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Chapter 1

Are Long-term Demographic Forecasts Possible? Turning Points and Trends

by

Hervé Le Bras*

This chapter serves as a methodological warning for the entire book: we demonstrate that it is the turning points that in fact play the most important role in demographic trends. We first discuss external migration, where the contrast between past and future is most glaring, and then show that the same holds true for the fertility trend, but with latencies and lags that are often lengthy. We close with a remarkable example of a turning point in the trend in age-specific mortality, to conclude that demographic trends cannot be extrapolated directly, but only explored through forward-looking scenarios incorporating political and economic factors.

* French National Institute for Demographic Studies (INED) and School for Advanced Studies in the Social Sciences (EHESS).

There is a great contrast between descriptions of the demographic past and future. While the latter is generally projected as being regular and as behaving in ways that tend to be self-perpetuating, the former is marked by numerous turning points. This difference is usually justified by treating the irregularities of the past as random fluctuations around a more stable trend. It is argued that only the trend is extrapolated into the future, for it alone is relevant. In this paper we shall propose a diametrically opposed vision by showing that, on the contrary, it is the turning points that in fact play the most important role in trends. This approach has its equivalent in the physical sciences with the catastrophe theory developed by René Thom who argued that, to describe a form, one need only know its points of discontinuity or catastrophes, which Thom categorised into seven distinct types (such as the fold, cusp, swallowtail, etc.). The entire form is deduced from these points alone through a generalised interpolation.

We shall begin by discussing external migration, where the contrast between past and future is most glaring. We shall show that the turning points can only appear as random to observers on a distant planet revolving around the star Sirius, but that for Earthlings they quite accurately mirror political and economic events. We shall then show that the same holds true for the fertility trend, but with latencies and lags that are often lengthy. We shall close with a remarkable example of a turning point in the trend in age-specific mortality, using a mathematical analysis to isolate this point amidst the complex mass of observations. This will enable us to conclude that demographic trends cannot be extrapolated directly, but only explored through forward-looking scenarios incorporating political and economic factors.

1.1. External migration: frequent turning points linked to political events

Figure 1.1 shows external migration trends for nine developed countries between 1950 and 2050. Until 2000, the data are drawn from two sources, the annual OECD reports of SOPEMI and the United Nations Population Division. For the period after 2000, only the latter organisation has ventured a general forecast of migration up until 2050. The contrast between before and after 2000 is striking. The point corresponding to the years 2000-04 is generally known, but beyond that date it is a forecast. We see that this forecast is doubly cautious: firstly, by 2015 at the latest, net migration levels off in all countries and remains constant year after year until 2050, independently of the total population trend in the country considered. Secondly, these net migration numbers are quite low, standing at 60 000 people annually in France and Spain, 200 000 in Germany and 120 000 in Italy. Yet the net migration shown for most developed countries in this figure seems to be in a phase of rising rather than levelling off.

Symmetrically, as we see in Figure 1.2 showing net migration trends in four major developing countries (China, India, Indonesia and Mexico), the trend is towards a rapidly growing migration deficit between 1950 and 2000, while the United Nations predicts that net migration will subsequently stabilise at a relatively low level.

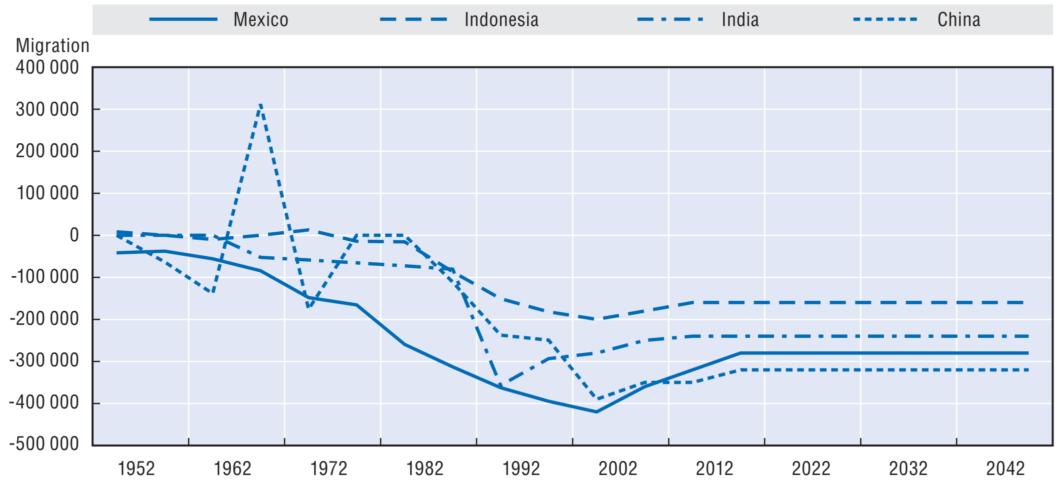
We shall not dwell any longer on these regular forecasts the ideological content of which is clear, but shall instead focus on the irregularities during the known period

Figure 1.1. **Migration observed between 1950 and 2005 and projected until 2050 in selected developed countries**

Source: OECD, SOPEMI (for migration observed only) and the United Nations Population Division (for migration observed and projected).

(1950-2005). Can these be considered random? First of all, the most rapid random fluctuations have been eliminated for we have already smoothed them by consolidating the net migration over five year periods (the figures show annual averages). Next, we clearly see a trough appear at the same time in nearly all the developed countries during the 1980-85 period. Next, country by country, the peaks of net migration coincide with major political events. For France, the peak in 1960-65 coincides with the return of repatriates from Algeria and other colonies that had gained their independence. For Germany, the peak between 1985 and 1995 reflects the return of "ethnic" Germans after the Berlin Wall came down. In Spain, Italy and Greece, entry into the European Union led to a reversal of the previous negative migration trend. It is not reasonable to consider these to be random factors that distorted a regular trend of the type forecasted by the United Nations. The idea underlying the projection of migration up until 2050 is that certain countries are structurally either receiving or sending countries. Yet there is, on the contrary, reason to believe that political and economic events are key factors in determining whether countries export or import labour.

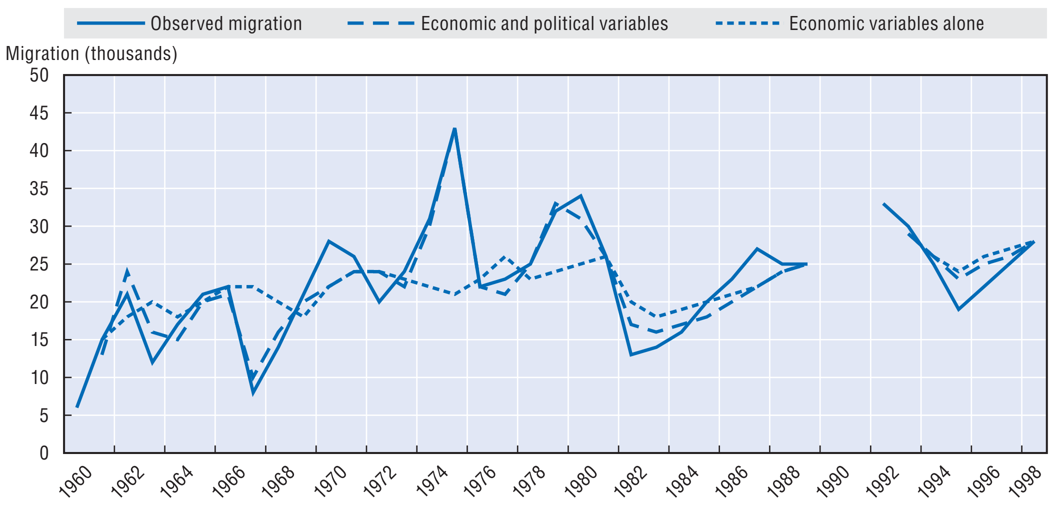
Figure 1.2. **Migration observed between 1950 and 2005 and projected until 2050 for selected major developing countries**



Source: United Nations Population Division.

Recent statistical work by Roel Jennissen clearly shows these interferences between economic and political factors and net migration. Jennissen adjusted net migration in the Netherlands between 1960 and 1999 using a regression model comprising economic variables (unemployment rates and per capita GDP) and political variables (dummy variables for political tension in New Guinea in 1963, the independence of Surinam in 1975 and its backlash 5 years later and, lastly, the 1967 recession). An auto-regression was added to take into account the inertia of the influences exerted by these factors. The coefficients are highly significant for all the variables except the tension in New Guinea. The net migration observed and the adjustment by this model are shown in Figure 1.3. We see the quality of the adjustment (R2 = 0.76) on the dashed curve. But when the political variables are removed (dotted curve), the adjustment becomes distinctly less good. Only

Figure 1.3. **Reconstruction of net migration in the Netherlands on the basis of multiple regressions using exogenous economic and political variables**



Source: Jennissen (2004).

per capita GDP and the autocorrelation are significant and the resulting curve follows the medium-term trend with the high and low fluctuations shaved off.

The conclusion to be drawn from these initial examples is that net migration does not follow an independent demographic rationale (for example, as a consequence of fertility and mortality levels). It is therefore impossible to forecast its future trend without also forecasting future economic and political trends. To project migration in 2020 or 2050 as the United Nations Population Division does, it would first be necessary to project economic and political trends for this time frame, which is clearly impossible.

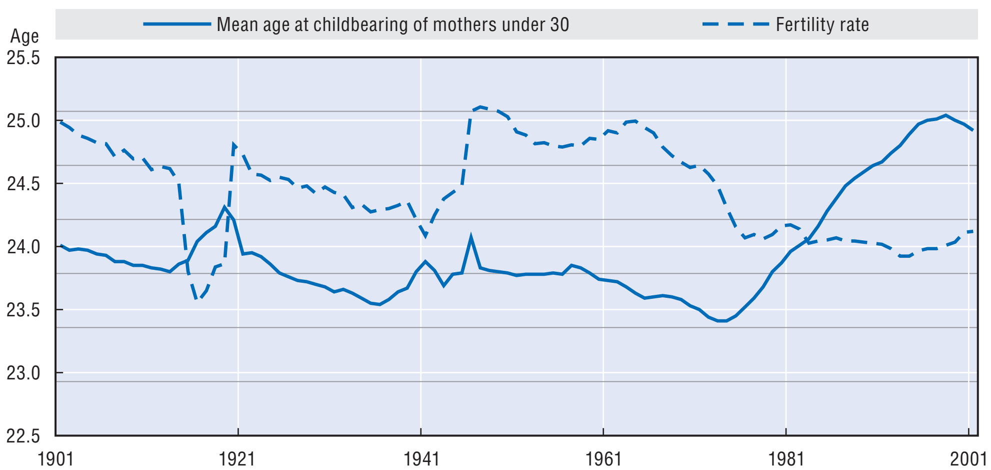
1.2. Fertility: infrequent turning points with lasting effects

Thus far, we have shown that political events (dummy variables) and economic events (continuous variables corrected by their autocorrelation) have an influence on net migration in a given year. In the case of fertility, two stronger factors emerge. The events that change fertility behaviour are infrequent and exert a lasting influence. We shall show this by studying the example of France and then extending the study to other European countries.

The case of France

The trend in France's total fertility rate over the past century is a good example (Figure 1.4). This trend is summarised by just three major events. The first is a fertility dip caused by the war of 1914, which separated young men from their families or delayed their marriage. As soon as the war was over, the men came home, married and had children. Demographers speak of "recovery". Then the long-term trend resumed. The other two events are quite different, *i.e.* the beginning of the baby-boom in 1945 and then its end, which was marked by a decline in fertility spread over the 1965-75 period. The characteristics of these two shifts are well known: as the prevalence of childless or single-child families diminished after the Second World War, the prevalence of families with more than one child increased and fertility therefore rose (families with more than one child replacing families with no children or with a single child). Starting in 1965, modern

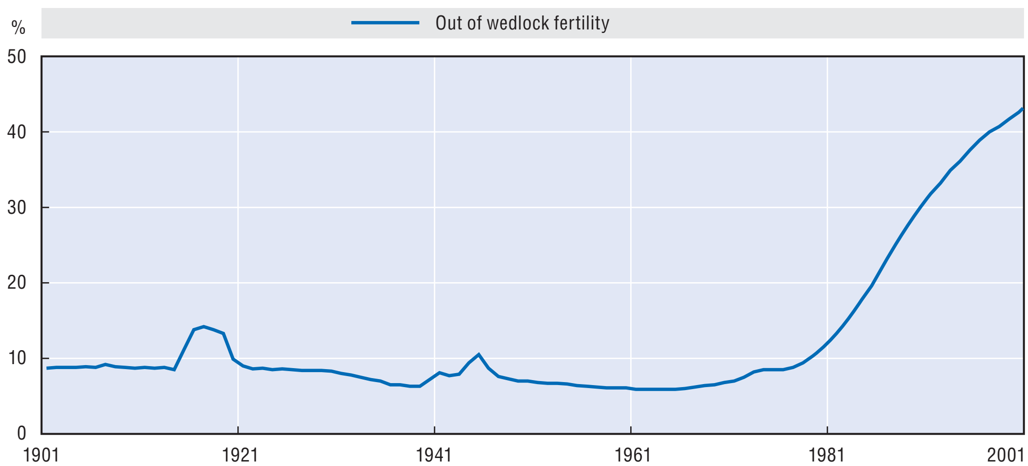
Figure 1.4. **Total fertility rate and mean age at childbearing of mothers under 30 (proxy of the age of first maternity) between 1900 and 2000 in France**



means of contraception enabled couples to avoid "unwanted" births which, according to surveys, accounted for 30% of total births, and this therefore lowered the birth rate proportionately. However, no one had foreseen these two developments.

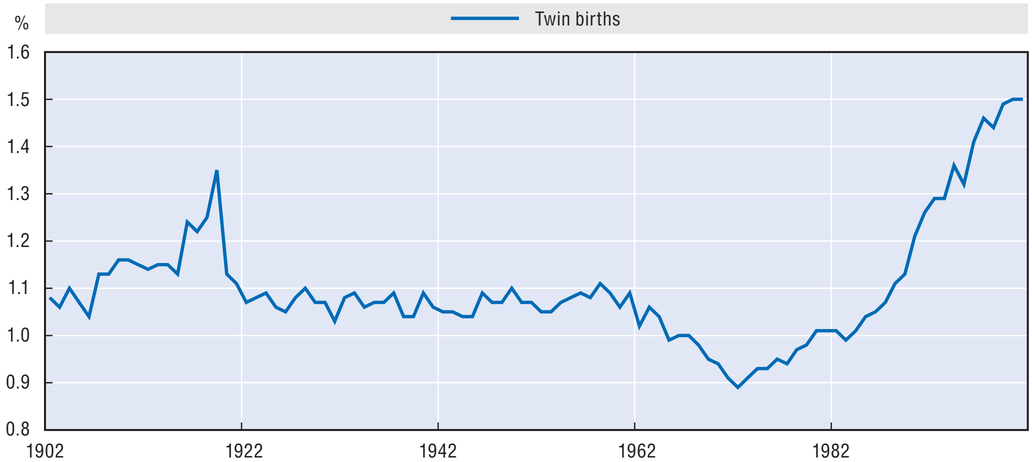
Analysing fertility more closely, it can be seen that birth control is accompanied by two even clearer shifts. The age of mothers when their first child is born (we approximated this in Figure 1.4 with the mean age of childbearing before the age of 30), which had been declining since the 19th century, suddenly began to rise in 1974. The influence of the oil crisis is obvious, but what is less obvious is that this age then continued to rise very regularly until 2000, when it seemed to level off. At the same time, the proportion of births out of wedlock, which had been stable at around 8% for over a century, also began to increase rapidly and steadily (Figure 1.5). Its fluctuations closely parallel those of the age of mothers when their first child is born. During the two wars, both indices grew and then returned to their initial values when hostilities were over. These simultaneous reactions can even be observed during the 1939-45 war, with in both cases a surge in 1940 and then in 1944-45. It is as if a change that had been germinating was released during the war and then brought under control once it ended. But in 1974, control could no longer be regained and a different form of family came into being in which women had children late, families averaged around two children and there was, so to speak, a decoupling of marriage and fertility.

Figure 1.5. **Proportion of out-of-wedlock births between 1900 and 2000 in France**



It is not our intention to explain how these trends are connected or were triggered – which is a difficult and still unfinished task – but to show that they are result of a combination of long periods of stability or latency and sudden changes that simultaneously affect some and perhaps all aspects of fertility. For example, because of the increasingly high age at childbearing, the fertility rate diminishes mechanically (exactly in equal proportion to the increase per time unit). Another more unexpected example, shown in Figure 1.6, is that the increase in twin births takes place at the same time as that of out-of-wedlock births and the age at first birth. This is neither a coincidence nor the effect of new assisted reproduction technologies, but once again a mechanical result of the higher age at childbearing, for the proportion of twin births increases with the mother's age.

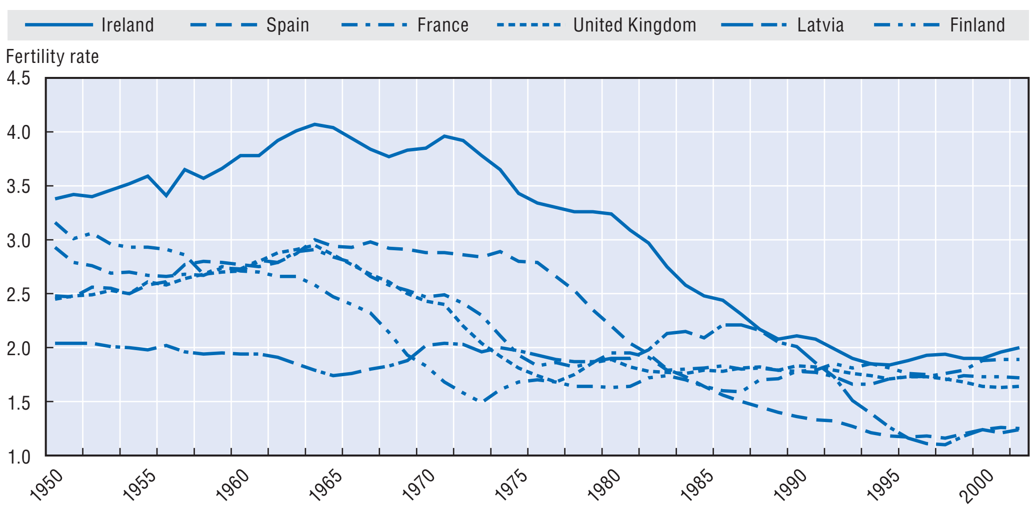
Figure 1.6. **Proportion of twin births in France between 1900 and 2000**



Other European examples: similarity without convergence

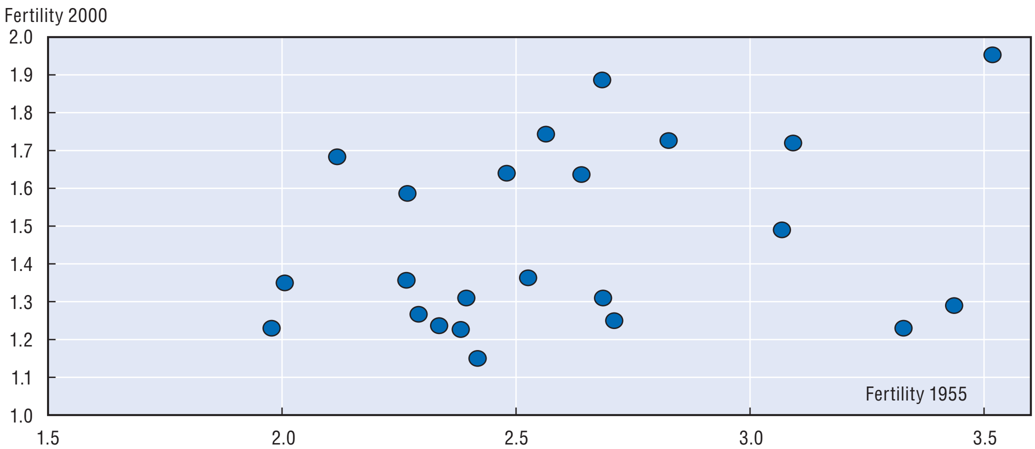
Is France's case representative of the other developed countries or is France on a different track? Looking at Figure 1.7 in which the trend of the fertility rate in selected developed countries has been superposed, one would be tempted to opt for the idea of diversity. Admittedly, the high fertility rates of the post-war period have disappeared everywhere, but at a very different pace. The beginning of the decline that started in France in 1965 came earlier in Finland (1950) and later in Spain and Ireland (1975) and later still in Latvia (1990). These few examples suggest that the form of political regimes is not unrelated to these time frames (death of Franco, fall of the Berlin Wall). They do not impose a level of fertility, but sustain it through a kind of inertia. It is also apparent that the countries' ranking by fertility rate varies broadly from the beginning to the end of the period.

Figure 1.7. **Trend of the total fertility rate in selected developed countries between 1950 and 2002**



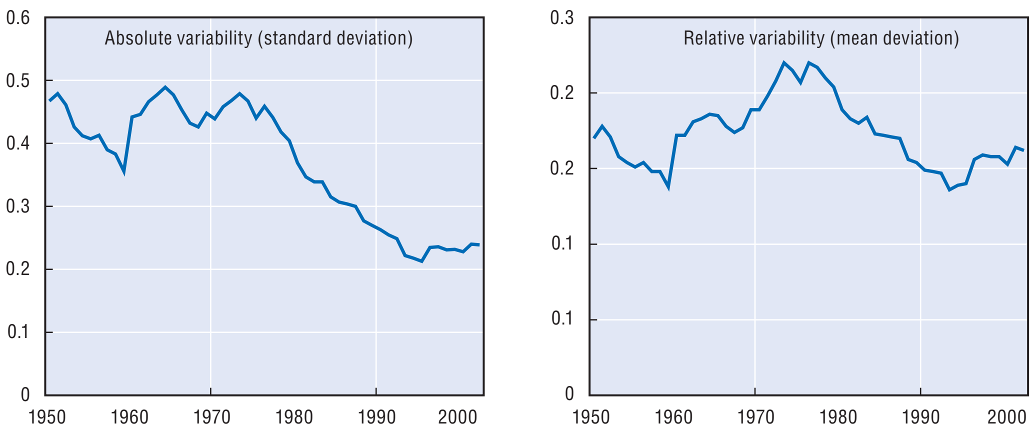
To show this more clearly, we have arranged the EU countries by fertility rate in 1950-55 and 2000-05 (Figure 1.8). The resulting scatter plot does not show any discernible pattern, which confirms the lack of correlation. As it is wider than it is high, however, this means that there is a convergence of European countries towards a single model, which deprives of their interest the fluctuations occurring before this common model is reached. Countries are moving towards this model haphazardly, each at a different pace.

Figure 1.8. **Comparison of the fertility of 23 EU countries (each country is shown by a dot) in 1955-60 and 2000-05 (EU24 less Cyprus)**



This hypothesis of convergence seems to be confirmed when the standard deviation of the fertility rates is calculated period by period (Figure 1.9). If we extrapolate the fairly linear trend, the differences in fertility should have disappeared in Europe by around 2025. However, this reasoning is made all other things being equal, *i.e.* without taking into account the drop in mean fertility. It is more accurate to follow the trend in the mean deviation, *i.e.* the standard deviation divided by mean fertility for the period. In this case,

Figure 1.9. **Variability of the fertility rate of 23 EU countries between 1950 and 2002 (EU24 less Cyprus)**

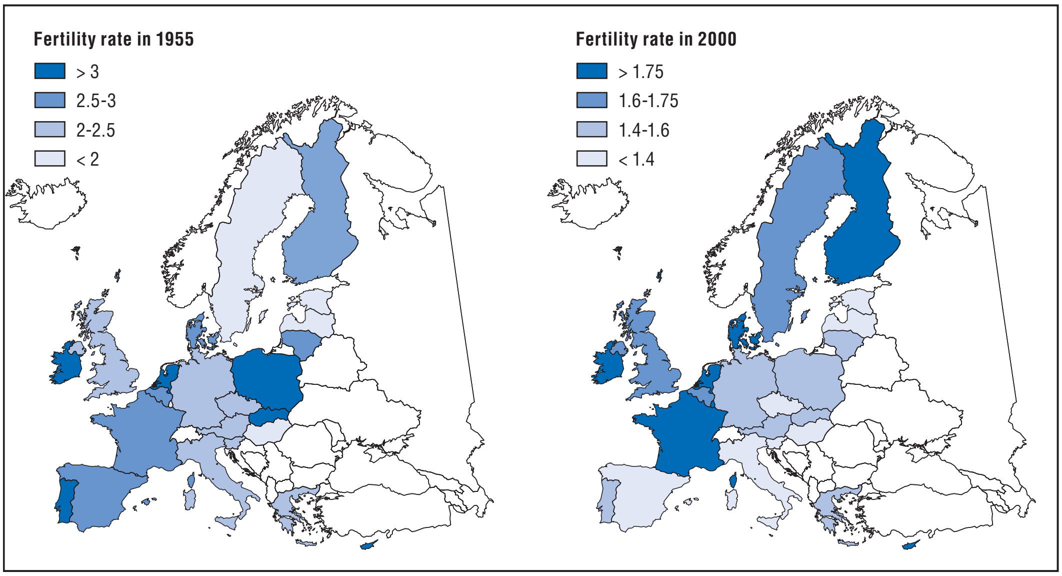


the trend shows no convergence. The mean deviation remains stable throughout the past half century. Its current value in 2000-05 is, for example, exactly the same as in 1955-60. For the time being, then, we must reject the idea of convergent European behaviour.

Geographic similarities and political differences

Might there at least be a geographic rationale for fertility rates? This time the answer is positive when we draw the map of fertility rates in Europe in 1950-55 and 2000-05 (Figure 1.10). During the first period, the countries of south-western and north-eastern Europe had higher fertility rates, while the countries of the central strip extending from the United Kingdom and Sweden to Italy and Greece had lower fertility rates. During the second period (2000-05), fertility was higher in a northern triangle with France at its bottom point and was lower to the east in the former communist countries and to the south. The autocorrelation coefficients calculated on the ranking of the 25 countries are respectively 0.35 and 0.55.

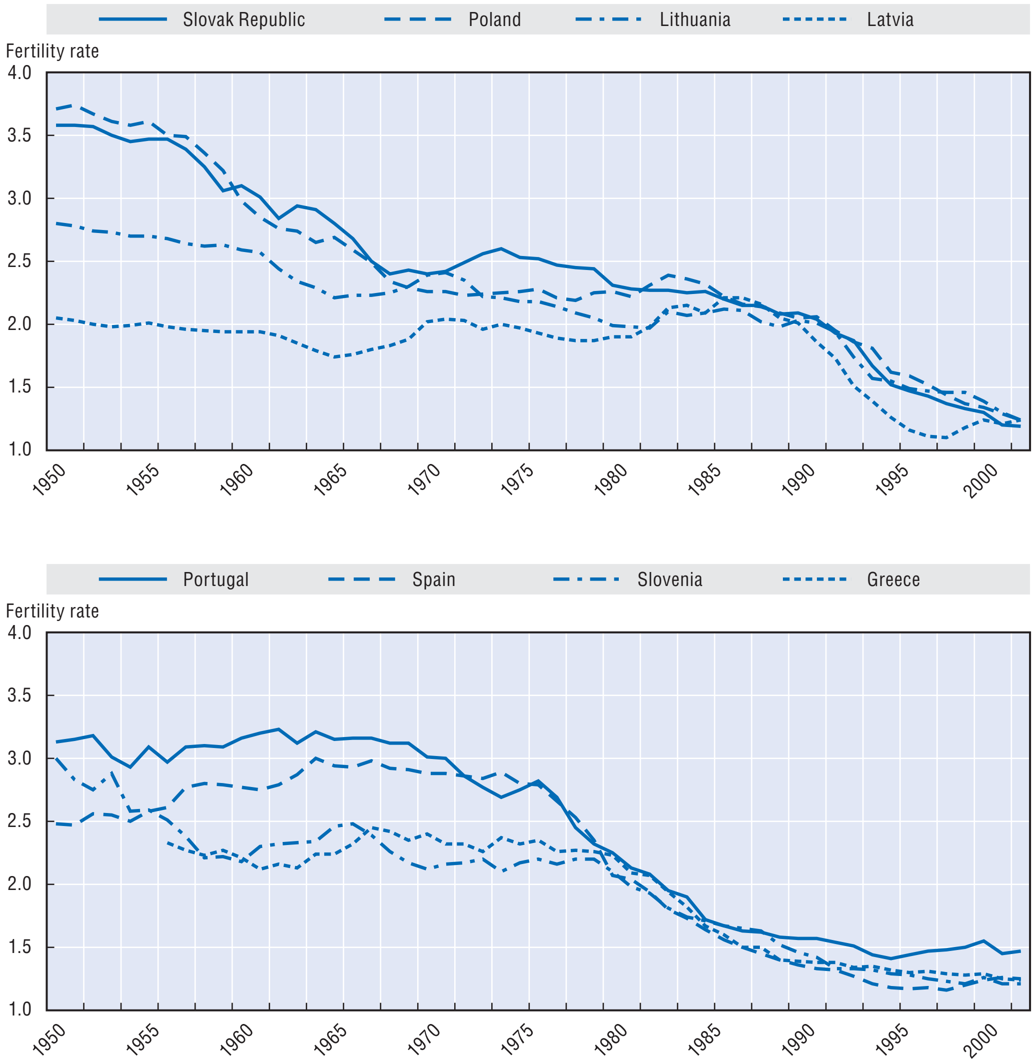
Figure 1.10. **Total fertility rate in 1955-60 and 2000-05 in EU countries**



One way of verifying the similarity of trends in neighbouring countries is to show them in a group. This is done in Figure 1.11 for several north eastern countries (Latvia, Lithuania, the Slovak Republic, Poland) and for some Mediterranean countries (Spain, Greece, Portugal and Slovenia). In the first case, we see the stronger influence of the Catholic religion in Poland and the Slovak Republic which became part of the Soviet block somewhat later than Lithuania, while this influence is of course absent in Protestant Latvia. Once this initial difference has been taken into account, the major event took place in 1989 with the fall of the Berlin Wall. The common situation of the four "transition" countries then imposed a remarkably similar trend in their fertility rates.

The pattern for the Mediterranean countries is similar, but the political events took place 15 years earlier, *i.e.* the fall of the regime of the colonels in Athens, the death of

Figure 1.11. **Trend in the total fertility rate for groups of neighbouring countries**



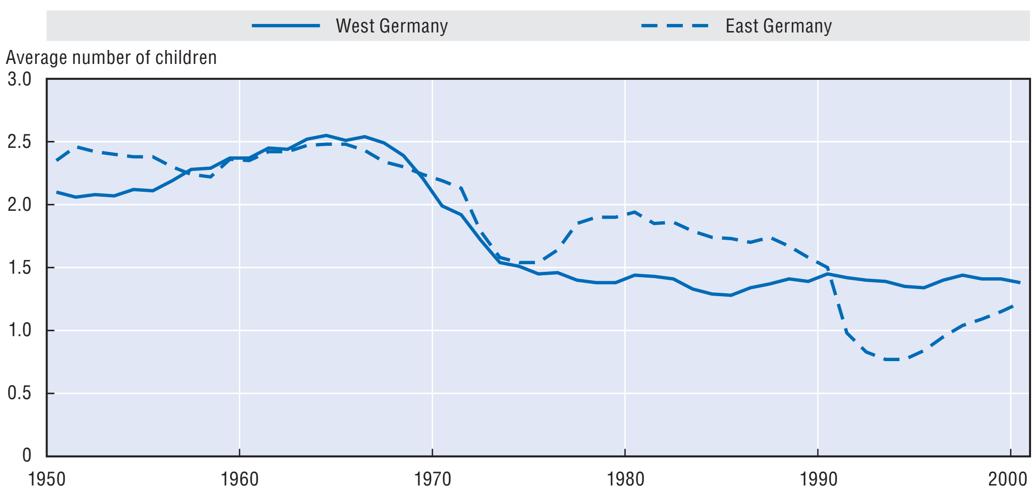
Franco in Madrid, the overthrow of Caetano in Lisbon and, to a lesser extent, the death of Tito for Ljubljana. More specifically, what these countries have in common is the concept of a blocked society: the political regime's rejection of change had the effect of preventing changes in fertility and thus in the organisation of the family. It then took a dramatic event, not to change demographic attitudes, but to enable society to adapt to a new set of circumstances, *i.e.* to readjust behaviour, bring it up to date and bring it into line with the economic and political situation. In order to understand these situations better and to be clearer about what is meant by "bring up to date" and "economic and political situation", instead of comparing countries that are close, we must compare countries that are very close in terms of their culture (religion, language, long-term history) but that have experienced different political regimes or legislative changes. In a sense, this is the biometric method of "matched tests" or pairings.

Three cases are especially interesting, *i.e.* West and East Germany, Romania and Bulgaria, and Sweden and Denmark.

West and East Germany

The only initial difference between West and East Germany was created in 1945 with the imposition of two radically different political regimes. In Figure 1.12, which shows the trend in the fertility rate year by year in both countries between 1950 and 2000 (the series have continued to be calculated by the Statistical Office in Wiesbaden since reunification), we see that between 1955 and 1975, fertility remained exactly the same in both countries. At the time, it was argued that this showed the importance of civil society and culture-specific behaviour, which thereby showed their resilience and, conversely, the inability of the State to control mentalities. In 1974, East Germany, more concerned than its neighbour about the declining fertility, passed pro-birth legislation that offered every mother a maternal salary for the three years following the birth of the child. The legislation was highly successful since fertility rose by 0.5 children, which is a significant increase, and this gap with West Germany was subsequently maintained. In fact, between 1965 and 1975, both countries had undergone the same changes as those that were discussed for France, for the introduction of modern means of contraception had made it possible to prevent unwanted births and had thus led to a drop in fertility. However, in 1974 in West Germany, the oil crisis had the effect, as in France, of delaying the age at childbearing and thus of keeping the fertility rate low. This age at childbearing rose since couples were having greater difficulty in finding work and housing and thus in settling down and starting a family. Since the origin of statistics, in particular thanks to the major study by Roger Schofield and Anthony Wrigley on England between 1550 and 1850, we know that during Kondratieff's depression phase real wages fall and delay the formation of couples and thus marriages and consequently fertility, which apparently falls. However, there was no reason for this mechanism to apply in East Germany where housing was granted to married couples who placed their names on a list. On the contrary, it was advantageous to put one's name on the list quickly and thus marry young. Similarly, since everyone of working age was provided with a job, there was no delay in entering working life. As of 1975, therefore, the difference in fertility between the two Germanies was based on

Figure 1.12. **Comparison of the trend in the total fertility rate in East and West Germany between 1950 and 2000**



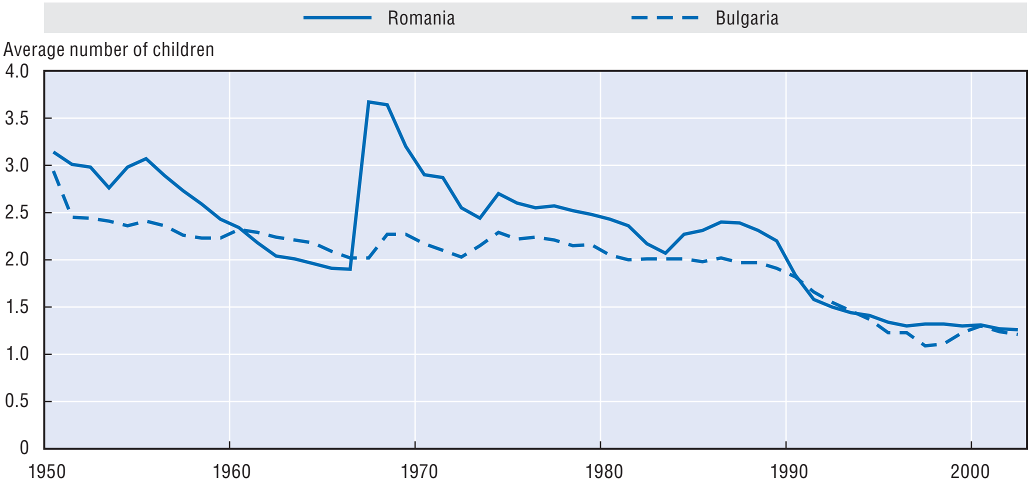
a difference in the timetable for starting a family. East German women continued to have their children very young until reunification (on average, they had their first child at the age of 24.5), while every year on the other hand, West German women postponed by approximately eight weeks the arrival of their first child (and consequently of subsequent children). As a result, by 1989 the age of women having their first child had risen in the West to 27 (today it is 29).

Still to be explained is the sudden upswing in fertility in East Germany in 1975. The immediate reason was, of course, the maternal salary law, which triggered a windfall effect. Women who were planning to have a child at a later date decided to do so earlier. This was exactly the opposite of what was happening at the same time in the West. As a result, the two demographic regimes suddenly veered in different directions, as the East adapted to the nature of work and housing under a communist regime. A development such as the availability of new contraception methods created a new situation in relation to the prior problem and risk of unwanted pregnancies. The Law of 1974 in the East was of a somewhat different nature. It led to an adjustment bringing fertility into line with the real situation. Before fertility became the target of government measures, it followed the same development on both sides of the Wall, but once a measure was introduced the long latency came to an end and the demographic regime responded accordingly. In 1989, with reunification, the situation again changed in the former East Germany, which was now subject to the same housing and employment constraints as in the West. The reaction was immediate and fertility plummeted as East German women adapted to the timetable (time lag) for establishing a family of West German women, who were now becoming pregnant later. The total deficit between the two rates (the surface between the two curves) is also practically the same as the total benefit that had preceded it between 1975 and 1989. Ultimately, both fertility rates seem destined to converge.

Romania and Bulgaria

Romania and Bulgaria have had a comparable history with the long Ottoman occupation, followed by authoritarian regimes, communism during the post-war period and now the transition and the entry of both countries into the European Union. Also, their respective fertility rates remained similar until Ceaucescu took a spectacular measure in 1968 (see Figure 1.13), when there was a virtually total ban on abortion, which had been almost the only available means of controlling fertility. Unprepared for this measure, Romanian women broke a record for births nine months later, doubling the fertility rate. Romanian women then adapted to the new situation and fertility fell fairly quickly, though not down to level preceding the new legislation, for which the fertility rate in Bulgaria was a sort of reference. Some of the additional children born as a result of this measure were rapidly abandoned and placed in orphanages, where the terrible living conditions later came to light when the country opened up in the 1990s. As early as 1990, the fall of the communist regimes led to a drop in fertility, as in the other Eastern countries, but in this specific case it resulted in a return to the same fertility rates in both countries. The difference in fertility was only induced by maintaining a constraint in Romania, while in East Germany it was due to the economic and political system.

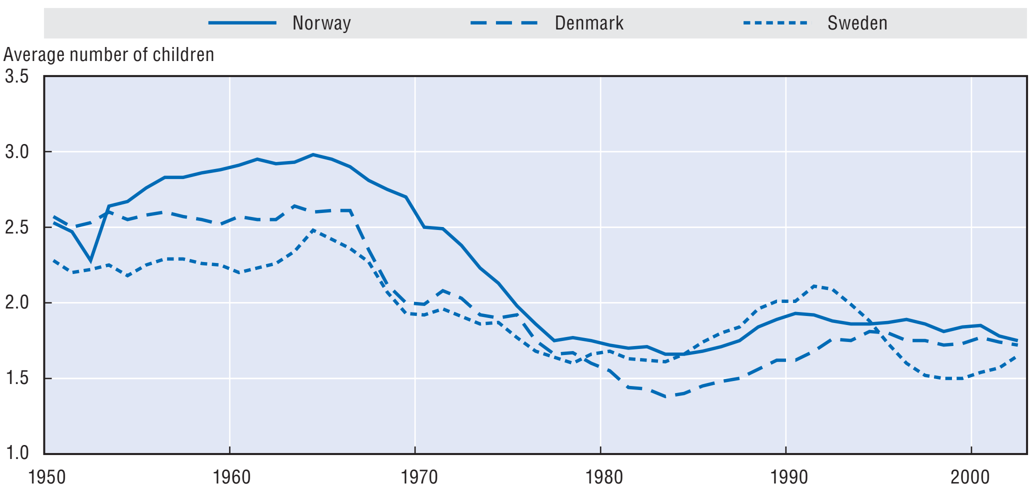
Figure 1.13. **Comparison of the trend in the total fertility rate in Romania and Bulgaria between 1950 and 2000**



Sweden and Denmark

There is no need to stress all the political, cultural and economic characteristics shared by Sweden and Denmark. As a result, their fertility rates followed a very similar pattern until the early 1980s, as can be seen in Figure 1.14. In 1985 and 1986, however, Sweden adopted a number of measures designed to enable parents to stay at home when their children were very young. The fertility rate immediately soared. A number of countries, including France, thought that Sweden had found the magic formula for pro-natalism, but they were mistaken. A few years later, once the benefit of the measures had been reaped, the fertility rate fell below Denmark's, largely offsetting the gain in fertility achieved earlier. Then, at the end of the period, both countries returned to the same rate.

Figure 1.14. **Comparison of the trend in the total fertility rate in Norway, Sweden and Denmark between 1950 and 2000**



The trend in fertility in Norway shows even more clearly the singular nature of the Swedish experience – Norway differing from the other two Nordic countries but gradually drawing closer to Denmark's fertility rate without undergoing Sweden's fluctuation since it did not adopt any major legislative measures in the field of family policy.

Conclusion

Three kinds of events thus occurred: in East Germany, the law of 1974 created a difference that persisted and no doubt would have continued if reunification, a counter event, had not eliminated it. The Romanian law of 1967-68, on the other hand, did not have a lasting effect because the constraint that it introduced was maintained and its effect disappeared when the constraint was ended. Lastly, the Swedish measure amounted to a windfall effect, for couples decided to start their families earlier when the law was adopted and then partly returned to their previous practice, which generated first a surplus and then a deficit in relation to Denmark. In other words, the event in East Germany was of a lasting kind for it took another major event to reverse it. Romania's event was much weaker in that it had lost its effectiveness by the second year. The Swedish event was not of a lasting nature.

In the light of this analysis, it can be seen why predicting fertility trends means predicting future events, especially political events as they will often have a lasting influence. However, to borrow from Hannah Arendt, who devoted a good deal of her thinking to the concept of the event, by definition an event is unpredictable. Arendt sums this up with the following formula: the event creates its own past. The causes of an event, to the extent that they can be determined at all, can only be found after the event has occurred. Consequently, we cannot claim that this or that set of causes will trigger this or that event.

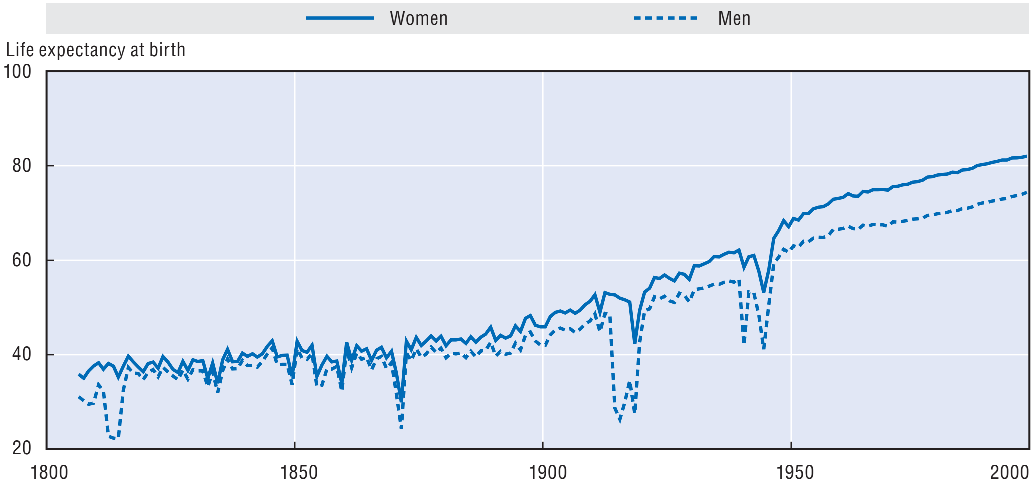
1.3. Mortality: a hidden turning point

The first section of this paper illustrated the case of relatively frequent turning points without major lasting effects, using the example of external migration. The second part identified turning points with effects that were lasting but sometimes less obvious and discussed them using examples of fertility trends. In this final section, we shall look at mortality and focus on a single turning point that escapes immediate observation. We shall confine ourselves to a single country, France, for which we have a very long statistical series, since the analytical work is more complex than in the case of visible turning points such as those that have been previously studied for migration and fertility.

Figure 1.15 shows that, in two centuries, life expectancy at birth in France rose from 38 to 75 for men and from 40 to 82 for women. It progressed slowly until approximately 1890, when the life expectancy of the two sexes stood respectively at 42 and 45 years, *i.e.* an average increase of three weeks per year. It then rose rapidly until 1960, when life expectancy reached 74 years for women and 68 years for men, *i.e.* an average increase of 5 months per year. Starting in 1960, the rate of growth slowed, levelling off at slightly over two months per year. The figure also shows the extent of the drop in life expectancy during the war years: 1812-1815, 1870, 1914-18 and 1939-45.

The chronology of the rising life expectancy is explained by the composite character of life expectancy, which takes into account the frequency of both child and old-age mortality. During the 19th century child mortality hardly diminished at all and then, around 1890, it

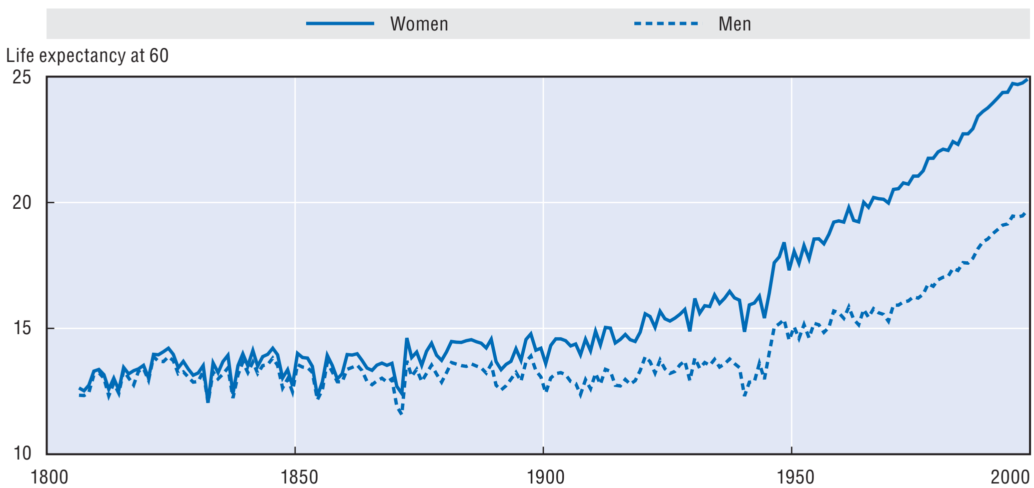
Figure 1.15. **Trend in life expectancy at birth from 1806 to 2000 in France**



began to decline, falling from 200 per 1 000 to 10 per 1 000 in 1960; in other words, the risk of children dying during their first year fell twenty-fold. While one of five children did not reach the age of one under the July Monarchy (1830-1848), 99% of children did so at the beginning of the Fifth Republic (from 1958 until today). Consequently, describing the trend in mortality using life expectancy merely reflects the drop in infant mortality since it includes the same crucial period from 1890 to 1960. To determine the mortality trend at the opposite end of life, we must use a different approach.

An initial method consists of calculating life expectancy starting at a relatively advanced age, such as 60. This would show the average number of years that people who reach this age can expect to live. The trend in this life expectancy at 60 for men and women is shown in Figure 1.16. The picture that emerges is very different from that shown in Figure 1.15 for life expectancy at birth. Until the 1914 war, there was no increase in life expectancy at 60. It remained stuck at around 9 years. It then started to rise slowly for women only, reaching

Figure 1.16. **Trend in life expectancy at 60 from 1806 to 2000 in France**

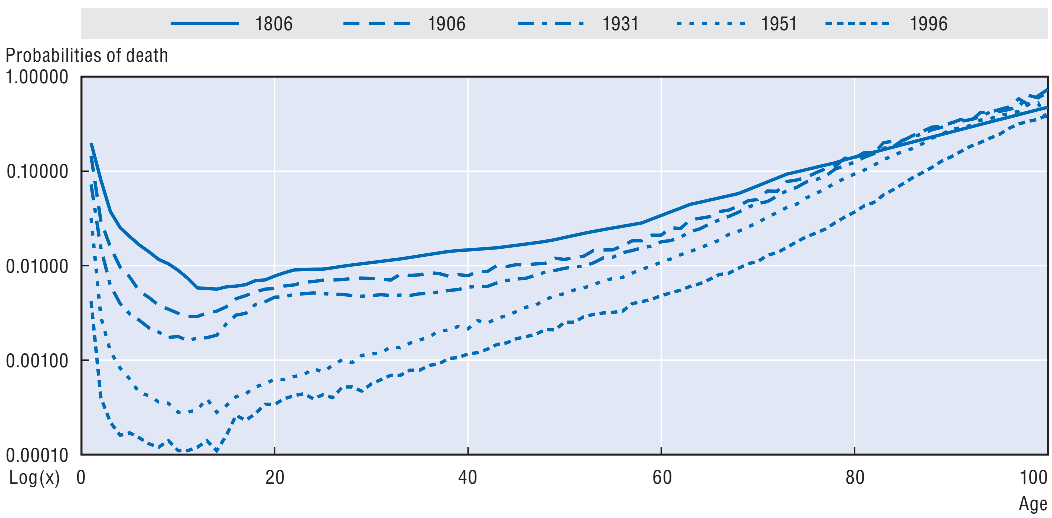


almost 12 on the eve of the Second World War. After the war ended, it suddenly jumped by two years and then rose steadily by a month and a half per year, reaching life expectancy at 60 of 25 years in 2000 for women, or more than double what it had been a century earlier (and 26.5 years in 2004). For men, the progress is even more recent. Their life expectancy increased almost not at all prior to the Second World War, then rose rapidly like women's after the war ended and then began to rise relatively slowly. After 1970, it increased at the same rate as for women, reaching 20 years by the end of the period (and 21.5 years in 2004).

Two other significant characteristics should be mentioned. The fall in life expectancy during the war years (despite people over 60 being non-combattants) was followed by a sharp increase. In all likelihood, the war accelerated the death of frail persons, so that after the war mortality was lower among the stronger people remaining. However, this is not necessarily the case. It could just as well be argued that the restrictions of the war weakened the population, thereby reducing its ultimate life expectancy. A second characteristic of the 1970 shift in the mortality trend is the virtual disappearance of annual fluctuations in mortality. These were very large in the 19th century and were already becoming smaller during the interwar period and after 1945, but as from 1970 they became imperceptible. This is an indication of a major regime shift. These fluctuations were caused by epidemics and cyclical variations in the environment (such as periods of very cold weather), the harmful effects of which may now be thought to be under control (which explains why there was such a strong emotional reaction to the consequences of the heat wave in the summer of 2003 in France, which took the people back to an earlier stage of mortality).

So two major changes in old-age mortality occurred around 1970: mortality began to decline at a faster pace and annual fluctuations disappeared. To understand these changes better, it is necessary to use more accurate data, *i.e.* the risks (or probabilities) of death at each age for each year. Figure 1.17 presents, in semi-logarithmic co-ordinates, the mortality curves (or tables) for female mortality, providing the values of these probabilities by age from 0 to 100 for five different years from 1806 to 1996.

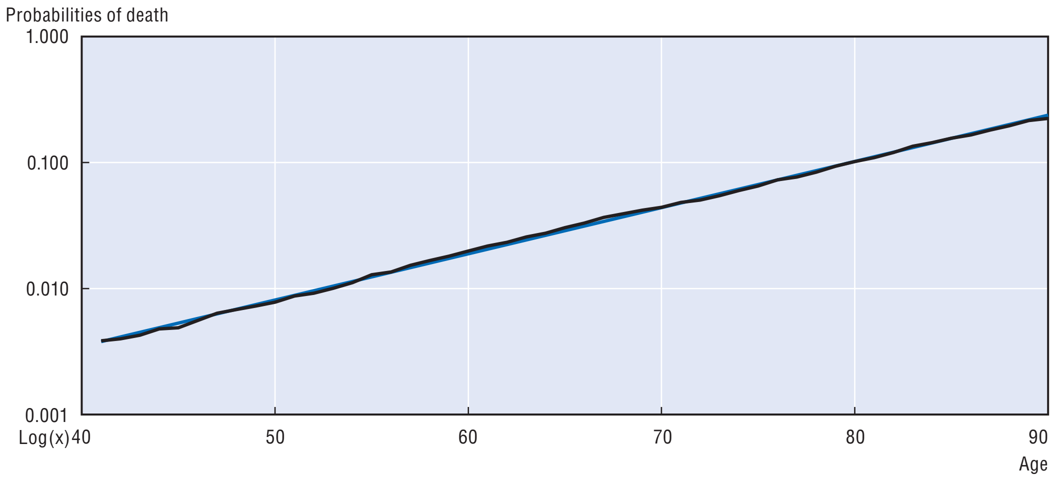
Figure 1.17. **Trend in the age-specific female mortality risk at different ages (mortality table) for different years between 1806 and 1996 in France**



Immediately apparent is the sharp decrease in mortality among the young over the last two centuries. But another element that attracts attention is the highly regular growth of probabilities starting at the age of 50, and even 30 for the most recent mortality tables. Since the probabilities are represented by their logarithm, the linearity signifies that for each year of age after 30, the risk of mortality increases by a fixed proportion (in the range of 10%). An actuary, Benjamin Gompertz, was the first in 1824, to point out this remarkable trend which has since borne his name. Later, Makeham proposed improving the adjustment by adding a fixed risk to each age. In mathematical notation, the probability q(x) at age x may therefore be written:

$$q(x) = K\,(b)^{x} + A$$

Figure 1.18. **Adjustment of age-specific mortality risks of French women in 1960 by an exponential**[1]

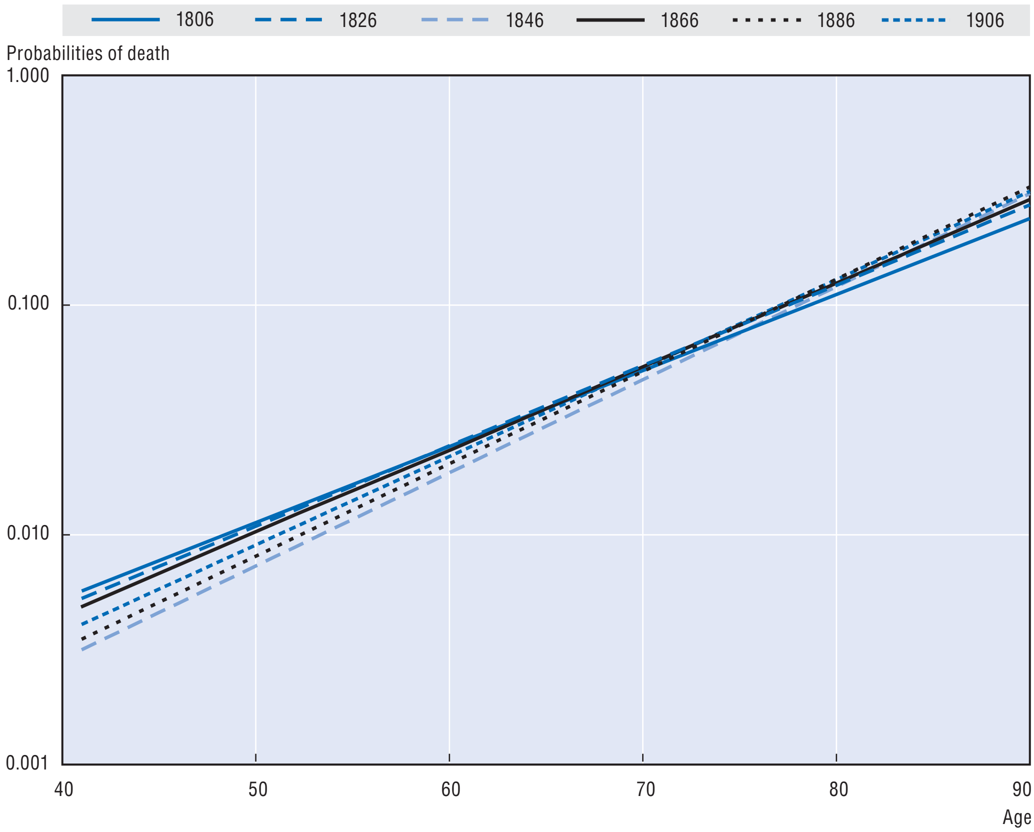


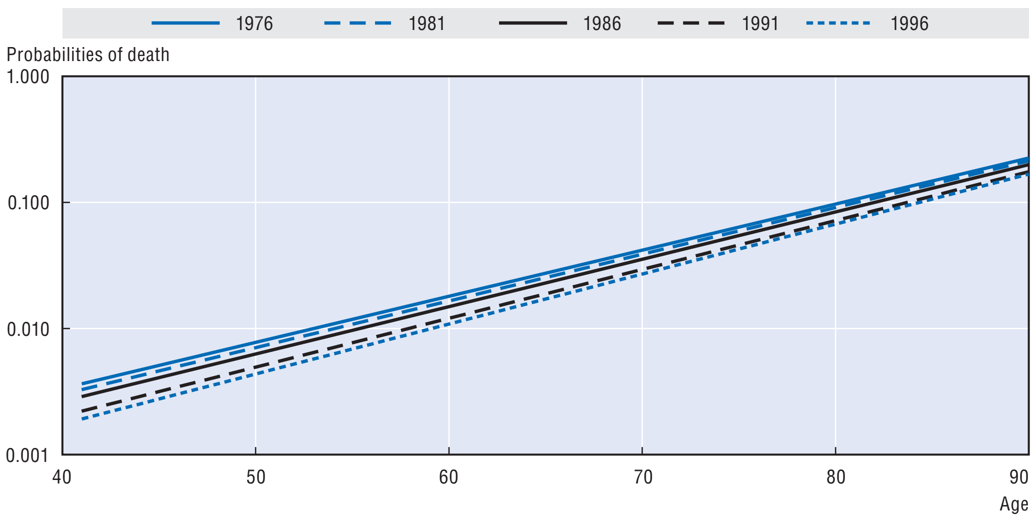
1. Thus by a straight line when the scale is in logarithms.

Figure 1.18 shows the extraordinary quality of the adjustment obtained in the case of the mortality risks experienced by French women between the ages of 40 and 90 in 1960. It is very rare to see such a close match in the social field. The advantage of the Gompertz-Makeham law is that it summarises a set of 50 risks (one per year from the age of 40 to 90) using three values, the constant K, the multiplicative factor b (close to 1.1 since we have seen that the annual increase was 10%) and the constant risk A. This latter is not relevant for old-age mortality, so we will only be concerned with the two initial coefficients K and b. We have estimated them for the value of A, which provided the best adjustment using the method of least squares on the logarithms. The trend of the two parameters since 1806 is interesting. Figure 1.19 shows the Gompertz lines corresponding to mortality risks before 1970 and after 1970.

The difference between the two periods could not be more obvious. Before 1970, the gradient of the lines (parameter b is their slope) increases in such a way that they seem to converge and intersect at an age of approximately 80. The older people grew, the less change there was in the risk of dying over time. This may be the source of certain beliefs in there being a maximum age or an age at which the Psalm of David says that it is normal to die. The fact that in the past there was a lower risk of dying after the age of 80 than in recent years

Figure 1.19. **Adjustments of mortality tables using Gompertz lines before and after 1976**





may be accurate (some, such as the probabilist Gumbel, contrasted mortality and longevity in the 1930s, thinking that they could explain the supposed presence of very old people in the past in countries with high mortality rates by a selection due to high mortality), but is much more likely to have been due to errors in recording the age of the oldest people who died at a time when civil records had not yet attained their current level of accuracy.

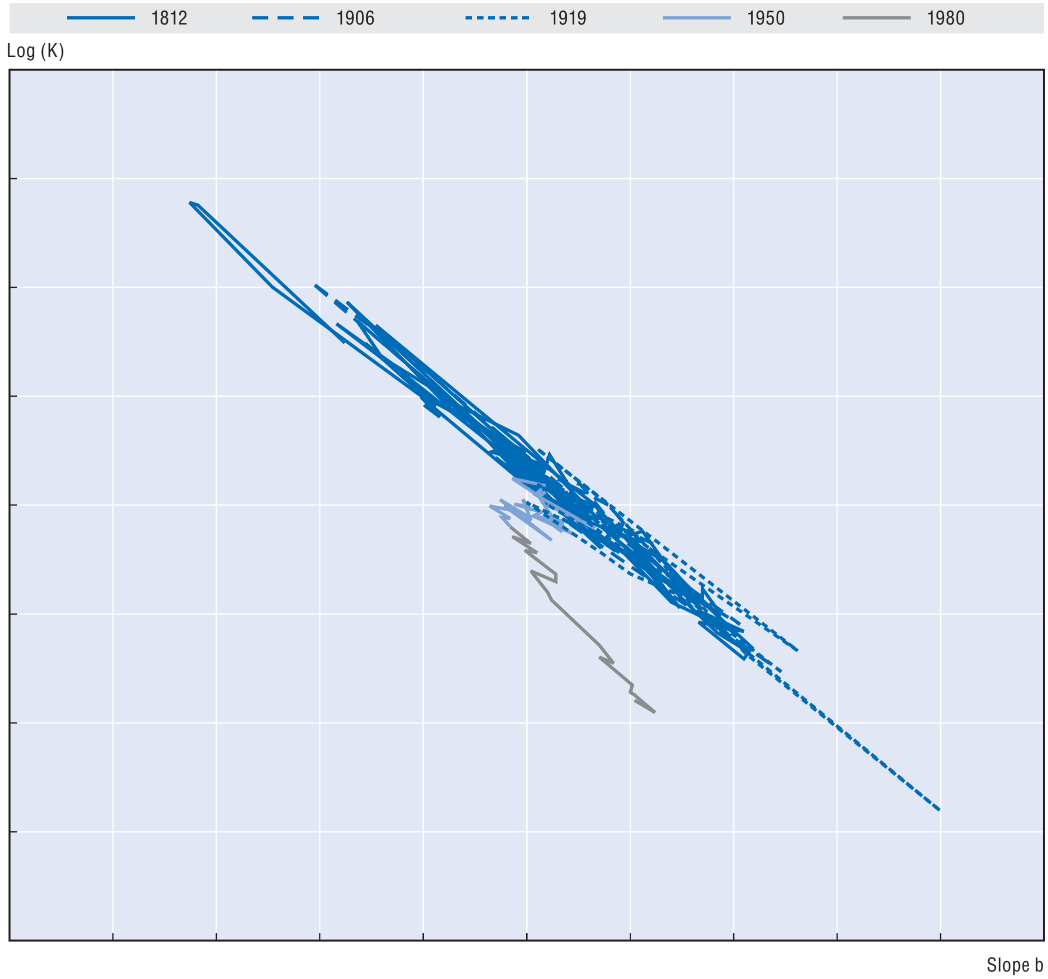
Be this as it may, up until 1970 the decline in mortality became proportionately lower as one advanced towards the biggest ages. However, everything is different after 1970. In figure 1.19, the Gompertz lines corresponding to mortality tables after this date now seem to be nearly parallel. This observation is of great importance. It means that mortality is declining uniformly at all ages and that the risk, whatever the figure put on it, is falling every year by a certain fraction, around 2%. This seems to be little but is actually a great deal when it is considered that, over a period of 35 years at this rate, the risk will be divided by 2. Another way of presenting these facts is to say that the mortality of people aged 60, 70 and 80 in 2000 is the same as the mortality of people 5 years younger in 1975, *i.e.* aged 55, 65 and 75 at that date.

There is a more accurate way of representing this change in old-age mortality around 1970. It suffices to represent each Gompertz line corresponding to a year by its two coefficients log(K) and b (we have chosen the logarithms of K because they are the coefficients of the line) and to consider these two coefficients as the two co-ordinates of a point located in a plane the horizontal axis of which measures slope b and the vertical axis the coefficient log(K). The result is shown in Figure 1.20. We have connected successive years in order better to identify the time path of these Gompertz lines. It can be seen that, before 1975, the points representing the Gompertz lines were themselves located along a line, which exactly expresses the intersection around a fixed point at about age 80, as shown in Figure 1.19. But suddenly, around 1975, this trend pattern no longer holds true. The path diverges horizontally from the line that it was following until then, which means that the slope is decreasing. This only lasts for a few years and, starting in 1980, another rectilinear path appears that is very clearly separate from the former one and much less inclined. This is exactly what we observed in Figure 1.19, where the slopes changed much more slowly while the coefficient K diminished rapidly.

Can this change in the mortality regime occurring around 1975 be explained? This is difficult as we do not know the biological or social reason that would explain the Gompertz law. Like the law of universal attraction that Newton observed but was unable to explain or justify, the Gompertz law, despite its universality (it is also valid for some of the animal kingdom), remains a mystery. Certain mathematical biology models indicate that it might be due to a gradual loss of competence in repairing errors in DNA replication coding and spontaneous mutations, but this is hardly useful from a practical standpoint and even less so for predicting the future mortality trend.

As a result, a turning point was concealed in the annual mortality tables. Unlike the turning points for fertility and migrations, this turning point cannot be related directly to political and economic events. It is therefore even more difficult to predict how long the situation corresponding to this turning point will last or when the next turning point will occur. This is unfortunate, for the trend in the two parameters K and b will affect the level of mortality at advanced ages in the coming years and is therefore relevant to any discussion of population ageing.

Figure 1.20. **The trend in the two parameters of the Gompertz laws adjusting age-specific mortality risks**



Note: Until around 1970, all mortality laws are in the same alignment, but they diverge from it and move in another direction, starting in 1980.

1.4. Conclusions

The conclusions of this brief study, which have been established on the basis of specific facts, are fairly negative about the possibilities of forecasting demographic trends. It is impossible to make a demographic forecast independently of an economic and political forecast. A long-term population forecast assumes implicitly that no event will occur. It drifts in an unreal world aptly illustrated by the migration projections conducted by the United Nations. Can political and economic events be predicted? Probably not. There remains one approach, *i.e.* using foresight and scenarios, assuming that this or that event will occur and deducing its impact on demographic patterns. This means forecasting possible rather than probable events, which cannot be foreseen.

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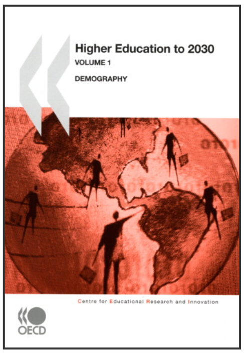

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