	…	0.507215	…	0.001183	0.000281
second children	0.780994	0.780868	…	0.252902	…	0.00004	0
third children	0.456382	0.43459	…	0.058299	…	0	0
fourth+ children	0.378537	0.335289	…	0.013959	…	0	0
total	2.499169	2.431803	…	0.832375	…	0.001223	0.000281
proportion of women with							
0 children (childlessness)	0.116744	0.118944	…	0.492785	…	0.998817	0.999719
1 child	0.102262	0.100188	…	0.254313	…	0.001143	0.000281
2 children	0.324612	0.346278	…	0.194603	…	0.00004	0
at least three children	0.456382	0.43459	…	0.058299	…	0	0

Subsequently, we applied these proportions to the population of the Netherlands for 2006 and 2007 in order to distribute all women by age over the states noChild, firstChild, secondChild and thirdChild (see Tables 4 and 5); for instance in 2006, there are 49727 women of age 30 estimated as having no children (0.4928 * 100910 = 49727)

Table 4 Population of the Netherlands 2006, females

Age 1 Jan	PopTot	0 ch	1 ch	2 ch	3+ ch	Average number of children
0	91268	91268	0	0	0	0
1	94909	94909	0	0	0	0
2	98037	98037	0	0	0	0
…	…	…	…	…	…	…
30	100910	49727	25663	19637	5883	0.83
31	105749	44862	27842	24984	8061	0.98
32	110211	40435	28871	30548	10357	1.12
33	119831	38535	29812	37986	13499	1.25
34	124951	35419	29610	43361	16560	1.37
35	130581	33388	28801	48824	19568	1.46
36	133369	30886	27831	52125	22527	1.55
…	…	…	…	…	…	…
97	2006	234	205	651	916	2.49
98	1308	153	134	425	597	2.49
99+	1978	231	202	642	903	2.49

Table 5 Population of the Netherlands 2007, females

Age 1 Jan	PopTot	0 ch	1 ch	2 ch	3+ ch	Average number of children
0	89797	89797	0	0	0	0
1	91358	91358	0	0	0	0
2	94691	94691	0	0	0	0
…	…	…	…	…	…	…
30	98851	48712	25139	19237	5763	0.83
31	100640	42694	26497	23777	7671	0.98
32	105415	38675	27615	29218	9907	1.12
33	109817	35314	27320	34812	12371	1.25
34	119402	33846	28295	41436	15825	1.37
35	124572	31852	27475	46577	18667	1.46
36	130215	30155	27173	50892	21994	1.55
…	…	…	…	…	…	…
97	2127	248	218	690	971	2.49
98	1392	163	142	452	635	2.49
99+	2053	240	210	666	937	2.49

The population at risk has been calculated by taking the average population in 2006. These average populations are denoted as pop0.5, pop1.5, etc. (see Table 6). For instance the population at risk age 30.5 is calculated as pop30 in 2006 + pop31 in 2007 divided by 2: (100910+100640)/2=100775.

Table 6 Population at risk, Netherlands 2006, females

Age Mid-year	PopTot	0 ch	1 ch	2 ch	3+ ch
	45679	45679	0	0	0
0.5	91313	91313	0	0	0
1.5	94800	94800	0	0	0
…	…	…	…	…	…
29.5	98956	51948	24382	17596	5030
30.5	100775	46211	26080	21707	6777
31.5	105582	41769	27728	27101	8984
32.5	110014	37875	28096	32680	11364
33.5	119617	36190	29053	39711	14662
34.5	124762	33636	28543	44969	17614
35.5	130398	31772	27987	49858	20781
…	…	…	…	…	…
96.5	2554	298	261	829	1165
97.5	1699	198	174	552	775
98.5+	2670	196	172	546	767

Table 7 shows the observed number of birth by parity (children ever born) for 2006 by age of the mother (age at 31 December)

Table 7 Number of births, Netherlands 2006

Age 31 Dec	Total	First births	Second births	Third births	Fourth+ births
-15	28	28	0	0	0
16	87	84	3	0	0
17	252	244	8	0	0
…	…	…	…	…	…
30	13937	6857	5217	1469	394
31	14661	6595	5829	1731	506
32	14745	5795	6379	1961	610
33	14007	4903	6217	2166	721
34	13637	4317	6154	2313	853
35	12032	3501	5334	2351	846
36	10110	2819	4243	2160	888
…	…	…	…	…	…
47	24	6	2	5	11
48	8	4	3	1	0
49+	12	3	2	2	5

To validate the estimated population at risk, we calculated fertility rates by birth order and compared them with the rates by birth order published by Statistics Netherlands. Table 8 presents the fertility rates by birth order (dividing the number of births by age of the mother by the total population of risk of the given age). For instance, the fertility rate at age 30 (total fertility) is calculated as total number of birth age 30 (31 Dec) / population at risk age 29.5 (mid-year population): 13937 / 98956 = 0.140840; the fertility rate at age 30 (first births) is calculated as number of first birth age 30 (31 Dec) / population at risk age 29.5 (mid-year population): 6857 / 98956 = 0.069293; etc. These rates are identical to those published by Statistics Netherlands (see Figures 1 and 2).

Table 8 Fertility rates by birth order, Netherlands 2006

Age at 31 Dec	Fertility rates (Total)	First births	Second births	Third births	Fourth+ births
15	0.000281	0.000281	0.000000	0.000000	0.000000
16	0.000872	0.000842	0.000030	0.000000	0.000000
17	0.002609	0.002526	0.000083	0.000000	0.000000
…	…	…	…	…	…
30	0.140840	0.069293	0.052720	0.014845	0.003982
31	0.145483	0.065443	0.057842	0.017177	0.005021
32	0.139654	0.054886	0.060417	0.018573	0.005777
33	0.127320	0.044567	0.056511	0.019688	0.006554
34	0.114006	0.036090	0.051448	0.019337	0.007131
35	0.096440	0.028062	0.042754	0.018844	0.006781
36	0.077532	0.021618	0.032539	0.016565	0.006810
…	…	…	…	…	…
47	0.000194	0.000048	0.000016	0.000040	0.000089
48	0.000066	0.000033	0.000025	0.000008	0.000000
49	0.000101	0.000025	0.000017	0.000017	0.000042
…	…	…	…	…	…
total	1.720446	0.796693	0.634677	0.209343	0.079733

For MicMac we do not need fertility rates by birth order, but fertility rates by parity. Fertility rates by parity are estimated by dividing the number of first births by age by the population at risk of women without children of the given age, the number of second births by the population of risk of women with one child, etc. (see Table 9 and Figure 3). For instance, the parity specific fertility rate at age 30 (first birth) is calculated as total number of first birth age 30 (31 Dec) / population at risk age 29.5 (women without children): 6857 / 51948 = 0.131997; etc. Parity-specific fertility rates are similar to transitions into higher parity; for instance once a woman gives birth to her first child, she moves from the state “Woman without children” to the state “Woman with one child”.

Figure 1   Age-specific fertility rates, Netherlands 2006 (calculated)

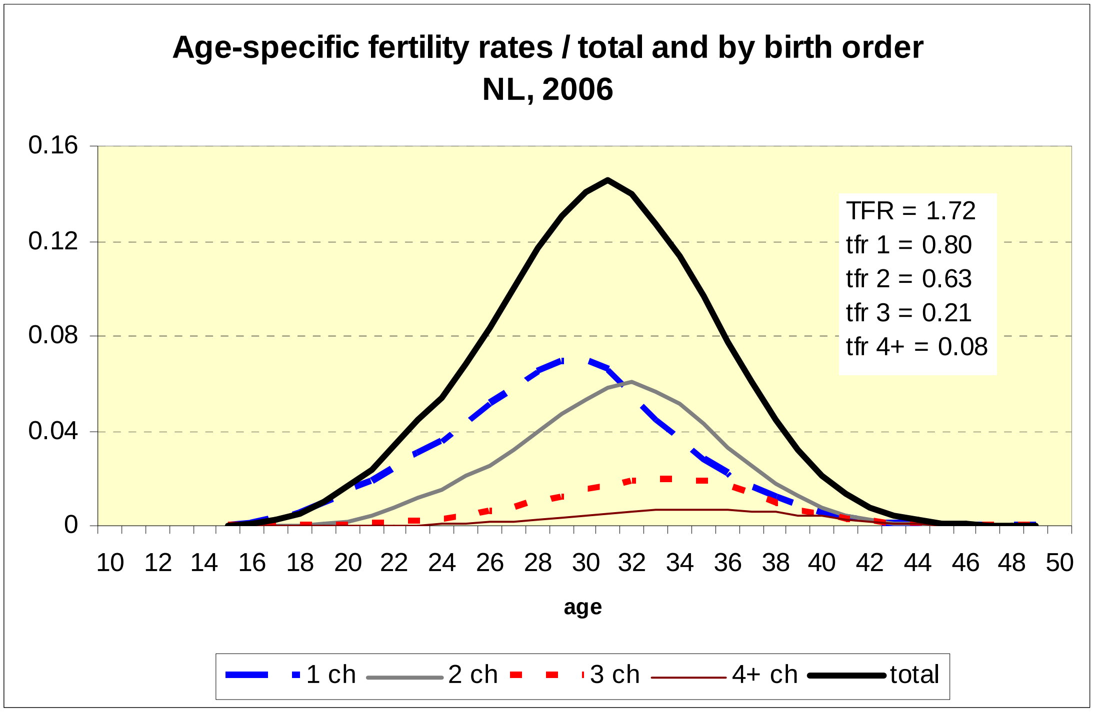


Figure 2   Age-specific fertility rates, Netherlands 2006 (published by Statistics Netherlands)

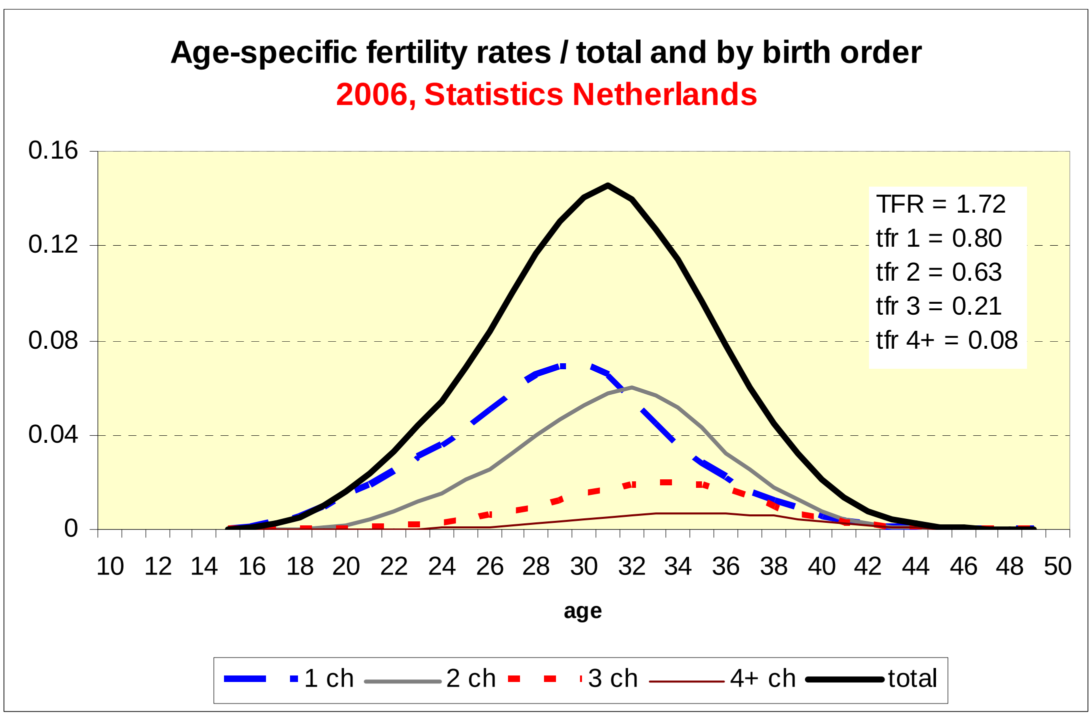
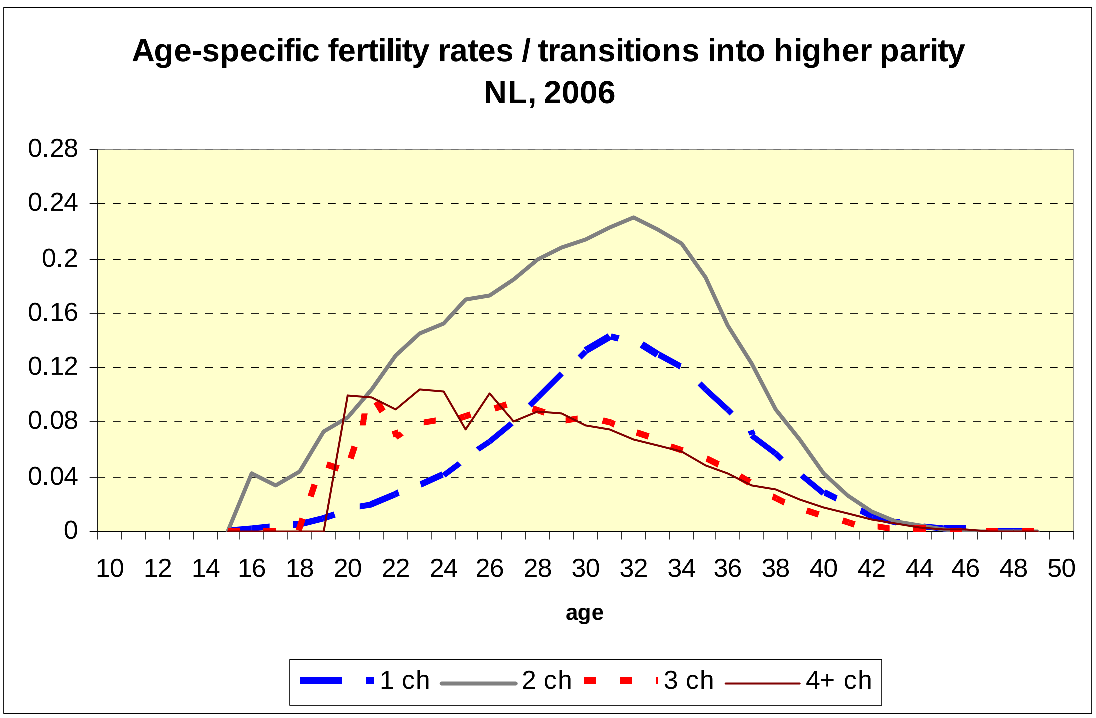


Table 9 Fertility rates and transition rates into higher parities, Netherlands 2006

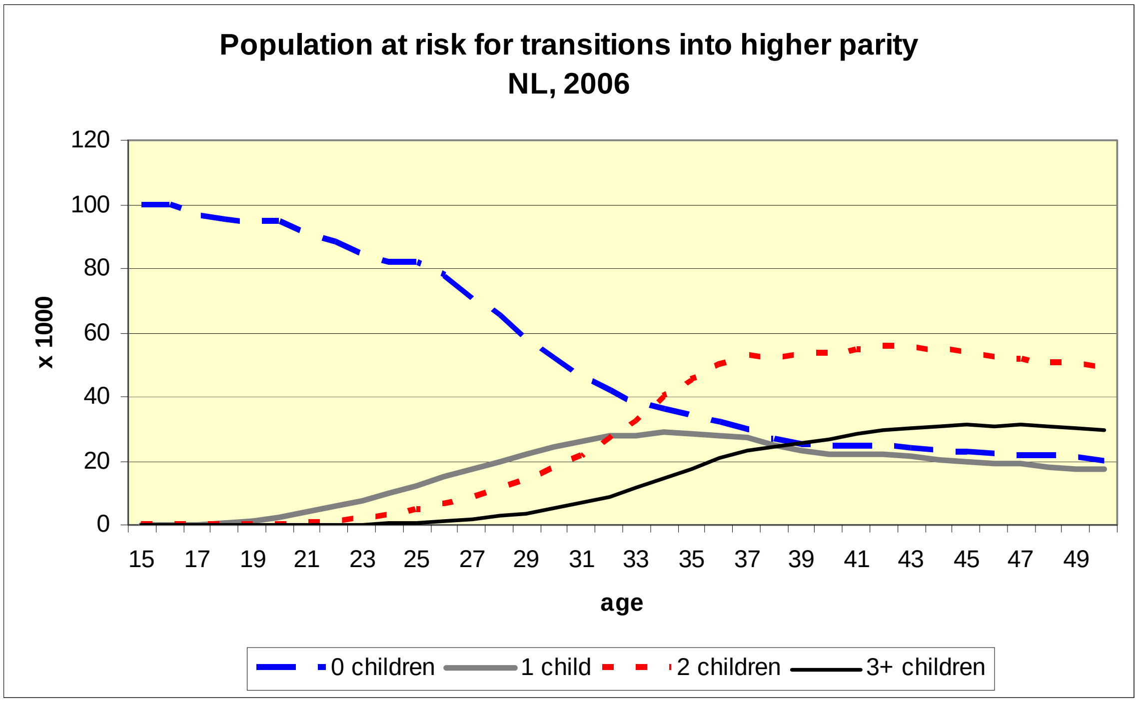
Age at 31 Dec	Fertility rates (Total)	Transitions to First births	Transitions to Second births	Transitions to Third births	Transition to Fourth+ births
15	0.000281	0.000281	0.000000	0.000000	0.000000
16	0.000872	0.000843	0.042232	0.000000	0.000000
17	0.002609	0.002533	0.033925	0.000000	0.000000
…	…	…	…	…	…
30	0.140840	0.131997	0.213973	0.083485	0.078327
31	0.145483	0.142716	0.223506	0.079743	0.074662
32	0.139654	0.138740	0.230054	0.072358	0.067900
33	0.127320	0.129453	0.221280	0.066280	0.063445
34	0.114006	0.119286	0.211816	0.058246	0.058179
35	0.096440	0.104086	0.186877	0.052280	0.048031
36	0.077532	0.088726	0.151606	0.043323	0.042731
…	…	…	…	…	…
47	0.000194	0.000277	0.000105	0.000097	0.000351
48	0.000066	0.000188	0.000166	0.000020	0.000000
49	0.000101	0.000145	0.000113	0.000040	0.000165

Figure 3 Transitions into higher parity, Netherlands 2006



At first sight, the parity specific fertility rates may seem to be rather high, especially at young ages and in general for second births. However, as the majority of women that do get a first child, also gets a second child at some point in time, the relatively high rates for transitions into second births may not be really surprising. Similar, a woman that gets a first child at young age may have a relatively high probability of getting a second child at young age as well. If we not only look at the parity-specific birth rates, but also at the population at risk, it also seems to make sense to have higher rates for second births compared to first births, given that the population at risk for the transition into a first birth is considerably higher than the population at risk for the transition into second birth (see Figure 4).

Figure 4 Population at risk for transitions into higher parity, Netherlands 2006



To test the data, we first smooth the parity specific rates and then apply them using Mac to a cohort of 10.000 women (age zero, state "Woman without children") disregarding mortality.

The results show exactly what we expect (see Table 10). As we do not take into account death or migration, the size of the cohort remains unchanged over the projection period (10,000 women) and therefore the number of births is similar to the rate x 10,000, summing up to the average of 1.72 children per woman.

Then we run another simulation for 10,000 women of age 0, taking into account fertility distinguished by parity. We use parity specific transition rates up to parity 4+, and use similar rates for all transitions into birth to 4, 5, 6, and 7 children. Again we follow this cohort until they reach the age of 50. This time we count the number of transitions into higher parities as each transition into higher parity implies the birth of a child. The sum of these transitions, therefore, is similar to the number of births (see Table 11).

Table 10 Macro analysis with age-specific fertility rates, cohort 10,000 women

Table 8: Lipro with age-specific fertility rates, cohort 10,000 women						
Age	Fertility rates	Births		Age	Fertility rates	Births
15	0.000281	3		36	0.077532	775
16	0.000872	9		37	0.060238	602
17	0.002609	26		38	0.044710	447
18	0.005307	53		39	0.032226	322
19	0.010247	102		40	0.021076	211
20	0.016424	164		41	0.013655	137
21	0.023497	235		42	0.007883	79
22	0.033433	334		43	0.004220	42
23	0.044420	444		44	0.002280	23
24	0.054311	543		45	0.001050	11
25	0.068170	682		46	0.000547	5
26	0.083637	836		47	0.000194	2
27	0.100197	1002		48	0.000066	1
28	0.117128	1171		49	0.000101	1
29	0.130388	1304				
30	0.140840	1408		total	1.720446	17203
31	0.145483	1455				
32	0.139654	1397		average		1.72
33	0.127320	1273				
34	0.114006	1140				
35	0.096440	964				

Table 11 Transition rates into higher parity, smoothed figures, Netherlands 2006

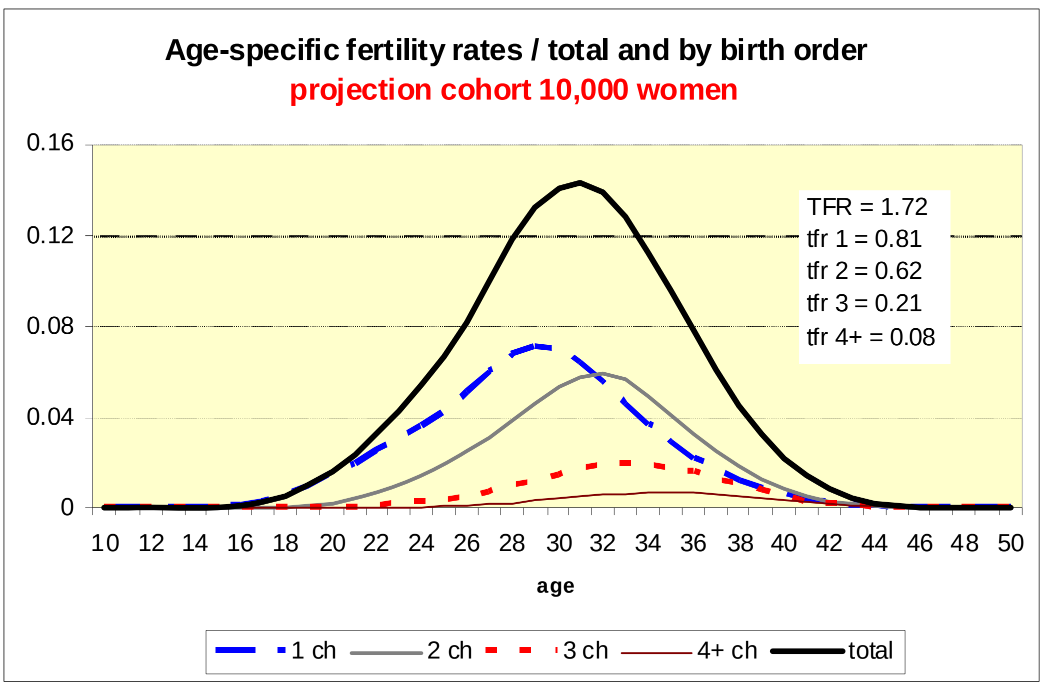
Table 9: Transition rates into higher parity, NL 2006, smoothed figures							
Age	1 ch	2 ch	3 ch	4 ch	5 ch	6 ch	7 ch
0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
…	…	…	…	…	…	…	…
15	0.000055	0.003654	0	0	0	0	0
16	0.001047	0.031179	0	0	0	0	0
…	…	…	…	…	…	…	…
30	0.131296	0.216045	0.082271	0.081216	0.081216	0.081216	0.081216
31	0.137637	0.224870	0.078273	0.076593	0.076593	0.076593	0.076593
32	0.137360	0.229129	0.072909	0.069990	0.069990	0.069990	0.069990
33	0.131190	0.224722	0.066337	0.062633	0.062633	0.062633	0.062633
34	0.119999	0.208862	0.058750	0.055525	0.055525	0.055525	0.055525
35	0.105248	0.183997	0.050480	0.048774	0.048774	0.048774	0.048774
36	0.088545	0.153887	0.041895	0.042259	0.042259	0.042259	0.042259
…	…	…	…	…	…	…	…
47	0.000272	0.000053	0.000000	0.000165	0.000165	0.000165	0.000165
48	0.000341	0.000000	0.000000	0.000054	0.000054	0.000054	0.000054
49	0.000123	0.000240	0.000000	0.000018	0.000018	0.000018	0.000018

Even though again the size of the cohort will not change, for this projection the distribution of the number of women over the different states will change (from “Women without children” (0 ch) to “Women with one child” (1 ch), etc.). Applying parity-specific rates gives information on the distribution over the states, the average number of children and the percentage childlessness (see Table 12).

As now we have information on the number of first, second and higher order births, we can use these numbers to calculate the resulting distribution by birth order (number of first, second, etc. births divided by total number of women, which is 10,000). Again, we find what we expect: tfr 1: 0.81; tfr 2: 0.62; tfr 3: 0.21 and tfr 4+: 0.08 (see Figure 5), which is highly similar to the observed pattern in 2006 (see page 11). Also if we look at the total number of children born by age of the mother we find highly similar numbers if we use parity-specific rates compared to the projection using overall fertility rates only (17,164 compared to 17,203). As we have smoothed the parity-specific transitions, we might expect some small differences between the two examples.

In two final pictures we compare the age-specific fertility rates by birth order based on the parity-specific rates, with the age-specific fertility rates for cohort 1991 as used by Statistics Netherlands for their latest population projections (2008). In case of using constant fertility rates, as we did in our simulation, in the end period TFR is similar to cohort TFR, which is similar to the average number of children. We can neglect mortality, as the impact of mortality in the age range 15-50 is only limited). Although SN assumes a slightly higher TFR (see Figure 6) the patterns are highly similar.

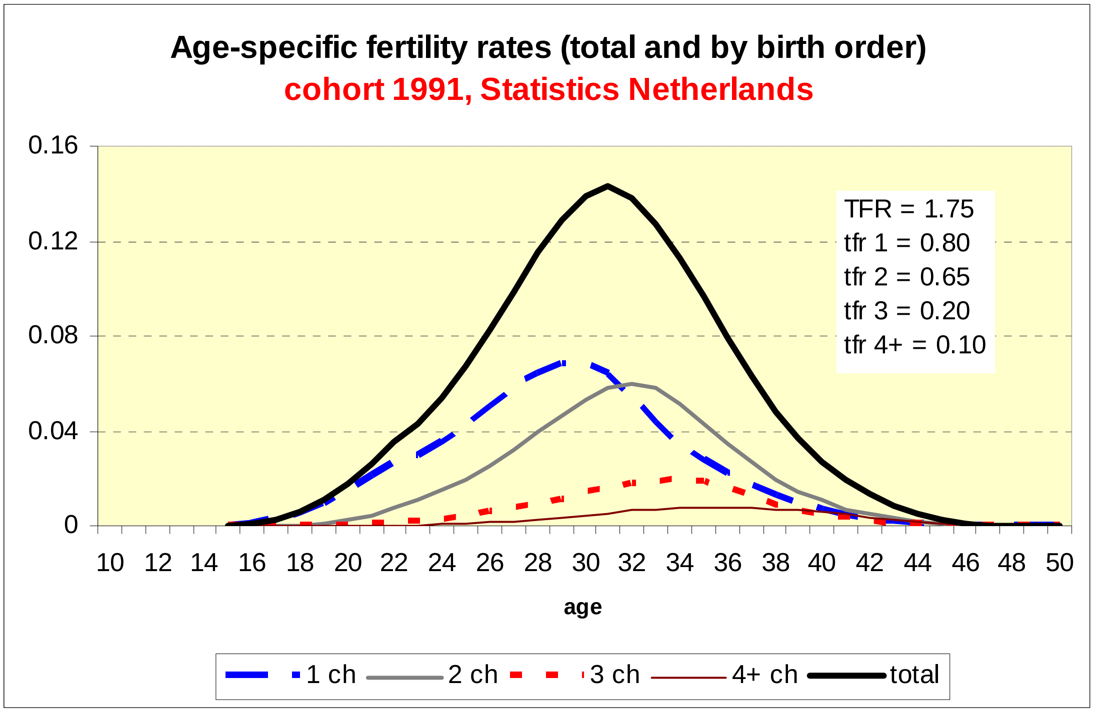
Figure 5 Age-specific fertility rates as outcome of projection, cohort 10,000 women



Number of transitions into higher parity, cohort 10,000 women

Age	1 ch	2 ch	3 ch	4 ch	5 ch	6 ch	7 ch	Total	Average number of children	Percentage childlessness
0	0	0	0	0	0	0	0	0	0.00	1.00
…	…	…	…	…	…	…	…		0.00	1.00
15	1	0	0	0	0	0	0	1	0.00	1.00
16	10	0	0	0	0	0	0	10	0.00	1.00
17	25	1	0	0	0	0	0	26	0.00	1.00
18	50	3	0	0	0	0	0	53	0.01	1.00
19	90	8	0	0	0	0	0	98	0.02	0.99
20	141	19	1	0	0	0	0	161	0.03	0.98
21	197	39	3	0	0	0	0	239	0.06	0.97
22	253	69	7	1	0	0	0	330	0.09	0.95
23	306	105	14	2	0	0	0	427	0.13	0.92
24	362	147	24	3	0	0	0	536	0.19	0.89
25	429	194	37	6	1	0	0	667	0.25	0.86
26	510	249	52	8	1	0	0	820	0.34	0.81
27	600	314	71	12	2	0	0	999	0.44	0.76
28	674	388	94	18	3	0	0	1177	0.55	0.70
29	708	463	119	25	4	1	0	1320	0.69	0.64
30	695	529	146	33	6	1	0	1410	0.83	0.56
31	637	576	169	40	8	1	0	1431	0.97	0.50
32	554	589	187	46	10	2	0	1388	1.11	0.43
33	462	562	196	50	11	2	0	1283	1.24	0.38
34	373	498	193	53	12	2	0	1131	1.35	0.33
35	292	416	180	53	13	3	0	957	1.45	0.29
36	223	330	158	51	13	3	1	779	1.52	0.26
37	166	251	130	46	12	3	1	609	1.59	0.24
38	121	183	101	40	11	2	0	458	1.63	0.22
39	86	127	73	33	9	2	0	330	1.66	0.21
40	58	82	48	26	7	2	0	223	1.69	0.20
41	37	49	28	19	5	1	0	139	1.70	0.20
42	22	27	14	13	4	1	0	81	1.71	0.19
43	12	14	7	8	2	1	0	44	1.71	0.19
44	5	7	3	5	1	0	0	21	1.71	0.19
45	2	4	1	2	1	0	0	10	1.72	0.19
46	1	2	0	1	0	0	0	4	1.72	0.19
47	1	0	0	0	0	0	0	1	1.72	0.19
48	1	0	0	0	0	0	0	1	1.72	0.19
49	0	0	0	0	0	0	0	0	1.72	0.19
Total	8104	6245	2056	594	136	27	2	17164		
rate by birth order	0.81	0.62	0.21	0.06	0.01	0.00	0.00	1.72		

Figure 6 Age-specific fertility rates, projection Statistics Netherlands, cohort 1991



2.2 A simulation based on parity specific fertility rates

In the second step of the case study, we ran MicMac using the following projection input:

- Initial population by age and sex; for women also distinguished by number of children ever born (hypothetical population for the Netherlands as estimated above)
- Fertility rates by age of the mother and parity
- Mortality rates by age and sex (EUROPOP2004 assumptions; source: Eurostat)
- Sex ratio: 0.485 (proportion girls)

Migration is not included. The projection period is 2004-2050.

Figure 7 shows the percentage of women by number of children ever born in the initial population, while Figure 8 presents the average number of children as well as cohort fertility as published by Statistics Netherlands (including assumptions on completed fertility for cohorts 1960-2004). Figures 10-11 show the age specific fertility and mortality rates. We modelled fertility rates up to parity 4+, but included states until "Women with seven children", using similar rates for the transitions into fourth, fifth, sixth and seventh birth.

Figure 7   Women by age and number of children ever born, initial population

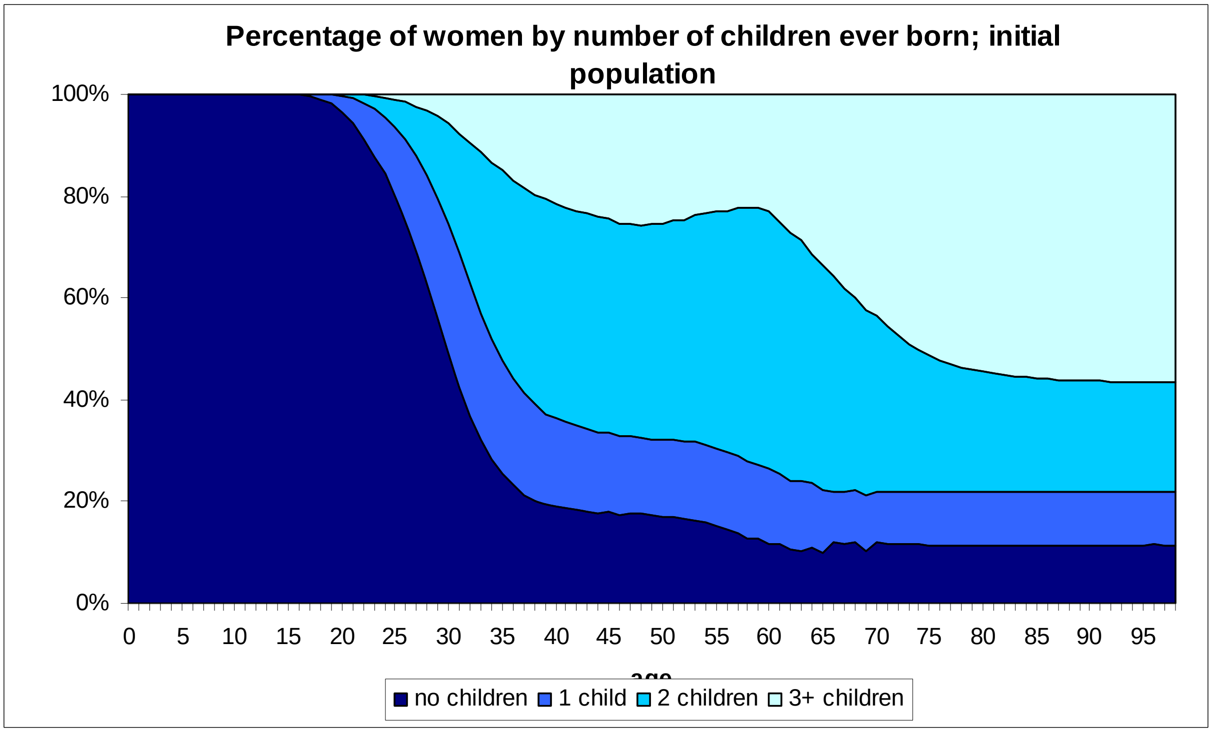


Figure 8   Average number of children, initial population

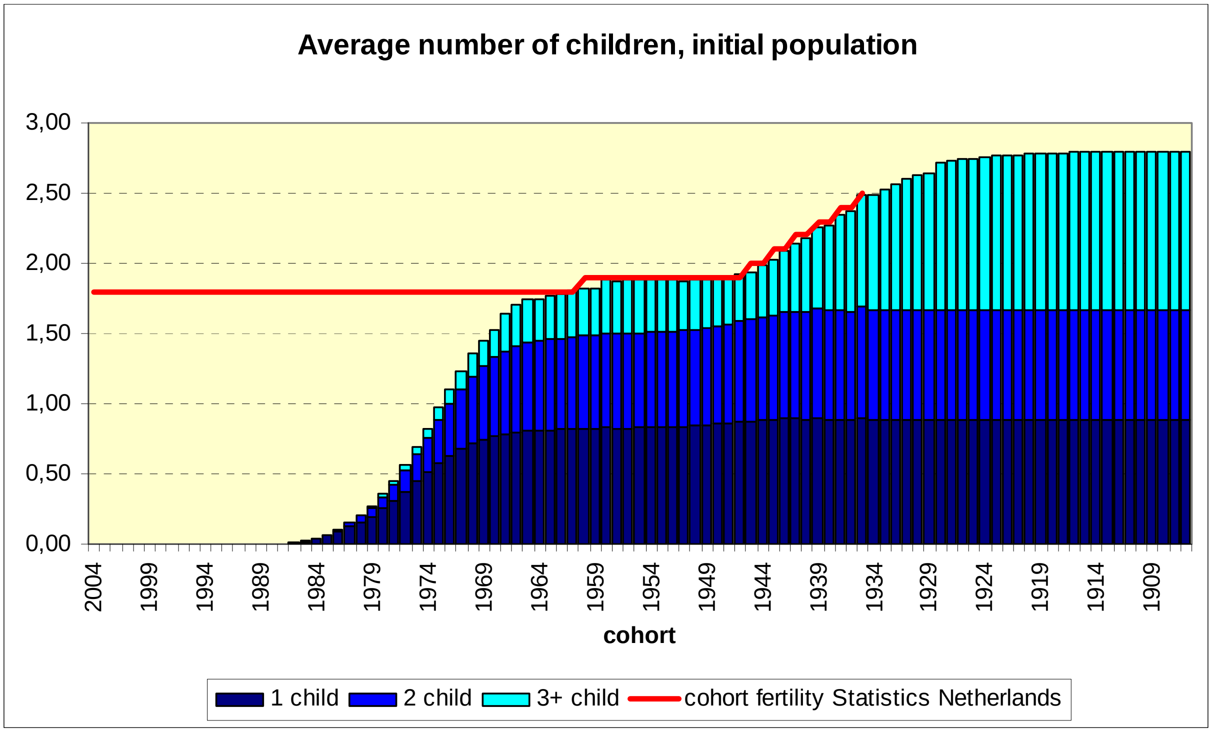


Figure 9 Parity specific fertility rates

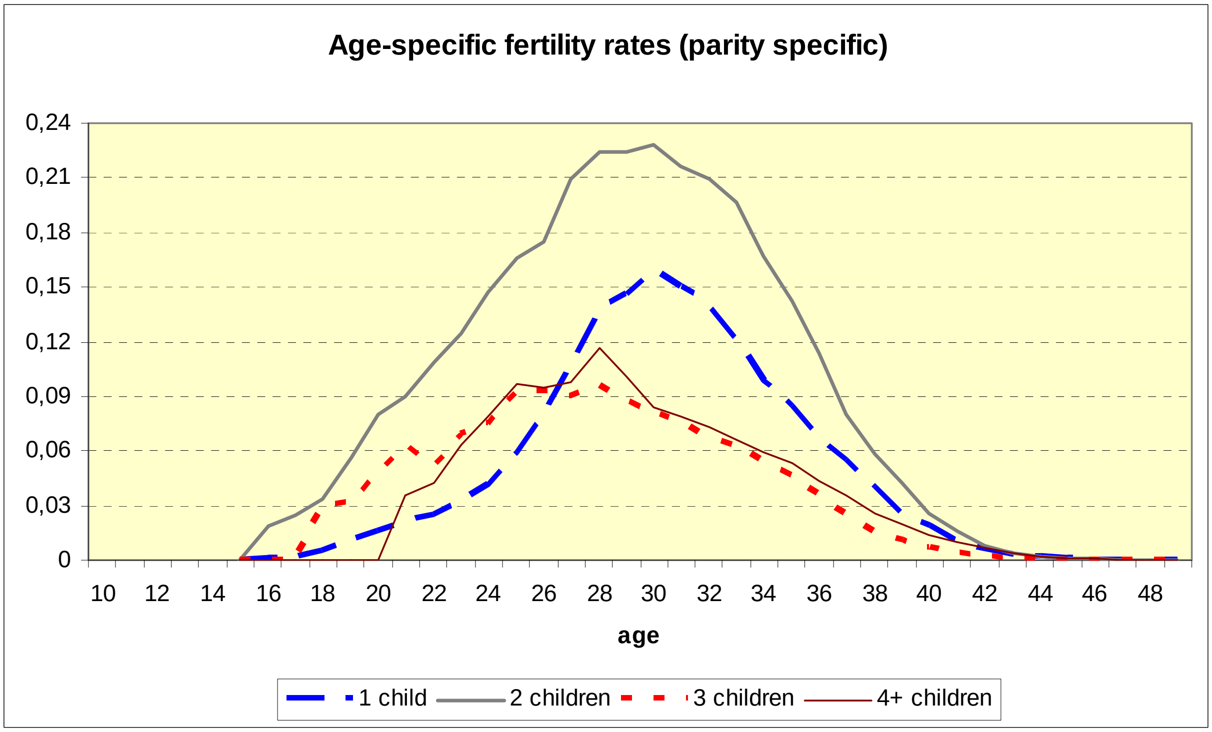


Figure 10 Mortality rates, females

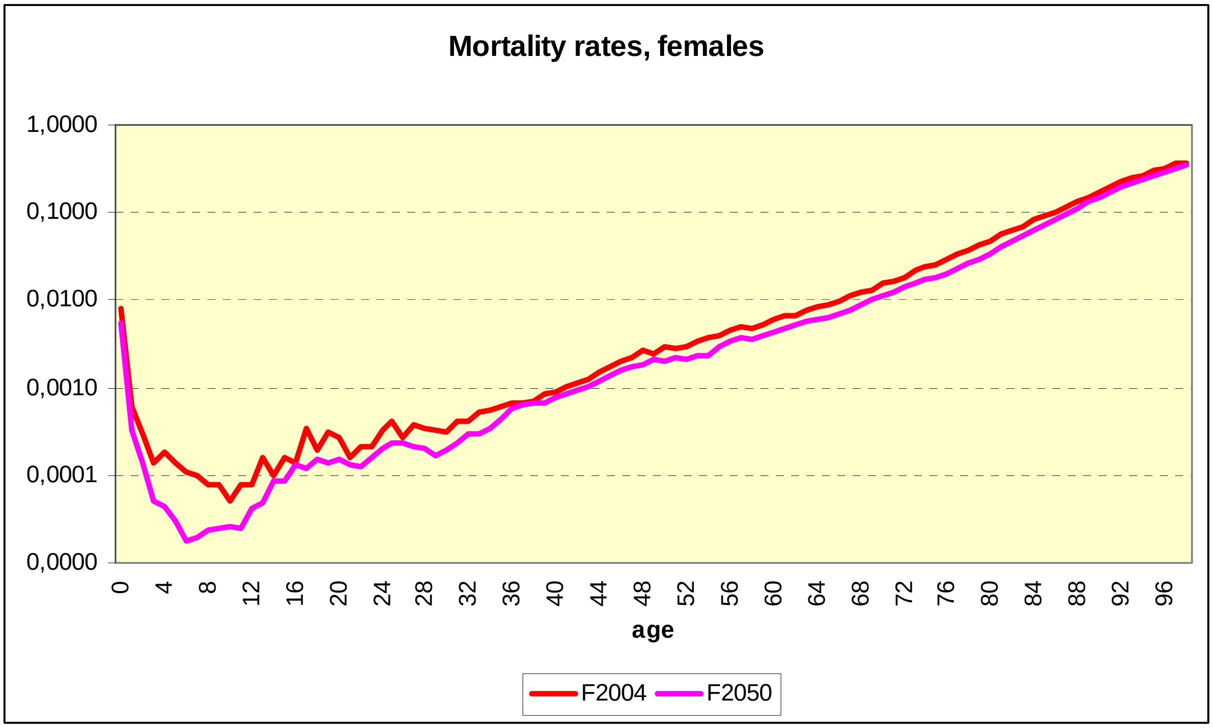
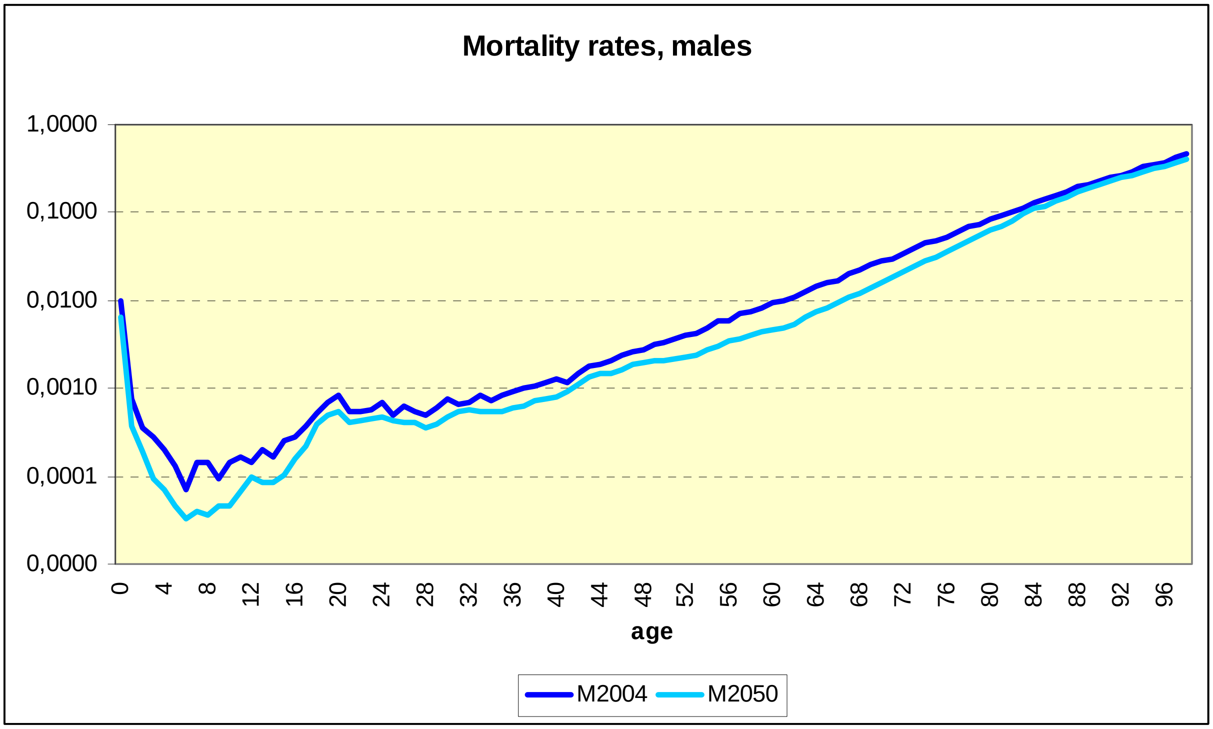


Figure 11 Mortality rates, males



Using these data we ran 1) a macro simulation (Mac) using overall fertility rates and an initial population of 16 million persons (the total population of the Netherlands at 1 January 2004); 2) a macro simulation (Mac) using parity specific fertility rates and an initial population of 16 million persons; and 3) a micro simulation using parity specific fertility rates and an initial population of 162 thousand persons (the population of the Netherlands, divided by 10).

A selection of output of MicMac includes:

- Population pyramids
- Population tables
- Transitions into and out of specific states
- Most frequently simulated life course(s)
- Life courses followed over time
- Different cohort distributions

Figure 12 shows the population pyramid for 2004, while Figure 13 shows the same pyramid taking into account the number of children ever born for the female population. Examples of summary tables of Mac are given in Tables 13-15. These tables present the female population by age, the number of exits of the population (in this case only numbers of death) and numbers of birth by age of the mother and sex of the child.

Figure 12 Population pyramid, Netherlands 1 January 2004

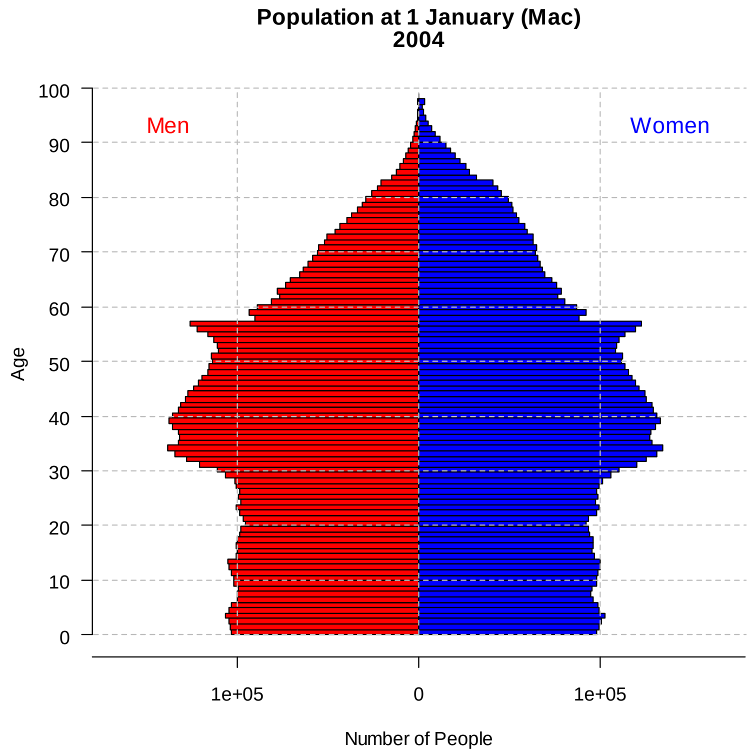


Figure 13 Population pyramid, Netherlands 1 January 2004, females by children ever born

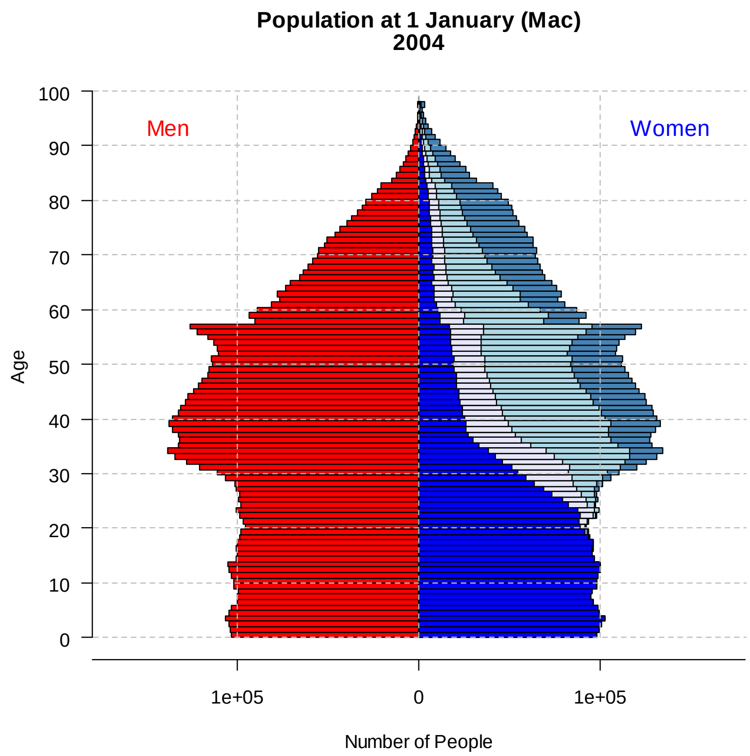


Table 12 Population by age and sex

[1]		females				
[1]		population numbers				
		year				
age		2004	2005	2006	2007	2008
	0	97670	90693	88549	86595	84861
	1	98996	97611	90639	88497	86545
	2	100249	98966	97582	90613	88473
	3	102204	100235	98953	97570	90601
	4	99302	102185	100217	98936	97553
	5	98652	99288	102171	100204	98924
	6	95995	98641	99278	102161	100195
	7	94296	95986	98632	99269	102152
	8	95122	94289	95978	98625	99262
	9	97726	95115	94281	95971	98618
	10	97631	97721	95110	94277	95966
	11	98349	97624	97714	95103	94270
	12	99977	98341	97616	97706	95096
	13	99933	99961	98326	97602	97692
	14	96586	99923	99952	98317	97592
	15	95389	96570	99907	99936	98301
	16	95600	95376	96556	99893	99921
	..	..	..	..	..	..

Table 13 Number of exits of the population

[1]		females	
[1]		2004	
		exits	
age		death	totExit
	0	365	365
	1	59	59
	2	30	30
	3	14	14
	4	19	19
	5	14	14
	6	11	11
	7	9	9
	8	7	7
	9	7	7
	10	5	5
	11	7	7
	12	8	8
	13	16	16
	14	10	10
	15	16	16
	16	13	13
	..	..	..

Table 14 Number of births by age of the mother and sex of the child

[1]	Number of births by age of mother and sex of child				
,	, sex = females				
	year				
age	2004	2005	2006	2007	2008
..	..	..	..	..	..
15	19	20	20	19	19
16	52	52	54	54	53
17	117	117	118	123	123
18	258	257	256	259	268
19	521	532	530	528	535
20	830	838	856	852	850
21	1096	1111	1122	1146	1140
22	1399	1375	1395	1408	1438
23	1996	1909	1876	1903	1921
24	2657	2609	2495	2452	2488
25	3573	3650	3584	3427	3369
26	4617	4567	4664	4581	4380
..	..	..	..	..	..

Figure 14 shows the resulted population in 2050 based on the macro simulation using overall fertility rates. As expected, the general trend is one of ageing: a declining percentage of the young combined with an increase in the percentage of the elderly. Figure 15 shows the resulted population in 2050 based on the macro simulation using parity specific fertility rates. From this figure we see a clear in crease in the number of childless women.

Figure 16 presents the results of the micro simulation with an initial population of 162 thousand persons. The shape of the pyramid turns out to be highly identical to that of Figure 14. If we multiply the population by four (to 648 thousand persons), the population pyramid (Figure 17) is almost exactly similar to Figure 14. In this case differences due to Monte Carlo variation are negligible. Figures 18 and 19 present the numbers of females by age and number of children ever born.

Another figure MicMac can provide, is a graph showing the transitions into and out of the different states. Figure 20 presents the transitions into and out of the state “Women with one child”. In this case it is obvious that all women that enter this state, come from the state “Women without children”. Of all women that leave the state “Women with one child”, 91 per cent gave birth to a second child, while 9 per cent left the state because they died. The percentage that leaves the state to give birth to a second child, should not be confused with the percentage of all women that will have at least two children, or with the percentage of women that have one child and give birth to a second. This figure shows the distribution of all exits (the sum is 100 per cent), but does not show the number or percentage of women that do not leave the state.

Figure 14 Population pyramid, 2050, Mac simulation overall fertility rates

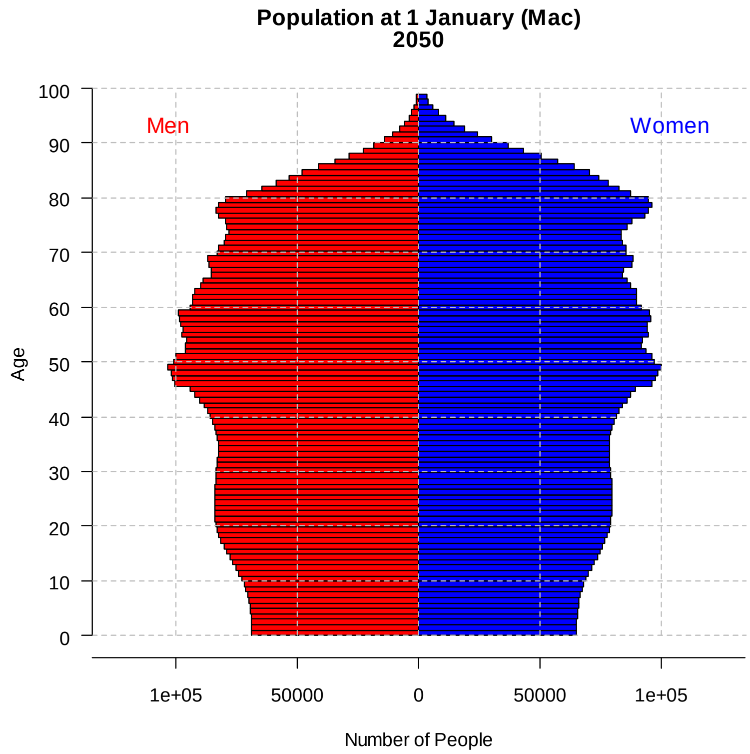


Figure 15 Population pyramid, 2050, Mac simulation parity specific fertility rates

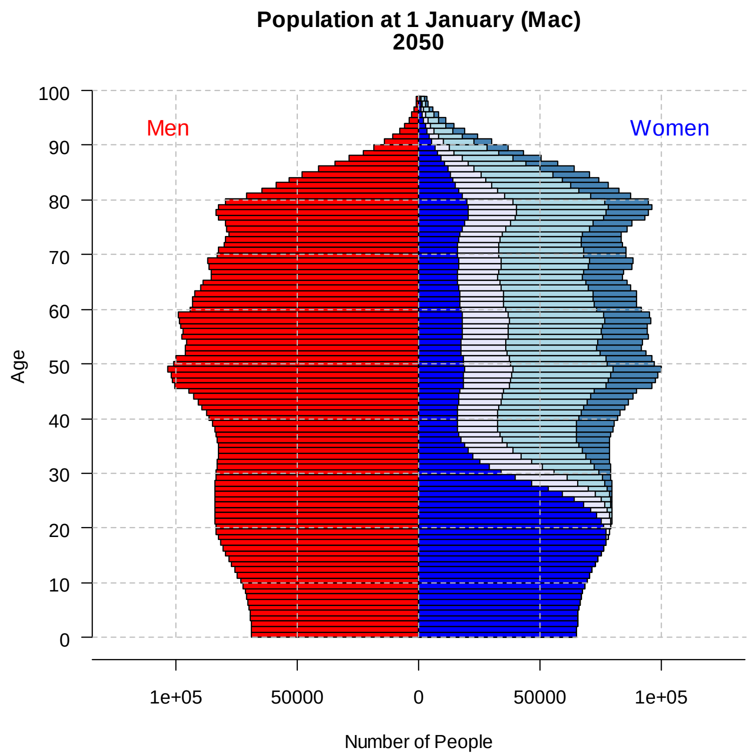


Figure 16 Population pyramid, 2050, Mic simulation, 162 thousand persons

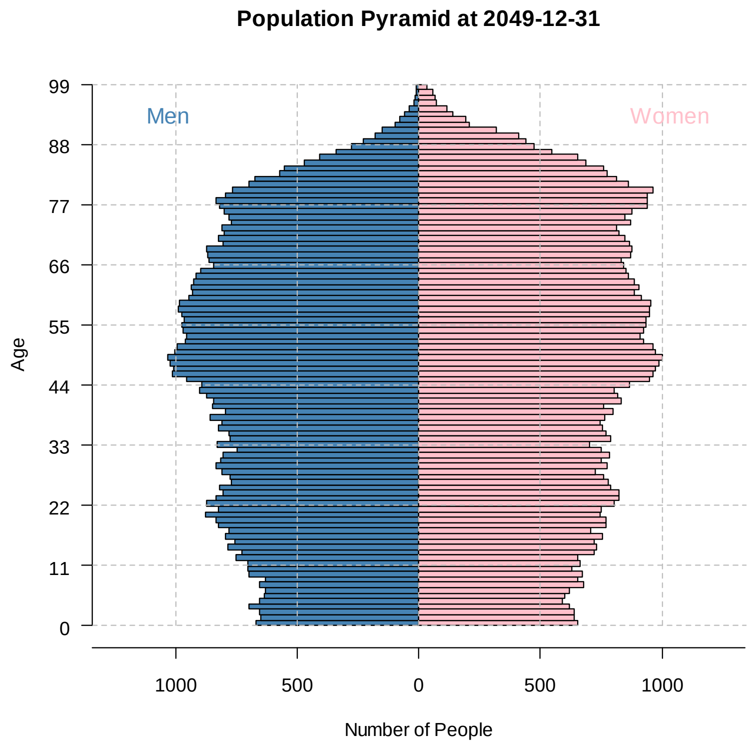


Figure 17 Population pyramid, 2050, Mic simulation, 648 thousand persons

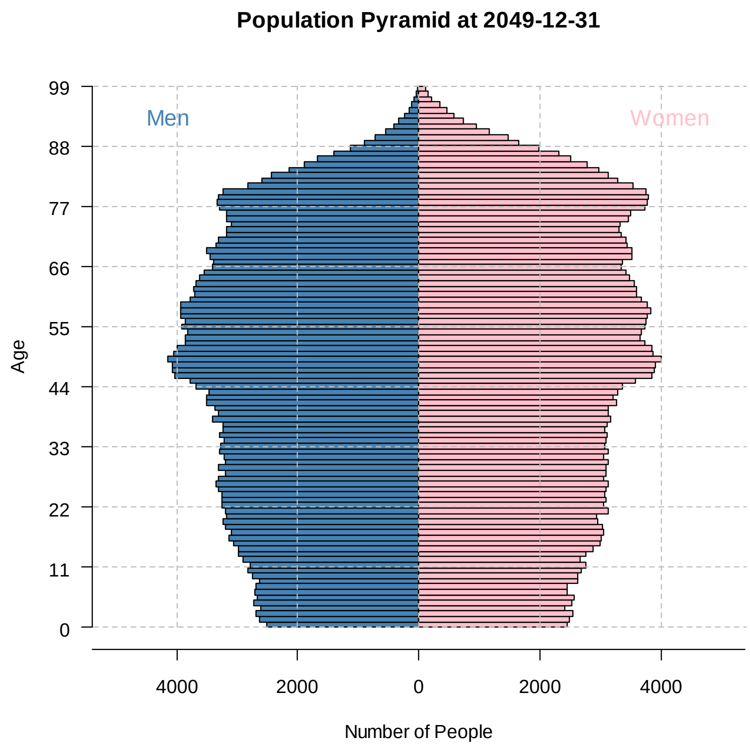


Figure 18 Females by number of children, 2004

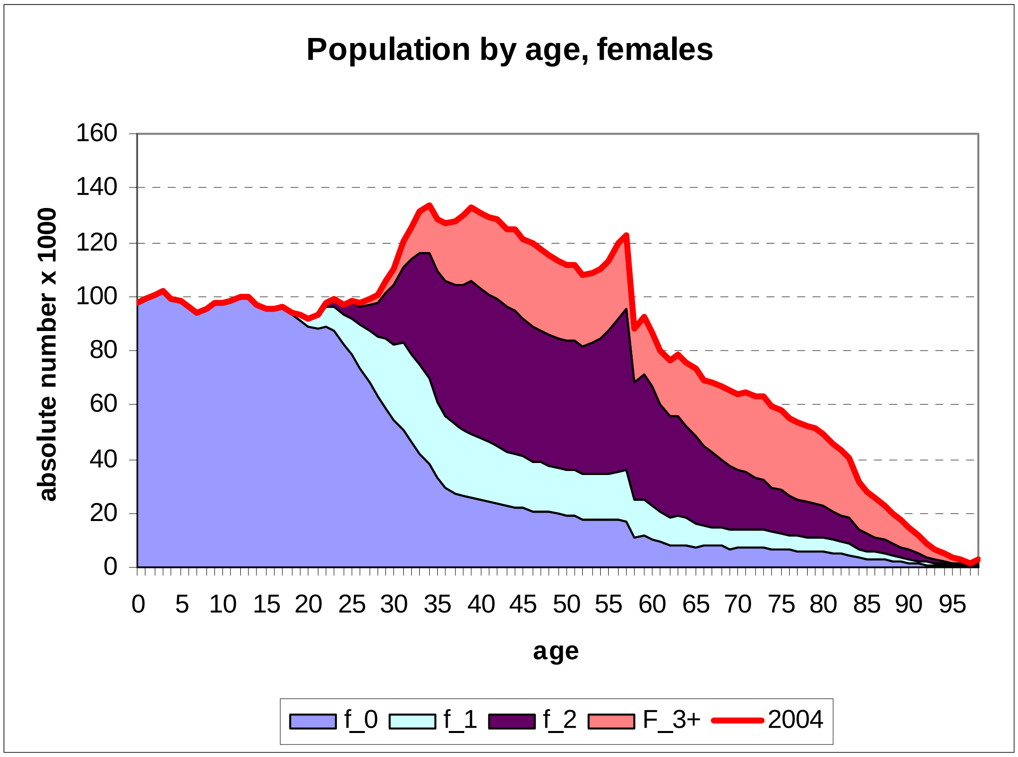


Figure 19 Females by number of children, 2050

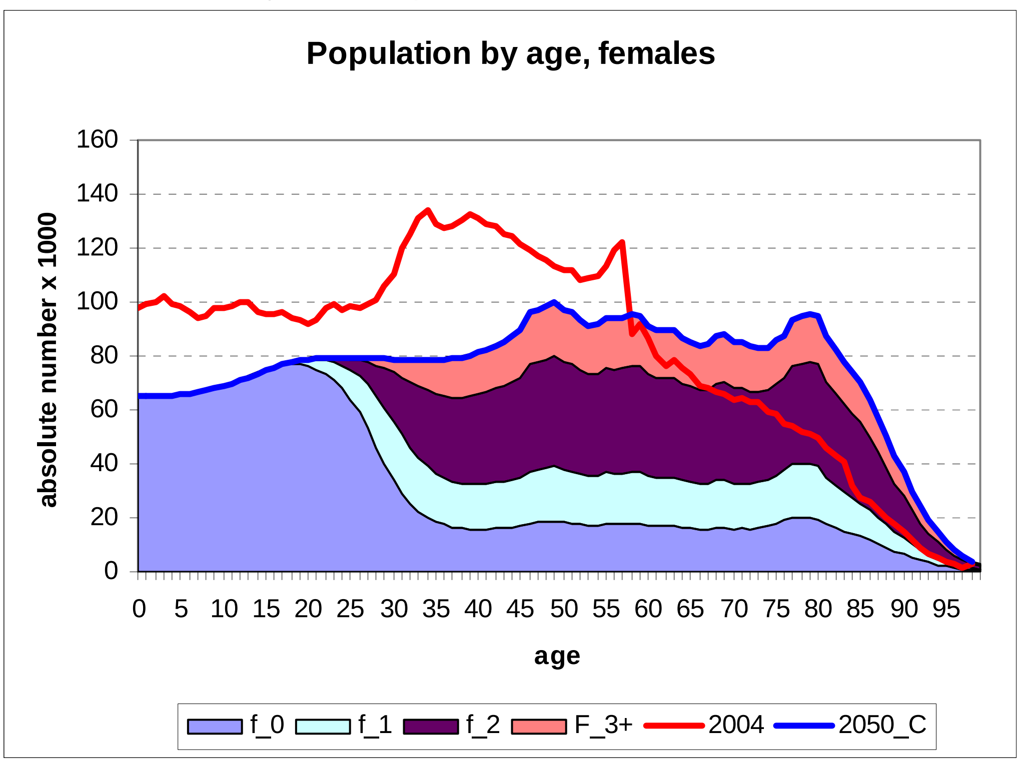


Figure 20 Transitions into and out of state 'firstChild'

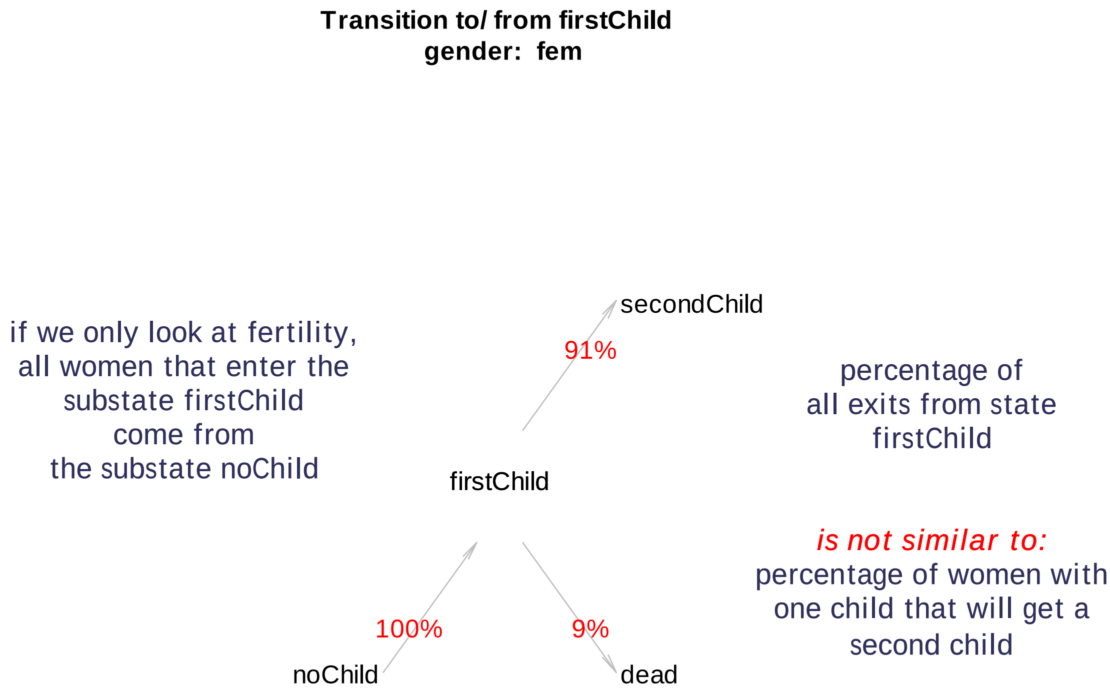
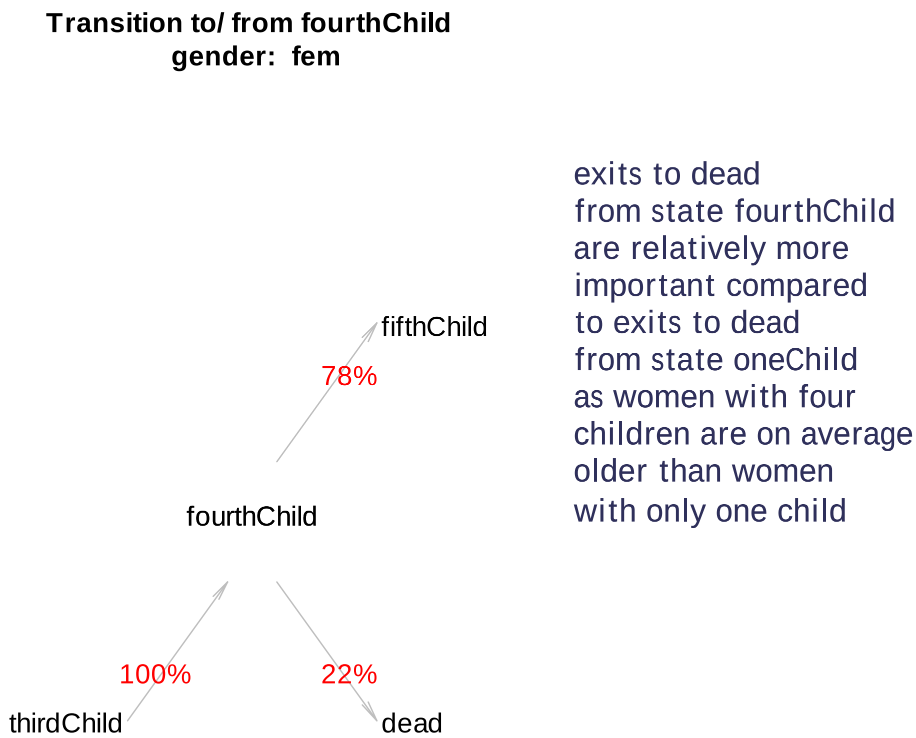


Figure 21 presents the transitions into and out of the state "Women with four children". In this case again all women enter the state out of the same state of origin, namely "Women with three children". Given that on average women with four children are older than women with only one child and transitions into fifth birth are lower than transitions into second birth, exits from this state due to death are relatively more important (22 per cent of all women that leave this state die, while 78 per cent give birth to another child).

A crucial feature of MicMac is the life course approach. Figure 22 shows the most frequently simulated life courses. For 20.9 percent of all women in the projection the following life course has been simulated: from "Woman without children" to "Woman with one child" to "Woman with two children". This refers to all women included in the projection, from the start of the projection period to the end of the projection period. The state "Woman without children" at the beginning of the life course therefore, includes all women that have no child at the start of the simulation plus all newborn girls. As a consequence, the life courses described in this figure refer to different cohorts. This figure also shows the average age at which these women gave birth to their first (age 27.9) and second (age 31.7) child.

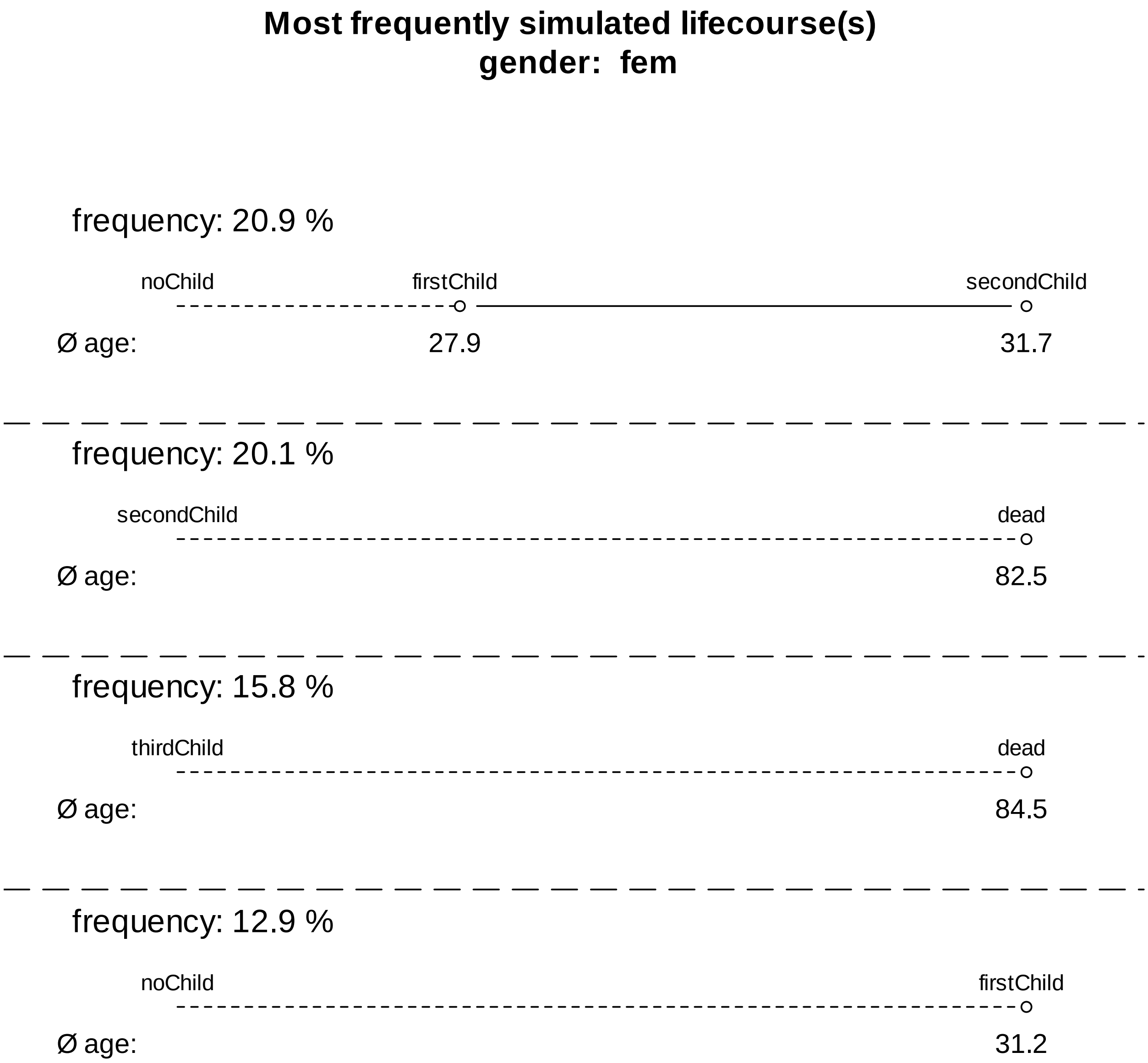
Figure 21 Transitions into and out of state 'fourthChild'



The second most frequently simulated life course is from second child to death (see Figure 22). One fifth of all women in the population experienced this life course. It is obvious that these women are on average older than the women that experience the life course "noChild" > "firstChild" to "secondChild", both at the beginning of the projection interval as at the end. The average age at death is 82.5 years. The third most frequently simulated life course refers to even older women: those that already had three children in 2004 and died the projection period. The fourth most frequently simulated life course refers in general to younger women: women without children that enter motherhood. Part of this group consists of young women that have not yet completed their fertility careers, but part of this group consists of women with final parity of one child only. It is not surprising therefore, that the average age at first birth in this life course is considerably higher (age 31.2) than that in the most frequently simulated life course (age 27.9).

Figure 23 shows the most frequently simulated life course of a cohort followed over time. The first life course refers to women that reach the age of 15 in 2004 (i.e. women that are born in 1989). For 40.2 percent of these women the following life course has been simulated: noChild -> firstChild -> secondChild (compared to 20.9 percent of all women in the projection).

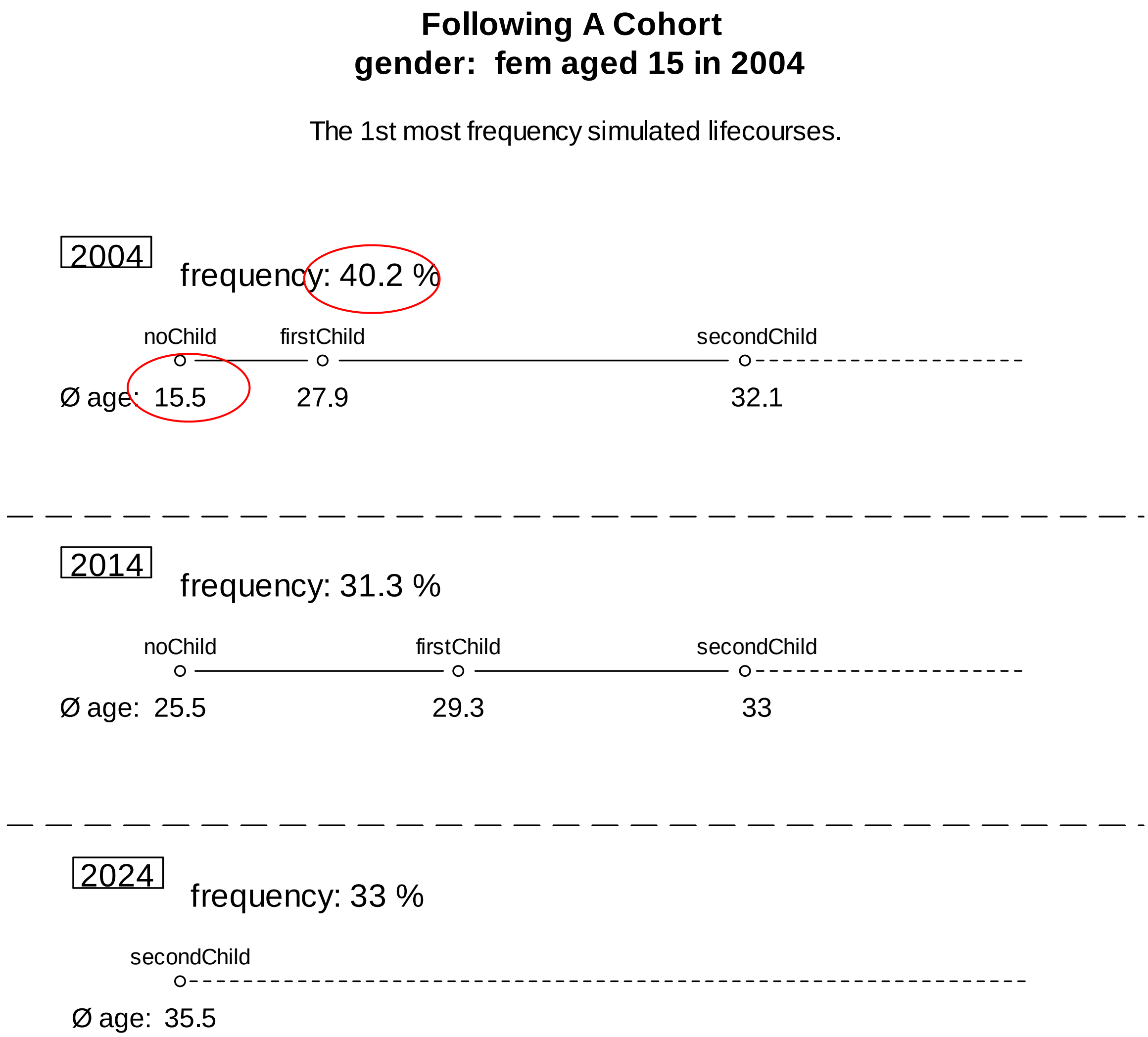
Figure 22 Most frequently simulated lifecourses, females



The average age at birth of first child (27.9) is similar as for all women. The average age at birth of the second child (32.1) is slightly higher compared to all women (31.7).

In 2014 these women have reached on average the age of 25.5. For these women, the life course noChild -> firstChild -> secondChild is still the most frequently simulated life course. In 2014 this life course is simulated for 31.3 percent of the women born in 1989 that are still without children.

Figure 23 Most frequently simulated life course, cohort 1989, followed over time



In 2024 these women reached on average the age of 35.5. The most frequently simulated life course for these women is ‘no transition (after the birth of their second child)’.

If we do not look at the most frequently simulated life course, but follow a specific life course, in this case that of noChild > firstChild > secondChild, we see that by 2024 there are 14 other life courses that are more frequently simulated than the life course noChild > firstChild > secondChild (see Figure 24). Looking at birth intervals, we see that these vary from 4.2 years for all women of cohort 1989, to 3.7 years for those women that are still childless on 1 January 2014, to 2.5 years for those women that are still childless on 1 January 2024.

Figure 24 Following a cohort, same life course at different points in time

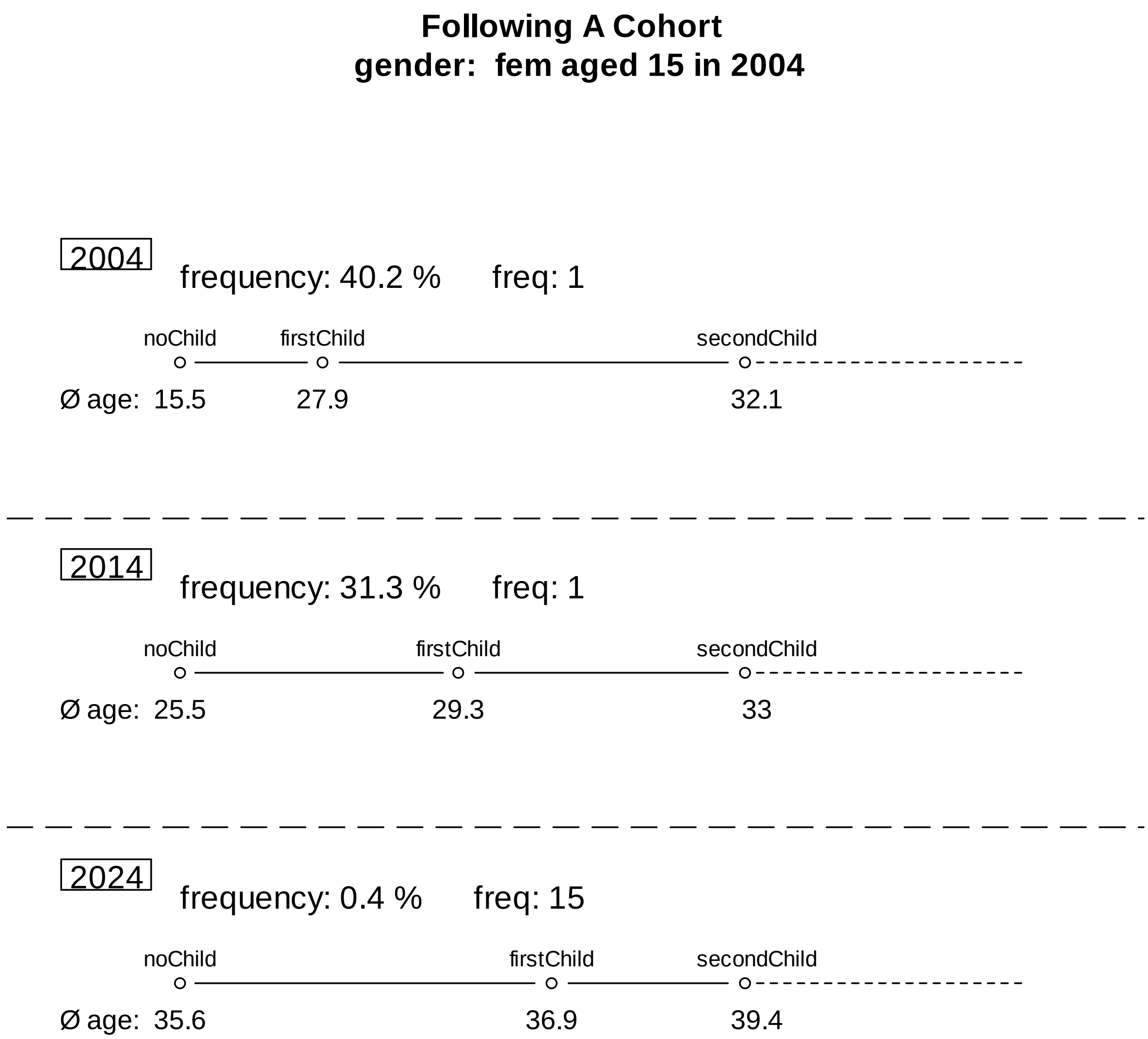
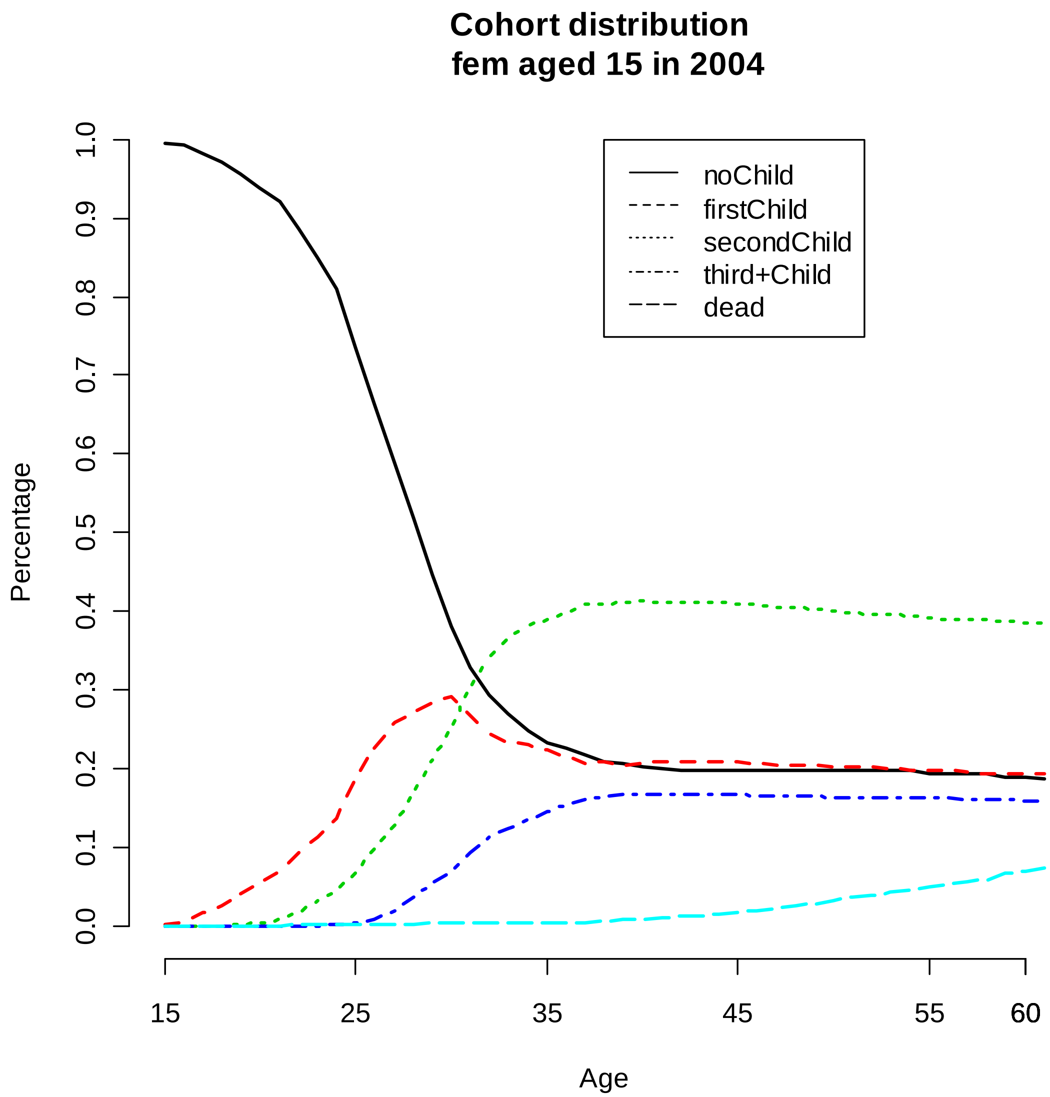


Figure 25 Distribution over states by age of women, women age 15 at start of the simulation



Figures 25-27 present the distribution over states by age of the women. Figure 25 shows the distribution for women aged 15 at the start of the simulation. All these women are still childless at the beginning of the simulation, while by the end of the simulation about 20 percent is still childless. About 40 percent of the women have two children and almost ten percent has died before the age of 60. If we follow women that are age 30 at the start of the simulation, we see that about 40 percent of these women were still childless at the beginning of the simulation and more than 20 percent has died before the end of the projection period. In the first ten years of the simulation, we still see the effect of childbirths. For women aged 50 at the start of the simulation, changes in the relative distribution over states solely is the result of mortality (see Figure 27)

Figure 26 Distribution over states by age of women, women age 30 at start of the simulation

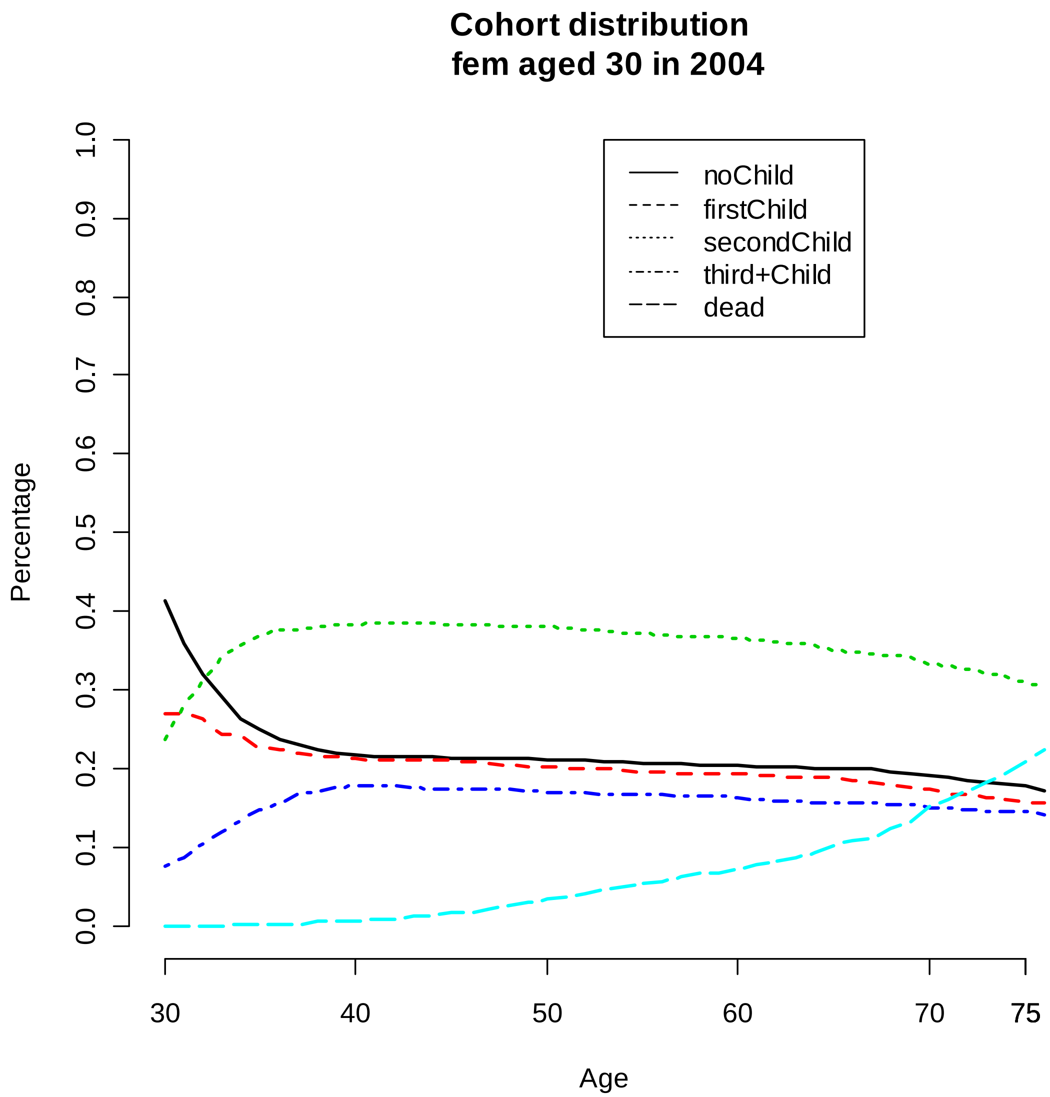
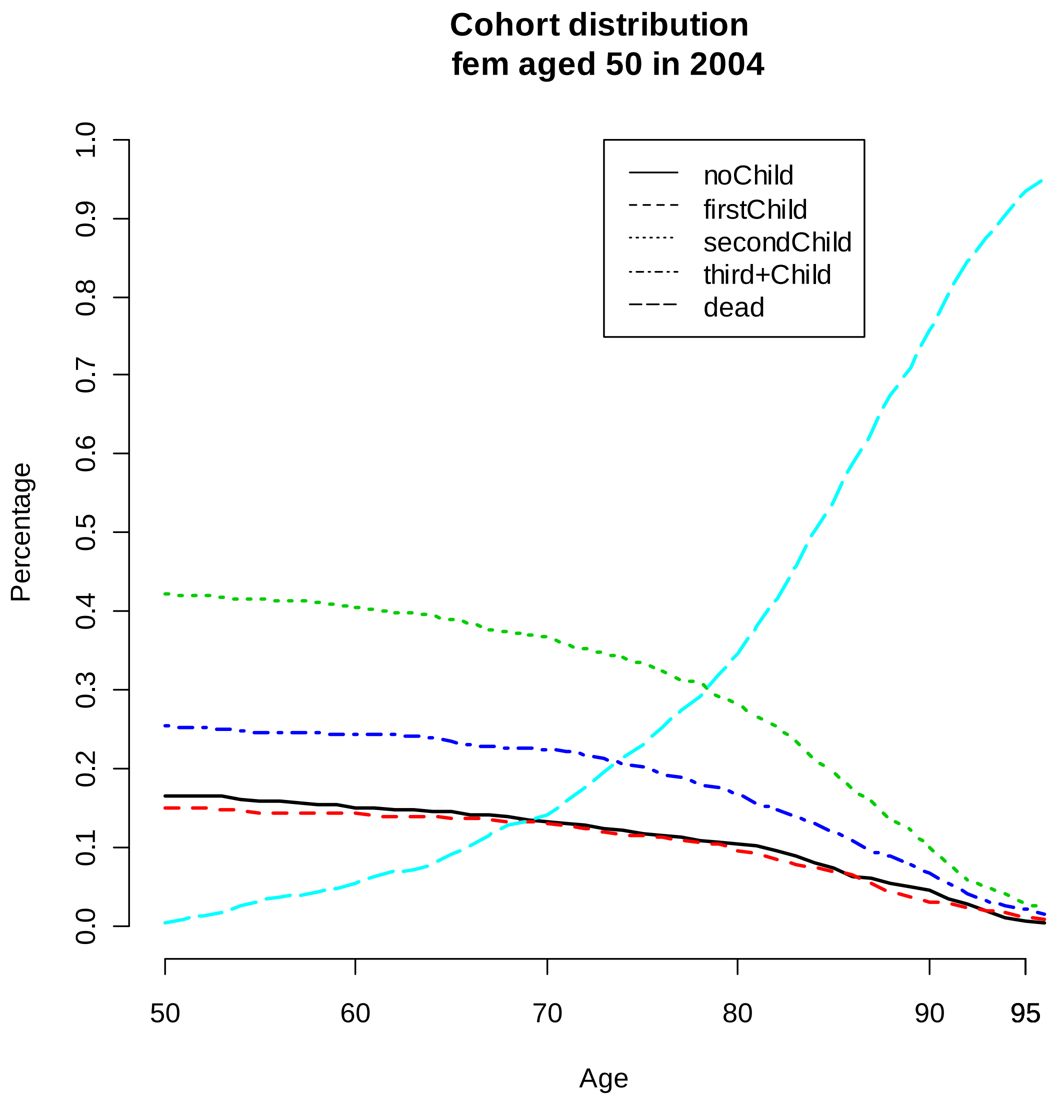


Figure 27 Distribution over states by age of women, women age 50 at start of the simulation



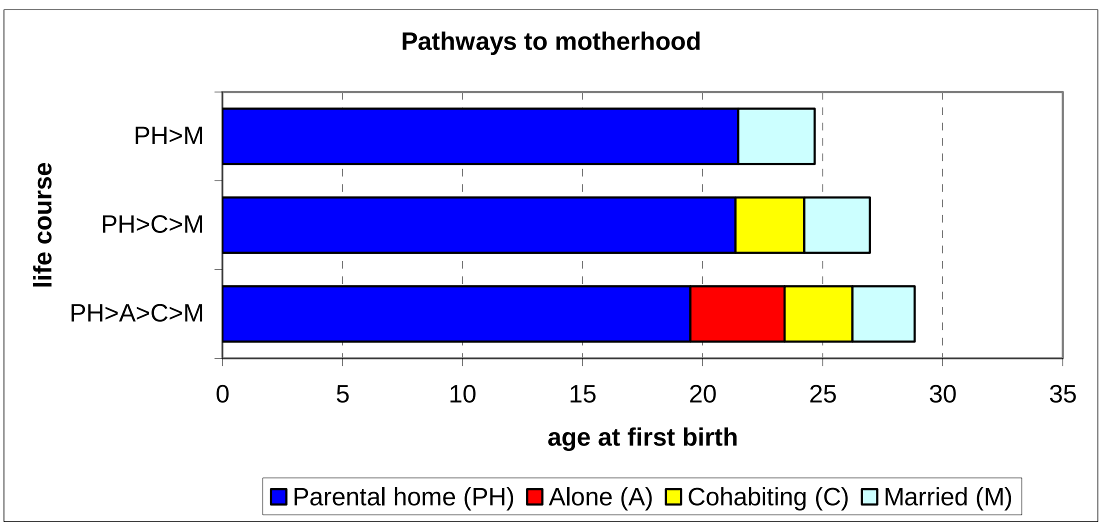
3 Extended example

3.1 General background

The current low fertility rates in Europe lead to rapid population ageing and to a decline in total population size. These low birth rates are a challenge for the public authorities as they constitute serious threats to the economy, labour market, and welfare system. Notwithstanding these low birth rates, there still seems to be a strong desire for two child families because of the value attached to siblings. Given this strong desire for two child families, the current low fertility may imply that numerous women do not realize their birth expectations. The difference between birth expectations and realized family size may be related to postponement, while postponement itself may be related to time spent in education and the lack of a partner (Agtmaal-Wobma and van Huis, 2008).

An example of an association between partnership careers and fertility is shown in Figure 28. This figure shows that a longer pathway to motherhood results in a higher age at first birth. Women with a traditional lifestyle, i.e. women who leave the parental home for marriage (upmost bar in the figure), have the first child considerably earlier than women who live alone and cohabit before marriage (lowest bar). The sequence of living arrangements before family formation therefore, is a predictor of the age at motherhood. Mothers who marry after leaving the parental home have their first child at about the age of 25. Cohabitation before marriage delays motherhood by more than two years, while an episode of living alone delays motherhood further by almost another 2 years.

Figure 28 Partnership pathways to motherhood



Data: the Netherlands Fertility and Family Survey 1998 (OG98)

A study of Statistics Netherlands (Van Agtmaal-Wobma and Van Huis, 2008) showed the following association between fertility patterns and level of educational attainment:

- in general low educated women have their first child at a younger age than high educated women (cohort 1965-69: about age 26 versus 31)
- more high educated than low educated women remain childless (cohort 1965-69: about 27 versus 16 per cent)
- on average high educated women have less children than low educated women (cohort 1965-69: about 1.63 versus 1.99 children)
- differences in average number of children between low and high educated women decreased over generations, but differences in age at first birth remained
- leaving out of consideration childlessness, differences in the average number of children for mothers are substantially smaller and relatively stable over generations (between 2.2 and 2.3 for low educated women and about 2.2 for women with high levels of education)

For the extended example we simulate life courses for women from the age of 15 to 50, taking into account their level of education, partnership status and fertility career.

3.2 The state space

To study the relationship between education, partnership formation and dissolution, and completed fertility, we have to define the categories of the variables taken into account. For education we used the ISCED classification. For partnership formation and dissolution we used a combination of the variables living arrangement and marital status. The tables below give a description of the variables and categories distinguished as well as of the states used in this application.

Table 15 Variables and categories included in the simulation

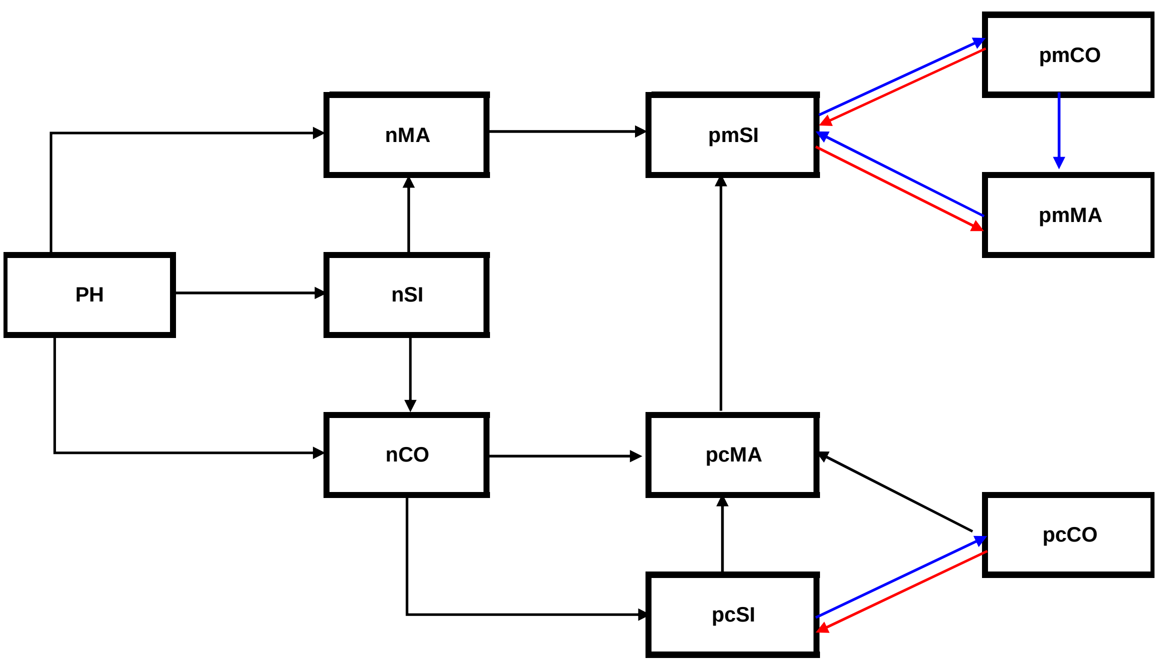
Variables	**Code**	**Categories**
Education	ISCED02	lower secondary education or less
	ISCED34	upper secondary education
	ISCED56	tertiary education
Living arrangement	PH	Parental home
	SI	Without partner
	CO	With partner (cohabiting)
	n	Never lived in a union before
	pc	Previously living with partner but never married
Marital status	MA	Married
	pm	Previously married
Children ever born	0	no children
	1	1 child
	2+	2 or more children

Table 16 Possible states for women without children, disregarding education

States	Description
PH-	Living at parental home without children
nMA-	Married (first union) without children
nSI-	Living without partner without children and without previously living in a union
nCO-	Cohabiting (first union) without children
pmSI-	Living without partner without children, previously married
pcMA-	Married without children, previously cohabiting
pcSI-	Living without partner without children, previously cohabiting
pmCO-	Cohabiting (second+ union) without children, previously married
pmMA-	Married (second+ marriage) without children
pcCO-	Cohabiting (second+ union) without children, without previously being married

Figure 29 shows the different partnership states and the transitions between the states. The state space is mutually exclusive and exhaustive. All persons in the simulation will occupy one of the states and all persons in one state will have the same risk (transition rates) to move to one of the other states.

Figure 29 State space diagram for partnership states



The full state space contains different layers for each category of education. Education is treated as a time-constant variable. That means we assume we already know at young ages (at the start of the simulation) what level of education a woman will eventually reach and we will model her behaviour with respect to partnership status and fertility according to this assumed level of education. Therefore, no transitions between levels of education are taken into account. As we also distinguish different numbers of children ever born (0, 1, 2+ children), for each level of education there are three additional layers referring to the number of children a woman has.

We assume that all women at the start of the simulation period live at their parental home (PH) and do not yet have children. Subsequently, a woman can leave the parental home either to start a cohabitation (nCO), to get married (nMA) or to 'live without a partner' (nSI). The state 'live without a partner' covers all other living arrangements than cohabitation or marriage. After a cohabitation, a woman can get married (pcMA), or she can enter the state of living without a partner (pcSI), and so forth.

Each arrow in the state space diagram refers to a transition rate. As we are interested in the association of partnership status, educational attainment and fertility careers, we have to estimate different rates for different levels of educational attainment as well as for different levels of fertility states (i.e. for women with zero, one and two or more children).

Given the specified model, a huge number of different partnership pathways can be simulated. For the outcomes, we concentrate on only two. In the first one we sum up all pathways where the woman starts at some point in time to live with a partner (either in a cohabitation or a marriage), after which she continues to live with this partner until the end of the simulation. The second group consists of women that start to live with a partner after which they experience at least one partnership dissolution within the simulation period. To sum up we compare four groups: mothers with high and low education that start to live with a partner and either or not experience a partnership dissolution before the end of the projection period (see Figure 30).

3.3 Approach

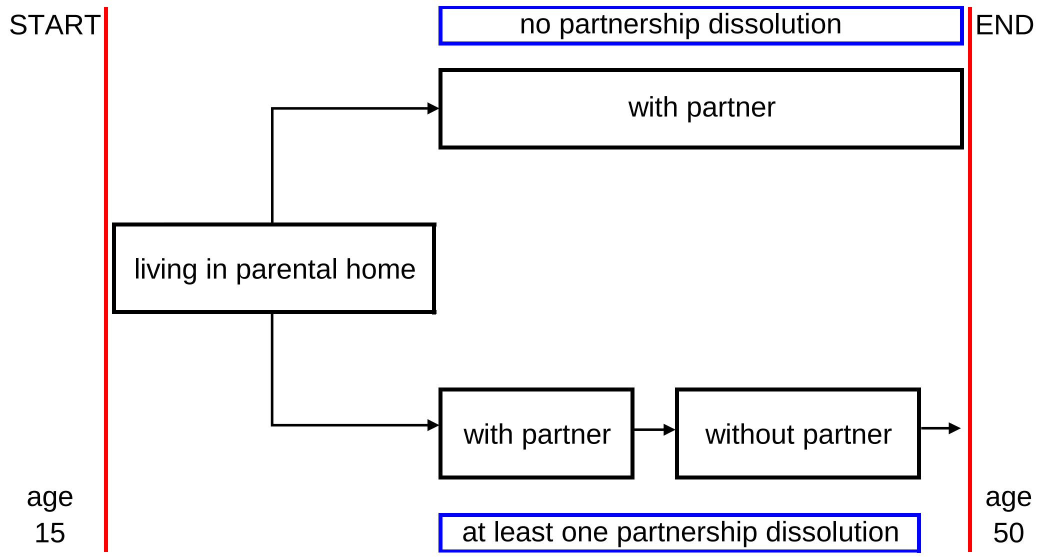
Below we summarize the approach:

- Estimate transition rates for all possible transitions in the model
- Simulate a virtual population of 100,000 women of age 15 at the start of the simulation until the age of 50
- Focus on mothers (as we study postponement and thus age at child birth)
- Examine differences between mothers with low and high levels of education, that at least once lived together with a partner and either or not experienced a partnership dissolution (based on the simulated individual biographies)

3.3.1 The transition rates

Based on data of the Netherlands Fertility and Family Survey (FFS-NL / OG) transitions have been estimated for living arrangement, marital status and children ever born using the MAPLES method (Impicciatore *et al*, 2008).

Figure 30 Pathways with and without partnership dissolution



In Table 18 we describe the transitions included in the simulation and the different covariates taken into account. TR1 to TR3 for instance refer to the transitions into marriage. TR1 is the transition from living at the parental home into first marriage. Different transitions are estimated for different levels of education. TR2a refers to the transition into marriage from the state living without a partner. In this case we cannot distinguish between first marriage with and without previously cohabiting. Similar transitions are available for women with 1 child and women with 2+ children[1] (see Table 19).

Table 17 Transitions and covariates

transitions into marriage	
TR1 PH- > nMA-	**Never married, living at parental home to first marriage**; four levels of education
TR2a nSI- > nMA- pcSI- > pcMA-	**Living without partner without previously being married to first marriage**; four levels of education; here we cannot distinguish between first marriage with and without previously cohabiting
TR3a nCO- > pcMA- pcCO- > pcMA-	**Cohabiting to first marriage**; four levels of education; here we cannot distinguish between first and higher order cohabitation
TR2b pmSI- > pmMA	**Living without partner previously being married to second+ marriage**; four levels of education (check); here we cannot distinguish between second and higher order marriages
TR3b pmCO- > pmMA-	**Cohabiting previously married to second+ marriage**; four levels of education (check); here we cannot distinguish between second and higher order cohabitation and marriages

[1] Originally we planned to continue until 3+ children; therefore transitions TR17, TR19, TR21, TR28, TR29 and TR30 are missing.

transitions into living without partner	
TR8 PH- > nSI-	**Living at parental home to living without partner without previously living in a union**; three levels of education (primary, lower secondary and upper secondary + tertiary)
TR9 nMA- > pmSI- pmMA- > pmSI- pcMA- > pmSI-	**First marriage to living without partner being previously married**; check levels of education; here we cannot distinguish between widowhood and divorce; neither between disruption of first and higher order marriages (but we can ask Roberto whether it is possible to add this distinction)
TR10 nCO- > pcSI- pcCO- > pcSI- pmCO- > pmSI-	**Cohabiting to living without partner previously living in a union**; three levels of education (primary, lower secondary and upper secondary + tertiary); here we cannot distinguish between cohabiting with and without previously living in a union (either married or cohabiting)
transitions into cohabitation	
TR15 PH- > nCO-	**Living at parental home to first cohabitation;** three levels of education (primary, lower secondary and upper secondary + tertiary)
TR16a nSI- > nCO-	**Living without partner without previously living in a union to first cohabitation**; four levels of education
TR16b pmSI- > pmCO- pcSI- > pcCO-	**Living without partner previously living in a union to cohabiting previously living in a union**; four levels of education; here we cannot distinguish between previously being married and previously cohabiting
transitions into motherhood (first birth)	
TR22 nMA- > nMA1 pcMA- > pcMA1 pmMA- > pmMA1	**Married without children to married with 1 child**; four levels of education; here we do not distinguish between first marriages and higher order marriages and between marriages with and without previously cohabiting
TR23 nSI- > nSI1 pcSI- > pcSI1 pmSI- > pmSI1	**Living without partner without children to living without partner with 1 child**; four levels of education; here we do not take into account whether a person is living without partner for the first time, or whether (s)he has been previously married or cohabiting
TR24 nCO- > nCO1 pcCO- > pcCO1 pmCO- > pmCO1	**Cohabiting without children to cohabiting with 1 child**; four levels of education; here we do not distinguish between first and higher order cohabitations and between cohabiting with and without previously being married or cohabiting
transitions from first to second+ birth	
TR25 nMA1 > nMA2 pcMA1 > pcMA2 pmMA1 > pmMA2	**Married with 1 child to married with 2 children**; four levels of education; here we do not distinguish between first marriages and higher order marriages and between marriages with and without previously cohabiting
TR26 nSI1 > nSI2 pcSI1 > pcSI2 pmSI1 > pmSI2	**Living without partner with 1 child to living without partner with 2 children**; four levels of education; here we do not take into account whether a person is living without partner for the first time, or whether she has been previously married or cohabiting
TR27 nCO1 > nCO2 pcCO1 > pcCO2	**Cohabiting with 1 child to cohabiting with 2 children**; four levels of education; here we do not distinguish between first and higher order cohabitations and between cohabiting with and without previously

pmCO1 > pmCO2	being married or cohabiting
transitions into higher levels of educational attainment	
TR31 ISCED01 > ISCED2	**Primary education or less to lower secondary education**; we assume this transition to be similar for all states (married, living without partner, cohabiting, with and without children)
TR32 ISCED2 > ISCED34	**Lower secondary education to higher secondary education**; we assume this transition to be similar for all states (married, living without partner, cohabiting, with and without children)
TR33 ISCED34 > ISCE56	**Higher secondary education to tertiary education**; we assume this transition to be similar for all states (married, living without partner, cohabiting, with and without children)

Table 18 Transitions distinguished by children ever born

Transition without children	Transition with 1 child	Transition with 2+ children
TR1	-	-
TR2a	TR4a	TR6a
TR3a	TR5a	TR7a
TR2b	TR4b	TR6b
TR3b	TR5b	TR7b
TR8	-	-
TR9	TR11	TR13
TR10	TR12	TR14
TR15	-	-
TR16a	TR18a	TR20a
TR16b	TR18b	TR20b

Figures 31 to 43 show examples of transition rates (more details on the estimation of the transition rates can be found in Impicciatore *et al*, 2008).

The first graph (Figure 31) shows fertility rates for first births for low educated women. These are parity-specific rates. The figure distinguishes different patterns for married and cohabiting women and women living without a partner. There is a sizable difference between married women and cohabiting women. As expected, a comparison with high educated women shows lower transitions into motherhood for high educated women than for low educated women.

Figures 35 and 36 refer to leaving the parental home. In both cases this is a two peaked curve for the transition into a household situation where the woman starts to live on her own, but without a partner. At young ages this might be related to entering into college or the labour market. As expected for higher education the probability to leave home at young ages to live on your own is considerably higher, while the probability to start a cohabitation at young ages is somewhat lower. For both groups of education, only a small group enters directly into marriage after leaving the parental home.

Figure 31 Transitions into motherhood, low education

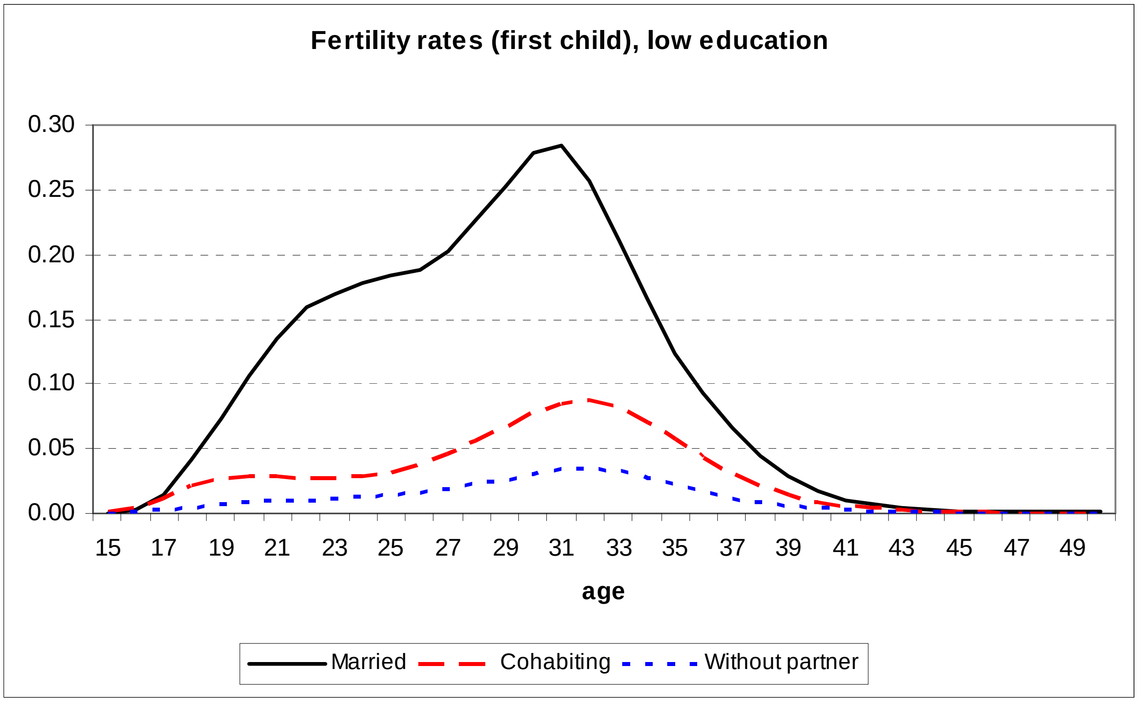


Figure 32 Transitions into motherhood, high education

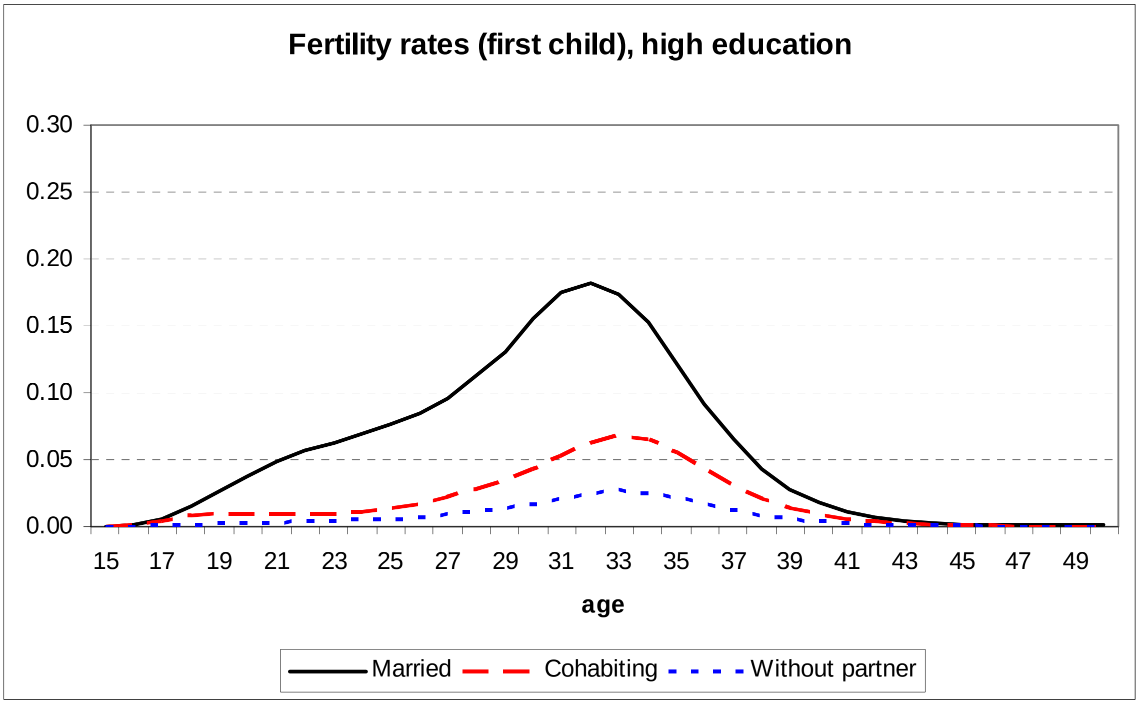


Figure 33 Transitions to two ore more children, low education

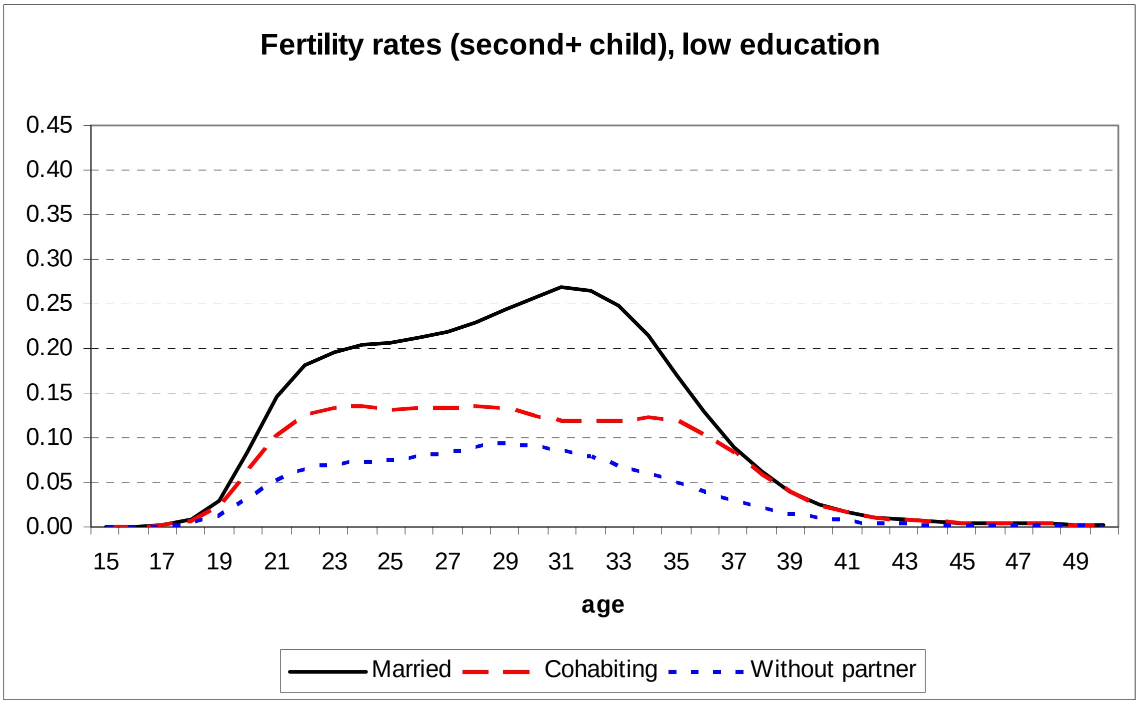


Figure 34 Transitions to two ore more children, high education

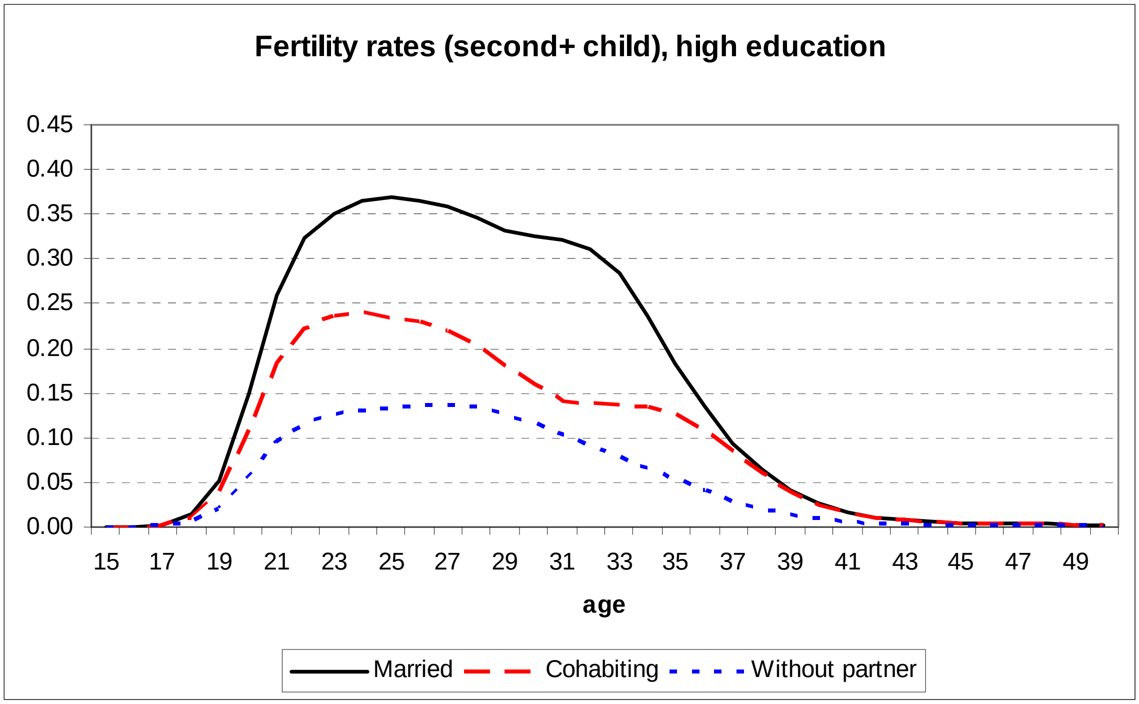


Figure 35 Leaving the parental home, low education

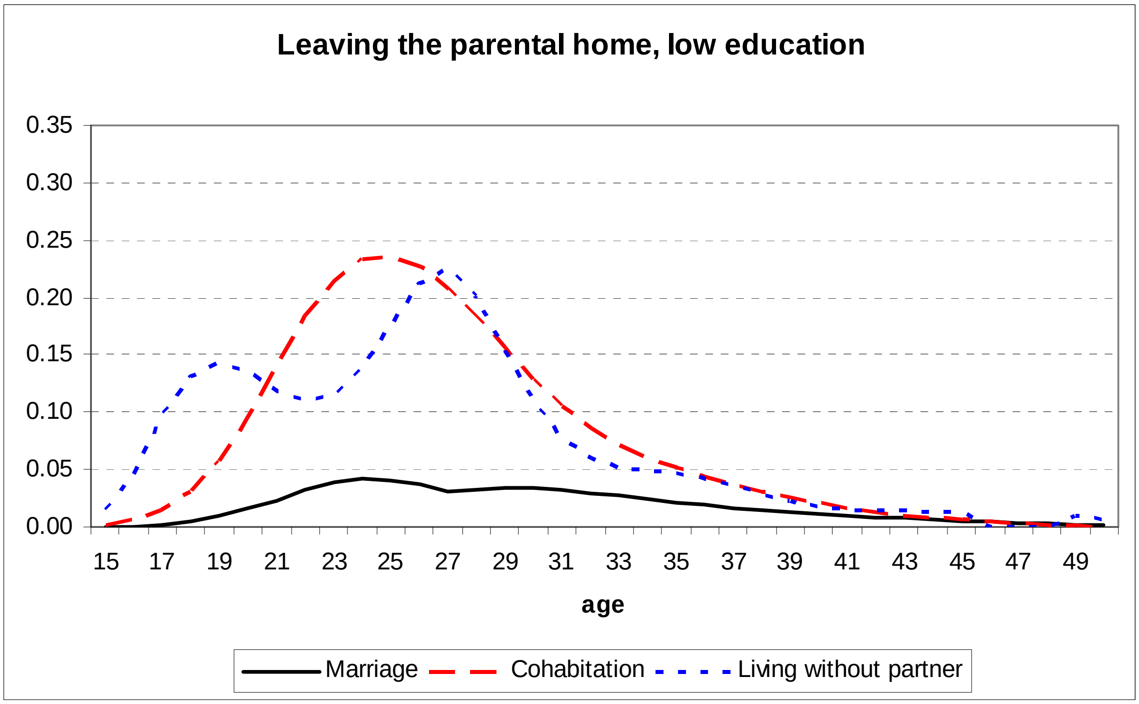


Figure 36 Leaving the parental home, high education

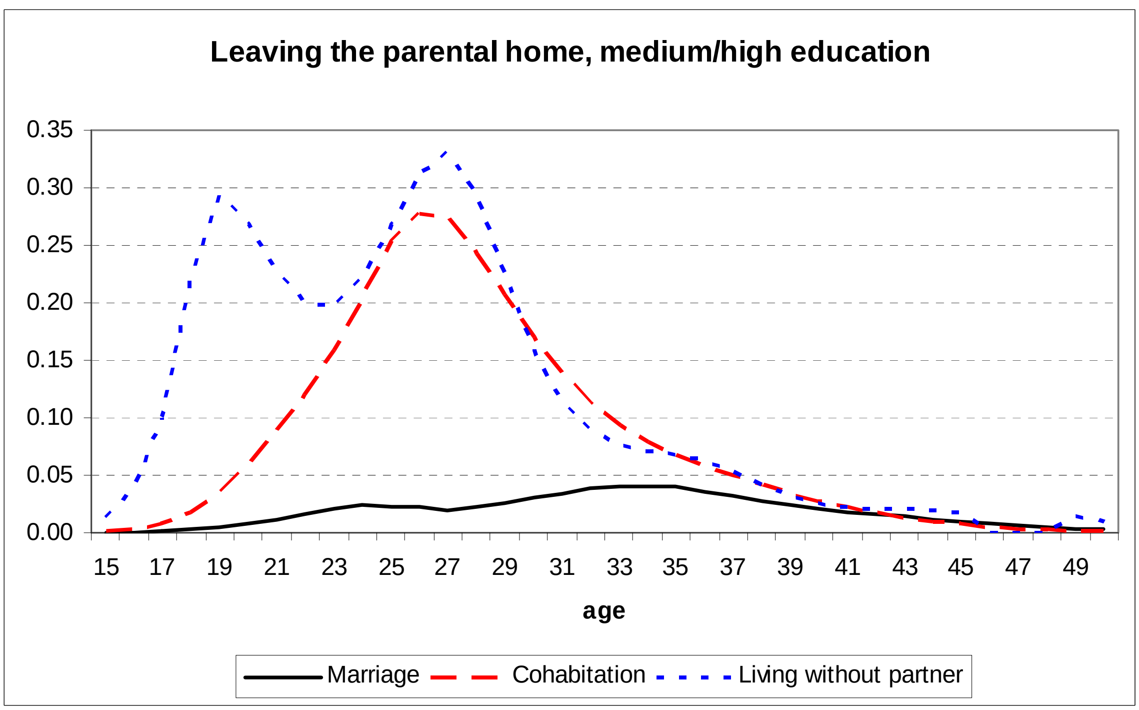


Figure 37 Transitions to living without partner after marriage, no children

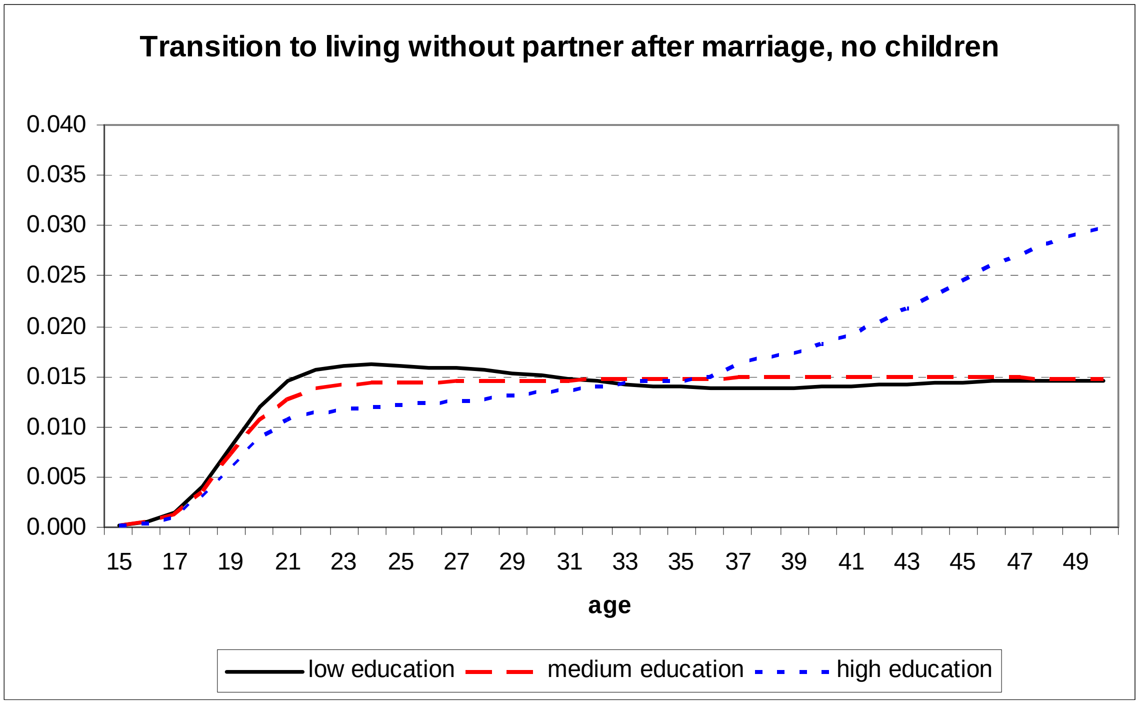


Figure 38 Transitions to living without partner after marriage, one child

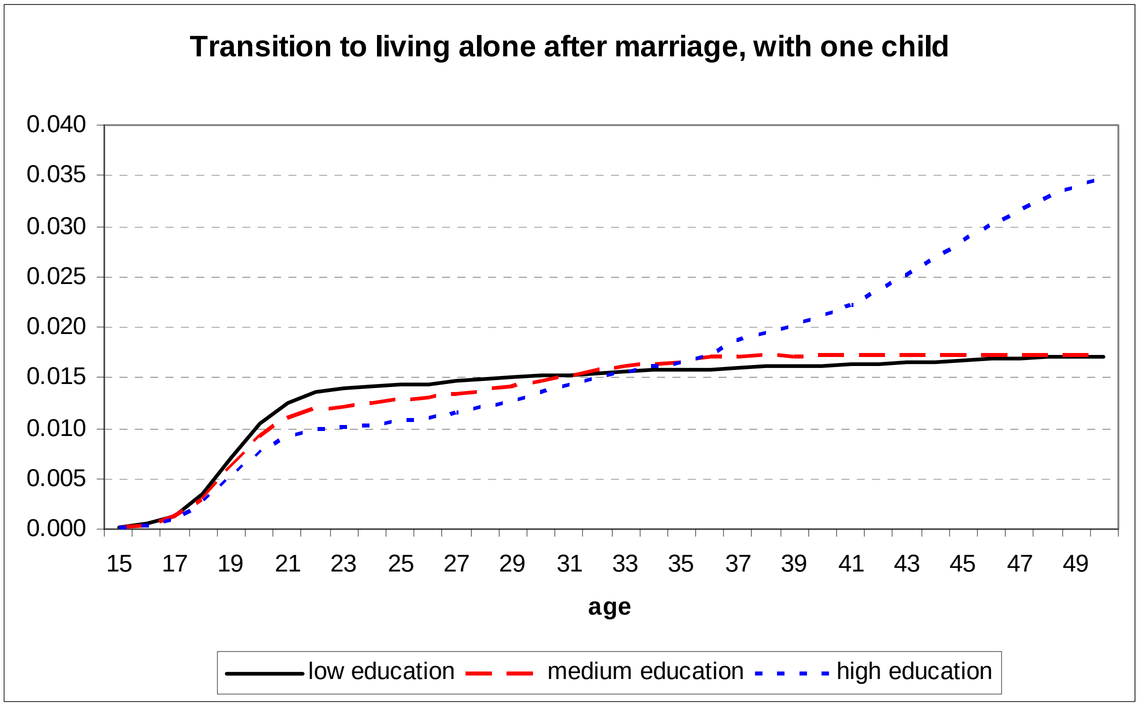


Figure 39 Transitions to living without partner after marriage, two or more children

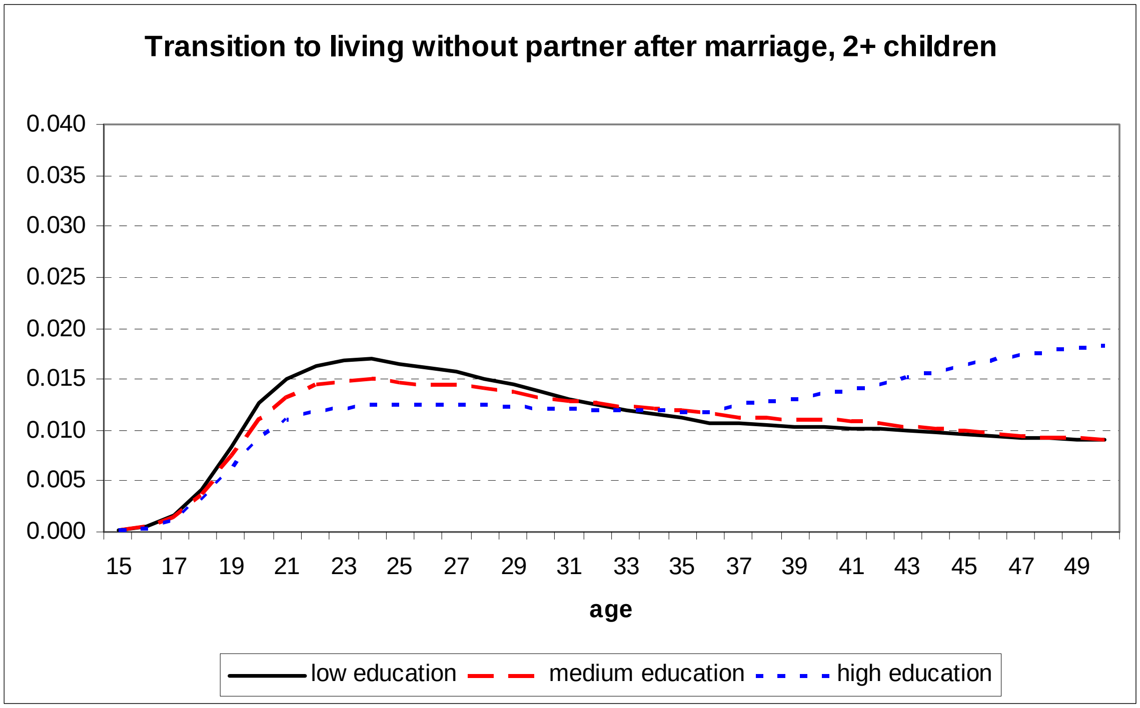


Figure 40 Transitions to marriage after cohabitation, low education

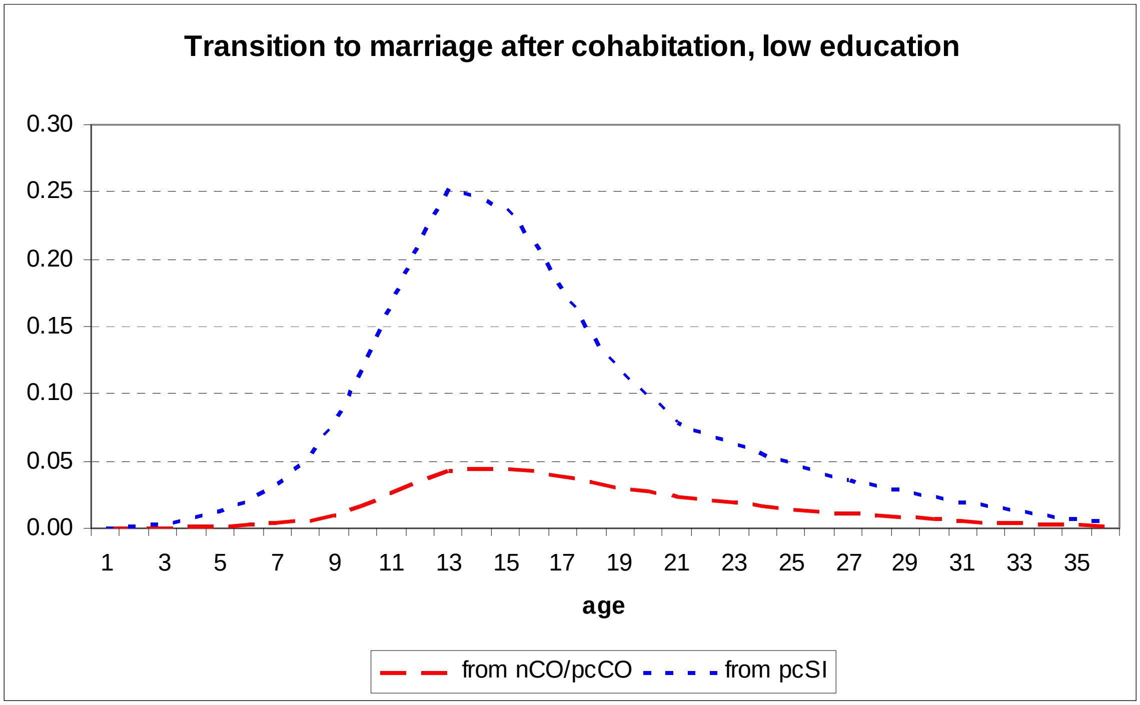


Figure 41 Transitions to marriage after cohabitation, high education

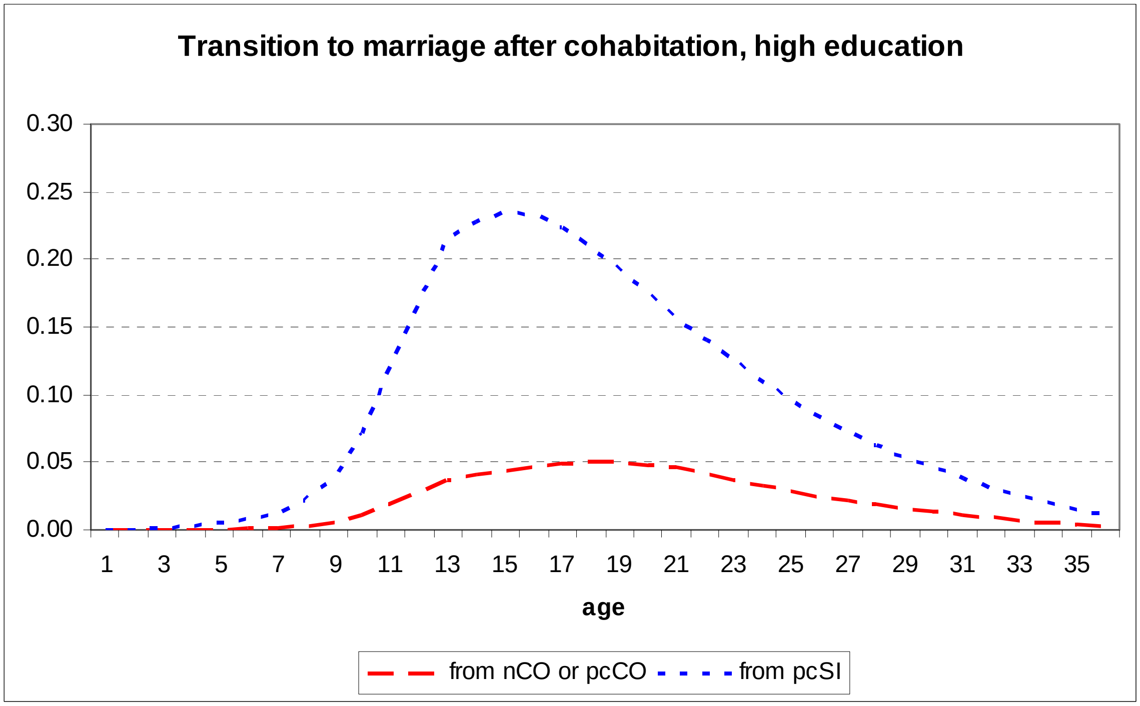


Figure 42 Transitions to cohabitation, low education

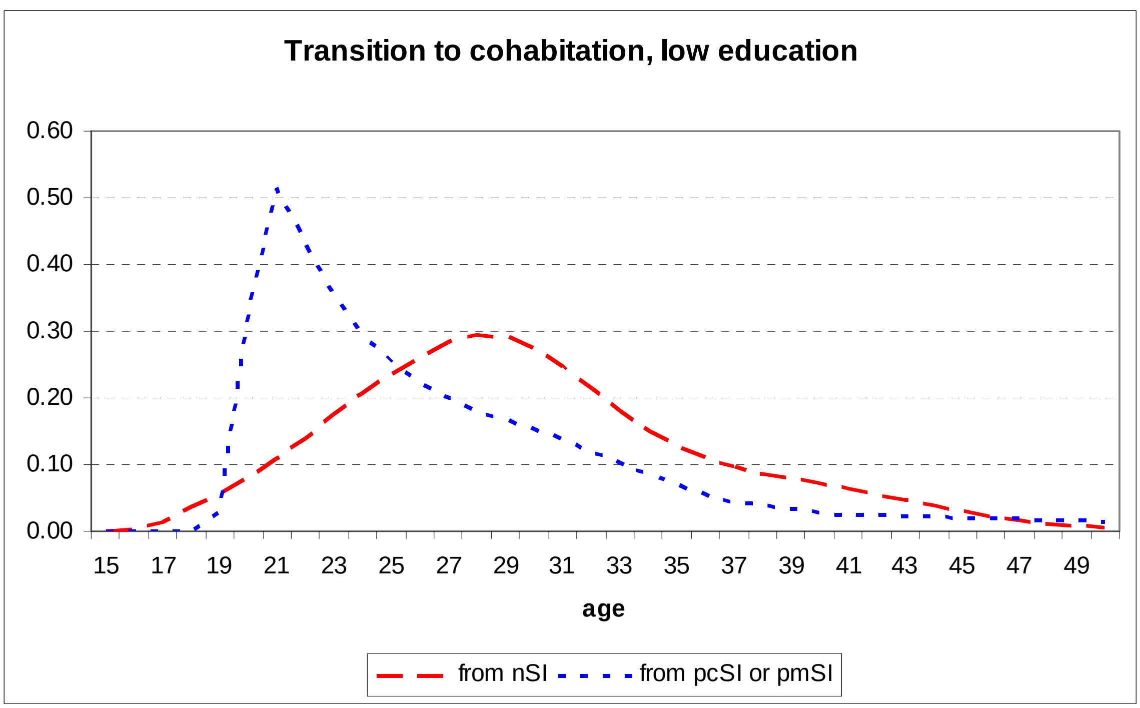
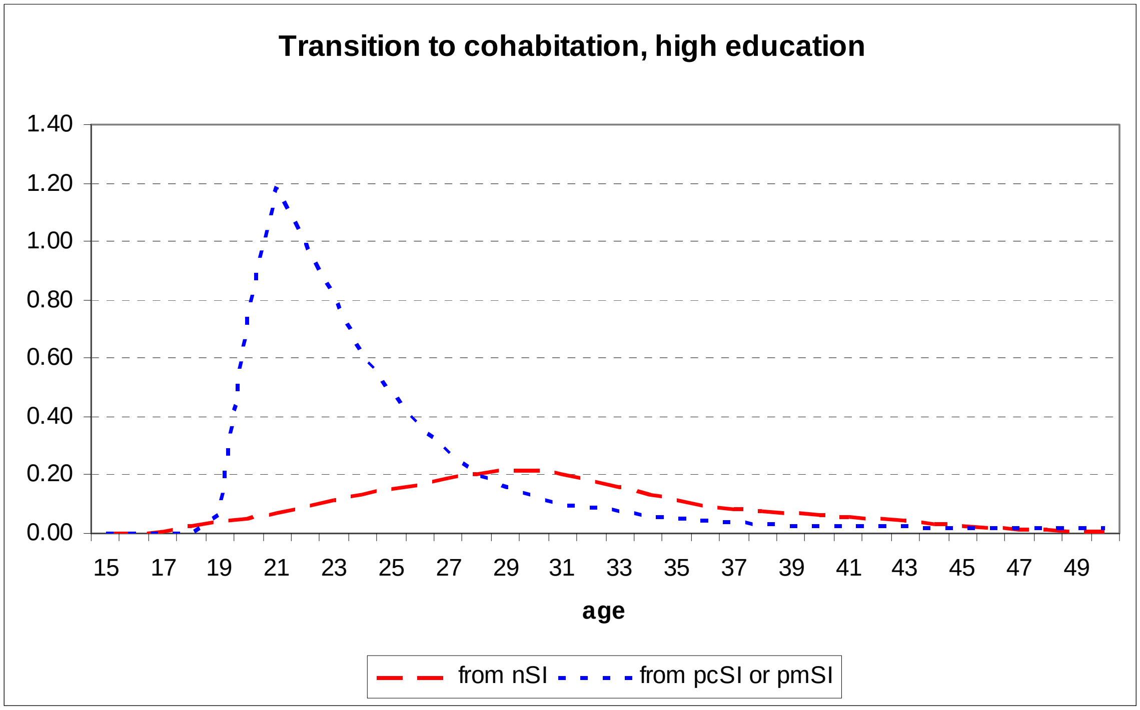


Figure 43 Transitions to cohabitation, high education



3.3.2 Underlying assumptions

The total number of different age profiles in the full state space is 108 (18 partnership transitions x 2 levels of education x 3 fertility levels). As not all interactions have been estimated, the total number of different age profiles used in the simulation is less. In a number of cases we assumed similar patterns for two or more transitions. For instance, while different fertility patterns were estimated for married and cohabiting women, the same fertility rates were assumed for first and second or higher order marriages or cohabitations. Therefore, even though a lot of details have been included in the simulation, there are still several underlying assumptions. Examples are

- All persons living at the parental home are not married and have no children
- Persons living at the parental home will not give birth
- All married persons live together with a partner
- Persons living at the parental home that enter into marriage also start to live with a partner
- Return to the parental home is not possible
- After divorce or dissolution of a cohabitation, a woman will first live without a partner before she starts another cohabitation or marriage

Finally we have to bear in mind that the rates are based on a retrospective survey covering women born between the 1940s and the 1980s. The transition rates therefore do not reflect a projection or forecast of current 15-year old women.

3.4 Simulation results

For the results we focus on the average number of children and the mean age at first birth. To have a closer look at postponement we have made a further distinction between those mothers that get their first child before the age of 30 and those who get their first child at age 30 or later.

Looking at the average number of children, the outcomes of the simulation are in line with what we may expect from the study of Statistics Netherlands: a slightly higher number of children for low educated women, whilst for both groups the average number is around 2.2. For low educated women this is somewhat higher, while for high educated women, it is somewhat lower (see Table 20).

Adding the dimension of partnership dissolution results in a significant difference between those mothers that remain in the same relationship and those that experience a partnership dissolution for both groups of education. Furthermore, it increases the differences between low and high educated women.

Table 19 Average number of children for mothers, by education and partnership dissolution

Average number of children	Partnership dissolution	
	No	Yes
Low education 2.29	2.46	1.80
High education 2.13	2.33	1.53

Table 21 shows the mean age at birth. As expected the simulation resulted in a higher mean age at birth for high educated women compared to low educated women. In this case, however, for both groups of education differences are relatively small between those women that do experience a partnership dissolution and those that do not. Based on this result, we might conclude that the experience of a partnership dissolution mainly affects the final number of children and only to a lesser extent the timing of the first birth.

Table 20 Mean age at first birth by education and partnership dissolution

Mean age at first birth	Partnership dissolution	
	No	**Yes**
Low education **29.1**	**28.9**	**29.9**
High education **31.2**	**30.8**	**32.4**

To have a closer look at the association between education and postponement, we divided the group in two subgroups: the first consists of women that gave birth before age 30, and the second of those that gave birth at age 30 or higher (see Table 22).

Almost 60 per cent of the low educated mothers gave birth to their first child before the age of 30, while for the high educated women this is somewhat less than 40 per cent. Between the groups of young and old mothers, differences between educational background seem to diminish. In both groups, low educated women are slightly younger when they enter motherhood, but the average number of children for high educated women is highly similar to that of low educated women. High educated women that become mother before the age of 30 even get slightly more children than low educated women (2.88 versus 2.73). Old mothers, on the other hand, probably will not reach the expected number of 2 children per woman; they get on average 1.7 children.

Table 21 Mean age at birth and average number of children by education and age of the mother

all mothers First birth before age 30	% of mothers	Mean age at first birth	Average number of children
Low education	**58%**	**26.2**	**2.73**
High education	**37%**	**27.0**	**2.88**
First birth at age 30 or later			
Low education	**42%**	**33.1**	**1.70**
High education	**63%**	**33.6**	**1.68**

Based on the simulations we may conclude that

- High education has a large effect on postponement which eventually leads to lower numbers of children
- Partnership dissolution has a small effect on postponement, but does have a significant effect on the ultimately level of children of mothers
- Unobserved heterogeneity plays a role: within the groups of 'young' and 'old' mothers, differences between low and high education diminish
- Although low educated mothers enter motherhood on average at younger ages than high educated mothers, high educated mothers that get their first child at young ages on average get similar number of children as low educated mothers that get their first child at young ages
- The experience of a partnership dissolution significantly reduces the ultimately level of children of mothers
- Nevertheless, mothers that experience a partnership dissolution (either before or after they enter motherhood) still might reach the average number of two children per woman if they enter motherhood at young ages

4 Conclusion and discussion

The aim of this case study was to illustrate the use of the MicMac software. We tested the model in the field of fertility and living arrangement. Based on data for the Netherlands, we first ran a macro and micro simulation with parity-specific fertility rates. We illustrated how to estimate parity-specific fertility rates and demonstrated several output options. In a second more extended example we simulated life courses for women from the age of 15 to 50, taking into account their level of education, partnership status and fertility career. In this extended example we distinguished between four different states of partnership: living at the parental home, living without a partner (either with, or without being previously married or cohabiting), cohabitation and marriage. For cohabitation and marriage, we distinguished first and higher order partnerships. The extended example clearly shows that even adding a limited number of additional characteristics to the model, significantly increases the complexity and data requirements of the simulation.

The results shown in this case study are only a limited selection of all output possibilities. As MicMac stores all simulated individual life courses in output files (all events and timing of events), the output options are almost unlimited. For the extended example, for instance, we also could pay attention to more detailed partnership life courses, to childlessness and birth intervals. One option is to distinguish between women that experienced a partnership dissolution before they gave birth and thereafter. Or we can look at the (expected) total number of partnerships. As there are considerable differences between childlessness of low and high educated women another interesting question is to study the effect of increased levels of educational attainment on childlessness and the final number of children. Whether postponement has been compensated, at least partly, by recuperation, can be studied by looking at birth intervals.

By running several scenarios in which one by one some of the transition rates will be changed, MicMac can be used for impact analyses. What will happen for instance if high educated women will get their first child on average one year earlier? Apart from analyzing the impact of these isolated changes, we also can study the impact of changes in some of the detailed transitions on aggregate output measures such as the total fertility rate. For macro analyses at country level, for instance, we can use the TFR and mean age at first birth to set the fertility assumptions. Given the more detailed model for the micro simulation, the assumptions for Mic are set on a much lower level. The input for Mac, the TFR and mean age at first birth for the total population, therefore can be based on the aggregated outcomes of the more detailed analyses for Mic.