Pilot short-term population projections (2007-2015)

Methodology

INSTITUTO NACIONAL DE ESTADISTICA

Contents

1. Introduction

This pilot exercise in short-term projection of the resident population of Spain is based on the "components method". Data for the basic demographic components – mortality, fertility and migration – and for the resident population in a given geographic area are processed on the basis of certain assumptions about how their growth and age structure will evolve, in order to produce population figures for later dates.

The projected figures for births, deaths and migrations relying on those assumptions are later compared with observed figures whenever new data become available. Projected populations will be compared with the observed data produced by every new census or population count. The annual updating of short-term projections – for which this exercise is a pilot test – will enable us to adjust projected figures to observed figures on the basis of the latest developments in demographic phenomena.

Retrospective analysis of each phenomenon and our assumptions about their future development enables us to estimate specific fertility rates by age group, projected mortality tables for the entire projection period, and foreign migratory flows for the period. Hence, by applying survival probabilities to the population by baseline age as at 1 January and to flows of births and immigrants for each year, we can produce the number of survivors broken down by age at the end of that year. As a result, we garner resident population figures broken down by sex and simple age (up to an open age group of "100 years and above") as at 1 January of each year in the projective period.

Specifically, if I = sex, J = age and K = year, we have:

$$P_{i,j,k} = (P_{i,j-1,k-1} + PEX_{i,j-1,k-1}) * T_{i,j-1,k-1}$$

where $P_{i,j,k}$ is the resident population figure of sex i, age j at 1 January of year k; $PEX_{i,j-1,k-1}$ is the net inbound foreign migration flow of sex I and age j during year k-1; and $T_{i,j-1,k-1}$ is the projected survival probability during year k-1 for an individual of sex I and age j-1 as at 1 January of year k-1.

2. Baseline population

The baseline population figures by sex and age are drawn from our present best estimate of the resident population as at 1 January 2007 according to the *Population Now-Cast*; our projections are thus necessarily consistent with that estimate.

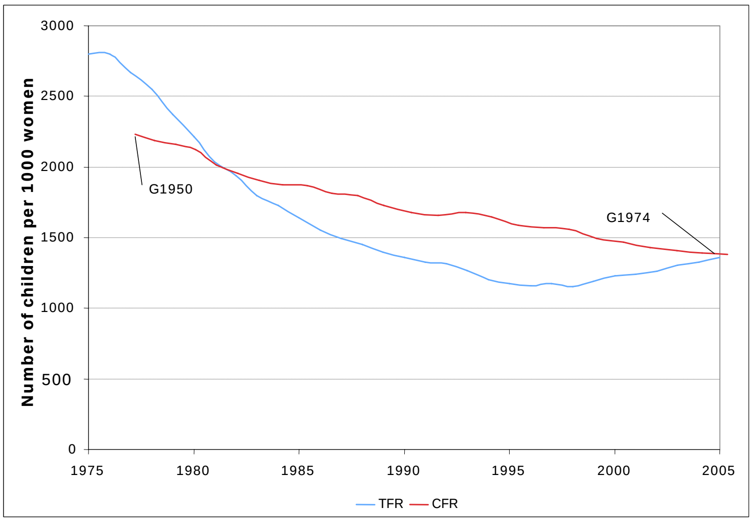
3. Fertility analysis and projection

3.1 Analysis of fertility change

(a) Change in period and cohort fertility

Chart 3.1 shows that over the past few decades fertility declined both in cross-section (TFR) and with respect to cohorts (CFR) up to 1996. TFR then underwent a slight recovery which holds to this day, but the downward trend of cohort fertility persists. The reversal of trends in TFR and CFR from 1996 onwards translates into a convergence of the two indicators, which should have drawn level in 2005. "Should have", because the CFR values for women born after 1960 increasingly converge with those for the 1974 cohort: the former were aged 44 and the latter were aged 30 in 2005, the last calendar year for which information is available on fertility by age.

Chart 3.1. Change in the total fertility rate (TFR) and completed fertility of cohorts (CFR) in Spain over the period 1975-2005



Source: NPC and population by sex and age, inter-census estimates to 2001 and INE population projections thereafter. TFR is the total fertility rate. CFR is the completed fertility of cohorts. From the 1960 cohort onwards, part of the fertility rate by age is estimated by the process described in section 2. The value of CFR for each year relates to the cohort reaching its mean age at childbearing, $t = g + m_g$, where g is the birth year of a cohort and m_g is its mean age at childbearing.

The comparative progress of TFR and CFR from 1975 to the present has undergone three major phases. First, from 1975 to 1981, estimated TFR values were above CFR values. In 1982, the two indicators drew level, and a new phase began, from 1982 to 1996, of gradual divergence. Now, TFR started to fall below CFR; in 1996, when the gap was greatest, CFR was 36% higher than TFR. In the third phase, from 1996 to the present, change moved in the opposite direction, with the two indicators drawing closer, with a convergence to presumptive equality in 2005.

These three phases of varying progress of period fertility and cohort fertility are accounted for by the change of pace and change of sign of variation in the mean age at childbearing. Ryder (1964) and, from a different standpoint, Bongaarts and Feeney (1998), have shown that the differences between period fertility (TFR) and cohort fertility (CFR) can be explained by a relationship of the following kind:

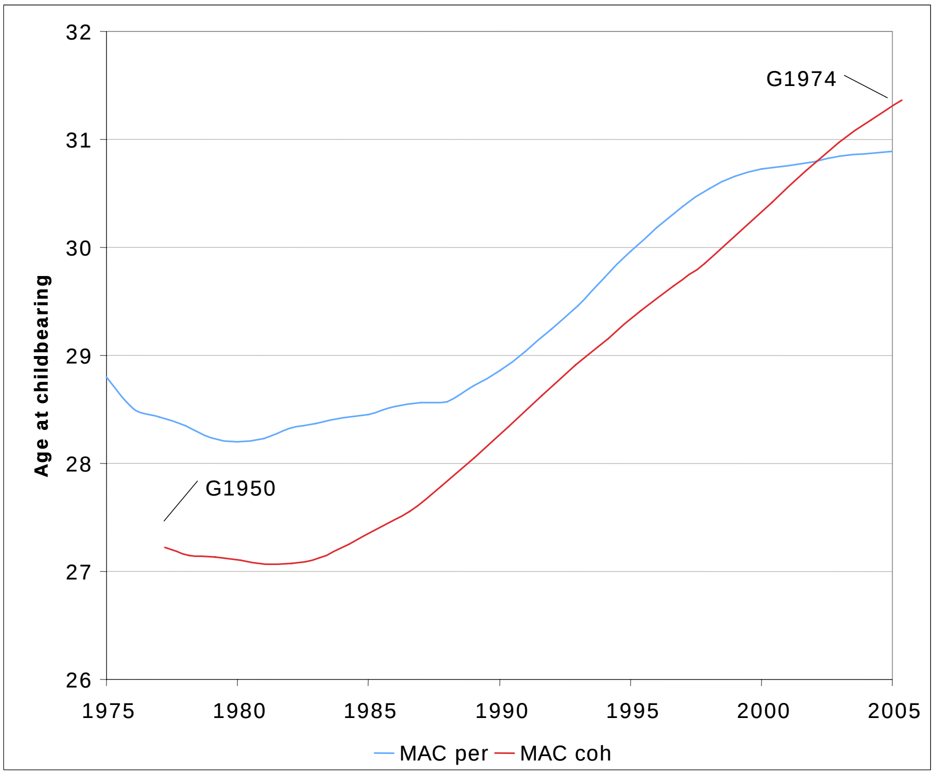
$$ISF_{g+m_g} \cong DF_g.(1-\Delta m_g)$$

where m is the mean age at childbearing of a cohort, Δm is its annual variation and g is the birth year of a cohort.

This means that when the mean age at childbearing of a cohort varies, the two indicators move apart. A similar relationship holds if the differentiating factor between the indicators is the variation in the period mean age at childbearing.

If we look at the values of the two average childbearing ages in chart 3.2, we find that in the first phase TFR values exceeded CFR values, associated with declines in the cross-sectional and the cohort mean ages: this agrees with the above formula. The second phase, in which CFR values rise above TFR values and the gap between the two indicators widens, is associated with a rising rate of increase of both the period and the cohort mean childbearing ages. The third phase, starting around 1995 and involving convergence of TFR and CFR, entailed a gradual slowing of the increase in period mean childbearing age. But this time parallel progress broke down, and the rate of age increase did not slow down in the same way for cohorts. The breakdown in parallel development between period and cohort childbearing ages is explained by the effects on fertility of foreign immigration, as we shall discuss later.

Chart 3.2. Development of period and cohort mean age at childbearing, 1975-2005

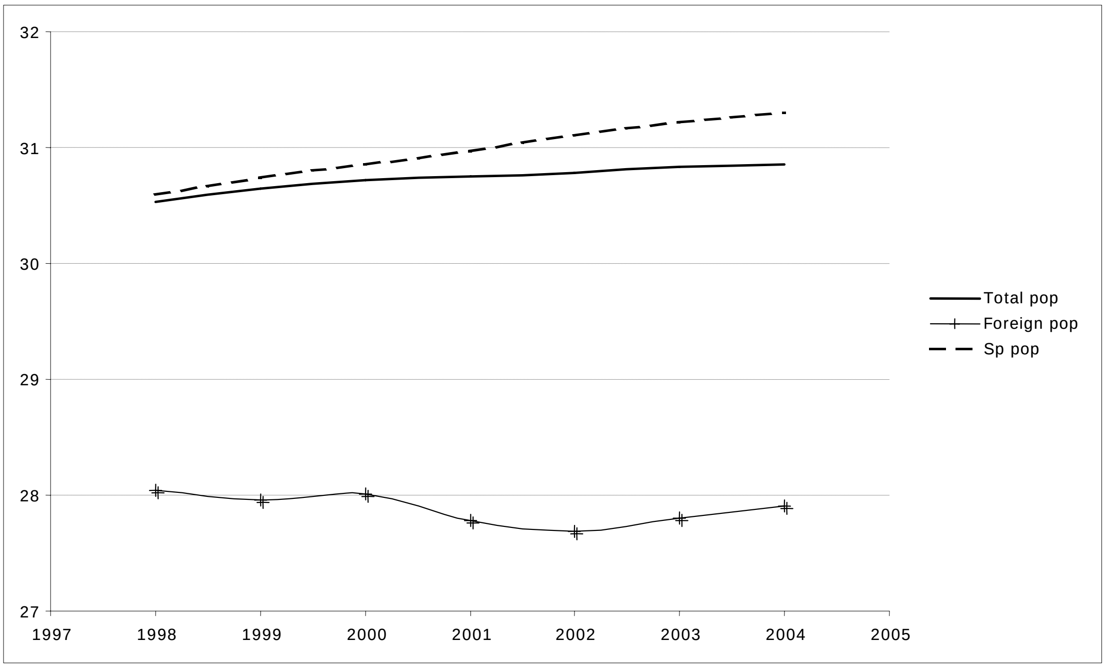


Source: NPC and population by sex and age, inter-census estimates to 2001 and the central assumption underlying INE population projections thereafter. MACper is the period mean age at childbearing and MACcoh is the cohort mean age at childbearing. As shown in the previous chart, the fertility rates by age of cohorts post 1960 increasingly converge. Also as in the previous chart, the mean age at childbearing of cohorts appears in the year in which women reach this age at childbearing.

(b) Effects of foreign migrants' fertility on the development of total fertility

Chart 3.3 shows that a noteworthy effect of the recent arrival in Spain of a large number of immigrants is that in recent years the increase in overall mean age at childbearing has slowed down, since foreign immigrant women generally bear children several years earlier than Spanish women. Spanish women's mean age at childbearing continued to rise rapidly in the recent past, so the recent slowdown in the increase of overall mean childbearing age is accounted for largely by a change in the make-up of the female population. However, the rate of increase of Spaniards' childbearing age has slowed appreciably. The annual increase in mean childbearing age across the total population remained above 0.2 years throughout the 1990s, but was only 0.03 years over the period 2000-2005. The annual increase in this recent period for Spanish nationals was 0.1 years: clearly higher than the increase for the total population, but only half the increase for the total population over the 1990s.

Chart 3.3. Change in mean age at childbearing in Spain over the period 1997-2004 for the total population and for Spanish and foreign nationals

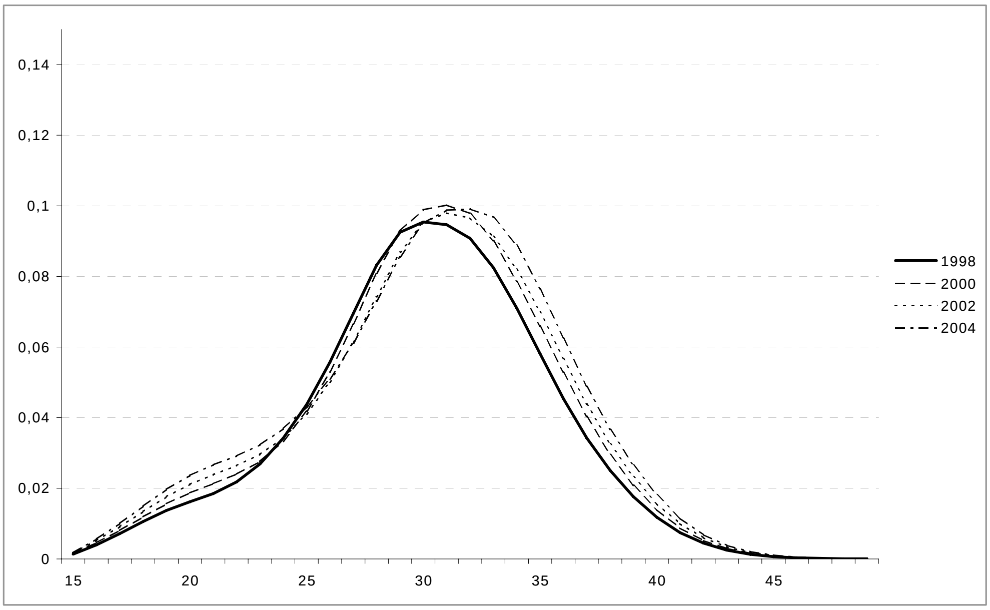


Source: NPC and *Padrón Continuo* population register. Population register data are used instead of census data because only the former are broken down by nationality.

The effect of the arrival of women with a younger fertility pattern can be seen likewise in the gradual change in fertility curves for ages under 30 years. Chart 3.4 shows a twofold trend in fertility rates by age: there is a rightward shift, given the ongoing deferral of childbearing age, and a gradual swelling at around age 22, given the growing presence of foreign women following an earlier fertility schedule.

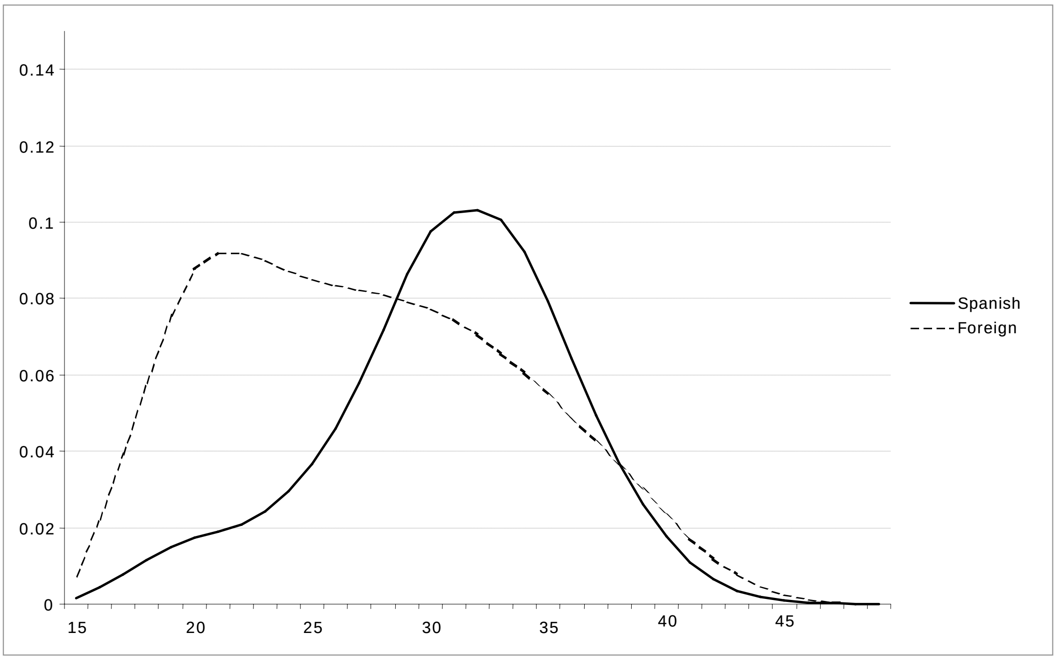
The difference in the pattern by age is all the clearer on direct comparison of the fertility rates by age of the two groups of women, as shown by the curves in chart 3.5.

Chart 3.4. Fertility rates by age for the total population. Spain, 1998-2004



Source: NPC and *Padrón Continuo* population register.

Chart 3.5. Fertility rates by age in Spain in 2004, for Spanish and foreign women



Source: NPC and *Padrón Continuo* population register.

We can now explain the divergence shown in chart 3.2 in the recent history of period and cohort mean ages at childbearing. Cohort mean age at childbearing was rising steadily, whereas period mean age at childbearing started to rise far more slowly from around 1998 onward. This is the upshot of increased fertility rates among women aged under 30 owing to the inflow at that time of female immigrants. The rise in fertility rates was particularly evident among cohorts born after 1975; the intensity and schedule of fertility of older cohorts was far less affected by recent foreign immigration.

(c) Change in fertility by major nationality groups

Table 3.1 gives an idea of the differences in fertility between Spanish and foreign nationals. Values are computed on the basis of figures drawn from the *Padrón Continuo* population register, which breaks down the population by nationality. Total population figures according to the *Padrón* are higher than inter- and post-census estimates. This is why the TFR values in the table are slightly lower than those calculated earlier. The main point of interest is that foreign women's fertility is generally 30 to 40% higher than Spanish women's fertility.

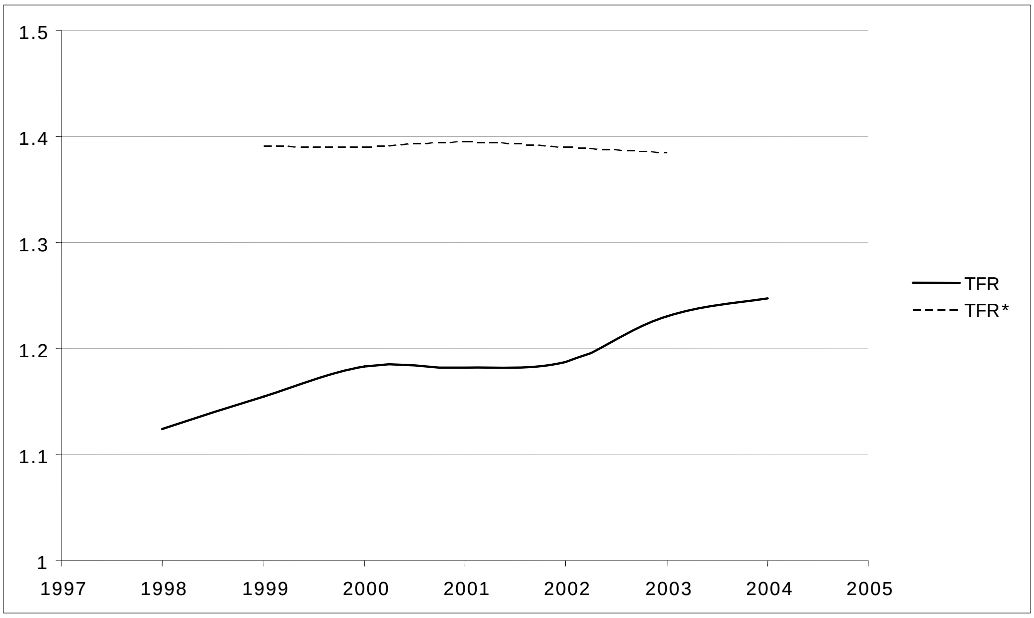
Table 3.1: Change in TFR in the period 1996-2004, by major nationality group

	1997	1998	1999	2000	2001	2002	2003	2004
North Africa	3.74	4.07	3.90	3.72	3.43	3.29	3.34	3.49
Rest of Africa	3.32	3.75	3.54	3.29	2.70	2.41	2.59	2.50
Central America	1.91	1.90	1.84	1.61	1.44	1.31	1.35	1.27
North America	2.86	2.56	2.30	2.04	1.80	1.52	1.48	1.22
South America	1.89	2.09	2.23	1.77	1.64	1.60	1.53	1.46
Asia/Australasia	2.88	2.78	2.71	2.59	2.30	2.20	2.04	2.16
Mediterranean Europe	1.82	1.58	1.51	1.55	1.43	1.22	1.15	1.12
Western Europe	1.41	1.33	1.29	1.29	1.21	1.12	1.17	1.12
Rest of Europe	3.00	3.31	3.03	2.19	1.69	1.53	1.51	1.37
Spain	1.14	1.13	1.16	1.19	1.19	1.19	1.23	1.25
Overseas	2.26	2.34	2.32	2.10	1.87	1.75	1.72	1.68
Total	1.16	1.15	1.18	1.21	1.22	1.23	1.27	1.29

Source: NPC and *Padrón Continuo* population register.

We pointed out earlier that the mean age at childbearing of Spanish nationals was increasing, while for foreign nationals it held mostly stable (chart 3.3). To compare fertility across the two groups more suitably, we applied the Bongaarts and Feeney adjustment (1998) to the fertility rate values by birth order for Spanish women to calculate a TFR series that, all else being equal, is free of the effects of age-specific variance (chart 3.6). The fertility of Spanish women held constant in recent years at around 1.4 children per woman. This analysis shows that the fertility gap between Spanish and foreign women is not as wide as direct comparison of TFR values suggests – around 25% of the fertility of Spanish women.

Chart 3.6. Change in TFR in Spain from 1998 to 2004, with and without adjustment for variation in age at childbearing by birth order, for Spanish women



Source: NPC and *Padrón Continuo* population register.

3.2 Fertility assumptions and projection method

The assumptions underlying our short-term fertility forecasts were:

(a) The intensity of total fertility will rise slightly in coming years, primarily as a result of the increased significance in total fertility of foreign women. The cohort fertility of Spanish women will remain unchanged until 2015, and intensity will hold steady at around 1.4 children per women, the value observed for the cohort born in 1974 and confirmed by application to recent TFR values of the Bongaarts-Feeney adjustment. The TFR for foreign women in the recent past was around 1.8 children per woman, but this is probably below the real value, because the *Padrón* register overestimates the number of individuals, and, moreover, most resident foreign women arrived only recently: the disruption that migration implies is likely temporarily to have decreased their fertility. The short-term rise in fertility for all women is assumed to spring chiefly from a composition effect, with foreign women increasing their share of the total female population.

b) The increased proportion of foreign women will have the effect of reversing the deferral of cohort mean age at childbearing. As discussed earlier, Spanish women's mean age at childbearing continues to rise, and this trend is reflected in the development of cohort mean age at childbearing. But the increased significance of foreign women, whose mean age at childbearing is about 3 years less, will slow down the rise in childbearing age across the total population and eventually bring it to a halt.

Given these two assumptions, our general method of forecasting was as follows:

a) We modelled the recent past of cohort fertility rates by age and birth order.

We computed cohort fertility rates using natural population change data for 1975 to 2005. We then used these rates to reconstruct the fertile lives of cohorts born from 1925 to 1992 – but always incompletely, because we only have rates for each cohort up to 31 years of age. The rates were calculated by birth order and grouped into rates for birth order 1 and birth order 2 and above. We modelled each age and birth order separately using the following log-linear formula, which relates rates at age x and birth order r to time logarithm t:

$$f(t,x,r) = a(x,r).\ln(t) + b(x,r)$$

Parameters a and b were estimated by ordinary least square analysis based on the last 9 observations for each simple age and the two birth-order groups. The estimated parameter values appear in the following table:

Table 3.2. Log-linear regression parameters for fertility rates in the period 1997-2005

Age	Birth order 1		Birth order 2 and above	
	A	B	A	B
14	0.165423442602989	0.250611640643518	0.000000000000000	0.030238762205851
15	0.391270945230179	1.082274901730800	0.007043379346856	0.034832715564835
16	0.809017102784319	2.911688627336040	0.047401267484593	0.156601975466314
17	1.126718028764470	5.867648026840640	0.113665695422323	0.440753972501790
18	1.904652582281920	8.447028727358860	0.295029368955720	0.943308086002149
19	2.504450064137090	10.714431326057000	0.525989717654509	1.673721148133560
20	2.643495499075300	12.140165782625800	0.647165747768053	2.834715827368230
21	2.509668964180500	13.357799167561400	0.747793419942462	4.156894027648030
22	1.949180292097290	15.509884108928900	0.697246472953115	5.906876992454080
23	0.934706816357626	19.153551718555100	0.101146666343556	8.679352132551200
24	-0.346338731492347	24.939720150897600	0.127555437995194	10.627743112667300
25	-1.464687069823180	32.430028398351500	-1.501326138280290	16.006876073966800
26	-3.056974442083300	41.936388449035200	-3.165574335892890	21.760505640016300
27	-2.457727457593110	49.199252171650100	-4.492429157011750	28.361740259187000
28	-0.891785096968102	54.272226725044900	-6.235342834638840	36.987300357979100
29	1.674011182224470	55.405157466860400	-7.375013119186030	45.708956034982500
30	6.028062600900510	49.263163937070500	-6.936845745902340	52.628649579461900
31	8.881538981113700	39.180362905810100	-5.540987435074730	57.038023623673200
32	9.745793203551670	29.815633747082200	-2.219584963430010	56.433909916130600
33	9.248670113595130	22.173037680434500	1.220391360516520	51.663077502130400
34	8.134598449447850	16.022798875725100	4.533546868535510	44.506326657534700
35	6.725177947578810	11.633779095945700	6.239718950626430	35.762105800754300
36	5.061976441308700	8.498245936167100	6.144826258888990	28.435826228284300
37	3.528098562709030	6.181287084980100	5.472541207329030	21.012435819119100
38	2.716363075220000	4.177715884164980	4.379635528566570	15.350559606354400
39	2.037682406350600	2.817176720764260	3.354175366227480	10.812211241272100
40	1.335912344794390	2.051948542062560	2.214921587892470	7.182309866509880
41	0.834616434252156	1.257697832381090	1.288307852820520	4.668618704118410
42	0.504181678476564	0.759864288380765	0.767380362443856	2.849350825247390
43	0.340717360199160	0.365447795350389	0.325148108829315	1.745359527884640
44	0.163245556651964	0.221373963056495	0.240946943484553	0.847062728854232
45	0.101342583640305	0.083758075633837	0.113036024119443	0.445741722184589
46	0.033992455899459	0.050936738071094	0.073058261899277	0.169361481796720
47	0.023353601279977	0.025209848474096	0.034086396565171	0.093410691308133
48	0.015185198867348	0.005371253574480	0.026799620438316	0.042046615855528
49	0.016859022391604	0.002865313403859	0.025255287417797	0.006414079757583
50	0.013263212161034	0.010255239826057	0.014179870773873	0.029976418296840

Note: Value of parameters a and b of linear regression of cohort fertility rates by age and birth order over the time logarithm. For each age were considered the 9 latest observations and a time index consisting of a series of values from 1 to 9.

b) This modelling exercise was the basis for completing cohort fertility to ensure realistic intensity results, given that the two assumptions on intensity change and the fertility schedule are formulated in period terms.

Cohort fertility rates by age and birth order were projected using the parameter a and b values estimated in the preceding step. The calculation formula was:

$$f(t+1,x,r) = \exp(\varphi(t)).\left(f(t,x,r) + a(x,r).\ln\left(\frac{t+1}{t}\right)\right) \quad [1]$$

A growth factor $\varphi(t)$ was introduced to the formula to account for the fact that the foreign population – with a higher fertility rate than the native population – has increasing significance in the development of total fertility. For the sake of simplicity, we elected to apply this multiplier to all ages. It would have been more accurate to consider the differences across the two groups in age-specific fertility patterns shown by chart 3.5, and adjust fertility rates on the basis of a changing fertility weighting factor by age for foreign and Spanish women separately. But this would have required our having available cohort fertility rates by age, birth order and major nationality group; these data are unavailable, because prior to 1996 the NPC statistic made no reference to mothers' nationality.

The formula for the growth rate over time is:

$$\varphi(t) = \exp\left(t\ .\ 0{,}0125\ .\left(1 - \left(\frac{t-1}{30}\right)\right)\right) \quad [2]$$

where t = 0 for 2004, 1 for 2005, etc.

The values produced by this formula are plotted in chart 3.7. The growth adjustment factor thus increases over time to 2020, and then declines to zero by 2035. The guiding principle of this approach is that the significance of foreign women among the fertile population will continue to rise, but at a slowing rate. It seems reasonable to presume that over the long term the fertility rates of the foreign and native populations will converge. The initial value of the growth parameter, 0.0125, was estimated on the basis of the following formulas:

$$ISF_t = (1 - p_t).ISF_{e,t} + p_t\ .ISF_{x,t} \quad [3]$$

Where TFR_t is the total fertility rate for year t, $TFR_{e,t}$ and $TFR_{x,t}$ are the total fertility rates, respectively, for Spanish and foreign women, and p_t is the proportion in year t of foreign women to the total fertile population (ages 15 to 45).

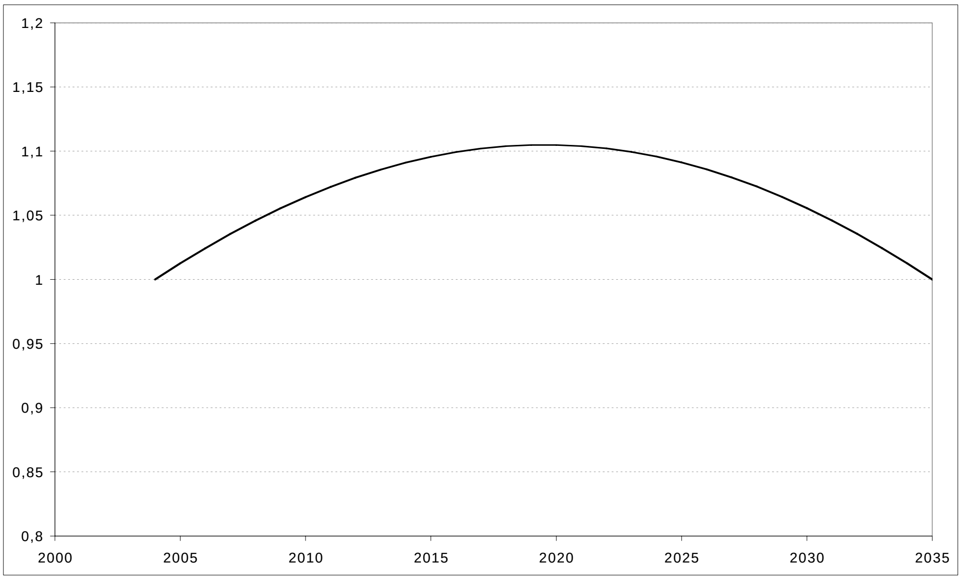
If we assume that the TFR for each nationality group remains constant over time, and the relationship between the TFRs for foreign women and Spanish women equals a factor k, we find that the rate of growth of overall TFR over time is equal to:

$$\frac{\Delta ISF_t}{ISF_t} = \frac{\Delta p_t}{p_t + \frac{1}{k-1}} \qquad [4]$$

The initial value of the TFR growth rate over time was obtained using the following values for the parameters of the above formula:

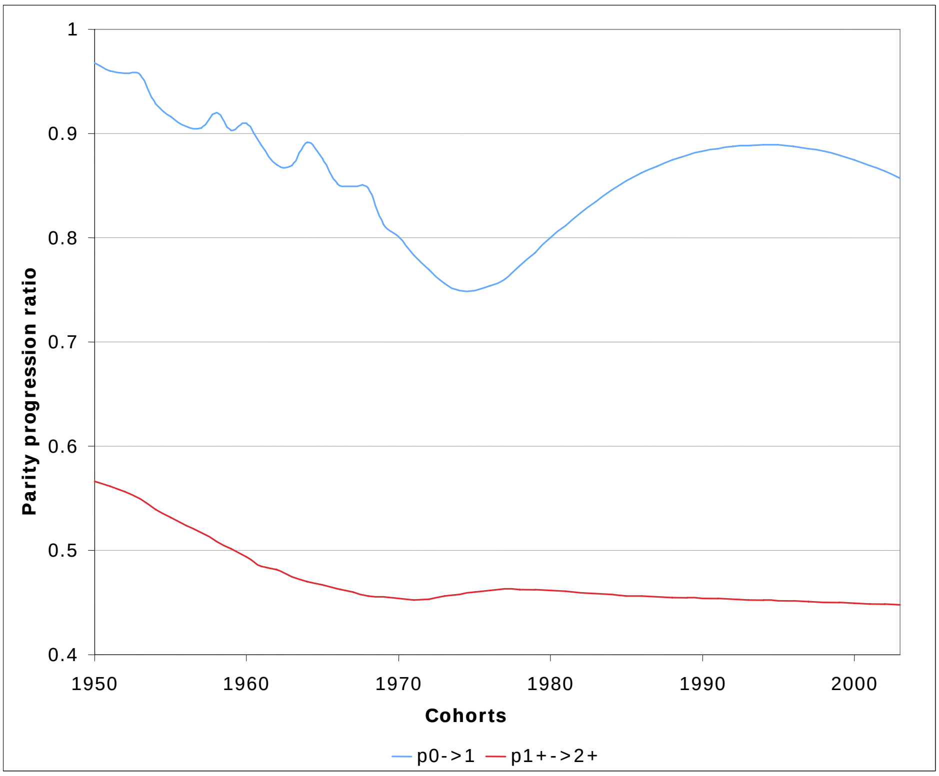
$$p_t = 13.5\%, \; \Delta p_t = 1.4\% \; k = 2$$

Chart 3.7. Change in the fertility increase factor associated with the significance of foreign women, 2004 to 2030



Formula [1] was applied to all ages and both birth-order groups, and rates were projected so as to produce full information up to the 2003 cohort. We went far beyond the strictly necessary time frame so as to use the data shown in chart 3.8 to evaluate the consistency of the results. We calculated two parity progression ratios for each cohort. The first indicates the proportion of women bearing at least one child, and its complement to 1 indicates the infertility level of the cohort. The second PPR is the probability, for women who have borne at least one child, of bearing a further child. We find that:

Chart 3.8. Parity progression ratios of cohorts, observed and projected data for cohorts born from 1950 to 2003



- For the first PPR, the maximum infertility value relates to the 1974 cohort, 25% of whom are childless. If we take into account the possibility of error in the NPC statistic in imputing birth order[1] (up to 5% of order 1 births could in fact be of a higher order), the real expected infertility level for this cohort is 30%. Compared to this very low level of the first PPR, and concomitant very high level of infertility, later development may seem surprising because, over the course of 20 cohorts to 1995, the level drops back down to close to 10%. This reflects two sources of change. First, an increase in the rates by age from age 30 onwards, given the continued deferral – though at a much slower pace – of Spanish women's age at childbearing; and an increase of rates at ages under 30, due to the increased significance of foreign women in the total female population. Nonetheless, the increase is somewhat anomalous for birth order 1, and is very likely due to the fact that birth-order imputation error is far higher for foreign women than for Spaniards. The fertility report cited above contains an estimate that over a third of birth-order 1 births to foreign women in fact belong to a higher order.

[1] *Informe sobre fuentes y metodología para la proyección de la fecundidad* ("Report on sources and methodology for fertility projection"), Centro de Estudios Demográficos [centre for demographic studies], May 2007.

- Family fertility for birth-order 2 and above stabilised, and women who have borne at least one child have a likelihood of around 45% of bearing a further child. For these birth orders, development figures are far more satisfactorily consistent.

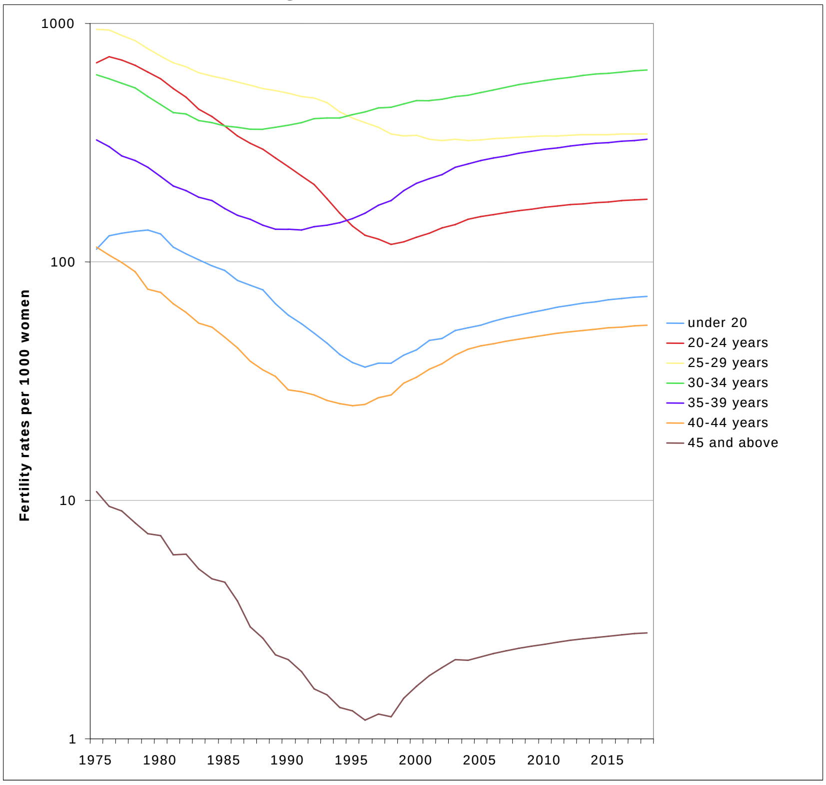
c) We converted cohort fertility rates into period fertility rates to produce fertility series up to 2016.

We first projected the rates to determined completed fertility up to cohort 2003, and then computed period rates so as to produce information for all ages up to 2016. Period rates were computed as the half-sum of rates at the same age for two consecutive cohorts.

3.2 Projection results

Our projection results are analysed in the range of charts presented below.

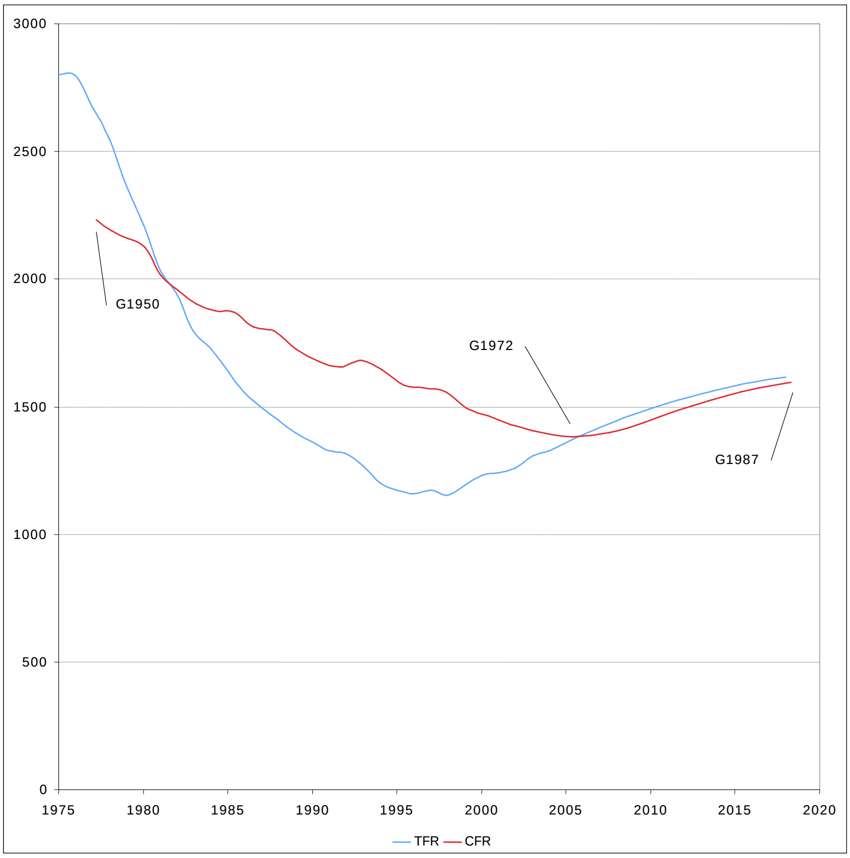
Chart 3.9. Fertility rates by five-year groups; observed data from 1975 to 2005, projected data to 2016. Semi-logarithmic scale



Source: To 2006, NPC, inter-census population estimates and anual population estimates.

Chart 3.9 shows observed and projected period fertility rates by five-year age group. We used a semi-logarithmic scale so as to compare increases over time and across age groups and, as an accessory benefit, to visualise more clearly the values for low-fertility age groups. Overall, there is a shift for all age groups from a declining phase to an increasing phase, but the years of minimum fertility are unmatched. The earliest upsurge occurs in the 30-34 age group around 1987; the latest occurs in the 25-29 age group in 2003. Rising fertility rates from age 30 onwards are the outcome of deferral in age at childbearing among Spanish women, and rising rates among age groups under 30 reflect the fertility of foreign women.

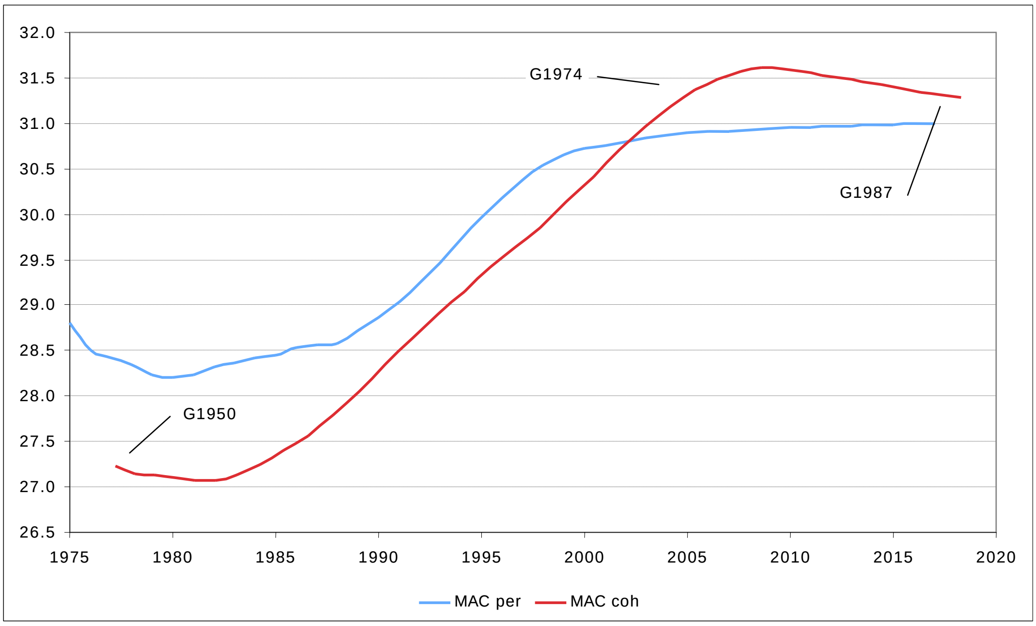
Chart 3.10. Comparative development of TFR and CFR; observed data from 1975 to 2005, projected data to 2016



Source: To 2006, NPC, inter-census population estimates and annual population estimates.

Chart 3.10 displays total intensity values for period fertility (TFR) and cohort fertility (CFR). The key result – consequent on the assumption that the increase in mean age at childbearing will come to a halt – is that from 2006 onwards TFR values could permanently surpass CFR values. The two fertility rates do not converge to equality because, as shown in chart 3.11, the increasing proportion of foreign women in the total fertile population gives rise to a somewhat unusual state of affairs. While this situation holds, period mean age at childbearing will continue slowly to climb, but cohort mean age will stabilise and then start to decline.

Chart 3.11. Development of period and cohort mean age at childbearing; observed data from 1975 to 2005, projected data to 2016



Source: To 2006, NPC, inter-census population estimates and annual population estimates.

Chart 3.12 shows change in the age-specific pattern of observed and projected period fertility. Up to 2005 the pattern shifted through two stages: from 1975 to 1985, fertility dropped vertically, without no substantial change in mean age at childbearing; then, from 1985 to 2005, the age-specific pattern underwent a rightward shift, reflecting the deferral of mean age at childbearing.

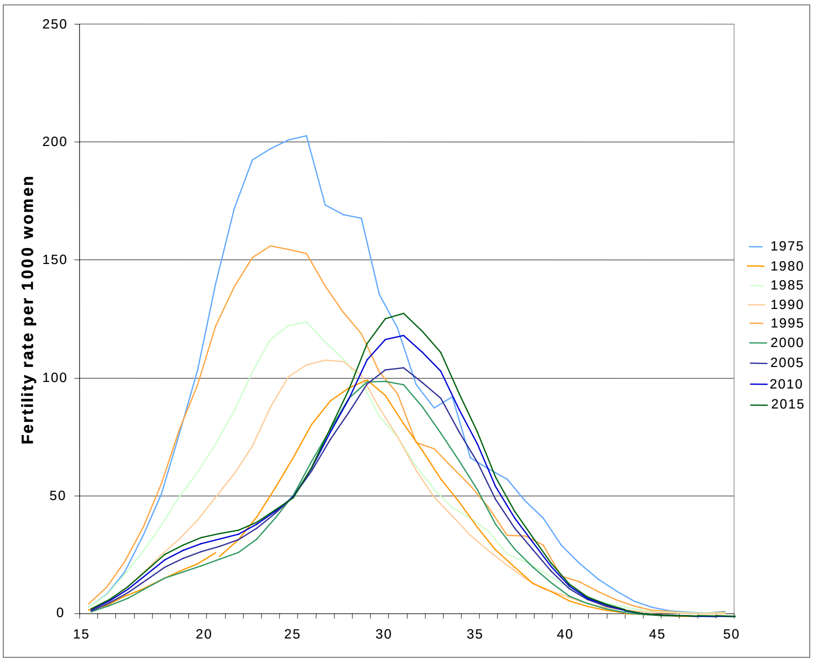
The projected fertility pattern evinces a threefold process, which chart 3.13 makes visible in more detail:

- an upward shift, reflecting increased fertility rates from age 28 onwards;

- a slight rightward movement, also from age 28, due to continued deferral of Spanish women's mean age at childbearing; and

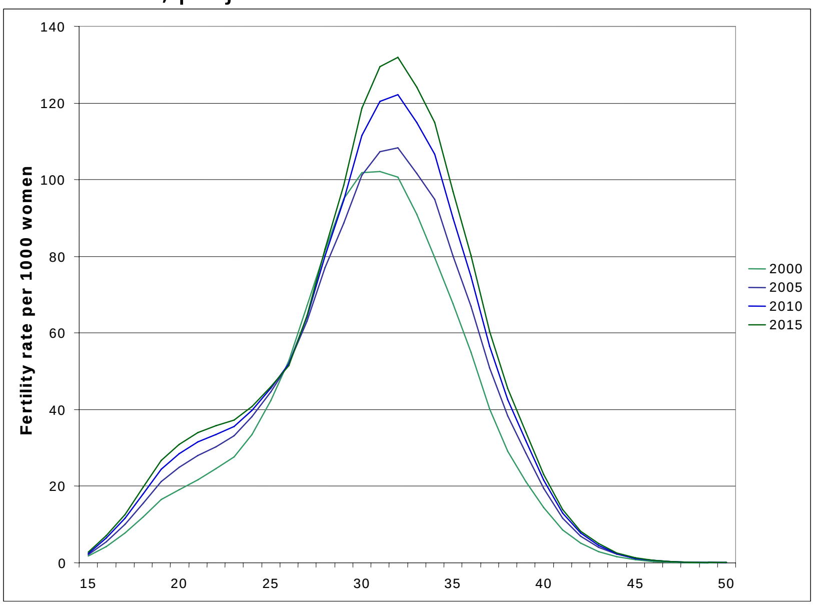
- an increase in the fertility bubble at age 22, owing to the greater proportion of foreign women.

Chart 3.12. Fertility pattern by age and period; observed data from 1975 to 2005, projected data to 2015



Source: To 2006, NPC, inter-census population estimates and annual population estimates.

Chart 3.13. Detail of the age-specific fertility pattern for the recent past; observed data from 2000 to 2005, projected data to 2015



Source: Observed data, NPC, inter-census population estimates and annual population estimates.

Table 3.3. Results of the projection exercise: fertility rates by simple age; observed data for 2005, projected data to 2016, per 1000 of each age

	2005	2006	2007	2008	2009	2010	2011	2012	2014	2014	2015	2016
14	0.068	0.010	0.025	0.039	0.052	0.065	0.077	0.088	0.099	0.109	0.119	0.128
15	2.018	2.080	2.139	2.193	2.245	2.293	2.337	2.379	2.418	2.453	2.486	2.516
16	5.376	5.522	5.659	5.787	5.907	6.019	6.124	6.221	6.310	6.392	6.467	6.535
17	9.987	10.225	10.447	10.656	10.850	11.032	11.200	11.356	11.500	11.630	11.749	11.854
18	15.351	15.745	16.114	16.459	16.782	17.083	17.364	17.623	17.863	18.082	18.281	18.460
19	20.935	21.476	21.981	22.455	22.898	23.311	23.696	24.052	24.380	24.681	24.955	25.201
20	24.701	25.310	25.881	26.415	26.915	27.381	27.814	28.215	28.584	28.921	29.227	29.501
21	27.772	28.414	29.015	29.578	30.104	30.594	31.049	31.469	31.855	32.207	32.524	32.808
22	30.127	30.736	31.308	31.842	32.341	32.805	33.235	33.629	33.990	34.316	34.608	34.866
23	33.055	33.542	33.998	34.425	34.822	35.188	35.524	35.829	36.102	36.344	36.554	36.732
24	38.293	38.719	39.119	39.491	39.836	40.152	40.439	40.694	40.918	41.110	41.269	41.396
25	44.593	44.823	45.042	45.244	45.427	45.588	45.724	45.835	45.919	45.974	45.999	45.994
26	51.887	51.885	51.886	51.884	51.873	51.849	51.807	51.746	51.662	51.554	51.419	51.257
27	62.905	62.960	63.016	63.064	63.099	63.115	63.107	63.074	63.011	62.916	62.788	62.626
28	76.434	76.630	76.818	76.990	77.138	77.258	77.345	77.394	77.404	77.371	77.294	77.170
29	87.794	88.262	88.704	89.114	89.485	89.813	90.092	90.320	90.494	90.611	90.669	90.666
30	99.779	100.855	101.865	102.808	103.680	104.477	105.198	105.841	106.402	106.882	107.277	107.587
31	105.704	107.263	108.726	110.093	111.364	112.538	113.613	114.590	115.466	116.242	116.915	117.485
32	106.942	108.924	110.783	112.521	114.141	115.645	117.033	118.307	119.464	120.507	121.433	122.243
33	100.814	103.013	105.072	106.999	108.799	110.474	112.028	113.460	114.772	115.965	117.037	117.990
34	94.391	96.729	98.918	100.968	102.884	104.672	106.334	107.872	109.288	110.583	111.756	112.810
35	80.033	82.233	84.292	86.220	88.025	89.710	91.280	92.738	94.084	95.320	96.446	97.464
36	67.162	69.040	70.797	72.443	73.984	75.424	76.765	78.010	79.161	80.219	81.184	82.056
37	51.100	52.575	53.955	55.249	56.459	57.590	58.645	59.626	60.532	61.366	62.128	62.819
38	38.455	39.597	40.665	41.666	42.603	43.479	44.296	45.056	45.759	46.407	46.999	47.537
39	28.803	29.665	30.472	31.228	31.936	32.598	33.216	33.791	34.322	34.812	35.261	35.668
40	19.506	20.081	20.618	21.121	21.593	22.033	22.444	22.827	23.180	23.506	23.803	24.073
41	11.716	12.060	12.382	12.683	12.966	13.230	13.476	13.705	13.916	14.111	14.290	14.451
42	6.967	7.173	7.365	7.545	7.714	7.871	8.018	8.155	8.282	8.398	8.505	8.601
43	4.105	4.218	4.323	4.422	4.515	4.602	4.682	4.757	4.826	4.890	4.947	5.000
44	2.224	2.289	2.351	2.408	2.462	2.512	2.559	2.602	2.642	2.680	2.713	2.744
45	1.061	1.094	1.126	1.155	1.182	1.208	1.232	1.254	1.274	1.294	1.311	1.327
46	0.577	0.594	0.610	0.625	0.640	0.653	0.665	0.677	0.687	0.697	0.706	0.714
47	0.271	0.279	0.287	0.295	0.302	0.309	0.315	0.321	0.327	0.332	0.336	0.341
48	0.123	0.129	0.134	0.139	0.143	0.148	0.152	0.155	0.159	0.162	0.165	0.168
49	0.116	0.121	0.126	0.131	0.136	0.140	0.144	0.147	0.151	0.154	0.157	0.160
50	0.068	0.071	0.074	0.077	0.080	0.083	0.086	0.088	0.090	0.092	0.094	0.096
TFR	1.351	1.374	1.396	1.416	1.435	1.453	1.469	1.484	1.497	1.509	1.520	1.529

4. Mortality analysis and projection

Mortality has recently taken on renewed significance in population projections, because of its effects on future demographic dynamics. Projections no longer work on the assumption that, beyond reduced infant and adolescent mortality, there was little room for gain. That argument has foundered on the evidence that average life expectancy has improved through sustained reduction of mortality at advanced ages. Increased longevity involves a greater number of individuals of each cohort surviving to increasingly advanced ages, thus aging the population pyramid from its apex; this will be a key determinant of the future development of the older population and of the changes in its internal structure.

4.1 Recent mortality trends

Decreasing mortality was one of the key aspects of the demographic dynamics of the twentieth century. Trends differed widely from country to country, and there arose a diversity of models of transition in terms of start time, intensity, duration and underlying causes. Spain, while falling within the western model, underwent a relatively swift transition, because the magnitude and intensity of the decline in mortality was compounded by its being concentrated in time. Over the course of the twentieth century, life expectancy for Spanish males lengthened by 42 years, and for Spanish females 47 years, and Spain reversed its position relative to other western countries in terms of longevity.

In the early twentieth century, the geography of life expectancy posited a sharp dichotomy between northern Europe and, to a lesser extent, continental Europe, where mortality declined early on, versus the countries of southern and eastern Europe. The unfavourable relative position of the Spanish population is exemplified by the fact that in 1910 only the inhabitants of eastern Europe, Portugal and Greece were less long-lived than Spaniards. In Italy, a country relatively similar to Spain in cultural and socio-economic respects, life expectancy was 6 years higher for men and 4 years higher for women. Spain's underdevelopment was all the more manifest in comparison with the countries of central and northern Europe. An average lifetime of 50 years for women was achieved in Sweden by 1870, and by 1900 in England and Wales and in France; Spain had to wait until the mid-1920s.

Despite Spain's initial backwardness and the effects of the Spanish Civil War and the harsh postwar years, life expectancy caught up with the European average by the early 1960s. This process of convergence followed the trend prevailing in most of the European countries that had started out from an unfavourable situation. That convergence broke up in the past few decades, with a new geographic dichotomy opening up between eastern and western Europe. Western European countries gradually entered a new stage of the epidemiological transition, with a reduction of chronic degenerative – chiefly cardiovascular – mortality, and a rise in survival at advanced ages. The reality of eastern Europe, however, has been more complex. Different paths were taken, depending on the social and economic aftermath of the collapse of the communist regimes and on countries' ability to adapt their social and healthcare systems to new health challenges and contexts.

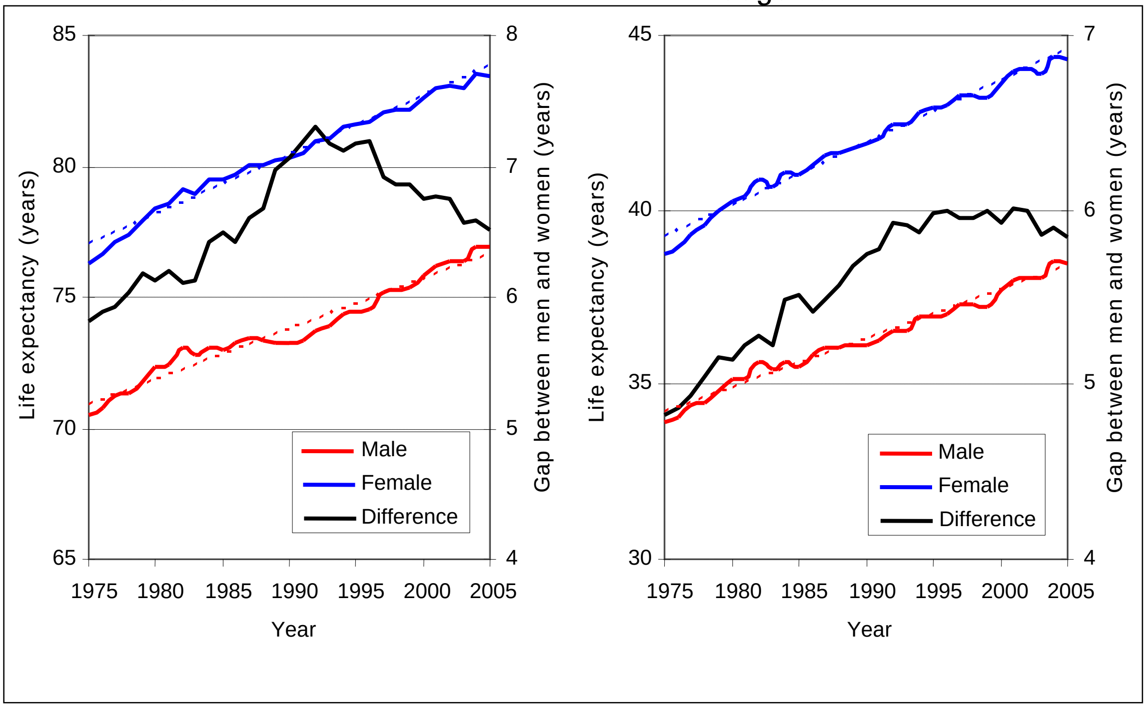
In the period 2000-2001, life expectancy for men across the EU-15 was 75.6 years, with a gap between countries of slightly more than four years, from Portugal's low of 73.4 years to Sweden's high of 77.5 years. In Europe, Spain lay behind only Sweden and Italy; in a world context, Spain was surpassed also by Canada, Iceland, Japan, Norway and Switzerland. Among EU-15 women, life expectancy was 81.6 years, ranging from 79.3 years for Danish women to 82.8 years for French women. Spanish, Canadian, Italian, French and Swiss women enjoyed the longest life expectancies, only about 1.5 years behind Japanese women.[1]

Since the 1980s, mortality in Spain has fully entered what is termed the "fourth phase" of the epidemiological transition. Here, the shift of mortality force to advanced ages means that any further decline in mortality rates has a decreasing effect on life expectancy at birth. From 1980 to 2005, male life expectancy rose from 72.3 to 77.0 years, and female life expectancy rose from 78.4 to 83.5 years, making for average annual increases of 0.19 and 0.20 years. Greater significance attaches to the upward – despite annual fluctuations – trend of life expectancy at advanced ages, as shown in chart 4.1 on the development of average remaining life expectancy at age 85. In Spain, gradual concentration of life expectancy gains at the end of life has been coupled with the distinctive behaviour of risks of death among the young male population. A powerful rise in young adult overmortality is the key fact explaining the stagnation of male life expectancy in the late 1980s and early 1990s. The later reversal of this factor also explains the major gains in male life expectancy in the more recent past, with an average annual advance of a little over 0.25 years from 1995 to 2005. Progress has been smoother and more sustained among women, owing to a lesser interplay of life-year losses and recoveries in early adulthood, with the key factor in this phase being the behaviour of survival at mature and advanced ages.

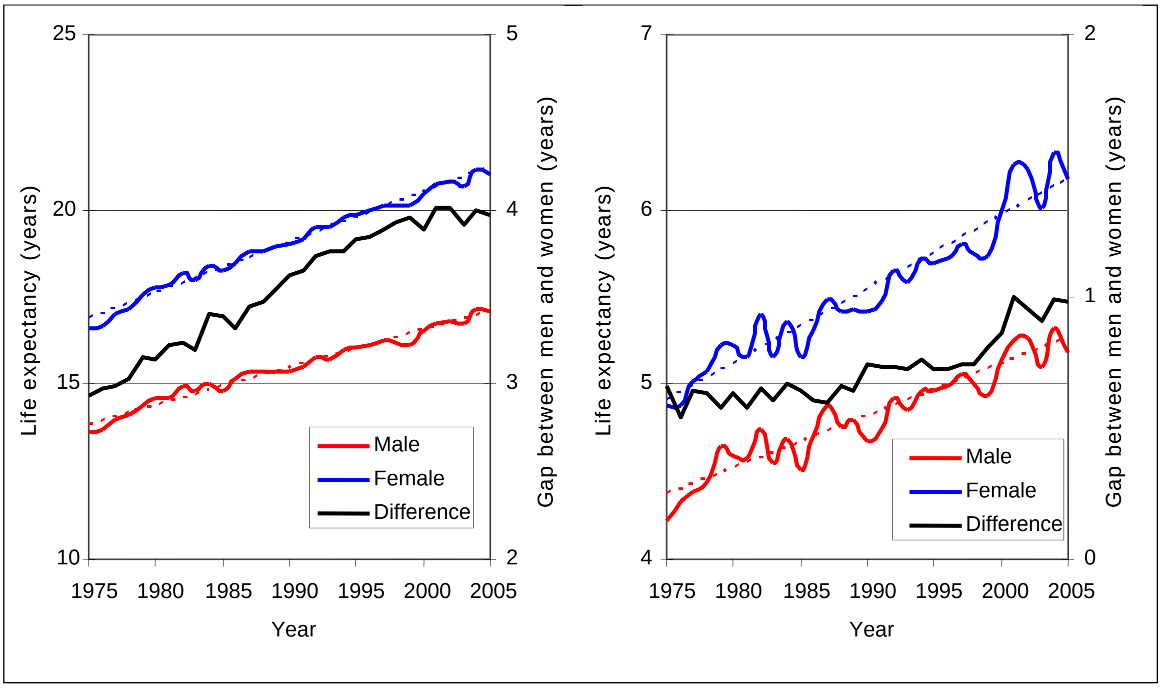
[1] The latest Eurostat data, with reference to 2005, place Spanish women in the European Union lead, with life expectancy of 83.9 years, followed by French women, with 83.8 years.

Chart 4.1. Life expectancy at various ages. Spain 1975-2005

At birth At age 40



At age 65 At age 85



The force now driving gains in life expectancy at birth no longer relates to the risks of dying in childhood or adolescence, but to events at maturity and in old age. To analyse mortality trends at the various stages of the life cycle, we used as an indicator truncated life expectancy between two exact ages, which expresses the potential years of life between the two ages for survivors at the initial age.[1] The decline in risks of death has led to increased potential years of life on an asymptotic trend approaching 100%, equivalent to an optimal health context, i.e., the absence of mortality in the age interval under consideration (chart 4.2).[2]

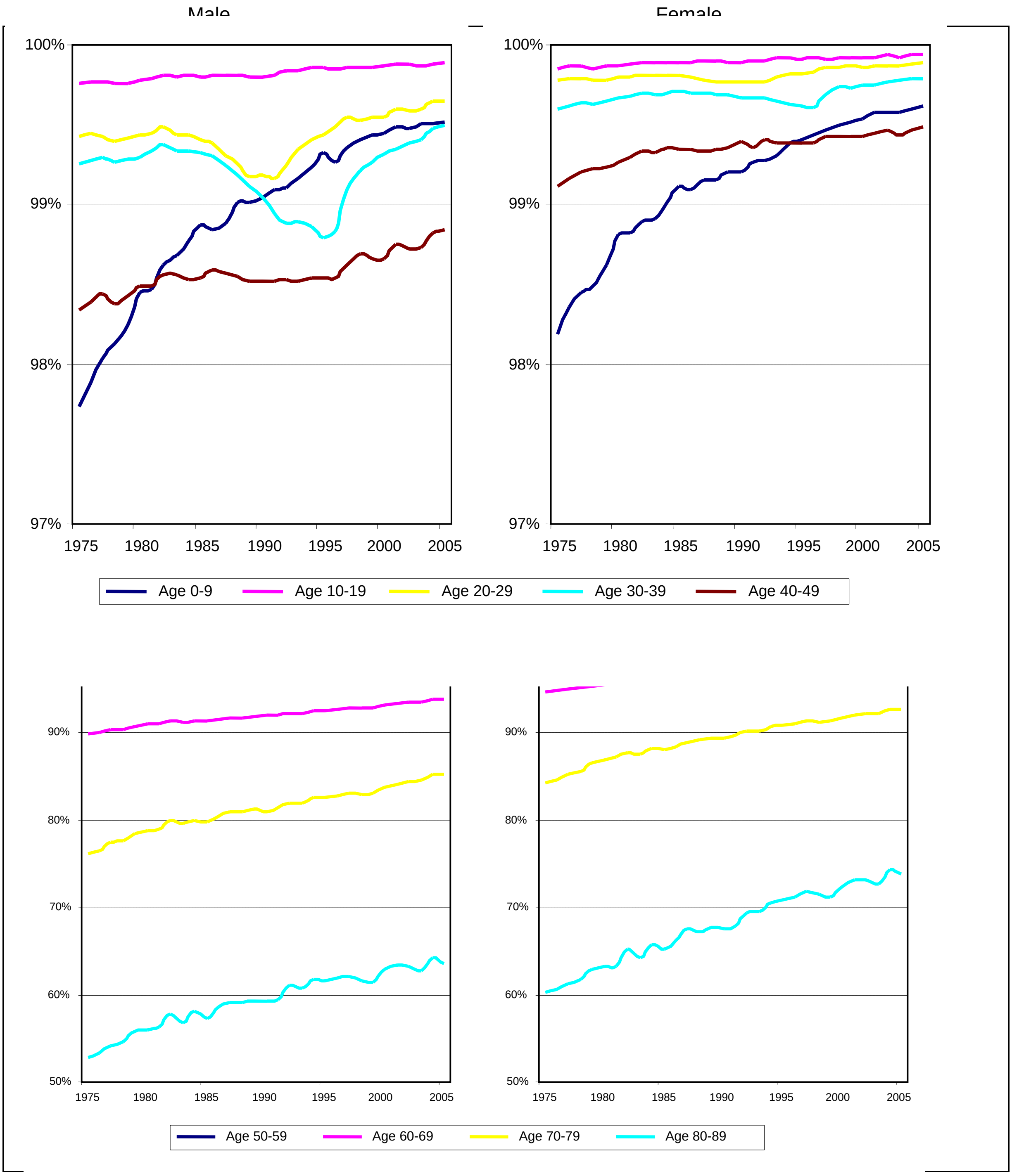
Analysis of change on potential years of life shows that from ages 0 to 10 a potential is achieved slightly above 99.5% for both males and females. This value, which is very close to optimum mortality, shows that the remaining improvement is scant, all the more so if we bear in mind that most deaths in the first year of life currently relate to endogenous disorders and congenital

[1] Life expectancy at birth, being an aggregate indicator of mortality conditions, is very much determined by risks of death in the early years of life. Use of average life expectancy at another age fine-tunes analysis but still does not permit accurate comparison in terms of stages of the life cycle, because it synthesises risks of death from that age to the end of life, and is not circumscribed to a given age range.

[2] We have simplified by assuming that deaths on the mortality table are uniformly distributed at each simple age, except those in the first year of life, for which we used the associated fraction of life years. The resulting value of truncated life expectancy was divided by the number of ages comprised by the interval of computation to produce a maximum level of reference. The value of such potential depends on the level of risks of death and is thus closer to the optimum in childhood and adolescence than at maturity and in old age. This indicator measures mortality within the age range irrespective of the number of individuals reaching such ages: the risks of death at earlier ages are disregarded.

anomalies which are harder to tackle. At young adult ages in the trajectory of potential years of life from 20 to 39 years, among men especially, there was a marked effect of increasing risks of death in the late 1980s and early 1990s, owing to AIDS, traffic accidents and drug-related deaths; the indicator recovered in the more recent past. At maturity and early old age, the indicator has gradually improved in the past thirty years until reaching the present level of over 95 percent for both sexes. The decisive aspect, however, has been the increase in potential for the oldest individuals from 1975 to 2005 in the region of 9 percentage points for both sexes in the age group 70 to 79 years, and, for the age group 80 to 89 years, of 11 points in men and 13 points in women. The charts show that men's potential is visibly below women's, and is today similar to the potential reached by women in the first half of the 1980s. These potentials demonstrate a sustained trend towards improved survival at advanced ages, though there remains significant room for further improvement, especially among men.

Chart 4.2. Potential years of life at various stages of the life cycle. Spain 1975-2005



4.2 Mortality assumptions and projection method

Our mortality projections considered both overall mortality, reflected by life expectancy at birth as a synthetic indicator of mortality conditions at all ages, and the age-specific structure or pattern of mortality. The mortality projection method combined an assumption about overall mortality, measured in terms of life expectancy at birth, and a range of assumptions on the future behaviour of risks of death at the various stages of the life cycle. We constructed the mortality scenario in three steps:

a) We projected aggregate mortality, measured in terms of life expectancy at birth, for every year in the period 2006-2050.

First, we established a normative value of life expectancy for 2050. The setting of that normative value connects to the debate surrounding longevity and maximum life expectancies in the population. Some writers[1] hold that the aging of the human body imposes a biological upper limit on further improvement, even if certain causes of detah, such as tumours or cardiovascular diseases, were eliminated; moreover, western countries are close to that ceiling. Other researchers, however, argue that in the coming decades a number of advancements in genetics and medical technology will enable us to tackle the underlying processes of aging and defer age at death by an increasingly significant margin.[2]

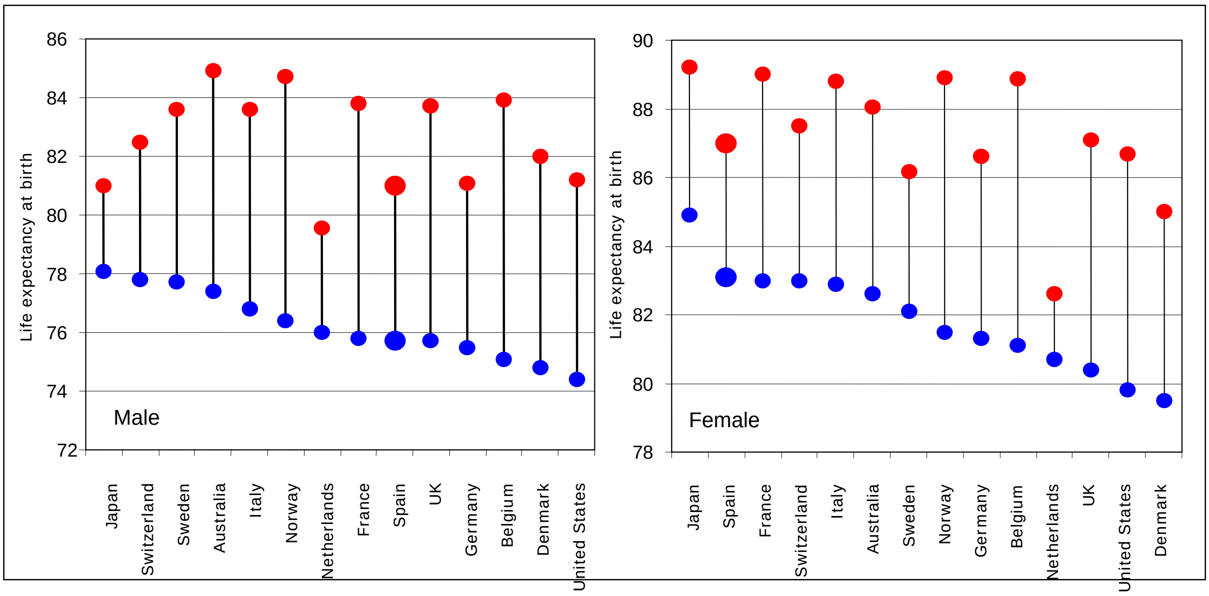
An examination of the core mortality assumptions underpinning population projections in western countries reveals the absence of clear agreement on the medium- and long-term levels of average lifetime of the population. The various countries' national statistical institutes posit expected gains for the coming five decades that are contrasting and largely independent from the baseline levels as at the start of this century (chart 4.3). INE's present mortality projection, especially for males, proposes gains in life expectancy which are relatively modest when compared with estimates in other European countries. In half of the western countries we have analysed, it is estimated that the average lifetime of men will by the middle of this century lie within a range of 83.5 to 85 years. The lowest forecasts are posited by the statistical bodies of Spain and Japan, at 81 years. The offices of national statistics of France and the United Kingdom, where values in 2001 were close to Spain's, expect gains of about 8 years from 2001 to 2050, while INE expects a gain of slightly over 5 years. For women, the most optimistic forecasts lie in the range 88-89 years, even in countries which presently behind Spain, such as Norway and Belgium. There are two highlight cases among the countries under review. In Japan, where trends differ widely by sex, the life expectancy gap is expected to widen from 6.8 years in 2001 to 8.2 years by 2050. In the Netherlands, the statistical office's assumptions are highly conservative, especially for women, who are forecast to attain an average

[1] Olshansky, S.J.; Carnes.; Cassel, C., L. and Pollard, J.N. (1990), "In search of Methuselah: Estimating the Upper Limits to Human Longevity." *Science*, vol 250, pp. 634-639.

[2] Oeppen,J. and Vaupell, J.W. (2002), "Broken limits of life expectancy." *Science*, vol 296, pp. 1029-1031.

lifetime in the mid-twenty-first century that is shorter than the average lifetime now observed in Spanish women.

Chart 4.3. Observed life expectancy in 2001, and life expectancy for 2050 estimated by the statistical offices of a range of western countries



Note: Where a national statistical office posits more than one scenario, we have selected the one designated by that office as its core or reference projection scenario. The blue circle represents life expectancy at birth as observed in 2001; the red circle represents life expectancy at birth forecast for 2050. Countries are placed in descending order of life expectancy in 2001. Source: *Experiencia de las oficinas de estadística de distintos países en relación con estimaciones y proyecciones, considerando tanto los aspectos técnico-metodológicos como los institucionales en relación con las disponibilidades de información y los resultados ofrecidos*, Centro de Estudios Demográficos, 2006.

Analysis of the latest trends in mortality by age, comparison of the hypotheses put forward by other statistical bodies and the discussion surrounding the upper limits on human lifetime have all contributed to our forecast scenario of a life expectancy of 83 years for men and 88.5 years for women by 2050. The forecast value for women is slightly below the highest estimates among western countries, being around 1.5 years less than the projections of the statistical institutes of France, Japan and Norway. For Spanish men, however, given the baseline negative differential at maturity and old age, our estimates lie within the lower middle range of the most widespread estimates in other western countries. In comparative terms, up to 2031 the forecast trajectory of women resembles the expectancy underlying INE's present population projection, but INE's assumption that the quotients subsequently stabilise means that in this scenario Spanish women's average lifetime is 1.5 years longer than INE's forecast for 2050. In men, the differences are more marked over both the medium and the long term; our scenario assumes a more favourable development of mortality at maturity and in old age, such that projected life expectancy at birth differs from INE's present forecasts by close to 1 year for

2031 and 3 years for 2050. The expectation of a drop in adult male overmortality makes for a contraction of the gap between sexes to 5.5 years by 2051.

This scenario rests on the following assumptions and conditions:

a) new diseases or disorders will not emerge;

b) at young adult ages risk factors will be gradually brought under control so as significantly to reduce preventable premature mortality;

c) healthier lifestyles will prevail, leading to lowered mortality in middle age and early old age, coupled with improved diagnosis and treatment of oncological diseases;

d) cardiovascular mortality will continue to evolve favourably; and

e) medical science will continue to make progress.

Having established normative life expectancies for 2050, we produced the figures for each year of the projected period by adjusting a logistic function to the data for the period 1960-2005. The function was adjusted by computing, first, the logits of the values observed from 1960 to 2005:

$$\operatorname{logit}(e_0^t) = \ln\left(\frac{e_0^{max} - e_0^t}{e_0^t - e_0^{min}}\right)$$

Next, we estimated parameters A and B of the regression straight line, and used them to compute the logits for each year of the projection period, under the constraint that the value for 2050 should agree with our normative assumption (chart 4.4). Finally, these values were converted into the associated life expectancies:

$$e_0^t = e_0^{min} + \left(\frac{e_0^{max} - e_0^{min}}{1 + \exp^{logit(e_0^t)}}\right)$$

Table 4.1 sets out the life expectancies forecast for each year in the period 2006-2050. The values produced for 2015, the horizon of the short-term population projection exercise, were 79.2 years for men and 85.4 years for women; for this time frame these figures are similar to those informing INE’s current population projection.

Chart 4.4. Observed and projected life expectancy. Spain, 1930-2050

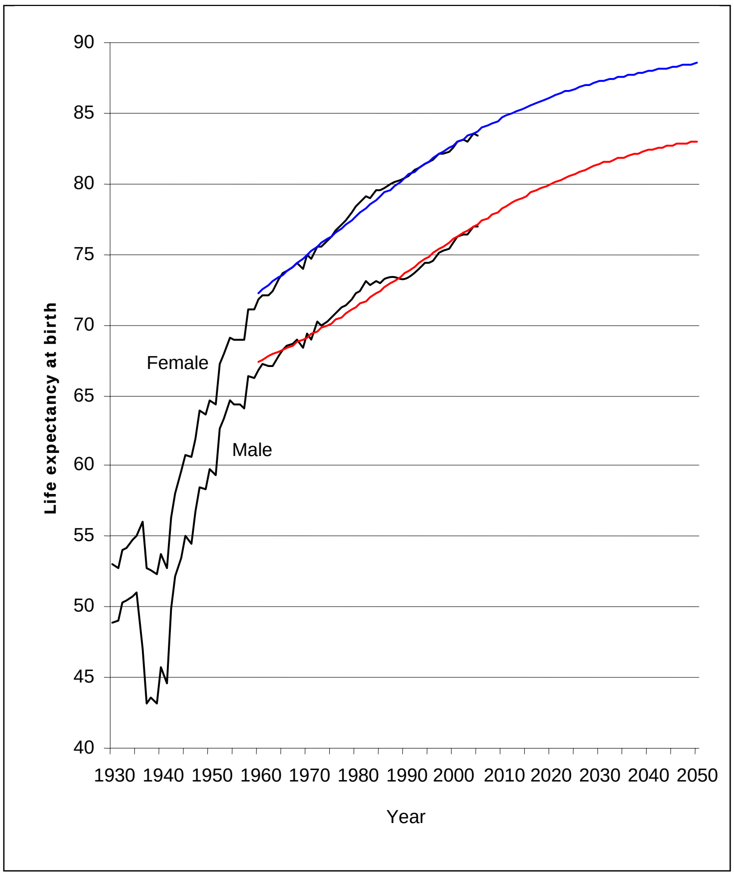


Table 4.1: Projected life expectancy at birth. Spain, 2006-2050

Year	Male	Female
2006	77.4	83.9
2007	77.6	84.1
2008	77.8	84.3
2009	78.0	84.5
2010	78.2	84.6
2011	78.4	84.8
2012	78.6	85.0
2013	78.8	85.1
2014	79.0	85.3
2015	79.2	85.4
2016	79.3	85.6
2017	79.5	85.7
2018	79.7	85.9
2019	79.8	86.0
2020	80.0	86.1
2021	80.2	86.2
2022	80.3	86.4
2023	80.5	86.5
2024	80.6	86.6
2025	80.7	86.7
2026	80.9	86.8
2027	81.0	86.9
2028	81.1	87.0

Year	Male	Female
2029	81.2	87.1
2030	81.4	87.2
2031	81.5	87.3
2032	81.6	87.4
2033	81.7	87.5
2034	81.8	87.5
2035	81.9	87.6
2036	82.0	87.7
2037	82.1	87.8
2038	82.2	87.8
2039	82.2	87.9
2040	82.3	88.0
2041	82.4	88.0
2042	82.5	88.1
2043	82.6	88.1
2044	82.6	88.2
2045	82.7	88.3
2046	82.8	88.3
2047	82.8	88.4
2048	82.9	88.4
2049	82.9	88.5
2050	83.0	88.5

b) We constructed age- and sex-specific mortality patterns in accordance with the life expectancies at birth projected for 2050.

Our method to obtain the mortality laws for 2050 was based on the parametric adjustment proposed by L Heligman and J Pollard,[1] specifically in their adjustment model 3. In its general formulation, that law segments the quotient curve into three periods of life: childhood; adolescence and early adulthood; and maturity and old age:

$$q_x = A^{(x+B)^C} + De^{-E(\ln x - \ln F)^2} + \frac{GH^{x^k}}{1+GH^{x^k}}$$

[1] Heligman, L. and Pollard, J.N. (1980), "The age pattern of mortality." *Journal of the Institute of Actuaries*, 107 (1(434)), pp. 49-80

- Parameters A, B and C synthesise mortality in childhood. Parameter A is similar to the probability of dying in the second year of life; parameter B measures differentials in risks of death in the first two years of life; and parameter C quantifies the rate of decline of mortality in childhood.
- Parameters D, E and F measure the presence of overmortality at young adult ages. The value of parameter F indicates the age of highest overmortality; D measures intensity; and E measures duration. A value for D equal to 0 or a high value for F point to an absence of significant overmortality at these ages.
- Parameters G and H express mortality linked to the aging process: G measures mortality level, and H indicates its rate of increase with age.

The mortality pattern for 2050 was constructed in two steps. First, we adjusted the observed mortality quotients by simple age for the period 2004-2005 to obtain the present values of the function parameters. The minimisation criterion was the sum of squared relative differences from birth to age 85:

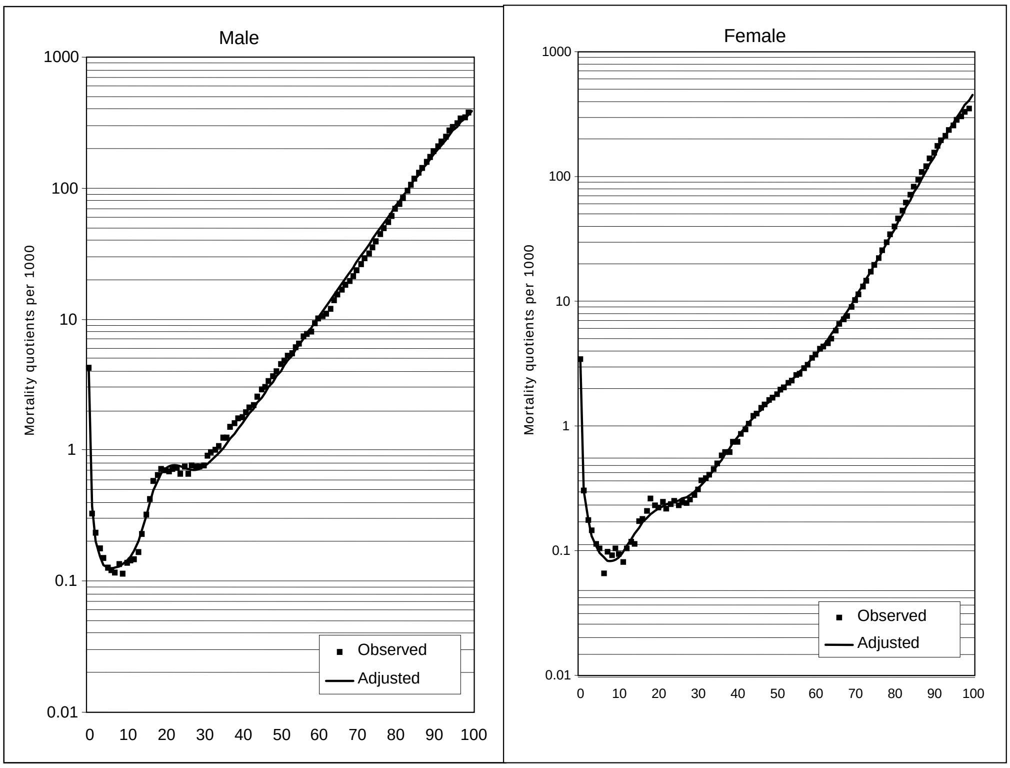
$$\mathrm{Min}\sum_{x=0}^{85}\left(\frac{q_x^o - q_x^a}{q_x^a}\right)^2$$

In men, the adjustment was made using Heligman-Pollard function 3. A brief spell of female overmortality at around age 50 is captured by the introduction of a further component into the adjustment function. This component, comprising parameters D', E' and F', is formulated in the same way as young adult mortality, but centres on mature adult ages:

$$q_x = A^{(x+B)^C} + De^{-E(\ln x - \ln F)^2} + D'e^{-E'(\ln x - \ln F')^2} + \frac{GH^{x^k}}{1+GH^{x^k}}$$

Chart 4.5 represents the observed mortality quotients by simple age for the period 2004-2005 and the adjusted values produced by the respective parametric functions.

Chart 4.5. Observed and adjusted mortality quotients. Spain, 2004-2005



We obtained the function parameters for 2004-2005 and then generated the mortality curve by sex for 2050. Simultaneous projection of all function parameters would produce different life expectancies from those projected by the logistic function, which are the reference for the overall mortality level. The solution is to construct hypotheses only on the first two function components, infant mortality and young adult mortality (and, for women, the mortality jump at mature ages); the parameters for the last component are obtained later, by adjusting the Heligman-Pollard function on the basis of life expectancy projected for 2050.

In operational terms, we first established a number of assumptions on the behaviour of mortality at the early stages of the life cycle:

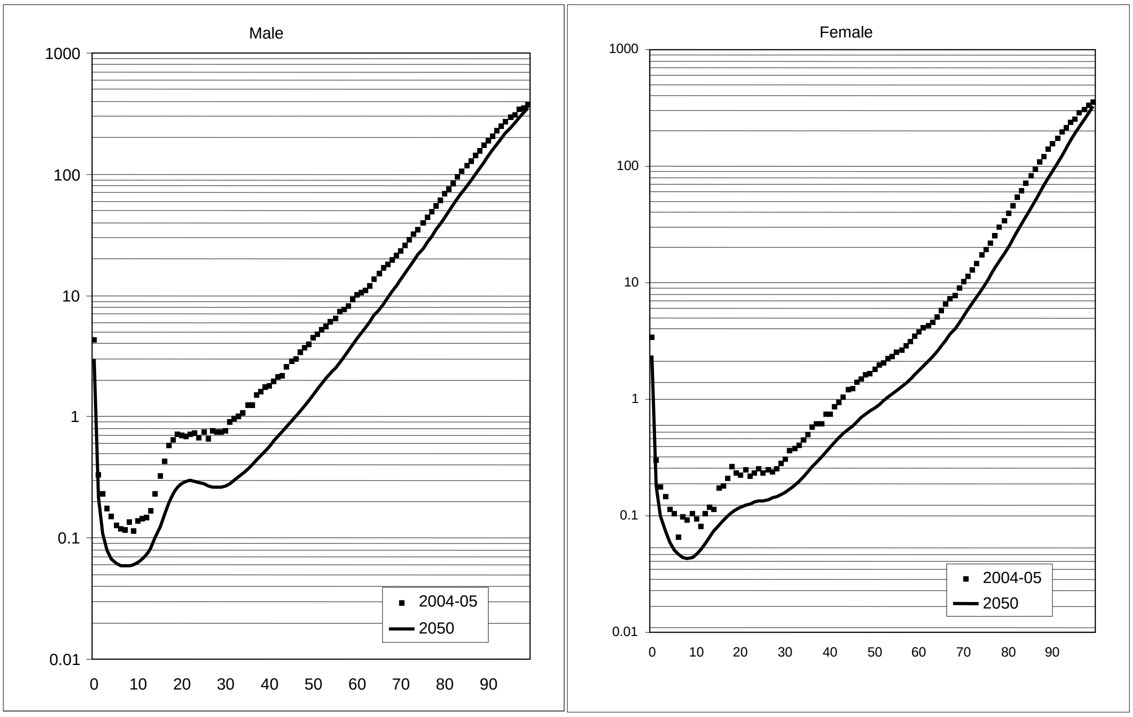
- Mortality in the early years of life. Parameter A of the adjustment function, which indicates mortality in the second year of life, was set at 60 percent of the estimated value for the period 2004-2005.
- Mortality at young adult ages. Parameter D, which indicates intensity, was reduced by 60 percent in men and 40 percent in women from the values for 2004-2005.

- Mortality at mature adult ages among women. Parameter D′, which indicates the intensity of the spell of overmortality in the age range 50-55, was reduced by half with respect to the value for 2004-2005.

Having modified the parameters of the first components of the function, we acted on the mortality component associated with aging, under the following constraints: (a) the resulting life expectancy at birth had to be consistent with the normative hypothesis for 2050; and (b) mortality quotients could not at any age fall below the mortality limit table constructed by J Duchêne and G Wunsch.[1] The modified parameter is H, synthesising the rate of increase of mortality with age.

Chart 4.6 compares, by sex, the observed mortality curves for 2004-2005 to constructed curves for 2050, which follow from life expectancy at birth of 83 years for men and 88.5 years for women.

Chart 4.6. Mean mortality quotients; observed data for 2004-2005, projected data for 2050



[1] Duchêne, J. and Wunsch, G. (1988), "From the demographer's cauldron: single decrement life tables and the span of life." *Genus*, Vol. 44, No. 3-4, Jul-Dec 1988, pp. 1-17.

c) We produced the mortality tables for each year in the period and analysed the consistency of projected change in age-specific mortality.

Once we had available the age-specific mortality pattern for 2050, we generated a wide range of mortality tables by linear interpolation between the mortality quotients by age and sex for 2004-2005 and the estimated data for 2050. In total, we constructed 250 mortality tables, positing average increases in life expectancy of 2.5 hundredths of a year for men and 2 hundredths of a year for women.

We selected from among that wide range of mortality tables those offering a life expectancy at birth that came closest to the previously projected figures for each year in the period 2006-2050 using the logistic function. Finally, we used the mortality tables to compute the respective survival probabilities for each year from birth to an open group aged 99 and above. These survival ratios from one attained age to the next constituted the mortality input into our projection system.

The time consistency of the projected series was analysed by linking the odds of dying observed for the period 1975-2005 to the projected data up to 2050.

4.3 Mortality projection results

The results of the mortality projection are best viewed over the long term, linking observed series for 1975 to 2005 with the projected data up to the normative horizon of the projection exercise in 2050. The analysis combines two indicators: risks of death (chart 4.7) and potential years of life between two exact ages (chart 4.8).

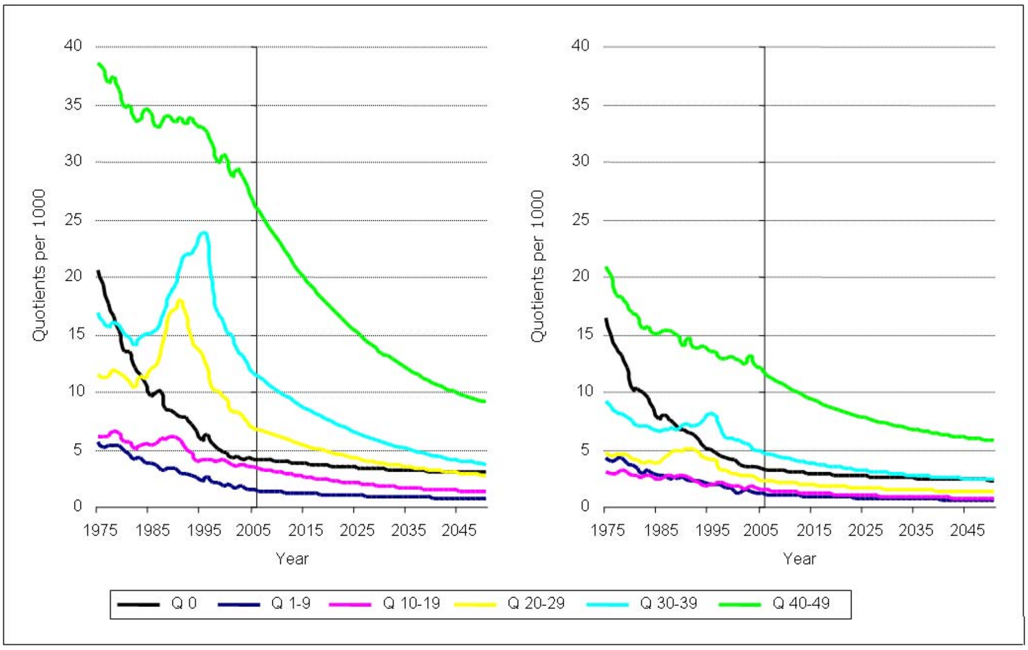
The key long-term results of the mortality projection exercise were:

- Mortality in childhood and adolescence. The mortality quotient for the first year of life for 2050 was forecast as 3.0 per thousand for boys and 2.4 per thousand for girls, making for a 30 percent decline from the latest observed values. Throughout the rest of childhood years, we forecast a 40 percent reduction in the mortality quotient for the second year of life, and a reduction of around 50 percent in risks of death from the third to the fourteenth year of life. In the 5-15 age group, the decline in the mortality quotient was forecast at 60 percent for males and 50 percent for females.
- Mortality at adult ages. Overall, the projection shows a sustained decrease in the mortality quotient from age 20 to age 40, and more intensely so among men, such that male overmortality in that age range is slightly reduced. The latest data show that the mortality “crisis” affecting young adults in the 1990s sprang from highly specific factors which in the more recent period have receded; a positive trend is expected for the medium and long term. The margin for improvement – in men especially – is very high, because approximately two thirds of mortality at these ages relates to causes of death regarded as avoidable, with a clear preponderance of preventable causes. In

quantitative terms, for the period as a whole the decline in the male mortality quotient between ages 20 and 40 (20q20) was estimated at around 60-70 percent, while for women the decline was forecast at 50 percent. These reductions, though relatively large, have only a very moderate effect on average lifetime, especially in women, given the low mortality levels now current at these ages.

Chart 4.7. Change in mortality quotients at various ages. Spain 1975-2050

Male Female



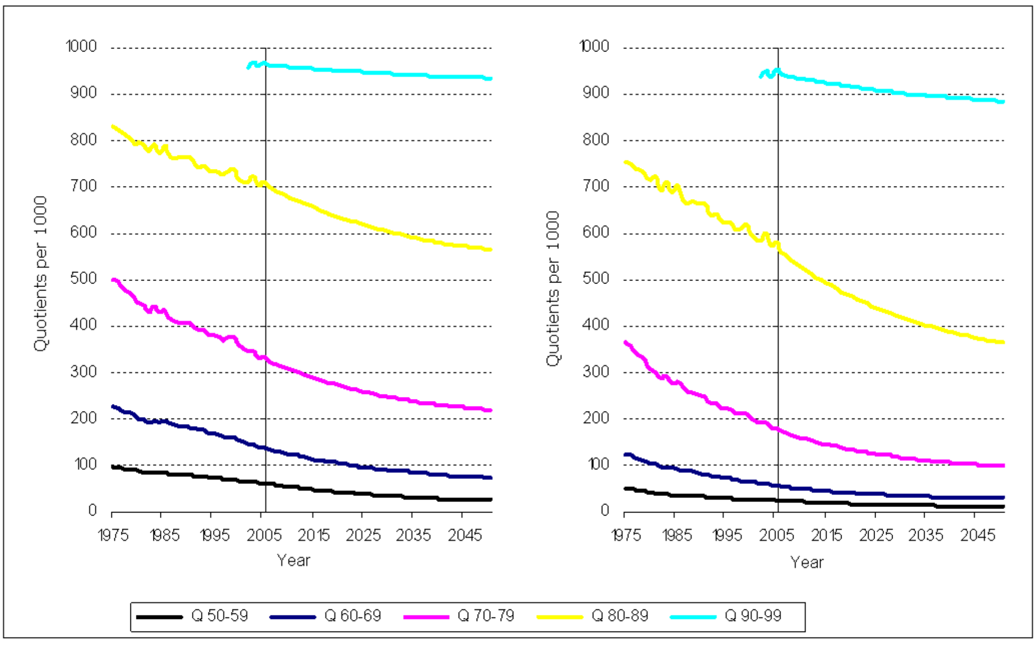
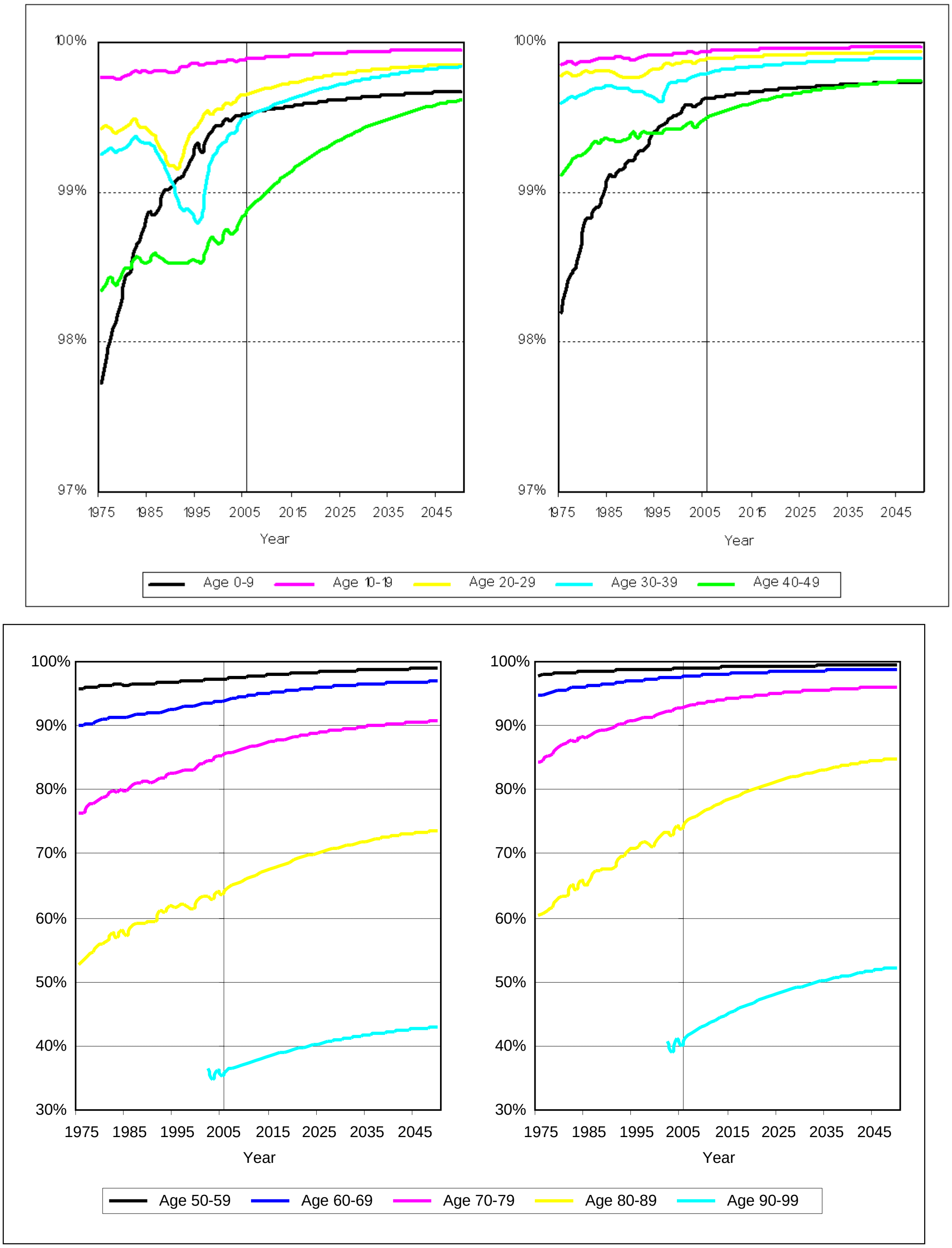


Chart 4.8. Change in potential years of life at various stages of the life cycle. Spain 1975-2050

Male Female



- Mortality quotients from age 40 to age 55 (15q40) are expected to improve in line with the groups discussed above. The trend observed in women over the past four decades will persist, while the decline of mortality among men will speed up, in consonance with the recent trend in cardiovascular mortality and the still more recent reversal of the trend for mortality associated with tumours, especially lung cancer.
- Mortality at maturity and old age. The outcome of the normative scenario on life expectancy at birth and its age-specific mortality pattern is an upward trajectory of potential years of life in age groups 60-69, 70-79 and 80-89, which links up with the observed trends of the past three decades. For example, we forecast that from age 80 to age 89 male Spaniards' potential years of life will increase by 10 percent, and female Spaniards' potential years of life will rise by 11 percent, to levels of 74 and 85 percent, respectively, by the mid-twenty-first century.
- Mortality in late old age. In late old age, uncertainty is very high, given the novelty of the decline in risks of death in the population aged 90 and above. There are questions about the continuity and intensity of the trend, and the phenomenon is in any event very hard to measure at these ages. The projection results posit the start of an upward trend in potential years of life for the Spanish population aged 90 to 99, with a greater impact among women, reaching a potential of 43 percent among men and 52 percent among women by 2050. Finally, our hypothesis on life expectancy from age 100 onwards is that the remaining lifetime will be slightly less than two years for both men and women.

5. Analysis and projection of foreign migrations

The process of projecting migrations is more complex than for other demographic phenomena. Form a strictly demographic standpoint, immigration is an endogenous phenomenon often forecast using prospective rates, given that the projected population is the at-risk population; immigration, however, is an exogenous phenomenon, and is treated as a population vector added annually to projected population. For this projection exercise, we have applied a new method, which estimates a vector of outbound foreign nationals depending on the number of arrivals recorded for that group in the years before and after the start of the projection.

The core aspect of the projection of foreign migrations originating or concluding in Spain is a normative assumption of inbound flow at the projection horizon, which then defines the set of estimation operations for foreign flows. The grounds of this assumption and our methodology are discussed below.

5.1 Projection of foreign immigration

Arrivals from overseas are treated as an annual vector of population, characterised by sex and age. As an input to the overall projection, foreign immigration could be viewed as a unit, but to analyse and formulate our scenarios we have distinguished between arrivals from overseas of foreign and Spanish nationals, because these two types of migration are highly distinct in terms of volume, structure and time profile.

Since a major part of foreign migratory flows is induced by the workings of the job market and economic growth, we have consciously chosen to rely largely on the forecast economic scenarios produced by the Ministry of Economy and Finance and on analysis by other Spanish and international bodies. This approach goes some way towards aiding the determination of an input – foreign migrants – which cannot be deduced from its relative incidence in the past, because its denominator is the population of the rest of the world. These economic scenarios rest partly on labour force forecasts which, in turn, are fed by population growth assumptions; therefore, we have taken precautions to avoid any undesired self-referential circularity.

To construct the core migration assumption – foreign immigration – we have therefore taken account of the macro-economic scenarios forecast by the Ministry of Economy and Finance for INE, which point to continuing strong GDP growth that will nonetheless slow down up to 2015. More significantly, the aggregate economic forecasts are not notably sensitive even to a very substantial difference in population scenarios.

Against this expected background, the immigration to be received by Spain was forecast in three steps:

a) First, we established the annual inbound flows for foreign nationals and Spaniards separately.

b) Second, we allocated that inbound volume by sex using masculinity ratios in two separate scenarios which converge at the horizon of the projection (chart 5.1), as explained later.

c) Third, we applied a migratory pattern to allocate immigrants to each age.

d) We describe below the processes conducted to project each flow:

We first established that the number of foreign immigrants arriving in Spain in 2014, the projection horizon, would be around 500,000, on the basis of a modification of inbound flows in 2007 in line with the trend of the recent past and with the macro-economic forecasts of various government bodies, which expect the Spanish economy to continue growing but at a slightly slower rate than at present (table 5.1). Arrivals in 2007 are thus equal to 95 percent of arrivals in 2006, and immigrant flows will decline gently up to 2010, and then drop off more rapidly to 2014, when the volume mentioned above will be reached.

The values at the projection horizon are thus the outcome of a prospective exercise that relies on the following assumptions: (a) the Spanish economy will continue to grow up to 2010, but at an increasingly gentle rate; (b) conditions for entering the country will gradually become more restrictive, as exemplified by the extension of visa requirements to the nationals of a growing number of countries; (c) inbound flows from countries recently acceding to the European Economic Area, such as Romania and Bulgaria, will dwindle insofar as these countries will undergo the economic growth already enjoyed by other recently acceding eastern European countries, whose issuance of migrants also abated markedly; (d) flows of Ecuadorians, Colombians and Bolivians will likewise recede; (e) conversely, that decline will be partly offset by the reuniting of family members and the emergence of flows from other countries, and inbound flows will be increasingly feminised.

Table 5.1. Development and projection of number of foreign immigrants by nationality. 1998-2014. Foreign nationals

	Arrivals of foreign nationals			
	Male	Female	Total	% male
1998	52,107	51,175	103,282	50.5%
1999	84,360	80,877	165,237	51.1%
2000	263,566	222,562	486,128	54.2%
2001	352,125	299,381	651,506	54.0%
2002	346,155	306,818	652,973	53.0%
2003	320,090	294,458	614,548	52.1%
2004	354,722	291,122	645,844	54.9%
2005	370,562	312,149	682,711	54.3%
2006	422,997	379,974	802,971	52.7%
2007	398,845	363,977	762,822	52.3%
2008	393,458	364,001	757,459	51.9%
2009	382,960	358,408	741,368	51.7%
2010	367,419	347,130	714,549	51.4%
2011	346,870	330,133	677,003	51.2%
2012	321,312	307,418	628,729	51.1%
2013	290,711	279,017	569,728	51.0%
2014	255,000	245,000	500,000	51.0%

Source: EVR, the Spanish statistic of change of residence, supplemented by entries by omission of foreign nationals drawn from the *Padrón Continuo* (population register) dataset, up to 2003. For the period 2004-2006, EVR.

1) Our assumption on inbound Spanish nationals involves a relative shift in trend, with inbound flows rising to 50,000 individuals by 2014 (table 5.2), as a result of future legal developments that will facilitate the acquisition of Spanish nationality by foreign nationals of Spanish ancestry, based mostly in Latin America. This has already happened with foreign flows into Italy.

2) Projected values for foreign nationals were produced by a parabolic adjustment that links the adjusted historic series (adding entries by omission of foreign nationals in the *Padrón Continuo* population register) up to 2006, with a normative value being established for 2014. A similar adjustment was made to projections for Spanish nationals.

3) The estimation of inbound flows of foreign nationals proposes, as pointed out above, a slight reduction in 2007 and a later faint reduction in the first years of the projection that becomes more pronounced from 2010 onwards, in consonance with the macro-economic forecasts available at the time of projection, while inbound flows of Spanish nationals are expected to grow to the figure mentioned above. The combination of the scenarios for inbound flows of foreign and Spanish nationals generates a reduction in the flow of immigration to 550,000 annual arrivals by 2014, a figure similar to the one prevailing immediately before the powerful migratory surge of 2001-2002.

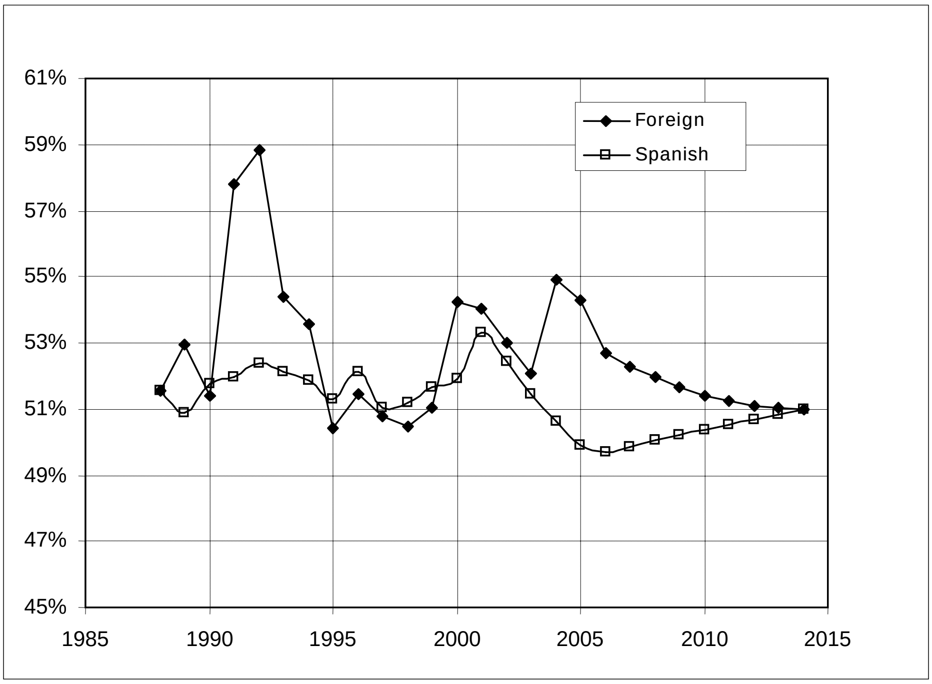
Table 5.2. Development and projection of number of foreign immigrants by nationality. 1998-2014. Spanish nationals

	Male	Female	Total	% male
1998	12,298	11,734	24,032	51.2%
1999	14,585	13,658	28,243	51.6%
2000	16,404	15,183	31,587	51.9%
2001	11,043	9,681	20,724	53.3%
2002	21,060	19,115	40,175	52.4%
2003	20,833	19,653	40,486	51.5%
2004	19,599	19,118	38,717	50.6%
2005	18,260	18,313	36,573	49.9%
2006	18,828	19,045	37,873	49.7%
2007	20,306	20,409	40,715	49.9%
2008	21,604	21,574	43,179	50.0%
2009	22,720	22,543	45,263	50.2%
2010	23,652	23,317	46,968	50.4%
2011	24,397	23,897	48,295	50.5%
2012	24,955	24,287	49,242	50.7%
2013	25,323	24,487	49,811	50.8%
2014	25,500	24,500	50,000	51.0%

Source: To 2006, EVR.

4) The distribution by sex of inbound Spanish and foreign nationals was obtained by a parabolic adjustment linking the historic series to a normative value established for 2014. Though similar for both groups, it follow a distinct time sequence, with a feminisation of foreign immigration owing to greater flows from Latin America and a rising trend towards the reuniting of family members, and a slight masculinisation of inbound Spanish nationals until reaching the average values for the period 1992-2004 (51 percent), which change follows naturally from the shift in trend suggested by the latest observed data.

Chart 5.1. Observed and projected data for the proportion of men in foreign inbound flows of Spanish nationals and foreign nationals. 1988-2014.

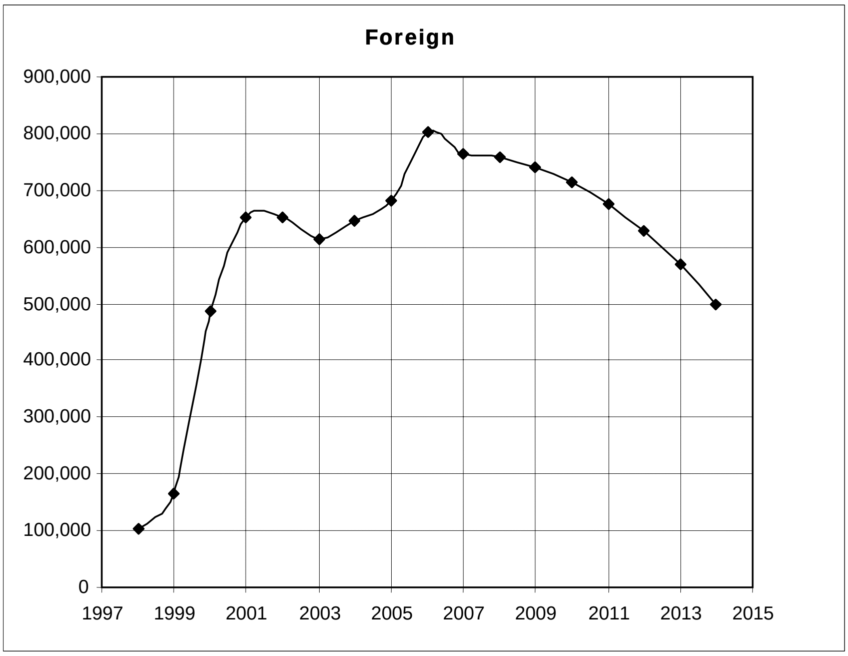


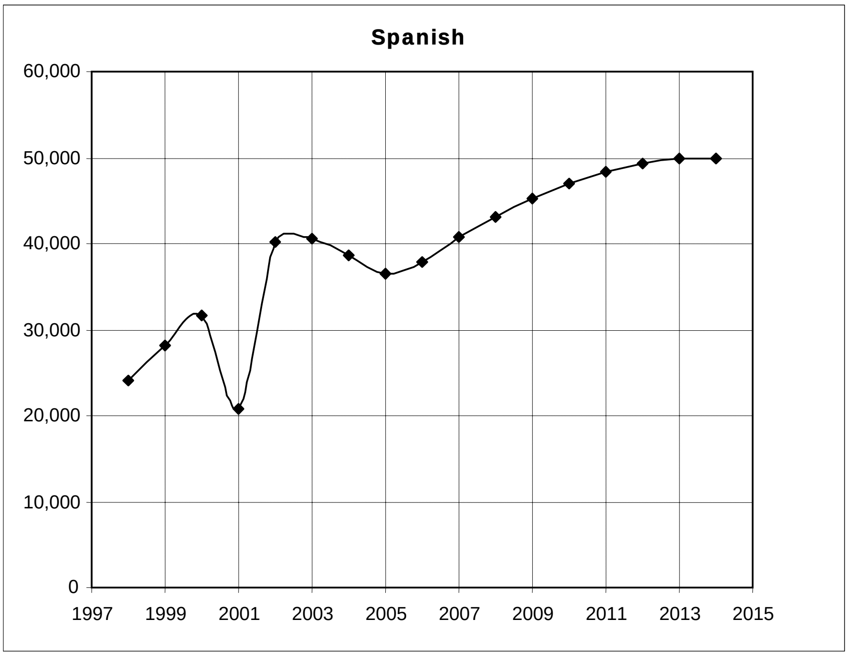
Source: Data for foreign nationals in the periods 1988-1997 and 2004-2006 come from EVR. The data for 1998-2003 were estimated by adding entries by omission recorded in the *Padrón Continuo* population register. Data for Spanish nationals are drawn entirely from EVR records for the period 1988-2006. Thereafter, total immigration flows are allocated by sex and age using distinct schedules for Spaniards and foreign nationals.

5) The schedule of arrival of foreign nationals follows the age structure for each sex deduced from the mean for the period 2004-2006 (chart 5.3). The mean holds constant throughout the entire projection.

5) The age structure of the flow of Spanish nationals holds constant for each sex at the values for the period 2002-2006 throughout the entire projection. This assumption reflects the stability of the schedule of immigration of Spanish nationals observed in recent years. However, the dissimilar time lines of immigration of Spanish and foreign nationals implies a variable schedule for overall immigration throughout the projection.

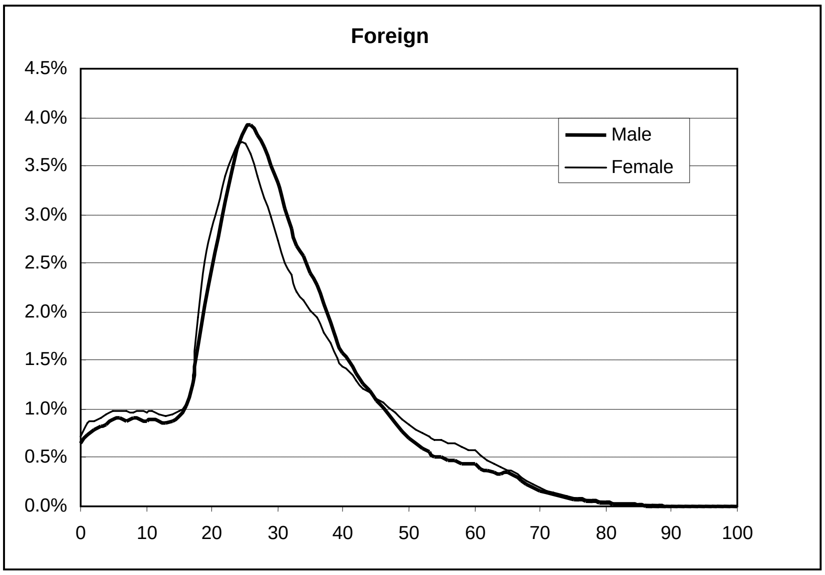
Chart 5.2. Development and projection of number of immigrants by nationality. 1998-2014.

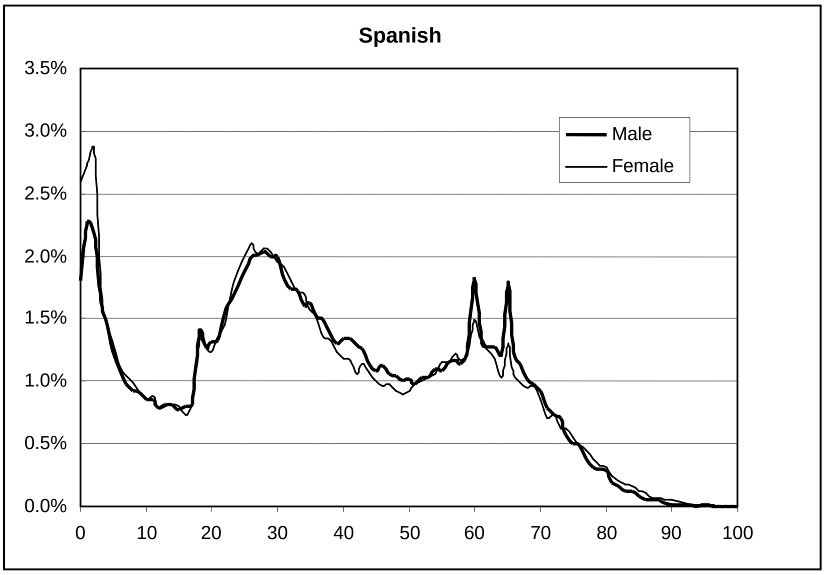




Source: Data for foreign nationals in the periods 1988-1997 and 2004-2006 come from EVR. The data for 1998-2003 were estimated by adding entries by omission recorded in the *Padrón Continuo* population register. Data for Spanish nationals are drawn entirely from EVR records for the period 1988-2006. Thereafter, total immigration flows are allocated by sex and age using distinct schedules for Spaniards and foreign nationals.

Chart 5.3. Distribution of immigrants from overseas by sex and age. By nationality





Source: For the period 2004-2006, EVR.

5.2 Projection of foreign emigration

The forecasting of inbound and outbound migrations has so far been the weakest point of Spanish statistics, primarily because municipal population registers (the *Padrón*) clearly under-record outbound departures.

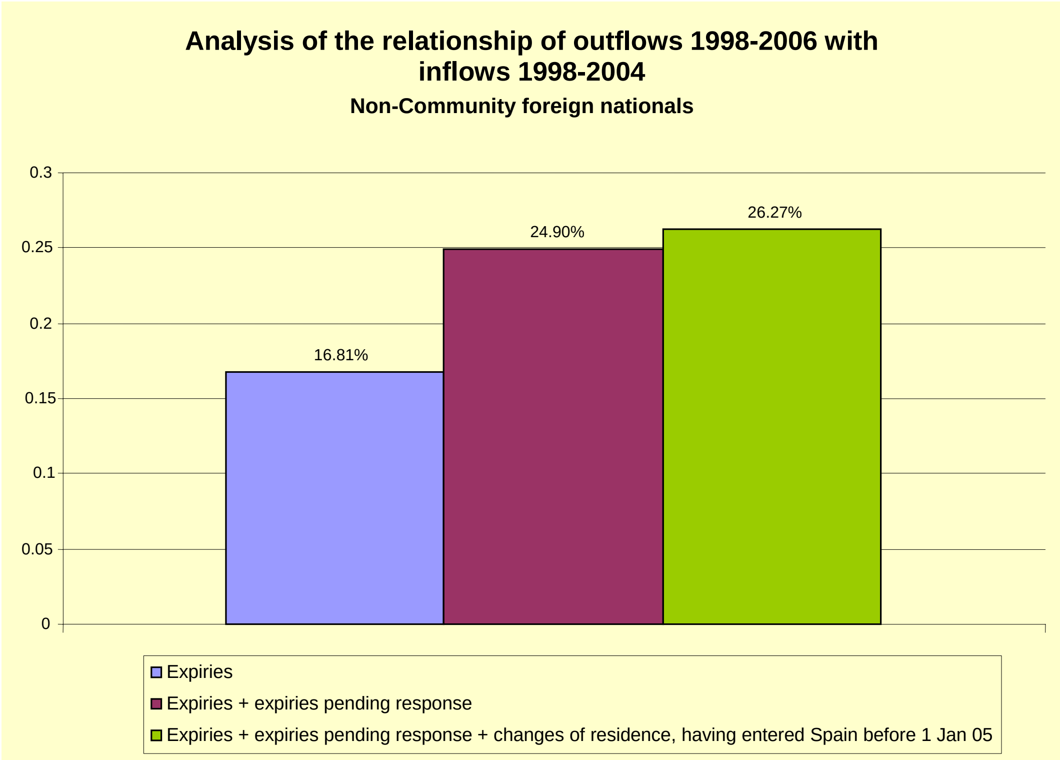
In order partly to solve this issue, the implementing regulations of the *Ley Orgánica 14/2003, de 20 de noviembre, sobre derechos y libertades de los extranjeros en España y su integración social* (a parliamentary statute on foreign nationals in Spain) compel non-Community foreign nationals who do not hold permanent residency to renew their registration with the municipal population register every 2 years. This administrative procedure is a good starting-point for estimating outbound flows, though incomplete. It suffers from two limitations which must be borne in mind when projecting outbound flows: (a) the administrative procedure affects only a subset of foreign nationals, in that it leaves out Community foreign nationals and non-Community foreign nationals who hold a permanent residency permit; and (b) it restricts the chronological scope of observation to two years after the latest population register entry.

But, however biased and incomplete, the information provided by registration expiries lays a statistically sound foundation for estimating the proportion of subsequent departures among immigrants arriving in previous years.

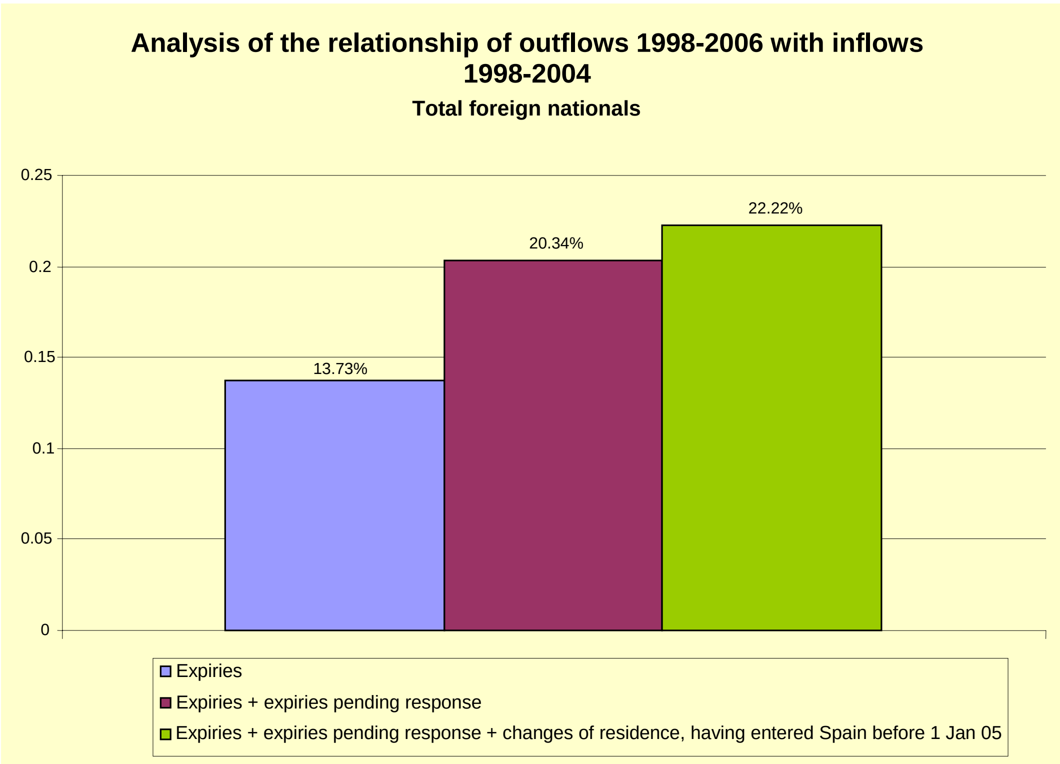
Hence the main novelty in our projection model is to link foreign nationals' departures to arrivals in previous years. The approach to outbound migrations thus depends on two closely linked factors: (a) the propensity of an inbound cohort to leave the country in subsequent years; and (b) the schedule or distribution over time of such departures.

An analysis of population register deletions of foreign nationals and of the registration expiry process suggests that 20 to 30% of foreign immigrants later leave Spain.

Chart 5.4.



Analysis of the relationship of outflows 1998-2006 with inflows 1998-2004
Non-Community foreign nationals
0.3
0.25
0.2
0.15
0.1
0.05
0
16.81%
24.90%
26.27%
Expiries
Expiries + expiries pending response
Expiries + expiries pending response + changes of residence, having entered Spain before 1 Jan 05



Analysis of the relationship of outflows 1998-2006 with inflows 1998-2004
Total foreign nationals
0.25
0.2
0.15
0.1
0.05
0
13.73%
20.34%
22.22%
Expiries
Expiries + expiries pending response
Expiries + expiries pending response + changes of residence, having entered Spain before 1 Jan 05

In addition, we assumed that outbound returns occur in accordance with a given time profile, characterised by a clustering of departures in the years immediately following arrival. These assumptions on the time profile of foreign nationals' departures are based on our analysis aimed at determining immigrants' length of stay, using registrations deletions due to change of residence in the *Padrón Continuo,* according to dates of departure from Spain and dates of first registration (date of arrival to Spain). The three charts below display the results.

Chart 5.5. Length of stay in Spain associated with change-of-residence deletions of outbound foreign nationals, by year of deletion

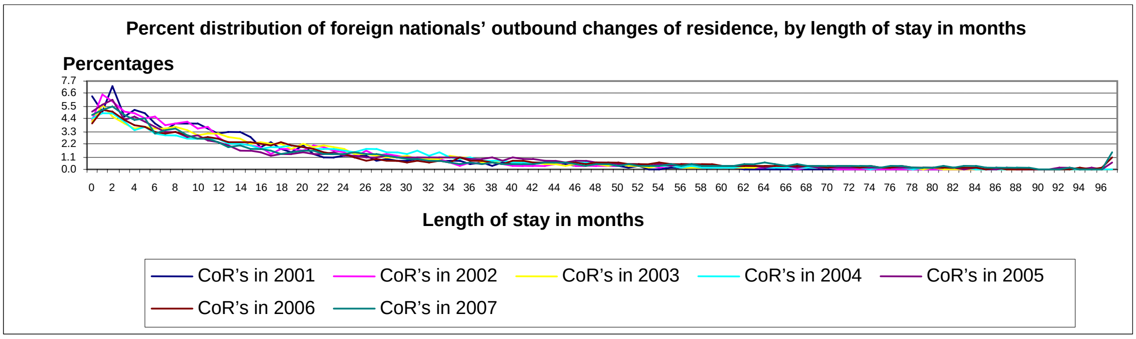


Chart 5.6. Length of stay in Spain associated with change-of-residence deletions of outbound Community and non-Community foreign nationals, 2001-2007

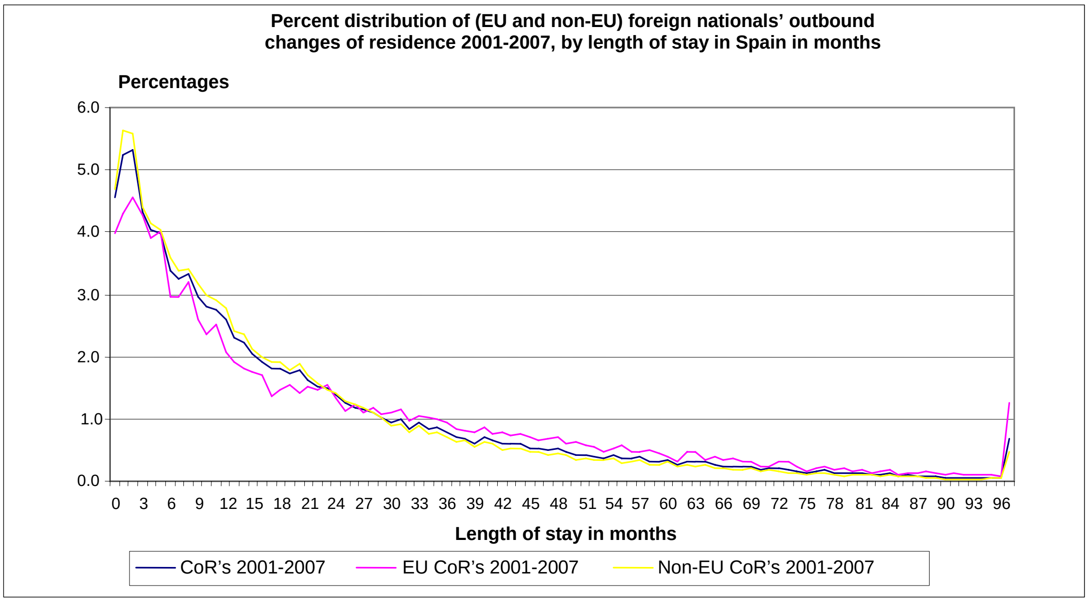
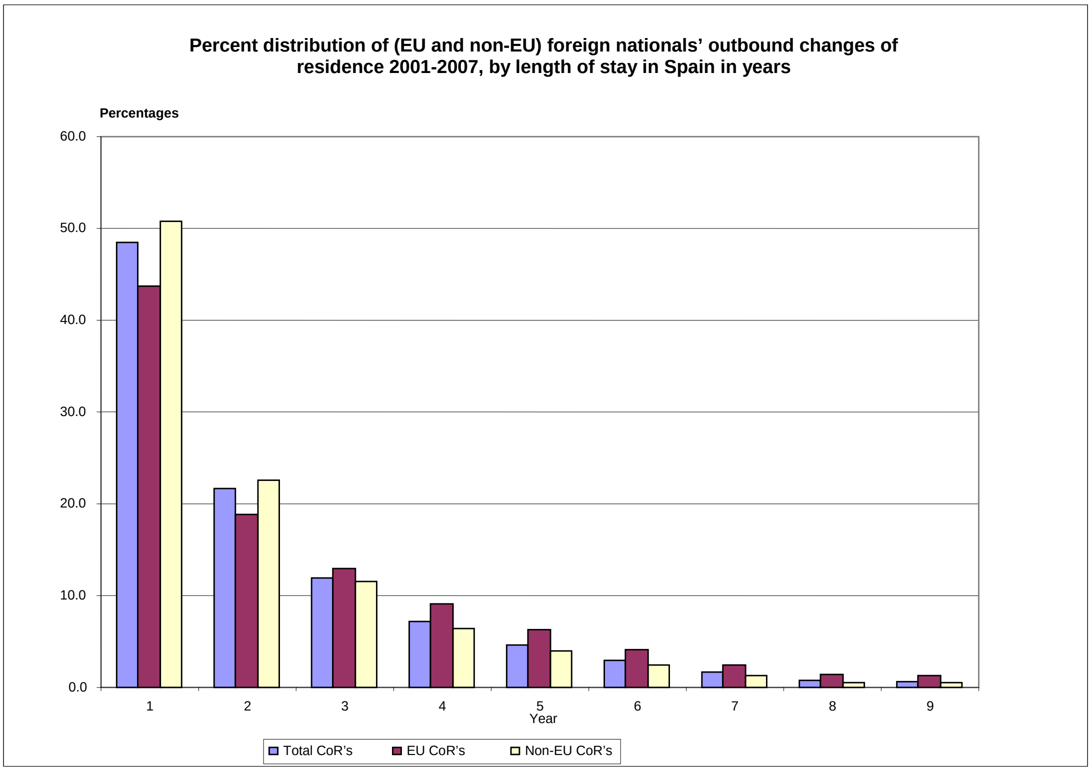


Chart 5.7. Length of stay in Spain associated with change-of-residence deletions of outbound Community and non-Community foreign nationals, 2001-2007



For non-Community foreign nationals not holding permanent residency, a similar study of registration deletions due to expiry also reveals this phenomenon of clustering of foreign nationals' departures in the months immediately following their arrival in Spain.[1]

On the basis of these considerations, we initially established a quantum of departures of 20 percent of inbound cohorts, and a schedule of eight years, in the first two of which 65 percent of cohort emigrants would leave the country. The emigration projection parameters are thus fixed as follows:

Inbound cohorts in the period 1998-2006 and throughout the projection period are associated with a propensity of departure of 20 percent of inbound individuals (1 out of every 5 immigrants will later leave Spain) over a period of 8 years. The distribution of departures over time follows a negative exponential functions, whereby approximately 40 percent of all departures occur in the first year and 25 percent occur in the second year after arrival to Spain. This distribution holds constant throughout the entire projection.

[1] *Protocolo para determinar las salidas de los caducados* ("Protocol to determine departures of foreign nationals associated with expired registration entries"), as part of the project *La población Inmigrante en España: un balance económico-estructural* ("The immigrant population in Spain: an economic and structural assessment"), resulting from a partnership among the Instituto de Estudios Fiscales (the Spanish institute of fiscal studies), INE and the Universidad Nacional de Educación a Distancia (Spanish open university), through the Centro de Estructuras Sociales Comparadas (centre for comparative social structures). June 2007:

The distribution by sex of outbound Spanish and foreign nationals was projected by a parabolic adjustment of the proportion of men in the total outbound flow, linking the observed series from 2002 to 2006 to normative values established for 2014, which differ for each group: masculinisation rises very slightly among foreign nationals from 59.3 percent in 2006 to 60 percent in 2014, while among Spaniards it moves from 49.1 percent in 2006 to 51 percent in 2014, in agreement with the slight increase in this parameter from 2004 onwards.

The resulting projected outbound flows are thus as follows:

Table 5.3. Development and projection of number of outbound emigrants by nationality. 1998-2014. Foreign

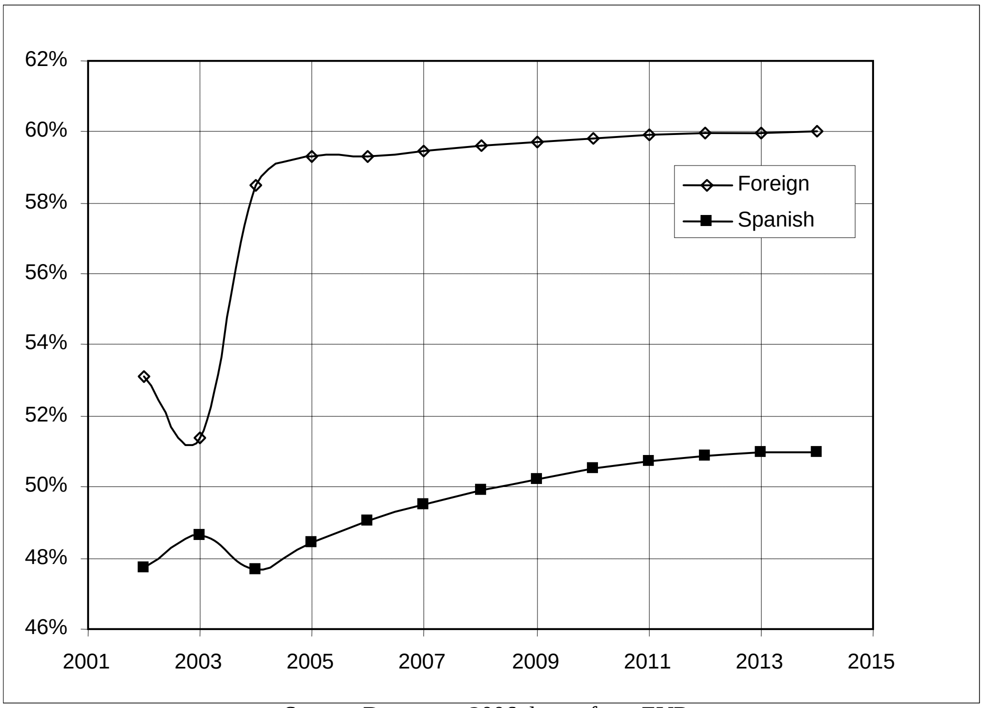
	Male	Female	Total	% male
1998	8,264			
1999	18,382			
2000	50,255			
2001	83,474			
2002	103,762			
2003	113,275			
2004	121,029			
2005	128,064			
2006	141,621			
2007	146,913	87,413	59,500	59.48%
2008	149,275	88,968	60,307	59.62%
2009	149,333	89,152	60,181	59.74%
2010	146,824	87,801	59,023	59.83%
2011	142,261	85,214	57,047	59.90%
2012	135,575	81,345	54,230	59.96%
2013	126,711	76,027	50,684	59.99%
2014	115,540	69,324	46,216	60.00%

Table 5.4. Development and projection of number of outbound emigrants by nationality. 1998-2014. Spanish nationals

	Male	Female	Total	% male
2002	14,168	15,506	29,674	47.7%
2003	7,775	8,215	15,990	48.6%
2004	6,275	6,881	13,156	47.7%
2005	9,345	9,945	19,290	48.4%
2006	10,812	11,230	22,042	49.1%
2007	11,546	11,775	23,321	49.5%
2008	12,192	12,238	24,430	49.9%
2009	12,745	12,623	25,368	50.2%
2010	13,202	12,934	26,136	50.5%
2011	13,560	13,172	26,732	50.7%
2012	13,818	13,341	27,159	50.9%
2013	13,973	13,442	27,415	51.0%
2014	14,025	13,475	27,500	51.0%

Source: Data up to 2006 drawn from EVR.

Chart 5.8. Observed and projected data for the proportion of men in outbound flows of Spanish nationals and foreign nationals. 2002-2014.



Source: Data up to 2006 drawn from EVR.

Emigrants by sex and nationality are later distributed on the basis of a specific age-based pattern given by the averages for 2004-2006 for foreign nationals and 2002-2006 for Spanish nationals. These age structures of emigration were held constant throughout the projection period. After computing these emigration figures, the values for the two groups are combined and become an input to the projection equations.

Chart 5.9. Sex and age structure of outbound migrations of foreign and Spanish nationals