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CHAPTER 2

FROM THE MACRO-MICRO OPPOSITION TO MULTILEVEL ANALYSIS IN DEMOGRAPHY

If educational science, examined in the previous chapter, was the first social science to develop a fully multilevel approach, one must also bear in mind that it is one of the most recently constituted social sciences. It was only in the late 1960s (Travers, 1969) that education emerged from the prevailing earlier discipline of pedagogy, whose focus was on the adjustment of teaching practices rather than on studying the processes linking teacher to student—the goal of education as a social science (Filloux, 2001). Demography, in contrast, has a far longer history. It traces its origins back to the "political arithmetic" of the late seventeenth century, illustrated by the work of John Graunt (1662/1977); in the nineteenth century, it pulled away from the other social sciences derived from the same source. The present chapter adopts a long-term perspective in order to discern the links between those historical stages and the aggregation levels—and to show the place of multilevel analysis in demography's evolution over the centuries.

We will show the privileged position of analysis at the aggregate level—most often, an individual country—from the inception of demography to the mid-twentieth century. This analysis was informed by methodological holism, which produced (1) population censuses, performed at regular intervals to obtain an instantaneous view of the population, and (2) comprehensive measurements of the events experienced by its members. There was no room for the individual in the analyses and tables derived from these censuses, which were attached to civil-registration statistics: the analyses and tables showed relationships external to the life of individuals, who expressed the constraints laid down by the society in which they lived. These constraints can remain identical for long periods; when they change, they can do so very gradually, adjusting to new economic or social conditions, or rapidly in periods of crisis such as a war or an economic recession. This effect occurs in a historical time-frame, which justifies the use of period analysis, and in a homogeneous national space, which justifies the analysis on aggregate data.

The lagged effects of World War II—on marriage, for example—cast doubt on the effects identified by period analysis. The use of fictitious cohorts displaying the behaviours observed in a given period led demographers to postulate the existence of a fictitious cohort that—in such demographic-recovery periods—would make a life-long effort to catch up on a lag it never actually experienced (Henry, 1966). Likewise, the *effects of period events may impact the lives of individuals much later than at the time of their occurrence—hence the need to develop an individual approach accommodating those effects.*

Cohort analysis initially enabled demographers to introduce the time lived by individuals and to illustrate more clearly the effect of wars or economic crises on the deferral of the events studied to better times. The implementation of such an approach, however, required very restrictive hypotheses: the homogeneity of the population studied and independence between events. These hypotheses allowed the use of individual data from civil-registration records in aggregate form to compile cohort tables. However, survey data, using much more abundant and detailed information than the civil-registration records, showed that the hypotheses did not hold up and needed to be waived.

Event-history analysis offered a solution to these difficulties, by examining the entire life of a sample of individuals: demographers could now analyse the interferences between the events experienced by individuals and the effects of individual characteristics on the events. The focus of the analysis thus shifted from society as a whole to the individual, situated in a heterogeneous society and experiencing interdependent events. This led to methodological individualism. However, the analysis centred not on the individual in all his or her complexity, but on a statistical individual, subjected to a specific process by the events and characteristics examined.

Whereas the aggregate-level analysis demonstrated processes at work at the population level, the individual-level analysis showed the mechanisms underlying individual behaviour. But are the two approaches entirely antagonistic? Might it not be possible to interlink them in order to improve our knowledge of human behaviour? Somewhat later than education, demography tried to gather individual data and aggregate data into a single model: Mason et al. (1983) and Wong and Mason (1985) conducted multilevel analyses—of fertility and contraception respectively—through a simultaneous study at the individual and aggregate levels: the aggregate levels consisted of the individuals' countries of residence. The authors used data from the World Fertility Surveys performed in several developing countries. Such analyses were later extended to a variety of segmentations (villages, ethnic groups, regions, etc.) and to fuller models than the logistic regressions used in these early examples. We will show how this led to the introduction of multilevel event-history models, which are still under development and continue to raise many issues examined here in detail.

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1. INRODUCTION

Although the word *demography* first appeared in print in the nineteenth century in Guillard's *Eléments de statistique humaine, ou démographie comparée* (1855), its origins can be traced back to what in the seventeenth century was known as *political arithmetic*, a term introduced by Petty in the 1670s (Dupâquier, 1983) and the title of his book published in 1690. The earliest application of thorough going statistical methods to the study of populations was in fact the work of Graunt (1662/1977), where for the first time the information contained in the Bills of Mortality was treated as a source for measuring the population of a country or region. This was a revolutionary idea at a time when the events of human existence such as birth, illness and death were believed to be the prerogative of God and hence not admitting of scientific inquiry.

Let us take a closer look at how Graunt envisaged this political arithmetic. In common with most of the natural sciences at the time, the approach was essentially descriptive, the purpose being to produce accurate measurements of a state's population and of the various phenomena responsible for keeping it at a given level. It is important to appreciate that no reliable census of the population existed at this time, so that the only means of estimating the population of a city, let alone a country, was by making highly speculative calculations. Contemporary estimates of the population of London, for example, varied between two million and six million. The first task was thus to produce a more reliable estimate of this population based on the sources available at the time (the Bills of Mortality and the Bills of Baptism) and with a careful and critical examination of their quality. Working with what he judged to be the most credible hypotheses, Graunt demonstrated that the population of London was close to 380 000 and not the millions previously thought.

As the above shows, although essentially descriptive in approach the new science found it necessary from the outset to propound hypotheses about the populations and events that formed its field of inquiry. The idea that prevailed in the eighteenth century was that a kingdom's population stayed more or less unchanging through history, and although epidemics, wars and natural catastrophes and so forth caused localized and short-term variations, these were quickly made good by the return of prosperity and the concomitant increase in births. By working on larger and larger populations, compensations would operate, revealing greater regularity and effacing these localized variations. In *The Divine Order* (1741/1979), Süssmilch interpreted this regularity as the action of Providence, a view that well illustrates the importance of the religious outlook in the early development of political arithmetic. Later on, however, rationalist thinkers suggested that human phenomena might be subject to laws as strict as those which had been discovered in the natural sciences.

The existence and assumed form of these laws provide the starting point for our discussion. The lack of censuses in the seventeenth and eighteenth centuries obliged the early analysts to make hypotheses about the relationships which existed, at a given point in time, between the events observed (births, marriages and deaths) and the populations in which they occurred. A question that began to be explored was that of the variation in a population consequent on the births and deaths it experiences. When Euler (1760) said that he had assumed that the total number living in one place remains the same, or that it increases or decreases uniformly, he was in effect anticipating the concepts of stationary or stable populations that were not formalized until the start of the twentieth century (Lotka, 1939).

In the nineteenth century, the main impetus for the study of populations came from Quetelet with his theory of the “average man”, but it was the sociologist Durkheim who did most to elaborate a theory for the quantitative analysis of human behaviour, based on clearly stated hypotheses and the method of concomitant variations. The same methodology was in fact presented fifty years later in Landry's (1945) treatise on demography, although the latter contains no reference to this famous precursor. This method implies adoption of a period approach, which is examined in the first part of this chapter. The main source for this approach are population censuses, which provide “snapshots” of the population under observation at nearly regular intervals.

Although the distinction between “historical time” and “individual time” was not at first clearly understood, some analysts had already made use of sources which followed individuals over their lifetime, such as data concerning tontines or annuities (Deparcieux, 1746). Later on, it began to be suggested that the period perspective employed by most authors might not be the only one possible (Delaporte, 1941). It was after the Second World War that demographers showed how this approach, based on hypotheses which completely ignored individuals' experience of time, produced results whose interpretation was problematic. Their solution was to develop methods of longitudinal analysis that could follow individuals over their entire lifetime and for which civil registration materials and population registers were the most important sources. So as to observe the various phenomena in isolation, this new paradigm treated them as mutually independent and occurring in populations that were assumed to be homogeneous. This approach is explored in the second part of this chapter.

These hypotheses of independence and homogeneity were challenged, however, by the growing volume of survey results that provided more detailed information than population registers and civil registration sources. A need was increasingly felt for methods that could handle the interdependence of phenomena and the heterogeneity of populations. This change came at the beginning of the 1980s with the introduction of event history analysis. These techniques employed more complex mathematics and probability theory than had previously been used. The third part of this article is given over to exploring the theoretical notions that lie behind these methods.

However, this approach is itself overly focused on the individual and neglects the influence on individual behaviour of the social context and its associated constraints and rules. A new theory was needed, one that retained the vantage point of the individual, in contrast to the period approach, yet that introduced multiple levels of aggregation so as to take account of the constraints which underpin individual behaviour. This methodological innovation is what is known as multilevel analysis. The fourth part of this chapter attempts to set out the conditions that must be met for this technique to be valid.

A general discussion of the various paradigms that have been proposed is the framework for examining their respective contributions and for considering the position held by the multilevel approach in the development of hypotheses in demography. The point to stress here is that demography does not possess a collection of perspectives and orientations that are fixed for all time; they are in fact specific to the society in which the researcher lives and are thus subject to change over time (Singleton, 1999). Our task, therefore, is to define carefully the different paradigmatic choices, identifying their specific features and assessing their fundamental premises.

2. THE AGGREGATE PERIOD APPROACH

Notwithstanding the great diversity in outlook and interests of those working in the field of political arithmetic up to the mid-nineteenth century, and in demography until the mid-twentieth century, we propose to show here that they had a certain number of intellectual positions and postulates in common. It is suggested that in consequence the whole of this long period can be identified with a single paradigm. This involves identifying the ideas and principles that underline this research, by demonstrating the unity which lies behind the apparent diversity of the authors and the research undertaken.

From divine order to secular order

The early authors discovered that the Bills of Mortality and Bills of Baptism could be used to count deaths by cause, births and so forth, and that from these figures firm conclusions could be produced. Graunt's (1662/1977) comment that he did not know what first led him to begin his completely unplanned work with the Bills of Mortality is clear evidence that contemporaries saw no interest in collating these weekly statements in tabular form. Yet such tables were to yield rich results, since providing care was taken to check the quality of the data, they made it possible to quantify with greater accuracy a large number of earlier approximations which now appeared far removed from reality.

Once this discovery had been made, it could be asserted that the events experienced by man could, like other natural phenomena, be subjected to quantitative study. This is what Petty (1690/1963) had in mind when he wrote: “The Method I take to do this is not yet very usual: for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course (as a Specimen of the Political Arithmetic I have long aimed at) to express myself in Terms of Number, Weight, or Measure; to use only Arguments of Sense, and to consider only such Causes as visible Foundations in Nature; leaving those that depend upon the mutable Minds, Opinions, Appetites of particular Men, to the Consideration of others” (p. 7). Although the result of his estimations contained numerous errors and approximations, Petty's comment in effect laid out what was to form the foundations of the social sciences.

The primary aim of these early authors was to count the population so as to have a more precise idea of the actual figures, for comparison with earlier estimates that lacked any statistical basis. Many of these authors drew up a list of very similar questions for which they attempted to find answers (e.g. Graunt (1662/1977), Süssmilch (1741/1979), Moheau (1778/1994)), such as, what is the size of the population? how many men and women are there? how many are married and unmarried? and so forth.

But the sources available to these early authors meant that sooner rather than later they had to resort to making hypotheses about the production of these figures for use in their estimations. For example, when they wanted to estimate the population of a city or a country, they had only the numbers of deaths, births and other incomplete figures relating to these units. Consequently the relationships that existed between populations, deaths, births and so on had to be expressed as hypotheses, which could then be applied to the enumerated quantities in order to deduce the total population. This concept of the "multiplier" used in these calculations was employed by many authors, and did not become redundant until the introduction of exhaustive population censuses in the late-eighteenth and early-nineteenth centuries meant that these hypotheses were no longer needed.

This technique presented a number of problems, as is illustrated by the argument that opposed Moheau and Condorcet (see Condorcet, 1776-1789/1994: pp. 130-141). Moheau (1778/1994) estimated the total population of France using observations for eight *Généralités* (administrative regions) in different parts of the country and for which population enumerations and birth statistics were available. The ratio between the number of births and the number of inhabitants was not constant across the regions but varied between 27.5 and 23.25. Taking the births registered for France as a whole and an average value for the multiplier of approximately 25.5, Moheau produced a figure of 23 500 000 for the total population. Condorcet attacked this estimation, stating: "If, on the basis of observations made on a certain number of men, I want to determine with accuracy what the situation is in a large country, my experiment must be conducted on men drawn from that country's different climates and types of air, from its different social orders and conditions of existence" (p. 132). In other words to obtain a valid estimate it is necessary to take a representative sample of the country's population, a criterion that Moheau's observations do not respect.

This criticism had far-reaching implications in that it opened the way for the study of population to go beyond simple enumeration to analysis. A satisfactory solution to the problem exposed by Condorcet required use of what would later be referred to as regression methods in order to determine relationships between births, populations and the characteristics of the different regions of a country. This leads us to consider the use of statistics and probability theory in the scientific study of population.

It is in fact crucial to realize that political arithmetic was born just a few years after the correspondence between Pascal and Fermat (1651/1986) in which they laid the bases of probability theory of. These concepts were employed in the very first works of political arithmetic. For example, Graunt (1662) reported that he bet equal odds that a man picked at random would live another ten years; and Deparcieux (1746) wrote an *Essai sur les probabilités de la durée de la vie Humaine* [*Essay on the probabilities of the length of human life*]. The emergence of probability theory opened the way for an entirely new way of considering human phenomena. Previously, because the timing of these phenomena could not be predicted it was thought that their occurrence could have no rational explanation. Each individual was believed to have a unique destiny that could be interrupted at any time. Consequently it appeared futile and unnecessary to try to find laws that implied a certainty of occurrence, comparable to those already known to govern the workings of physical phenomena. In other words, calculations about a man's death were excluded, whereas the laws governing the trajectory of a falling stone, which under fixed initial conditions will always be the same, had been formulated.

A full account cannot be given here of the bases of probability calculation (see for example: Matalon (1967), Suppes (1981)), which is a vast field of inquiry. Attention is instead focused on how the basic hypotheses of probability and statistics have been applied in the social sciences. The important point to appreciate is that the two disciplines developed at the same time and that progress in probability theory was paralleled by progress in the social sciences.

As an example let us consider the study of mortality. It is not hard to see that these applications were conducted from the "objectivist" perspective. The law of large numbers propounded by Bernouilli (1713) states that the value of the ratio between the number of events observed and the total number of individuals exposed to the risk, approaches the theoretical probability as the number of individuals observed approaches infinity, the assumption being made that this population is homogeneous. A probability of dying can thus be considered as closer to the corresponding probability the larger the population being observed. This is why uncertainty is justified when small populations are being observed and indicates the desirability of working on complete data. Süssmilch (1741/1979) stated that the inexactitudes of small figures disappear when the numbers being compared are large, thereby showing his commitment to the objectivist approach. This is also the reason why censuses and an exhaustive system of civil registration became accepted during the nineteenth century as the indispensable source for the study of society.

Towards a statistical period analysis

Let us now consider the type of inference that is required in order to move beyond simple description to explanation and an authentic analysis of phenomena. Establishing whether or not the phenomenon being studied is influenced by a particular factor raises the question of how to define and measure this factor, and of how to identify the relationship between the phenomenon being studied and those which may explain it. We begin by considering the problems of measurement.

As was seen earlier, in the perspective adopted here measures have to be aggregated to estimate the probabilities of different events. This means that the probability of a given event can be determined by working either on an entire population or on a large enough number of sub-populations. But if the aim is then to relate this event to another event or to another characteristic, this is impossible when considering the whole population, since two marginal probabilities tell us nothing about any link that may exist between them. Such a relationship can only be identified when working on sub-populations. To take a simple example – that will be referred to throughout this chapter – if we know only the migration probabilities for the whole population and the proportion of farmers in that population, no relationship can be established between these two quantities. One solution is to divide this population into a large number of sub-populations and to estimate the same quantities for each. The migration probabilities can then be calculated for farmers and for the rest of the population, under certain hypotheses which, as will be seen shortly, may vary.

This way of reasoning was obviously not present when this approach first developed, but it did underlie early efforts to identify relationships between demographic phenomena. The work of Süsmilch (1741/1979) was already moving in this direction. When comparing urban and rural mortality in different countries, he concluded: "The difference between the towns and the villages must be traced to the forms of nourishment, the manners and the customs" (p. 335), thus implying that different phenomena could be inter-related. Likewise, rather later, Quetelet (1869/1997) when introducing his theory of the average man affirmed that “man is under the influence of causes of which most are regular and recurrent. By means of a sustained study, it is possible to determine these causes and their mode of action, as well as the laws they give rise to, though to succeed in this, very large groups must be studied, so as to eliminate from the observations all that is merely accidental or individual. Probability calculation shows that, all things being equal, one comes closer to the truth or to the laws one is trying to define, the larger the number of individuals on which observations are based” (p. 33).

Of the various applications of this approach, we give here an example that Quetelet borrowed from Sadler (1830). Examining the link between fertility and nuptiality in a given country, he divides the country into departments (France) or provinces (Belgium). For each of these units he then calculates the proportion of marriages and the number of legitimate children per marriage. A comparison of these two quantities leads him to observe that “the places which have the greatest number of marriages each year are those where the fertility of marriages is lowest, by a form of compensation which prevents a country from having too rapid a growth of population”(Quetelet, 1869/1997, p. 80). It is clearly a correlation that he observes between these aggregated quantities, and no attempt is made to show that one is the cause of the other. A correlation of this kind carries no causal implication and may be due to a third factor, without any causal relationship existing between the first two.

In my view it was Durkheim (1895/1937, 1897/1930) who gave the clearest statement of the objectives of this social science and of the means for their realization, at the same time as offering a critique of his predecessors' approach, and in particular of Quetelet's “average man”. The latter theory can provide explanations of human behaviour, if it is accepted that it depends solely on the country in which it occurs and on the correlations that exist between the various social facts in the society. But the raison d'être of this behaviour is not explained and the underlying causes have to be sought elsewhere.

Durkheim's starting point is that social facts are independent of their function in society and that without being changed they can be employed for different purposes. This function is the priority for study, whereas identifying the usefulness of a social fact is of secondary importance. However, this function cannot be considered without taking account of the various constituent elements present in the society being studied, such as the religious, domestic and political groups, and how these are associated. Social phenomena must therefore vary according to the forms of this association and the organization of these constituent parts of society. The function of a social fact can thus be identified by relating it to other social facts, though the social system itself is the basis of this explanation (Franck, 1994).

In these conditions how can it be proved that one phenomenon is the cause of another? Ethical considerations preclude use of authentic experimentation in most of the social sciences. Some form of comparative method has therefore to be used, and of these the most effective is the method of concomitant variations, as proposed by Durkheim (1895/1937). The idea behind this is to see whether the variations exhibited by the phenomena in a sufficient number of cases are evidence of interdependency between them. Thus when Durkheim observed that the proportion of suicides in different provinces of Prussia varied with the percentage of Protestants (Durkehim, 1897/1930), he concluded that suicide was inversely proportional to the degree of integration of religious society, since in his view the Protestant church was "a less strongly integrated church than the Catholic church" (p. 159). This method is the same as that proposed by Landry (1945), for whom understanding of a temporal or spatial variation required identification of the relationship of concomitance between the phenomena being studied. It amounts to what in present-day vocabulary would be described as a regression analysis between the percentage of suicides and the percentage of Protestants living in different regions. A simple example, that has already been referred to, can be used to give this model a more precise formulation.

For this purpose we work with Norwegian data[1] relating to the generation born in 1948, which gives each individual's occupation at the 1970 census. Individuals are identified who have changed region in the following three years, distinguishing between farmers and the rest of the population. If m_a and $m_{\bar{a}}$ are the migration probabilities of farmers and non-farmers, which are required to keep the same level in every region of the country, it can easily be shown (Courgeau, 2000b) that the migration rate for region , $m_{.j}$, will be a linear function of the proportion of farmers in each region, $a_{.j}$ (see figure 1):

$$m_{.j} = a_{.j} m_a + (1 - a_{.j}) m_{\bar{a}} = a_{.j}(m_a - m_{\bar{a}}) + m_{\bar{a}} \qquad [1]$$

Figure 1: Aggregate-level model

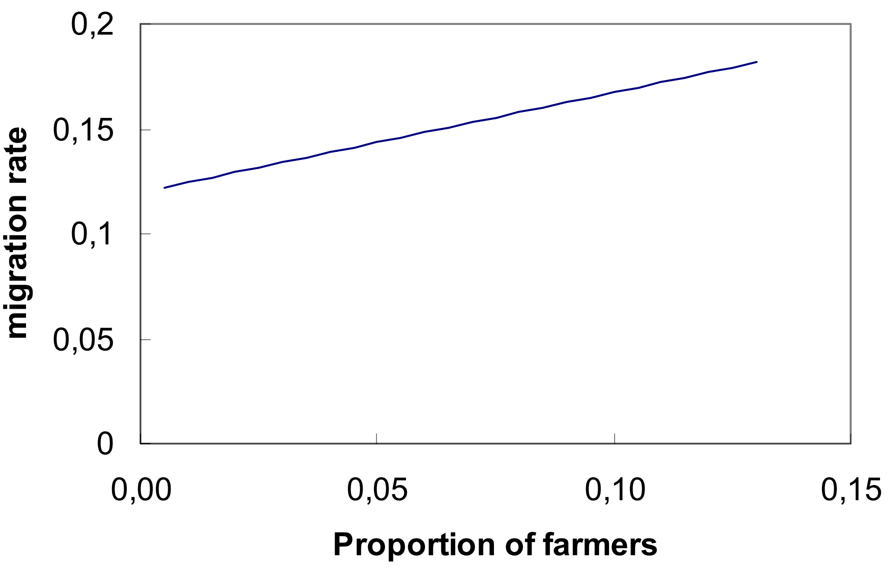


Figure 1 gives the increase in the estimated migration rates with the proportion of farmers and the extrapolation of these results shows the migration probability of

[1] The Norwegian statistical services allowed me to use the files produced from the population register and created by Kjetil Sørlie and Øysten Kravdal

farmers to be five times higher than that of non-farmers (0.60 as against 0.12), if the hypothesis that these probabilities are independent of the regions is verified.

Can this approach be generalized to handle any number of explanatory characteristics? If these are independent of each other it can be shown that separate relationships of type [1] give the same result as a single relationship that combines all these characteristics. Durkheim (1895/1937) used separate analyses of various characteristics to show that suicide was inversely proportional to the levels of religious, domestic and political integration prevailing in the society. The same result could have been obtained by examining all these characteristics simultaneously, if the hypothesis of independence in their effects is verified. If this hypothesis is violated, however, the relationship between the phenomenon being studied and the explanatory characteristics cannot be estimated accurately, when we have only the marginal percentages for individuals presenting these various characteristcs (Courgeau, 1999b).

We also need to consider how time is incorporated in such an analysis. For the early authors, who suspected the existence of laws as strict as those governing the physical world, human phenomena could not be time-dependent as such but merely experienced short-term variations that were quickly followed by a return to equilibrium. This is what Halley (1693) had in mind when he spoke of "the mortality of mankind". However, observation of increasingly large populations revealed this hypothesis to be untenable and showed that populations could in fact experience very long periods of continuous growth or contraction, for example. Notwithstanding this fact, observation of a population at a given point in time, by means of a census, is not affected by such a variation. The great strength of this approach is that by basing analysis on "snapshot" views of a population it does not initially have to consider its changes over time. These can be analysed later by comparison of two or several "snapshots" taken at different points of time.

This approach is at the origin of what demographers refer to as cross-sectional or period analysis, and which was used almost exclusively until the end of the Second World War. It makes the assumption that behaviour in any given period depends on the events of an economic (e.g. economic crises, periods of full-employment), political (e.g. wars, revolutions) or more generally social nature (e.g. changes in the integration of social groups, in values) occurring at the same time. On the other hand, it also makes the assumption that the past, the lived experience of generations, has no influence on present behaviour.

Recent developments of this approach

Given the difficulties of estimating the populations of different countries in the seventeenth and eighteenth century, before the introduction of censuses, it is clear that any attempt at estimation of long-term change in the population would have been futile. Moreover, as already noted, in the early days of political arithmetic the dominant hypothesis was that of a constant population. Before long, however, observation had shown that demographic phenomena could not realistically be treated as constant over long periods and that these variations could be interpreted in relation to each other.

These observations were at the origin of demographic transition theory, which has provided an analytic context for the comparison of the snapshot views produced by successive censuses. A partial formulation of this theory had already been given by Landry (1909/1982) and a definitive statement was produced by Notestein in 1945. Although it cannot be described in full here the essentials of the theory as they relate to the period approach in demography need to be identified. A more comprehensive account can be found in Burch (1999).

Demographic transition theory aspired to offer a universal explanatory framework for relating long-term demographic change to the various economic, sociological, ecological and psychological changes occurring in the world over the same period. The theory was closely associated with the cross-sectional approach since it sought to explain changes in conditions at a point in time by reference to characteristics that were also specific to one point in time. However, inasmuch as it introduced results from a range of social sciences it did represent a broadening of perspective.

The demographic indicators used in the model were extremely simple - rates of mortality and fertility and of international immigration and emigration - and were usually single country-level though larger groups were also employed. Slightly more sophisticated indicators were sometimes used but they were always period measures: child mortality rates, life expectancy, total fertility rate, and so forth. The explanatory factors were intended to characterize different turning points in the history of a country, such as agricultural and industrial revolutions, diffusion of new norms, and cultural changes.

This theory was developed from an initial schema which presented industrialization and urbanization as the main driving forces in this transition (Davis, 1945). The changes wrought by these two major phenomena brought about a decline in mortality, which, with some lag, was responsible for a reduction in fertility, consequent on larger family size due to the survival of more children and the higher cost of child-rearing. This explanation is in fact not always empirically substantiated – in some countries a mortality decline has not preceded a reduction in fertility, and the change has occurred in the opposite direction (Coale, 1973), thus contradicting the universality of the sequence.

Zelinsky (1973) argued that this transition had to be situated in geographical space and demonstrated that expanding the list of phenomena to include spatial diffusion in the analysis helped make sense of the “mobility transition” which occurred in parallel to the “fertility transition”. This spatial approach was completed by Cleland (1985) whose “ideational theory” explains the differences in the timing of the transition in different countries by reference to information diffusion and the establishment of new social norms concerning fertility control.

Economists have also contributed to the debate over this transition. Becker (1960) and Schultz (1973) have emphasized the role of three characteristics in explaining couples' decisions: the relative cost of children compared with other goods; couples' income levels; and their preferences over the choice between bringing up children and other forms of consumption. Easterlin (1961) postulated that women from large birth cohorts tend to have fewer children than those from smaller birth cohorts, thereby causing cyclical variations in period fertility. A more detailed formalization of this approach (Easterlin and Crimmins, 1985) has eventually led to a new economic model, with the addition of a number of sociological determinants: "the supply of children", denoting the number of children the parents would have in the absence of conscious birth control; "the demand for children", corresponding to the stated desired number of children; and "the costs of fertility control" which are psychic, social and monetary. However, attempts to fit this model to empirical data have not been wholly convincing (Wachter and Lee, 1989).

Lesthaeghe (1983) has suggested in addition to economic considerations a shift in personal values in favour of individualism and self-fulfilment, attributed to the rise of secularism and materialism in society. For his part, Caldwell (1982) speaks of the "emotional nucleation of family", whereby the money, goods and services that used to go to parents now go to children, a process he refers to as an intergenerational reversal of "wealth flows".

More generally, these theories have contributed to a systemic approach to population change. In common with those already outlined, this method attempts to establish links between facts occurring in very disparate domains at a given time and from them deduce the evolution of the system at the next instant. The complexity of the system results in recourse to simulation models. Unfortunately such models often impose a simplification of the relationships between the different elements of the system and this can quickly lead to outcomes very different from those actually observed.

Lastly, Bonneuil (1997) has applied viability theory to introduce a random component into these deterministic models. As in the previous examples, it is assumed that the evolution of a group can be represented by a small number of characteristics. This group is subject to a certain number of constraints. The trajectories which allow its survival are thus not insignificant and will be determined by the various controls which the group can act upon. The author uses the theory to calculate which among all the possible trajectories produce viable outcomes, and to identify the periods of stagnation and of jumps between norms. Applied to changes in Swedish fertility since 1930 (Bonneuil, 1994), this model has outperformed the Easterlin hypothesis in predicting the sharp changes in population behaviour associated with the Second World War.

The different theories presented above may describe changes affecting demographic phenomena in some parts of the world yet fail to explain the behaviour observed in others. The question thus arises of their legitimacy, since they postulate a purely holistic approach to the evolution of humanity. Is it the case that the transitions occurring in different countries have the same causes? Is a decline in mortality a prerequisite for the reduction in fertility? Would we not expect the changes to differ widely depending on when and where in the world they occurred? The countries which had their transition at the end of the nineteenth century are not in the same position at all as those which had it the end of the twentieth century.

As can be seen, these theories are based on the same hypotheses as the period analyses: changes affecting populations are related to the conditions in which they live. The validity of the theories thus depends on the solidity of these hypotheses. It is time now to examine the paradigm which links all these results together.

An underlying paradigm

This paradigm, never clearly stated by the early authors, can be deduced from the presentation given above. Broadly construed, a paradigm dictates what constitutes legitimate activity in the scientific domain that it governs (Kuhn, 1972). While such a paradigm is by its nature hard to define with precision, its form can be delimited by principles that are sufficiently general. Thus in the present case it can be said that social facts exist independently of the individuals whose lives they regulate. They are shaped by the economic, political, religious, social and other characteristics of the society, and the result is a form of causality that originates not in the individual but in society itself and whose effects are felt by the population as a whole. From this interpretation follows the form of data collection, namely the comprehensive recording at regular intervals of information on the characteristics of the population and its physical and social environment. This approach can thus be described as a holism, in that it explains change in a society by reference to its overall structure and not to individual free will.

Development of this paradigm can be traced to the period of consolidation of political arithmetic, when data from registers began to be analysed in a cross-sectional perspective, and it was reinforced from the start of the nineteenth century with the creation of official national statistical services and the introduction of censuses. These supplied "snapshot" views of the population in its totality and recorded numerous characteristics of individuals and households. Combined with civil registration data, also treated in a cross-sectional perspective, they were the raw material for a comprehensive study of the mortality, fertility and nuptiality of populations at a given point in time. Where population registers also existed or where censuses contained a question about the previous place of residence, the country's internal migrations could be analysed in the same way.

The analytical method elaborated by Durkheim was perfectly suited to this approach. Indeed, he acknowledged the value of statistics for isolating social facts (Durkheim, 1895/1937): "They are in effect expressed in numerical form, with real accuracy, by the rates of nuptiality, births, suicides, that is by the number obtained by dividing the total annual average of marriages, births, and deliberate deaths, by the number of men of an age to marry, procreate, and commit suicide" (pp. 9-10). These rates are too simple to give an accurate reflection of the phenomena being studied but although more sophisticated period measures can of course be elaborated the principle remains the same.

Other tools for the analysis of these period statistics, some of which had been prefigured by the political arithmeticians, were developed in the course of the nineteenth century and the first half of the twentieth century. The shortcomings of concepts such as the birth rate and the ratio of baptisms to marriage, for measuring the fertility of populations were soon recognized. New indexes were devised, requiring new questions to be included in the censuses or civil registration system. For example, the method elaborated by Körösi (1896) for construction of cross-sectional fertility functions by the age of spouses gave a more complex but more realistic measurement of fertility. A number of summary indexes were also developed, such as the total legitimate fertility rate and the cumulated marriage frequency – the problems associated with their use will be discussed later. Other refinements were proposed, such as the introduction of women's age at marriage for legitimate fertility, the sex and birth order of children, the religion and occupation of the parents, etc. An excellent synthesis is provided by Landry's *Traité de démographie* (1945).

Indices of this kind can be used with regression methods that relate them to each other and, more importantly, to various aggregate characteristics of the zones inhabited by the individuals. Such regression models still find applications today. Puig (1981), for example, relates emigration and immigration rates for the French regions to selected aggregate characteristics of these regions (e.g. average income, unemployment rate). He states clearly that these characteristics had been selected according to a preconceived explanatory schema of individual migratory behaviour, applying hypotheses identical to those framed by Durkheim nearly one hundred years earlier.

Problems encountered in the application of this paradigm

This paradigm predominated almost unchallenged until the end of the Second World War. Exceptions had first been noted during the early days of political arithmetic. The relationship between the value of annuities and the mortality of the population led some authors to adopt a longitudinal rather than cross-sectional analysis of mortality. Following the example of earlier authors, such as Jean De Wit in 1671 (Dupâquier, 1985), Deparcieux (1746) constructed life tables of annuity holders for 1689 and 1696, observed up to the start of 1742, by their age when the annuity was purchased. But this use of a longitudinal approach was not incompatible with the period approach, since the underlying hypothesis was that of a stationary population.

It was however the use of summary indices constructed on the basis of period life tables that generated a renewed interest in this longitudinal approach. Elaborated to provide answers to entirely legitimate questions, these indices sometimes produced results that were hard to interpret and even logically inconsistent with what they were supposed to be measuring. For example, when estimating a survival probability at a particular age, the complements to one of the period mortality probabilities from birth to the age in question can be combined. But the result obviously cannot refer to any real generation, since it measures the effect of mortality conditions at a particular point in time (e.g. epidemic, harsh winter) on a synthetic cohort. Comparison of such an estimate between different populations or sub-populations of the same country, observed at the same time, is thus not as straightforward an operation as it first appears. In particular, it is important "that the generations do not start the year to be studied with particular experiences which largely condition their mortality in the course of the year" (Pressat, 1966, p. 137). What is being attempted here is a use of cross-sectional analysis to obtain results for generations, although the analysis is actually on a synthetic generation that does not correspond to any real generation.

Still more serious difficulties are encountered when studying phenomena such as fertility or nuptiality, where periods of postponement are followed by periods of recovery, as after an economic crisis or a war, for example. As Henry (1966) explains: "in the course of a period of recovery, behaviour is influenced by the earlier delay. Attributing to a synthetic cohort a set of indices observed during a period of recovery in fact amounts to postulating the existence of a generation which, during its entire existence, is trying to make up ground that it had never lost" (p. 468). This explains why the period sum of first marriage rates by age, which measures the quantum of nuptiality and which in a real cohort must always be less than unity, can take a value much higher than unity in a synthetic cohort. The figure stands above 1.5 in 1946 for France, just after the Second World War. For a more detailed discussion on this topic see Keilman (1986) and (2001), van Imhoff and Keilman (2000).

In addition, the assumption that behaviour is influenced only by the economic, political and social conditions prevailing at that particular time has raised a growing number of questions. For example, the demographic problems caused by wartime conditions are problems not just at the time but affect the generations experiencing them over the very long term. More generally, greater weight needs to be given to the effect of fundamental factors which are much more closely linked to generations, who, as Ryder (1965) observes, share a common historical location and have lived the same experiences at the same ages. Period factors are in fact experienced at very different stages of life depending on the generation and may well also have different consequences. For example, for a young person an economic crisis may be an opportunity to experience different kinds of employment, between which he or she can later chose on the basis of experience, whereas for an older person it is more likely to produce successive periods of unemployment from which it will be hard to escape.

Another consideration is that while the use of aggregate data was legitimate under the previous paradigm, this may not be the case for individual-level data. Using new methods, such as logistic regression, models can be estimated based on individual characteristics. But the results obtained are not necessarily consistent with those obtained with aggregate data. For instance, the positive association observed earlier between the percentage of farmers and the percentage of migrants merely shows that the highest probability of migration is associated with a high proportion of farmers, but we do not know if it is in fact the farmers or the non-farmers who migrate most from these regions. It is perfectly conceivable that the presence of a high percentage of farmers, by limiting employment opportunities in other occupations, means that non-farmers are forced to migrate to find better employment, whereas farmers themselves do not have a greater reason to migrate out of these areas.

Such a problem was highlighted some fifty years ago (Robinson, 1950). When the results obtained with aggregate data are not identical to those obtained with individual data, this produces what is known as the *ecological fallacy* . For example, it is often found that the correlations between two characteristics measured by binary variables for individuals and by proportions for regions give different results. Indeed, they may even be of opposite signs, thus leading to completely misleading results if we try to make individual-level inferences.

3. COHORT ANALYSIS

From the end of the Second World War, questions such as those described above encouraged demographers to reconsider the assumptions on which their analyses were based. Behind this change was the idea that the multiple problems associated with the period approach might be overcome by a cohort analysis which gave a more realistic account of individuals' own experiences over time.

The introduction of lived time

Period analysis examined relations between events and characteristics considered simultaneously. Time had only a secondary role in the analysis, when it was necessary to move from one date to the next. The innovation involves placing biographical time, that is, the time actually lived by members of the population, at the centre of the analysis. Attention will then focus on the change over time of a *generation*, born in the same calendar year in a country, or of a *cohort* that experienced a defining event at a specific point in time. The behaviour observed corresponds to the various demographic phenomena (deaths, births, marriage, migration, etc.) that will occur in the lifetime of the members of this generation.

Adoption of this perspective means that the various phenomena will appear inextricably linked to each other – a death can prevent a marriage, a birth may occur before or after a migration, and so forth. Faced with this complexity, the demographer can adopt a simplifying approach to facilitate analysis, by assuming that the various phenomena are independent of each other. In this way the effect of other phenomena, considered to be interfering events, could be eliminated, thereby isolating the phenomenon being studied in the *pure state* (Henry, 1972).

Let us see how the demographer proceeds in order to obtain these events in their pure state, for example first marriages. For this we will follow the argument developed by Henry (1972): "a premature death prevents unmarried people from marrying; this is the origin of the interference of mortality on nuptiality. To eliminate this we need to know how the people who died unmarried before age 50 would have married if they had lived. Since this is not known a hypothesis has to be made: it is assumed that those dying unmarried at a certain age a would have married, had they lived beyond age a, as did those who were not dead at this age" (p. 77). A hypothesis of independence between marriage and mortality is thus made here, and an equivalent hypothesis has to be made for international migration. Once these hypotheses have been made, a marriage probability can be calculated from the population observed, which will be the same as that calculated if we had been working with a population not exposed to mortality and migration. If we use the term "quantum" to denote the proportion of individuals in such a cohort who ever experience a vital event, these indices allow the quantum of nuptiality up to age 50 to be estimated. If we use the term "tempo" for the timing of this event during the life course, their distribution in time will give its tempo.

These notions of quantum and tempo can be used to obtain a correct analysis of the occurrence of all types of demographic phenomena. For example, the quantum for mortality thus calculated will necessarily be equal to unity, since everyone is mortal, while its timing will show if child mortality is very high, how mortality varies with age of individuals, and so on. It is possible to work with order-specific fertility and define the quantum and tempo of each birth; one can also look at fertility for all birth orders combined and calculate the completed fertility and age-specific rates, to see their timing, and so on.

The results from such an analysis, based as it is on observation of a real generation or cohort, are free from some of the problems noted earlier for period analysis. For example, the quantum of nuptiality (first marriage) will always be less or equal to unity. The impact on nuptiality of a war or any other historical event can now be clearly evaluated and measure the course of the subsequent recovery, according to the ages at which the generation experienced these events.

This analysis makes the assumption that the population being studied is homogeneous. The key question is: How can the heterogeneity of the population be included so as to get a more realistic picture? Heterogeneity is harder to integrate in a longitudinal perspective than when working with period data. In the latter case, a region can be represented simply by each of its characteristics at the time of a census (proportion of shopkeepers, farmers, individuals with a given income, and so forth), which can be related to certain of its demographic characteristics (e.g. percentages of deaths, births) measured in the following year, for example. By contrast, when working in a longitudinal perspective the question arises of which characteristics to take into account, since they will be changing continuously over time. In addition, a continuous indicator of changes in, for example, occupation or income, is no longer available, because the civil registration data that are used to measure demographic events over time do not supply sufficiently detailed information about these characteristics.

The solution envisaged by differential longitudinal analysis is to examine the occurrence of a particular phenomenon in groups defined by various characteristics (e.g. occupation, labour market status). In this case, however, there are losses from observation through mortality and international emigration but also because of exits from the group being studied. And there will also be entrances by individuals who take up the profession being studied, for example. These individuals will usually not be measured over the whole time and, more importantly, the hypothesis of independence between studied and interfering phenomena cannot usually be considered to be verified.

Extension to multistate models

This approach which analysed phenomena in isolation from each other was extended in the 1960s and 1970s by the introduction of models with the capacity to handle two or more demographic phenomena simultaneously while retaining the condition of independence between them. Schoen and Nelson (1974) introduced a model to analyse the transitions between marriage, divorce and mortality. Similarly, the multiregional models developed by Rogers (1973) introduce regional mortality and fertility by age as well as migrations between the different regions, also broken down by age. These provide the basis for multiregional population projections in which several demographic phenomena are treated simultaneously. This leads to the construction of Markovian models with a large number of states, in which the probability of experiencing an event is independent of the individual's past history and depends only upon his or her state immediately before its occurrence.

The condition of independence between the different phenomena appears harder to satisfy when working on regional data than in the national context. It implies, for example, that an individual's probability of dying must immediately become the same as that of the zone to which he or she has moved. Yet individuals who have lived in regions where, for example, alcoholism-related mortality is very high and who themselves may be alcoholics, are unlikely to adopt a new pattern of behaviour as soon as they migrate to a region with lower alcoholism. In the same way, female migrants from abroad or indeed from a region with lower fertility than the destination zone may not adopt the latter's fertility level immediately. It has been shown that female migrants to France from the developing countries adopt the fertility behaviour of French women, not immediately but only after a delay of varying length. Equally, different regional fertility levels are likely to be reflected in longer or shorter periods of adaptation.

The probability of migrating from one region to another can of course depend on the age of the individual but is required to be independent of the length of stay in the initial region, of the earlier stages of the itinerary and of the length of these stages. This means that the individual's probability of returning to a region they had previously inhabited is the same as if they had never lived there. There is abundant evidence, however, that return migrations are much more common than migrations to third and not previously inhabited destinations (Courgeau, 1982).

Finally, these models can only include migration rates from the different regions to other regions calculated in relation to the initial populations; they cannot include the populations of the destination regions. Yet it is known that inter-regional migration flows often depend on both the starting populations and the arrival populations. The elaboration of models incorporating both of these populations produces solutions that are no longer linear as in all the previous cases (Courgeau, 1991). In contrast to the previous Markovian model which produces projections with an ultimate stable growth ratio and distribution, these new models produce solutions that are completely distinct over the long-term: solutions that are cyclical and in some cases even “chaotic”.

In conclusion, all these models show that the conditions in which longitudinal analysis is valid can be highly restrictive. We must now state its paradigm more explicitly in order to identify these conditions and the limits of their validity.

Paradigm of longitudinal analysis

The aim of this analysis is to isolate the various demographic phenomena in the *pure state*, thereby freeing them of interfering phenomena and allowing comparisons between countries or regions. Its paradigm can be approached by the following postulate: the demographer can study only the occurrence of one single event over of the life of a generation or cohort, in a sub-population “that retains *all its characteristics and the same characteristics* as long as the phenomenon is present” (Blayo, 1995, p. 1504). We have already seen that this population is considered to be *homogeneous*, but for the analysis to be correct a further condition is that the interfering phenomena be *independent* of the phenomenon being studied (Henry, 1959). These two conditions are always present in the multistate models, where they are applied to each of the sub-populations being analysed: the events that a sub-population may experience occur independently of each other, in conditions that are specific to the region the individuals inhabit.

Under these hypotheses, data from civil registration and population registers can be used to obtain clear information about the demography of generations or cohorts defined by initial events such as marriage for studying legitimate fertility or a birth for studying the transition to the next birth. Census data can also be used to measure, for example, the frequency of celibacy or the proportion unmarried at different ages in different generations. The fundamental hypothesis, of independence between the nuptiality and mortality of unmarried people, allows these estimations to be made. When migration also occurs, the hypothesis of independence between nuptiality and migrations seems less credible and caution is needed when interpreting census observations on the proportion unmarried.

Behaviour which appears so strongly influenced by short-term events in a cross-sectional analysis exhibits much greater regularity when considered at the level of generations. The curve of fertility variations fluctuates wildly when period analysis is used but appears much clearer in a longitudinal perspective, evolving smoothly from one generation to the next. Starting from seven children per women born before 1760, it falls continuously until the generations born in 1896, where it reaches a value of less than two children, followed by a recovery up to the generations born in 1930, when it stands at 2.6 children, followed by a steady decline to 2.1 children for the generations born in 1948, with finally a levelling out leading to 2.0 children forecast for the generations currently aged 40, that is those born in 1960.

This paradigm makes possible the analysis of civil registration data, by measuring the *quantum* of various phenomena (e.g. proportion never-married at age 50 in a particular generation, parity progression ratios) and the *tempo* of these same phenomena (e.g. distribution of age at first marriage for the first marriages in this generation before age 50, age-specific birth rates). Comparisons can be made of the behaviour of different generations or cohorts in the same country or between different countries. The demography textbooks associated with this approach treat phenomena such as fertility, mortality, migration, in separate chapters, since they are isolated in the pure state (Pressat, 1966; Henry, 1972).

Henry (1959) gave a clear statement of the conditions necessary for a correct application of this longitudinal analysis:

"The use of probabilities assumes that the cohorts are homogeneous, either for the event being studied or for the interfering event, or that there is no correlation between the two risks, that corresponding to the event being studied and that from the interfering event.

This condition is still not sufficient to justify use of differed observation, at least not without correction of its results; it also requires that the risk due to the interfering event is not modified by the occurrence of the studied event.

Given the multiple differences between people, we can be certain that no human group is homogeneous; everyday observation and reflection lead us also to the view that usually there is not independence between the risks" (p. 31).

These conditions are fully consistent with the proposed paradigm. The author of the preceding comments, which actually establish very strict conditions for the validity of the longitudinal approach, indicated that in practice the approximate procedures employed to perform such an analysis are acceptable: "The answer would appear to be affirmative for fertility interfering with mortality. We have also given an example where at first sight it did not appear justified to treat a group as if it was homogeneous, and where, nonetheless, acceptable results were obtained" (Henry, 1959, p. 31).

These analyses thus appeared to be acceptable, even though the underlying paradigm was not fully respected. It was when surveys providing more detailed information than the civil registration and census data began to be used that the limitations of this approach really became apparent.

Problems in the application of this paradigm

The first point to note is that the focus of this analysis is not individual life-courses observed over time, but rather a population into and out of which some individuals are moving. It is in this population, which is assumed to remain homogeneous over time, that the quantum and tempo of a phenomenon are calculated. Such an approach in effect denies any specificity to individual lives, and instead considers only the occurrence of an event in a population which as a whole remains identical over time because it is made up of units that are interchangeable. When this analysis divides the population into sub-groups between which there is migration, each of these must again be homogeneous. This approach is in fact a holism, albeit different from the previous one, being concerned only with comparisons between homogeneous groups and ignoring the existence of their component individuals.

The events governing entrance to and exit from the target population must occur under precise conditions. The interfering events, such as mortality and emigration, which prevent some individuals from experiencing the studied phenomenon, and the competing events, such as unmarried cohabitation, which is in competition with marriage, must be independent of the studied phenomenon. If they are not, an obvious selection bias will remove from the population at risk some individuals having specific characteristics, and introduce other individuals who will modify the composition of the group. Since many demographic events occur within a short span of the life-course, they are competing with the studied phenomenon: a longitudinal analysis on the lines proposed means considering that the event is independent of the others, or abandoning the analysis because it is impossible.

A further difficulty is that because this paradigm only allows the study of one single event, it is impossible to study losses from observation due to the occurrence of a competing event. Cause-specific mortality studies are thus completely excluded, unless the various causes are assumed to be independent of each other. In fact, it is obvious that eradicating one cause of mortality will affect the probabilities of dying from other causes, and this in a way that is virtually impossible to predict as long as the first cause still exists. In the same way, moves out of the unmarried state through either cohabitation or marriage cannot be studied, since the unrealistic assumption has to be made that these are independent phenomena. Finally, it is "also why a study should not be conducted on a population which can be entered through several different events" (Blayo, 1995, p. 1507). In all this adds up to a great many cases where the postulate rules out all possibility of analysis.

Another set of problems is associated with the hypothesis of homogeneity. This was not a source of difficulty when analysis was carried out using civil registration data - for the simple reason that the hypothesis could not be verified. Civil registration data is valuable because of its exhaustivity, yet in consequence it supplies little very detailed information about the population being studied. For example, it tells us whether a birth is legitimate or not and about its parity, but it contains little about the life history of the couple on which to base a more detailed analysis of fertility. However, it is obvious that the population being studied is in many respects heterogeneous.

Period studies (Roussel, 1971) have shown that nuptiality in 1968 was much lower among farmers and farm labourers than among other occupational groups. There is thus a clear interest in studying this more specific sub-population, which is more homogeneous than the initial general population. But a new phenomenon then has to be taken into account, namely the departure from farming of the unmarried individuals. This will involve far more individuals than mortality or internal migration, and occurs at the ages when most marriages take place. Furthermore, it is hard to imagine that if these individuals had remained in farming their nuptiality would have been the same as those who actually did remain in farming. Even before they left farming they are likely to have formed a subgroup with a nuptiality different from that of the initial population. Moreover, within this group it is quite possible that farmers will have a marriage behaviour very different from that of farm labourers, and also a different likelihood of leaving the farming population. In this case the marriage probabilities, calculated on the sub-population of those who stayed in farming, are unreliable since the condition of homogeneity is not verified.

The classical approach is then to divide this sub-population into an ever-growing number of sub-sub-populations, in an attempt to guarantee homogeneity in respect of the phenomenon studied. As Henry (1959) remarked: “To determine exactly the practical significance of heterogeneity of human groups, differential demographic research needs to go down to the level of individual physical and psychological characteristics, so as to study both the dispersion and correlation of demographic indices within the crudely defined groups considered so far” (p. 25). These sub-populations could be distinguished by place of residence – the probability of marriage for a farmer from the rich plains of the Beauce will certainly be different from that of a farmer from the rugged uplands of the Ariège – and by income, educational level, for example. Yet in this case we will end up with groups with so few members that they will be too small to sustain longitudinal analysis. Moreover, it is impossible to be sure that all the factors of heterogeneity in the population have been taken into account. There always remains an unobserved heterogeneity, whose effect on the probabilities will be completely unknown, which, as will be seen shortly, is not the case with event history analysis.

Finally, analysis is further complicated by the possibility that individuals have of moving between groups. This can be illustrated using the earlier example of how migration among Norwegians is influenced by the fact of being a farmer. Applying longitudinal analysis to this case, it can be seen that in the course of their lives individuals can not only migrate but also change occupation. An individual who starts out as a farmer can change occupation, become unemployed or leave the labour market. Being a farmer is thus not a stable state through time, and the Norwegian population register does not provide a continuous observation of this occupation. Occupation is known only by means of censuses, which are only held at ten-year intervals. In this case, therefore, it is not possible to perform a longitudinal analysis of migration by farmers. But even if these changes were subject to continuous registration, there is no longer any reason to assume that the hypothesis of independence between entering and leaving farming is verified, as could still be assumed for the interaction of mortality and nuptiality. In this case, the longitudinal analysis, based on this hypothesis of independence, is not valid.

The conclusion would thus seem to be that a strict application of this paradigm to real demographic problems amounts to denying any possibility of serious longitudinal analysis of demographic events. It requires the target population to be sub-divided to such an extent that the calculations lose all precision. In addition, it is so restrictive as regards the events being studied that it effectively rules out entire sectors of demographic analysis (analysis of competing events, of interactions between events, of events occurring in a population subject to entrance and exit).

Given these multiple difficulties, it is reasonable to ask whether there is not a need to change the hypotheses underpinning the analysis, and provide a firmer basis for the arguments developed.

4. EVENT HISTORY ANALYSIS

More than thirty years after the introduction of longitudinal analysis, the beginning of the 1980s saw the development of a new approach in demography. This took the form not of further refinement of the methods of differential longitudinal analysis, the difficulties with which have been outlined above, but of a generalization of logistic regression methods, initially in cross-sectional perspective and subsequently in a longitudinal approach (Cox, 1972). We begin by examining the changes that made possible this analysis of individual-level events and how, by introducing time into analysis it offered a solution to the problems indicated above, before going on to set out the paradigm on which it rests.

Introducing individual behaviour

The first point is that the analysis of individual behaviour was not a possibility with either cross-sectional or longitudinal analysis. Both approaches, as has been seen, considered population from an essentially aggregate standpoint. The new approach innovated, firstly, by considering the phenomena studied as individual.

In the period analysis of aggregate data, examined earlier, and by working on a certain number of sub-populations, the probability of experiencing an event was related to the probability of experiencing another event or of having certain characteristics. In this case, it was enough to know the marginal distributions of the events studied to be able, under given hypotheses, to estimate the relationship. The next step is to try to estimate the joint distribution of all the combinations of variables at the individual level, thus establishing a different kind of relationship between the occurrence of an event and the characteristics of an individual. Naturally this requires much more detailed data than an aggregate-level analysis, but the advantage is that it makes possible a clearer estimation of individual effects. In this way we reach a logistic analysis, which prefigures an event history analysis.

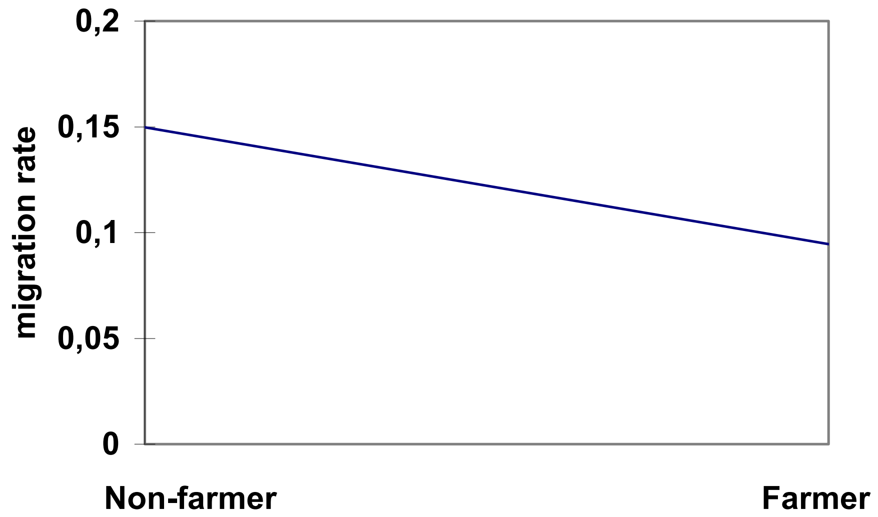
Let us take another look at the example examined earlier of the effect of the proportion of farmers on the rate of inter-regional migration in Norway (Courgeau, 2000b). An aggregate-level analysis produced a positive association: the more farmers in a region, the higher the probability of migration out of it. Working now with individual-level data, these probabilities can be estimated in another way, by a logit model, for example, which in this simple case is equivalent to estimating separately the migration probabilities of farmers and non-farmers. The probability for the individual i

present in region *j* of migrating ($\mu_{ij} = 1$) depending on whether he is a farmer ($a_{ij} = 1$) or not ($a_{ij} = 0$) can be written in the following form, which is independent of the region of residence *j*:

$$P(\mu_{ij} = 1 \mid a_{ij}) = (1 + exp - [\alpha_0 + \alpha_1 a_{ij}])^{-1} \qquad [2]$$

Once the parameters of this formula have been estimated, it is straightforward to calculate the migration probabilities of farmers and non-farmers (see figure 2) and the estimates of migration rates for each region (Courgeau, 2000b).

Figure 2: Logit Model



This gives an opposite result to the previous one – the probability of migrating for farmers (0.09) is now more than a third less than that for the other occupations (0.15) – and the estimate of the regional migration rate with this model will decrease wile its proportion of farmers increases. The individual behaviour brought to light here contradicts the results obtained using aggregate-level data and which also estimate migration probabilities. Another look is thus necessary at the hypotheses that underpin these two approaches, which are mutually incompatible. This problem cannot be resolved until later, when the paradigm for the event history approach has been more precisely stated. For the moment let us continue to examine this approach.

This analysis can easily be generalized to include any number of individual characteristics in order to explain a given behaviour. The problems of dependence between these characteristics are not the same in this case as in aggregate analysis. Indeed, if two characteristics are not independent of each other, this approach allows us to consider separately the individuals who have separately one of these characteristics but not the other and the individuals who possess both characteristics simultaneously. A logit model can still be used to explain the behaviour of these different groups.

This approach, whereby the events experienced by individuals over a short period of time are explained by their characteristics at the start of the period, presents a number of drawbacks. The first concerns the considerable information loss caused by aggregating events that occur over a period, in this case three years, and excluding their exact date of occurrence. Also excluded is the date of arrival in the region of residence in 1970, thus preventing measurement of an effect of duration of stay on the migration probability. Nor does it let us observe a time-dependent effect of the initial characteristics. The second drawback is that these characteristics are fixed at their measurement in 1970, and cannot vary over time. Once again, there is no reason to suppose a move out of farming will not modify the migration probabilities of individuals. Unfortunately this variation cannot be introduced in a logit model.

Introducing time-dependent regressions

We indicated earlier that an analysis with exhaustive longitudinal data could not be as detailed as one using cross-sectional data from combined census and civil registration sources. Further progress thus appears to be conditional on breaking out of the rigid straight-jacket of these administrative records. At the same time, however, when the information becomes too voluminous and detailed, its collection has to be in a non-exhaustive form. The solution to this double constraint lies with the gathering of individual life history surveys.

Use of surveys means that questionnaires can be designed to provide answers to precise questions. It is therefore possible, bearing in mind the difficulties associated with longitudinal analysis, to collect more comprehensive information about the lives of the individuals being surveyed. We can then establish whether the effect of so-called interfering phenomena is really independent of the phenomena being studied and, if it is not, elaborate new analytical methods for measuring clearly its effects.

These surveys must therefore record the maximum of events in the subjects' lives, including the timing of their occurrence and the intervals between them, so that the interdependencies between them can be explored fully. The surveys must also record as much information as possible about the respondents' characteristics and personal environments for inclusion in the analysis of behaviour. Two types of survey, each with its own advantages and disadvantages, are suitable for observing these various events and states.

The first is the *prospective* survey in which the members of a sample are observed over their entire lifetime. Depending on the specific aims of the survey, it can begin at the birth of these individuals or at any other stage of their existence (at marriage, for example, in order to study their legitimate fertility, union dissolution, remarriage, etc.). The respondents can be re-interviewed annually so as to have a small number of events or characteristics to record. This produces extremely accurate reporting of the timing of the events. By contrast, many analysts are deterred by the time that has to elapse between the start of observation and analysis of the data, which can only take place after a sufficiently long period of time. In addition, subject loss in the course of the research, mainly due to moves to unknown destinations and to refusals to participate further, can be a source of bias in the results. The best example of such a survey is that carried out by Cribier and Kych (1999) on a sample of just-retired people.

Investigators often prefer to carry out a *retrospective* survey in which all the relevant events of interest and individual characteristics are recorded in a single round. The survey can be used immediately and there is no problem of subject loss in the course of the survey. On the other hand, such surveys are time-consuming and expensive to conduct (Courgeau, 1999a). It can be noted that there is a risk of bias due to selection by survival of the respondents, which is usually negligible (Lyberg, 1983). Reporting errors of timing, and omission of events by the respondents can also be a problem. We had the opportunity to evaluate these recall errors in Belgium, a country which possesses population registers. We were able to show that errors arose over the dating of events (Poulain et al., 1991) but that their logical sequence was remembered correctly (Courgeau, 1991).

Whichever type of survey is used, some of the intervals between events will not be observed fully. Observations may be interrupted (censored) either by the date of the survey, in the case of a retrospective survey, or by the ending of the observation, in the case of a prospective survey, unless it is continued until all the respondents are dead. It is in fact possible to use this information, which tells us that the individual has not experienced the event being studied before the observation.

The first analyses were concerned with observation of a single phenomenon that was to be explained by various individual characteristics. Menken and Trussel (1981) analysed marriage dissolution in relation to various socio-demographic characteristics of the respondents. Subsequent studies explored more complex interactions between a variety of demographic events, while taking into account the heterogeneity of the population being examined.

The aim here is merely to present the general procedure involved, not to examine the methods of analysis in detail, and those interested are referred to works with a more mathematical (Andersen et al., 1993) or demographic content (Courgeau and Lelièvre, 1989, 1992). The example we will consider now is the interaction between nuptiality and leaving farming (Courgeau and Lelièvre, 1985), working with the generations born between 1911 and 1936 and resident in France in 1981. This is because the two phenomena studied, migration and leaving farming, cannot be observed through time in the Norwegian example used above.

The principle of this method is to estimate the instantaneous hazard rates for nuptiality, for the same age, depending on whether the individual is still in farming or has left. Symmetrically, the instantaneous hazard rates for leaving agriculture are estimated for still single and already married individuals, still for the same age. If T_i^m and T_i^a are two random variables, corresponding to the date of marriage and the date of leaving farming of individual *i*, the instantaneous hazard rate of nuptiality can be written, if the exit from farming has not occurred before time *t*:

$$h_i^{am}(t) = \lim_{\Delta t \to 0} P(T_i^m < t + \Delta t \;\left|T_i^m \geq t, T_i^a \geq t\right.) \qquad [3]$$

and the instantaneous hazard rate of nuptiality, if the departure from farming has occurred before *t*:

$$h_i^{\bar{a}m}(t) = \lim_{\Delta t \to 0} P(T_i^m < t + \Delta t \;\left|T_i^m \geq t, T_i^a = u\right.) \qquad u<t \qquad [4]$$

A symmetrical formulation is given for the hazard rates of leaving farming depending on whether the individuals are not yet married or married. Estimation of these hazard rates is by the maximum likelihood method, which uses data about the individuals experiencing the various events, the populations at risk, and the right censored intervals at the survey date.

These four sets of hazard rates give a preliminary indication of the interdependence between these various events, even before the other characteristics have been taken into account. If marriage of men who began their working lives in farming is appreciably more frequent after their departure from farming, whereas their change of occupation is not dependent on their marital status, this means that there is a *local dependence* (Schweder, 1970) of marriage on the exit from farming. This is what is actually observed in France for the male generations born between 1911 and 1935 - their working life takes precedence over their family life, with the former determining the latter, whereas the latter has no effect on the former. Conversely, for women there is a local dependence in the opposite direction - marriage has the effect of strongly "anchoring" them in the farming sector, whereas leaving farming does not modify their probability of marriage.

This concept of local dependence is much closer to the concept of causality - even if strictly speaking causality can never be established in the human sciences - than the correlations measured in period analysis. Because it introduces time, it indicates that the occurrence of one phenomenon can bring about a change in the probabilities of experiencing another. A correlation, by contrast, gives no indication of causality, since the two phenomena may depend on a third, unmeasured phenomenon, and yet be independent of each other.

It is of course possible to observe a *reciprocal dependence* between two phenomena, as is the case for the interactions between fertility and migration to metropolitan areas (Courgeau, 1987). A *total independence* between these events is also possible though this case appears much rarer. However, it is exactly one of the preconditions for application of the methods of longitudinal analysis, requiring independence between events, which is thus called into question.

More complex dependencies can also be identified. For example, in the study of interactions between fertility and migration to metropolitan areas (Courgeau, 1987), a large reduction in fertility after the birth of one child is observed among women who migrate. The question thus arises of whether this is evidence of an adaptation to the behaviour of the destination area, whereby the women who migrate adopt the low fertility of city-dwellers, or of a selection, if the women who migrate are those whose fertility is already different from the women in the initial area. The women who migrated to the metropolitan areas timed their fertility before migration differently from that of women who remained in non-metropolitan areas. Moreover their timing was the same as that of women who had already moved to these areas. What is revealed here is an *a priori dependence* of fertility on future migration, which is responsible for this selection within the original population.

Likewise, migration to areas of high fertility is observed to have a positive effect on the chance of having a second and third child. Using research of the same kind as above, it is possible this time to show an authentic adaptation of fertility behaviour among women who migrate to less urbanized areas. This is because their initial fertility behaviour is no different from that of the women who remain in the metropolitan areas, but becomes identical after migration to that of women who have not moved from the less urbanized regions.

Non-parametric analysis can be used to show how dependencies change with age. Thus, for example, young women born between 1911 and 1936, who have had a first child and gone back to work, are more likely to have a second child than those who have not returned to work. After age 30, however, the pattern is reversed, and it is the older women who are less likely to have a second child than those who have not returned to work (Lelièvre, 1987).

Finally, a generalized Cox model can be used to examine the effect on these behaviours of various individual characteristics, some of these being subject to modification once individuals have experienced one of the events. For the nuptiality of farmers with a certain number of characteristics this model can be written in the form of a column vector Z:

$$h_i^{am}(t \mid Z_i(t)) = h_0^{am}(t) exp[\beta Z_i(t)] \qquad [5]$$

where $h_0^{am}(t)$ is a baseline hazard rate independent of the characteristics $Z_i(t)$, which may or may not be time-dependent, and β is a row vector of parameters to be estimated. As indicated above, it will be possible to take account of the interactions between these characteristics.

Estimation of these effects is possible by means of maximizing the partial likelihood. In the case of women leaving farming, the fact of having many brothers and sisters is observed to hasten their departure, whether or not they are married, whereas the fact of being the eldest child or of having a father who is a farmer, keeps women in this sector as long as they are unmarried. Once they are married, however, these characteristics no longer influence their departure from farming. In addition, the characteristics of the husband can then also be introduced. Thus having a farmer for a husband greatly increases the likelihood for a woman of staying in farming, presumably because of the possibility of combining the two farms to create one larger and more profitable holding.

The foregoing examples suggest that event history analyses can produce more firmly based conclusions than those obtained with longitudinal analysis. This approach had been used in different social sciences such as sociology (Tuma and Hannan, 1984), economics (Lancaster, 1990), epidemiology (Commenges, 1999; Keiding, 1999) and so on.

In the next section we examine the paradigm which underlies these methods and assess its advantages compared with those of period and longitudinal analyses, as well as the drawbacks it nonetheless presents relative to the issues of demographic research.

A paradigm for event history analysis

The focus of interest is no longer the study of homogeneous sub-populations but a set of individual trajectories between a large number of states. The unit of analysis is no longer the event but the individual life history, considered as a complex stochastic process. The aim is no longer to isolate each phenomenon in the pure state but, on the contrary, to see how an event in an existence can influence the rest of the individual's life, and how certain characteristics can induce one individual to behave differently to another.

In this case, the paradigm can be approached by the following proposition: throughout his or her life an individual follows a complex itinerary, which at any given moment depends on the life-course to date and on the information acquired in the past (Courgeau and Lelièvre, 1997). This approach is unequivocally *individualist*. It postulates that a person's behaviour is to be explained by reference to his or her past life history, and not by looking to society for the reason for these actions. It is therefore diametrically opposed to the aggregated period approach which, as was seen, is a methodological holism.

The first principle is that a group of individuals belonging to a particular generation or cohort is tracked through time. The main way that an individual can be lost to observation is by leaving the sample at the date of the survey, or of the study if the prospective technique is being used. Insofar as there is no reason for these dates to be linked in any way with the individual's life, the condition of independence is fully satisfied: the observation is said to be non-informative and these losses from observation can be allowed for when estimating the hazard rates. This it can be seen how the change of perspective overcomes the problem of interfering events.

On the other hand, however, selection bias can occur, especially in retrospective surveys, since only the individuals who survive and are in the country at the time of the survey can be interviewed. In this case, it is often necessary to work on the assumption that the losses from the population under observation are not selective, unless population register data is available to adjust for this bias (Hoem, 1985). Such selection bias is reduced, however, if the event being studied does not occur in an elderly population or one particularly concerned by emigration.

Analysis can be done on sub-populations that have experienced the same initial event, such as entrance to the farming population, for example, and then study the occurrence of an event such as marriage. If these individuals experience so-called “interfering” events (exit from farming), they do not move out of observation but can change their behaviour in respect of marriage. This can be tested by comparing the behaviour of farmers of the same age or with that of the population which had never been farmers. By this means, as was shown earlier, we can establish whether selection has occurred or, on the contrary, if behaviour has been adapted.

Whereas in classical longitudinal analysis there was no need to distinguish between interfering events and competing or concurrent events, these now have to be examined separately. As has just been shown, an interfering phenomenon – that we prefer here to call “interacting phenomenon” – modifies the probability of the studied event occurring. Conversely, what are described as competing or concurrent events are the different modalities of an event which has the same final outcome: e.g. cause-specific mortality, union formation by marriage or by cohabitation.

It is important to be clear that the aim is not to find out what mortality from a particular cause would be if other causes were assumed to be eliminated, or the marriage probabilities if there was no cohabitation. Such questions are beyond the scope of the statistics with which we are working, and the answers proposed by some social scientists should be treated with extreme caution. Our objective is rather to show how these various causes act simultaneously, to examine how exit from the never-married state occurs by either marriage or cohabitation, without attempting to distinguish these effects. In these conditions it is no longer possible to define a quantum for the transitions into these different states but merely to compare the relative probabilities and timing of the different transitions.

We are thus equipped to examine how an event, be it of a family, economic or other nature, experienced by an individual whose past trajectory is known, will modify the probability of other events happening to him or her. For example, we might wish to examine how marriage influences professional career, spatial mobility, and the occurrence of events such as the birth of a child or the break from the family of origin. This corresponds exactly to what we have described as the analysis of interacting demographic phenomena, and is clearly consistent with the proposed paradigm.

An analysis along these lines assumes an initial population that is homogeneous in terms of the process being studied, that is, at the start of the analysis the individuals are in the same state in relation to the process. But the population becomes increasingly heterogeneous with the passage of time, as it experiences the different interacting events. This hypothesis of homogeneity used in the first stage of the analysis in order to unravel the interactions between phenomena, must necessarily be discarded in a second stage. There is in fact no reason that the individuals of the initial population should be identical, and the time-dependent regression methods employed in a second stage enable us to explore their initial heterogeneity and that which is introduced over time.

Any understanding of an individual's behaviour must take account of his or her social origins and past history. Behaviour is assumed to be not innate but to change over the course of the individual's lifetime in response to what is experienced and learned with time. Two individuals born into families initially very close in terms of, for example, social background, religious beliefs, occupation, but who followed completely different career paths, can be expected to have increasingly divergent behaviour in respect of the various demographic phenomena.

In this way we arrive at an analysis of population heterogeneity, using a dynamic approach rather than a static approach as in period analysis. Regression analysis, used in cross-sectional analysis to relate aggregate behaviour to the characteristics of populations that are also aggregate, now has to be extended to the analysis of individual characteristics. When an individual is born, the range of possible life-courses is large. But these different trajectories are far from being of equal probability. The life history of an individual can therefore be defined as the result of a complex stochastic process, occurring over the time lived by the individual.

These processes have been studied by probability specialists and statisticians using the theory of martingales (Dellacherie and Meyer, 1980), stochastic integration (Dellacherie, 1980) and counting processes (Brémaud and Jacod, 1977). These methods cannot be presented here and the interested reader is referred to the excellent synthesis by Anderson et al. (1993). All that is given here are the main aspects of this approach, to illustrate its potential for making the best use of the proposed paradigm.

An individual's life course is modelled as interacting stochastic processes occurring within a given generation or cohort (Willekens,1999, 2001). These individuals can experience a certain number of demographic events which cause them to change state. The order in which these events are experienced is of course not specified and may vary widely. But it is also obvious that the probability of experiencing one of these events at any given time will be related to the prior history of the individual (events experienced, the order and timing of their occurrence) and to characteristics that are time-invariant (e.g. social and geographical origins, number of siblings) or time-dependent (e.g. economic crises, wars).

These transitions are studied using an essentially semiparametric model, in which the effect of the characteristics of interest for the research is modelled parametrically but no assumption is made about the form of the distribution of the duration of stay in each of the states studied. This model is dynamic in that it can model the instantaneous hazard rates of the various events being studied, in relation to the different populations exposed to the risk. It also offers the possibility of introducing time-dependent characteristics, thus allowing a truly dynamic model of the change in stochastic processes over time to be estimated. These changes are related primarily to individual events and characteristics.

Another important property of these models is their capacity to introduce the effects of interaction between individual characteristics. For example, if an individual's migration at a given time depends on the fact of being a farmer and of being married, a difference in behaviour may be observed between unmarried farmers and the rest of the population, and between married farmers and the rest of the population. This interaction effect can be taken into account by also including the product of the binary variables that correspond to the two characteristics and estimating the model which includes the three variables. This logistic model can of course be generalized as an event history model, into which is introduced this same interaction between characteristics, which will now be time-dependent.

Finally, this model is largely exempt from a number of problems. Loss of subjects from observation at the time of the survey, for example, can be fully estimated, as can the occurrence of competing events, or the existence of unobserved heterogeneity. The last point is very important for the validity of the analysis and is worth examining in more detail.

When carrying out an analysis it is clear that not all the factors which influence the process being studied will be included, either because they have not been captured by the survey or because they are believed, mistakenly, to have no effect. This is referred to as unobserved heterogeneity and it can invalidate results obtained from the observed data only. When regression models are used to analyse period data, incorporating this unobserved heterogeneity is known to have no effect on the estimated parameters if it is independent of the observed variables. Unfortunately this is no longer the case when we use a semi-parametric model that incorporates time.

However, the effect of non-observed characteristics on parameters estimated with observed characteristics has been successfully modeled by Bretagnolle and Huber-Carol (1988). They showed that when the omitted characteristic is independent of the observed characteristics, its omission does not change the sign of the estimated parameters. On the other hand, it does reduce the absolute value of the parameters. This means that if the effect of a characteristic appears fully significant when the other characteristic is omitted, introducing it into the model will merely reinforce the effect of the first characteristic. On the other hand a characteristic with no significant effect on the phenomenon being studied could acquire a completely significant effect when the unobserved characteristic is introduced.

These results are very important since they allow us to be certain about the direction of the effects observed to be significant, and of their degree of significance, whereas we do not know if all the characteristics affecting the durations of stay have been introduced into the model. In the presentation of longitudinal analysis we saw how this problem compromised the validity of the approach. The procedure mentioned above give us a means of verifying its effect on the results of an event history analysis.

Risk of the atomistic fallacy

Factors of a demographic or non-demographic nature can now be identified and their influence on individual behaviour subjected to very detailed analysis. In most cases, however, this behaviour is explained in terms of the characteristics of the individual. The danger here is of committing the *atomistic fallacy*, since no attention is paid to the context in which human behaviour actually occurs. This context can be defined as the family environment in which the individual lives, or more generally as a “contact circle” of varying size organized around the individual and based on the neighbourhood or commune, for example. In fact this context does have an influence on individual behaviours and it seems fallacious to consider individuals in isolation from the constraints imposed by the society and milieu in which they live.

The danger of this fallacy - which can be compared with the ecological fallacy – was first identified by sociologists (Lazarsfeld and Menzel, 1961). They showed the need for careful definition of various types of groups, communities, organizations and, more generally, other groups of individuals. These can be composed of members who are comparable in respect of the studied behaviour and must be described by a certain number of properties. What appears as a group in one study can be treated in another study as a member of a more general grouping. This property is very important since it shows the relative nature of the individual that the event history approach treats as the principal unit. Used carefully it should make it possible to move beyond the individualism-holism dichotomy.

How this can be done is considered in the next section.

5. CONTEXTUAL AND MULTILEVEL ANALYSIS

For the investigator wishing to avoid the atomistic fallacy the solution is to work at several levels of aggregation simultaneously. Such an approach can take two forms that will be explored successively. One is to introduce the effect of aggregated characteristics in the individual-level model being used; the other is to try to take into account the various levels of aggregation available for analysis.

From contextual analysis …

The conditions that have to be satisfied in order for a model estimated on individual data to be identical to an equivalent model calculated on aggregate data have been specified for linear regressions (Firebaugh, 1978) and for logistic regressions and event history models (Baccaïni and Courgeau 1996). It is shown that once the fact of the individual having the explanatory characteristic (being a farmer, for example) has been controlled for, the corresponding aggregate characteristic (the percentage of farmers, for example) no longer influences the probability of experiencing the event studied (migrating, for example). In this case, the aggregate- and individual-level models are perfectly equivalent. The problem is that this is seldom what is actually observed, as we have established with the Norwegian example.

The simplest solution is to introduce data measured at several levels of aggregation to explain a behaviour which is still individual. We can then see the difference between this approach, in which aggregate characteristics are used to explain an individual behaviour, and the aggregate approach in which an aggregate-level behaviour is explained by characteristics that are themselves defined at the aggregate level.

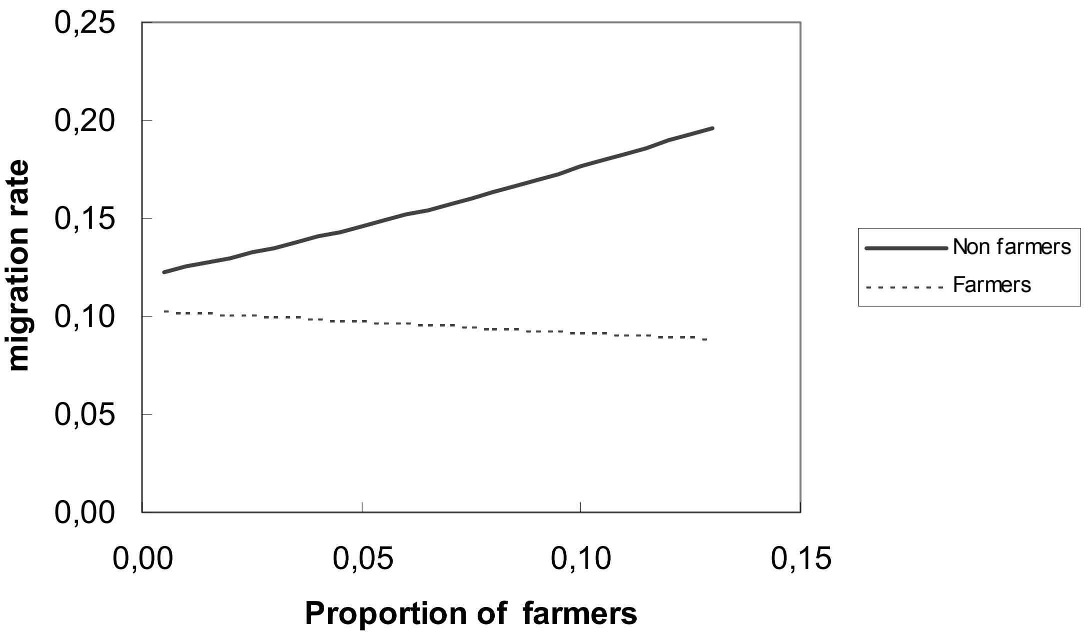
In this way the risk of ecological fallacy is eliminated, since the construction measured by the aggregate characteristic will be different from that measured by its equivalent at the individual level. It no longer operates as a substitute but as a characteristic of the sub-population with an influence on the behaviour of an individual belonging to it. Simultaneously, the atomistic fallacy is eliminated by the inclusion of the context in which the individual lives. One may wonder, however, if the introduction of aggregate level characteristics is really adequate to model this context. We will see later that it is necessary to move further towards a genuinely multilevel analysis.

Returning to the example of migration among Norwegian farmers, application of a contextual model can include the fact that the individual is a farmer and the percentage of farmers in the region of residence, $a_{.j}$. This model can be written:

$$P(\mu_{ij} = 1 \mid a_{ij}, a_{.j}) = (1 + exp - [\alpha_0 + \alpha_2 a_{.j} + (\alpha_1 + \alpha_3 a_{.j}) a_{ij}])^{-1} \qquad [6]$$

The results it produces, given in figure 3, can be used to harmonize the contradictory results obtained earlier: the fact of being a farmer still strongly reduces the probability of migrating, while the fact of living in a region with a large percentage of farmers increases the chances of migrating for both farmers and non-farmers (Courgeau 2000b). This time, however, the reason for the emigration rates increasing as the percentage of farmers increases is completely different. In the analysis on aggregate data, it is the stability of the migration probabilities of farmers and other occupations - at different values - that explains, through the calculations of the percentages of farmers, why the regions with more farmers are those with higher rates of migration. In the present model it is the variation of these migration probabilities according to the percentage of farmers which explains the same result. This shows us that this higher migration probability relates primarily to non-farmers, since the migration probabilities of farmers are not significantly modified by the percentage of farmers. This model supports the hypothesis we put forward earlier: a high proportion of farmers in a zone increases the probability of migration for those in other occupations. This could be explained by a relative shortage in these regions of non-agricultural employment which encourages those in other occupations to emigrate more than farmers when looking for a new job.

Figure 3: Contextual logit model



It is interesting to see now that the characteristics which are introduced may be of very different types. Although the characteristics to be analysed will always be treated as individual, they may be period characteristics and thus analysed using a logit-type model, but they can also be life history characteristics and analysed as such. The explanatory characteristics can be much more diverse.

Initially we could introduce individual characteristics, measured just before the occurrence of the event in the case of a logit model, or measured over time in the case of an event history model. Then, for a given level of aggregation, some of these individual characteristics could be simply aggregated so as to estimate the percentages or averages for a given region, such as its percentage of farmers, or the average number of children per family, for example. More complex analytical procedures could be used: as well as the average number of children, the standard deviation of this number could be included, or the correlation between this number and income at each level of aggregation.

The structural characteristics are the properties of each of the units at a given level of aggregation. They are obtained by quantification of certain relationships existing between members of these units. If we consider a household for example, its structural characteristics are the number of children it contains, the proportion of its members not related to the head of the household (live-in staff, for example), and so on. Other characteristics are more general and concern the units in their entirety: number of hospital beds or population density, for example. These do not correspond to any individual characteristic, but they can be aggregated at various levels. Thus the number of hospital beds in a region is the sum of the number of beds in each of the departments that make up the region, and its density is the sum of the densities weighted according to the population of each department. Other collective characteristics are well defined for a given level of aggregation but cannot be aggregated at higher levels. The electoral orientation of a commune, as defined by the party affiliation of its mayor, for example, cannot be aggregated with those of neighbouring communes which may range over a wide spectrum. This characteristic does not exist at either the individual level, or the departmental and regional levels.

The use of contextual models imposes very restrictive conditions on the formulation of the logarithm of relative risks (log-odds) in relation to the characteristics. In particular, the behaviours of individuals within a group are treated as independent of each other. In practice, it is more likely that the risk faced by an individual in a given group will depend on the risks faced by the individuals in the same group. Failure to include this within-group dependence usually produces bias in the estimations of the variances of the contextual effects, resulting in confidence intervals that are too narrow. Also, these “log-odds” for individuals in different groups cannot vary freely but have restrictive constraints imposed by the model being used (Loriaux, 1989). In the previous case, for instance, if the migration probabilities of non-farmers ($a_{ij} = 0$) and farmers ($a_{ij} = 1$) in each region are linked by segments of line, it can be shown that all these lines will pass through a common point (Courgeau 2001).

In view of these constraints, it becomes necessary to formulate the proposed model in its full complexity, which brings us to authentic multilevel models.

… to a multilevel analysis

For a clearer idea of what we intend to do, it is useful to review what was said earlier in the discussion of longitudinal analysis, concerning the effect of different characteristics on demographic behaviour. It was shown that subdivision into more homogeneous sub-populations, according to different regions or different characteristics, meant that the numbers exposed to the risk quickly fell to very low levels. The results from such an analysis are too unstable for significant relationships to be identified. In these conditions the large number of random variations (noise) are likely to mask any interesting result.

This problem was overcome using the methods of linear or, more usually in demography, logistic regression, which identify the relevant results of the analysis. The introduction of time into Cox-type models has made it possible to study the heterogeneity of the population and obtain results that are completely significant even when large numbers of characteristics are introduced. However, this method implies making new hypotheses, whose validity must be tested using tests whose power, unfortunately, is so low that they provide no adequate basis for rejecting the model even if the error component is very large. The contextual models which generalize these methods by introducing regions or groups of different individuals, offer no solution to the difficulties outlined above. In these conditions the best approach may be to look for a compromise between a model which does not constrain its estimators but fails to produce a significant estimation, and a model that sets excessive constraints but whose validity cannot be tested.

In our view the solution to this two-fold problem lies with multilevel models. These introduce random effects into the previous individual or contextual models, thus allowing the regression methods considered to be generalized.

Let us have another look at the example of Norwegian migrations. First of all we have the possibility of estimating a logistic model by region, suitable for measuring the effect of a characteristic, in this case that of being a farmer, on the migration probability:

$$P(\mu_{ij} = 1 \; | i \in j, a_{ij}) = (1 + exp[\alpha_{0j} + \alpha_{1j} a_{ij}])^{-1} \qquad [7]$$

This is the first stage of the analysis, in which the whole set of regional parameters (for 19 regions there are 38 parameters) are estimated. But when a large number of regions is included or the parameters are numerous, these parameters resemble random noise when plotted and are subject to a very large error that prevents any firm conclusions from being reached. The solution envisaged involves placing constraints on these parameters to obtain more accurate results. If it is assumed, for example, that they are distributed randomly around their mean value, estimated by models [6] and [7], we can then write:

$$\alpha_{0j} = \alpha_0 + \alpha_2 a_{.j} + u_{0j} \qquad \text{and} \qquad \alpha_{1j} = \alpha_1 + \alpha_3 a_{.j} + u_{1j}$$

where u_{0j} and u_{1j} are random values of expectation zero. Attention can thus be limited to the variances and covariances between these random values:

$$var(u_{0j}) = \sigma^2_{u0} \qquad var(u_{1j}) = \sigma^2_{u1} \qquad cov(u_{0j}, u_{1,j}) = \sigma_{u01}$$

The full model can now be written in condensed form:

$$P(\mu_{ij} = 1 \; | a_{ij}, a_{.j}) = (1 + exp - [\alpha_0 + \alpha_2 a_{.j} + u_{0j} + (\alpha_1 + \alpha_3 a_{.j} + u_{1j}) a_{ij}])^{-1} \qquad [8]$$

Now we need to estimate only 7 parameters, compared with the 38 previous ones.

Remaining with the Norwegian example, let us see in table 1 what light these models shed on migration behaviour. If the aggregated characteristics of the regions are not introduced (simple model), the individual-level parameters remain almost the same as those estimated without including regional effects in the previous logit model, both for farmers and for other occupations (Courgeau, 2000b). By contrast, significant effects appear for the regional random variables, showing a very diverse behaviour for inhabitants of the different regions. When the proportions of farmers of the regions are introduced (model with aggregate characteristic), as in the contextual model estimated earlier, their effect appears entirely significant and identical to that observed with a single level of aggregation. By contrast, at the level of the regional random variables, a sharp reduction of one half is observed for non-farmers, showing clearly that introduction of the regional percentages for farmers has an influence on this variance, whereas for farmers the effect remains as high as before. However, the fact that the regional variance remains significant shows that the aggregate characteristics do not explain everything. This model, while confirming the results of the previous contextual model, is nonetheless more complete.

Parameter	Multilevel Model	
Fixed:	Simple	With aggregate characteristic
α_0 (non-farmer)	-1,710 (0,070)	-2,067 (0,119)
α_1 (farmer)	-2,306 (0,133)	-2.017 (0,340)
α_2 (proportion of farmers)		5,420 (1,209)
α_3 (farmer × % farmers)		-8,691 (3.238)
Random:		
$\sigma^2_{u_0}$ (non-farmer)	0,088 (0,032)	0,047 (0,024)
$\sigma_{u_{01}}$ (covariance)	0,054 (0,044)	0,085 (0,042)
$\sigma^2_{u_1}$ (farmer)	0,167 (0,135)	0,181 (0,119)

Table 1 .- Multilevel analysis parameters and their standard error in parentheses

A multilevel model, because it uses all the available information, avoids any arbitrariness in the choice of characteristics for inclusion in the model and in the means of selecting the variables to be used. Consequently the variances and covariances between characteristics present at a given level of aggregation will no longer be bound by the restrictive conditions that apply when a contextual model is used.

A similar approach is now used in different social sciences as educational sciences (Goldstein, 1995), epidemiology (Greenland, 1998; Morgenstern, 1998), human geography (Jones, 1997), and so forth.

More generally, such a model is suitable for showing how differences between rates estimated for groups can be explained by differences in the distribution of various individual characteristics. A first level might consider the individual risks within each group with regard to a large number of characteristics of these same individuals. A second, more aggregated level, is then used to predict the first level coefficients for various characteristics, not only aggregate but also particular to the groups. The underlying hypothesis is that the coefficients of the groups are random samples of a more general population of such parameters. By combining the results obtained for each level, it is possible to predict the probability of an event's occurrence, for a given individual, in relation to his or her individual characteristics, and the characteristics of the various groups and their interactions.

Multilevel event history models can also be set up by introducing random variables both in the baseline hazards and in the effect of the various characteristics of a generalized Cox-type model. Using the previous example of nuptiality among farmers (model [5]), we add the effects of regions *j* (regional percentages with the individual characteristic, $Z_{.j}(t)$, or other regional characteristics, $Y_j(t)$, leading to estimate probabilities of the following type:

$$h_{ij}^{am}(t \mid Z_{ij}(t)) = h_0^{am}(t)exp[(\beta + \gamma Z_{.j}(t) + u_j)Z_{ij}(t) + \delta Y_j(t) + v_j + w_{ij}] \qquad [9]$$

We see that with this model we can write $h_{0j}^{am}(t) = h_0^{am}(t)exp(\delta Y_j(t) + v_j)$, which introduces the underlying regional baseline hazards, that depend on regional characteristics. In the same way, the effect of each characteristic can now depend on the region. Finally, an unobserved individual heterogeneity is introduced by the parameter w_{ij}.

Models of this kind facilitate the study of several processes taking place simultaneously. Thus, for example, fertility in different regions of a country can be studied at the same time as the migrations occurring between these regions. In this way we can see if a change in the fertility behaviour of migrants takes place and to measure the time needed to adapt to the fertility of the region of immigration, if this is the case, or conversely to see if there is not a selection of migrants from in the initial population.

The statistical models necessary for handling this data are now well developed (Goldstein, 1995). However, it has to be noted that multilevel event history models still require major extensions before they can be applied to complex situations. On the other hand, they offer the possibility of being able to introduce any number of levels, regardless of how they are organized in relation to each other.

The simplest and most widely used structure is hierarchical. For example, individuals live in communes, which are themselves in departments, and so on. Each level is formed by the grouping together of all the units of the preceding level. The division adopted may be administrative, as in the example just given, or of a completely different type: workshops, factories, companies, production sectors, and so one.

More complicated relationships between the levels can be envisaged. Individuals can be distributed between towns classified by ascending size order but also between administrative, industrial and tourist centres, for example. In this case there is a cross-classification, according to whether the towns are classified by size or by function. It is of course possible to have relationships that combine hierarchical and cross-classifications. For example, individuals may be classified by type of residential neighbourhood and by the type of place of work (cross-classification), which are themselves subject to a hierarchical classification of departments and regions.

New forms of surveys are required for carrying out analysis on these lines. Such surveys need to distinguish carefully between the various groups to be considered and must be capable of producing aggregated measurements. Individual characteristics can of course always be aggregated, but as was shown earlier there are other group characteristics which cannot be obtained in this way. These must therefore be measured, independently of the survey conducted on the members of the group. This data-gathering exercise is likely to be particularly time-consuming and complicated for the purpose of multilevel event history analysis. Information has to be collected on the variations of these characteristics over time.

Towards a more comprehensive paradigm

This new approach does not imply a dramatic change in the paradigm used for event history analysis since the focus of analysis remains at the individual level. Rather, by introducing the effects of groups or regions on individual behaviour it extends and completes that paradigm.

Within the new paradigm the behaviour of an individual is still considered to depend on his or her past history, but the perspective is broadened to recognize that this behaviour can also depend on the external constraints that weigh on the individual, and of which he or she may or may not be aware. In this way it becomes possible to examine the “unintended side effects” of individual actions with initial aims completely different from the results obtained (Boudon, 1977). These effects are a product of the milieu in which the individual lives and can be identified by means of multilevel methods. Similarly, individuals may be unaware of the constraints that society places on its members, though these may influence their behaviour without their knowledge. Finally, individuals may be fully aware of these constraints and act accordingly, so as to resist their influence, to avoid them, or even use them to their own advantage.

With this approach it is possible to study individual biographies situated in a multi-dimensional space. This context can be defined not merely in the conventional physical terms, making a distinction between regions and towns, for example, but could also be socially-defined, introducing the networks of relations between individuals, or economically-defined, taking account of the companies and public utilities, for example, where these individuals are employed, or of any other functional space.

This paradigm also opens the way for a new statistical perspective on human behaviour. The “subjective” position elaborated by Bayes in 1763 introduces a larger dimension to this approach. Starting from the "prior" probability of a particular event, this method uses new empirical information from observation in order to calculate a "posterior" probability for the same event. The application of such a formulation was vigorously rejected by the proponents of an "objective" viewpoint, for whom the notion of "prior" probability was completely meaningless since the probability was that of a one-off event. The "objectivists" worked to develop methods of inference that were compatible with this conception of probabilities and avoided recourse to Bayes's theorem. The multilevel approach is a powerful stimulus for a renewed use of the Bayesian conception of probability.

Model [7] produces estimations for a large number of coefficients, in the present case 38 for 19 regions, some of which may be determined on small numbers and thus have a very high variance. As was indicated, it is hard to reach any firm conclusions from this first stage. For this reason we go back to model [6], which this time requires estimation of only four coefficients, and attempt to make a synthesis of these two models, leading to the introduction of four fixed parameters and two random variables for which only the variances and covariances are estimated, representing seven quantities in all (model [8]). However, the residuals can be estimated, making it possible to situate the regions in relation to each other and to identify those in an extreme position in relation to the others, by estimating a confidence interval for each region. This is what is commonly referred to as an empirical-Bayes estimator, in which the "prior" distribution is estimated from empirical data as is the "posterior" distribution (Lee, 1997). It is of course possible to go further and introduce at a third level an authentic "prior" estimation, thereby producing a model operating on more fully Bayesian principles leading to a Bayes empirical-Bayes estimation (Greenland, 2000).

By its simultaneous introduction of individual characteristics and aggregate characteristics at different levels, this provides both a synthesis of and an improvement on the three previous approaches. It introduces the aggregated characteristics, and is therefore able to explain the results obtained with a period model, though using different hypotheses, as was seen. It incorporates the individual characteristics, and therefore produces results comparable to those obtained with event history models. Finally, by its improved capacity to take into account the diversity of behaviour at different levels of aggregation, it provides a solution to the problems encountered in longitudinal analysis, where the sub-division of categories and places quickly renders analysis impractical.

Unanswered questions

A rapid review was given earlier of the various types of divisions or groupings that can be used in analysis: sociological and anthropological (e.g. family, "contact circle", clan), geographical and administrative (e.g. communes, cantons, departments, regions, countries), religious (e.g. parishioners of a Catholic church, or a Protestant church, animists), and many others. Some of these divisions are obvious candidates for use in analysis (such as the family or the workshop), since the potential influence of these groups on individual behaviour is already well established, but the use of others can be less obvious.

First of all, if, as is theoretically possible, a large number of levels of aggregation are introduced, there is a danger of duplication between some of the levels. For example, if local government divisions were being used, duplication might well occur between the division by communes (of which there are roughly 36 000 in France) and by cantons (roughly 3000 in France). Use of multilevel analysis should supply an answer to these questions, since the random variables corresponding to one level of aggregation can disappear when another is introduced that takes account of these variables correctly. Another point is that some divisions may be entirely appropriate for studying one phenomenon but not another. Thus for example the regional division that we used in Norway is clearly suitable for the analysis of inter-regional migrations; but it would be inappropriate for studying migrations at a more detailed level.

Further advance in this field requires a very thorough examination for each type of study of the various possible levels of aggregation. It would also be useful to see if combining zones gives results as good as those obtained using a larger number, and with no loss of information. A broad investigation to assess the validity of existing divisions and the creation of new and more relevant divisions is needed and as yet remains to be undertaken.

From another point of view, this analysis, in which individual behaviour is explained by reference to both individual and aggregated characteristics, may fail to explain evolution in the rules which apply at higher levels of aggregation. It is important to understand that these rules result from the transmission between individuals in the same group of behaviour which is similar at a certain point in time but which can change over time. There is thus a two-fold problem for analysis: that of the change in these groups over time, and that of the changes in the different behaviours.

How are appropriate groups formed? What are the factors responsible for their survival or demise? And what are the mechanisms which explain their evolution? These are all questions which require answers and which to date have received little attention. Studies do of course exist on the rise and fall of great cultures in the past, but analysis of cohesion and change in smaller-scale groups is still in its infancy. Research in this direction must be continued in order to place multilevel analysis on firmer foundations.

Another problem concerns an investigation of how particular types of behaviour come into being, are modified or disappear. Little work has been done on this genesis of social behaviour, although the various demographic transition theories attempted to provide general explanations. Thus, for example, in the case of the developed countries, the emergence and spread of cohabitation as an alternative to marriage in the 1960s has still not been satisfactorily explained. The explanation is doubtless that it was a form of behaviour better adapted than traditional marriage to the prevailing conditions at the time and for this reason was able to spread in these countries. Attention needs to focus on how isolated individual actions, occurring in a given community, can produce an awareness of a problem that affects society as a whole and stimulate an acceptable solution; then examine how these new behaviours are diffused and prompt the introduction of policies (such as the civil solidarity pact or PACS recently introduced in France, giving legal recognition to couples of either sex, for example), taken at a higher level of aggregation. These measures will in turn, of course, influence individual conduct, producing new actions to counter their negative side-effects, and so on and so forth.

Finally, more attention needs to be given to the social structure of the groups being considered. Existing multilevel models do introduce a correlation between the behaviour of the members of a particular group, but this correlation applies without distinction to each couple of individuals in this group. For some groups, usually of small size, it could be worthwhile to consider the interactions existing between some members, for example the spouses in a family. These interactions can be examined by means of "models of shocks" (Lelièvre et al., 1997). However, many difficulties remain to be overcome before these models can be fully implemented.

7. CONCLUSION

Having reached the end of this chapter, it is time to broaden the debate over the different approaches presented here by raising a number of more fundamental questions about the hypotheses that underpin demography. As we have indicated, the prerequisite for the emergence of the discipline was the development of the bases of probability theory. Our discussion will thus focus on the application of this theory to human populations and on the ways of interpreting the results obtained.

Let us remember, first of all, that for ethical reasons there can be no experimental research in demography. The demographer therefore has to work on populations that possess certain characteristics and whose behaviour is observed at a particular point in time, or over all or at least part of their lifetime. The question to be answered is: does this provides the material for deducing, not a theory of causality in the social sciences (Wunsch, 1988; Duchêne et al., 1989; Franck, 1994; Courgeau, 2000a), which is not the object of discussion in this article, but rather an empirical theory of human behaviour, such as can be verified by means of this observation? In these conditions it is easy to understand the important role played by the methods of observation in this verification and in the development of new empirical theories.

A first theory assumes that an individual's membership of a certain number of groups influences the occurrence of various demographic events. For the analysis to be meaningful, the existence and relevance of these groups has to be assumed. If they are defined by a property or by a founding event, their existence is not problematic: the members of a particular profession, married individuals, inhabitants of a geographical unit, followers of a religion, for example, constitute clearly defined groups, membership of which may change over time. There is, however, an important difference between these groups: some are actually relevant to the analysis, whereas others are used to break down the population for the purpose of testing the relationship that is being studied.

In period analysis, the relevant groups are those defined by demographic, religious, economic and similar criteria, whereas the geographical or administrative groups are used to reveal the relationship between the event being studied and the various social groups. The underlying assumption in such an analysis is that an individual's membership of a particular geographical unit has no effect on his or her behaviour, other than that induced by the different social composition of each unit. Moreover, since the analysis uses period data, the movements into and out of these groups will not distort the results. This leads to using data from censuses or other cross-sectional sources.

However, as has been seen, this theory runs into difficulties because it fails to take into account the time lived by individuals. This was the idea behind adoption of a longitudinal perspective that could introduce the events occurring in their lifetime (e.g. wars, economic crises) and explore their effect on this life as a whole. Such a theory has to set extremely strict conditions of homogeneity for the populations being studied and of independence between the various phenomena under examination. This is the reason for using data from civil registration or other exhaustive longitudinal sources. However, if the aim is to analyse the effect on the phenomenon of belonging to a group, the movements into and out of it can no longer be omitted. Unfortunately these are not usually recorded in the civil registration statistics; and even if they were, the conditions of homogeneity of the group would no longer be satisfied, nor the conditions of independence between the event being studied and the movement into or out of the group. An entire sector of demographic analysis of populations is thus ruled out.

Escaping from this impasse requires this fragmented view of independent events to be abandoned. The solution is to consider human existence as a process that is dependent on the individual's entire past history. This becomes possible with event history analysis. An individual's membership of a group is no longer defined once and for all, but can vary from one moment to the next – either the individual will be able to move from one group to another, or the membership of a group will be defined as a time-dependent variable. In this way the occurrence of any number of demographic events can be studied simultaneously, with all the interactions that may exist between them. This makes it possible to examine the effect of a large number of characteristics which may or may not be time-dependent.

New questions then arise, however. Are the individuals questioned, who possess certain characteristics, all exposed to the same risk of experiencing the event being studied? An initial hypothesis is to consider each observed trajectory as the realization of an individual random process, whose probability is specific to each individual. In this case, however, because only one realization of the process, an individual trajectory, is available, the probability of this process cannot be determined. A second hypothesis is required in order to move the analysis forward: this is the assumption that the group observed follows an underlying stochastic process, whose probability structure it is possible to identify from the set of trajectories followed. It is important not to confuse the person surveyed and the statistical individual who follows this process. No hypothesis is made about the personal processes, which are by nature evanescent, but the process followed by the statistical individual can be analysed.

Other problems also arise from the fact that this approach no longer has to consider the various geographical or administrative entities in which the individuals are located. Although these were useful in the period approach for examining the effect of demographic or economic characteristics, for example, they appear to be of no interest for an event history analysis. Yet an examination of some results obtained with this analysis appear in contradiction with those obtained by the period approach, even though they concern the same populations.

An extension of this event history analysis thus seems necessary to produce a synthesis of these contradictory results. Such a synthesis can be achieved with the multilevel event history approach. It no longer treats the differences between regions or between any other territorial division as random variables devoid of interest, but actually tries to identify and if necessary explain them by aggregate or other characteristics. These aggregate characteristics are thus brought into the analysis, but the underlying hypotheses employed are different. Instead of affecting individual probabilities in a uniform way, as in the period approach, these characteristics will on the contrary modulate the probabilities according to the regions in which the individuals live.

This multilevel approach thus accommodates the various earlier observations with each other, at the same as clearly setting out the hypotheses on which it is based: it seeks to explain a behaviour at the individual level by introducing various levels of aggregation with some of their characteristics. In contrast to the aggregate approach, which was supposed to reveal the virtually unchanging bases of social organization as passed down in more or less final form from preceding generations (Durkheim, 1897), this approach not only no longer postulates stability in social organization, but on the contrary actually facilitates understanding of its rapid changes over time. If a sufficient number of generations are used in the analysis, the modifications can be identified in the effects of individuals or aggregated characteristics on one or several behaviours under study. In this way the existence and pace of these changes can be verified and measured at various levels of aggregation.

It is possible to produce a table with these different approaches, according to the fact that they introduce or not space and time and, for the time points of view, according to the fact that they are with or without explicit characteristics. The following table gives eight patterns of analysis. We have already presented in this paper the major part of these patterns, except the one made between national and regional period analysis. As a matter of fact, it is not necessary to add such a distiction as the methods used to undertake national or regional period analysis are nearly similar.

Time →	Absent		Present	
Space ↓	Without explicit characteristics	With explicit characteristics	Without explicit characteristics	With explicit characteristics
Absent	National period analysis	Demographic transition analysis	Cohort analysis	Event history analysis
Present	Regional period analysis	Regional regression analysis	Multistate analysis	Multilevel analysis

Might it be possible to go further still and show the genesis of these changes in behaviour and track their diffusion in a context that is social as well as geographical? Imagine that we have a survey involving a large number of generations, with which we can observe the emergence and development of a new behaviour, such as cohabitation in the generations born after the Second World War. Because observation is of individuals living in a large number of geographical regions and social groups, it will be possible to identify where this behaviour first appeared and to try to find out what is particular about these zones and why it has appeared here. Attention would then turn to the next affected zones and to how they differed from those where this behaviour was still not present despite their proximity, and so on and so forth. Such detailed case studies are an opportunity to link the quantitative multilevel approach to approaches of a more qualitative nature, and to allow a more precise identification of the mechanisms at work.

By way of conclusion it can be said that while raising numerous and as yet unresolved questions, this approach constitutes a major advance in demography, since it provides a statistical basis for a synthesizing analytical instrument that is both more rigorous and more flexible than all the others described in this article. Its rich potential for application has only begun to be developed, but in our opinion it holds the key to an improved understanding of human behaviour.

REFERENCES

Andersen, P., Borgan, O., Gill, R., & Keiding, N. (1993). *Statistical models based on counting processes*, New York: Springer-Verlag.

Baccaïni, B., & Courgeau D. (1996). Approche individuelle et approche agrégée: utilisation du registre de population norvégien pour l'étude des migrations In J. P. Bocquet-Appel, D. Courgeau, & D. Pumain (Eds.), *Analyse spatiale de données biodémographiques* (pp. 79-104), Paris: John-Libbey/INED.

Bayes, T.R. (1763). An essay towards solving a problem in the doctrines of chance. *Philosophical Transactions Royal Society London*, *53*, 370-418.

Becker, G.S. (1960). An economic analysis of fertility. In *Demographic and economic change in developed counties: A conference of the Universities-National Bureau Committee for economic research*, Princeton: Princeton University Press.

Bernoulli, J. I (1713). *Ars conjectandi*, Bâle: Impensis Thurnisiorum Fratrum.

Blayo, C. (1995). La condition d'homogénéité en analyse démographique et en analyse statistique des biographies, *Population*, *50*, 1501-1518.

Bonneuil, N. (1994). Capital accumulation, inertia of consumption and norms of reproduction. *Journal of Population Economics*, *7*, 49-62.

Bonneuil, N. (1997). Jeux, équilibres et régulation des populations sous contrainte de viabilité. Une lecture de l'œuvre de l'anthropologue Fredrik Barth. In Courgeau (Ed.) *Nouvelles approches méthodologiques en sciences sociales*, *Population, 52*, 947-976 ((1998), Games, equilibria and population regulation under viability constraints: An interpretation of the work of the anthropologist Fredrik Barth. In Courgeau (Ed.) *New methodological approaches in the social sciences, Population : an English Selection*, *10*, 151-179).

Boudon, R. (1977). *Effets pervers et ordre social.* Paris: Presses Universitaires de France.

Brémaud, P., & Jacod, J. (1977). Processus ponctuels et martingales: résultats récents sur la modélisation et le filtrage. *Advanced Applied Probabilities*, *9*, 362-416.

Bretagnole, J., & Huber-Carol, C. (1988). Effects of omitting covariates in Cox's model for survival data. *Scandinavian Journal of Statistics*, *15*, 125-138.

Burch, T.K. (1999). Something ventured, something gained: Progress towards a unified theory of fertility decline. In D. Tabutin, C. Gourbin, G. Masuy-Strobant & B. Schoumaker (Eds.), *Théories, paradigmes et courants explicatifs en démographie*, *Chaire Quetelet 1997* (pp. 253-278). Louvain-la-Neuve: Academia-Bruylant/L'Harmattan.

Caldwell, J.C. (1982). *Theory of fertility decline.* London: Academic Press.

Cleland, J. (1985). Marital fertility decline in developing countries: Theories and the evidence. In J. Cleland and J. Hobcraft (Eds.), *Reproductive change in developing countries: Insights from the World Fertility Survey* (pp. 223-252). Oxford: Oxford University Press.

Coale, A. J. (1973). The demographic transition reconsidered. In *International Population Conference, Liège, Vol. 1* (pp. 53-72). Liège: IUSSP.

Commenges, D. (1999). Multistate models in epidemiology. *Lifetime Data Analysis*, *5*, 315-327.

Condorcet (1994). *Arithmétique politique. Textes rares ou inédits (1767-1789),* Édition critique commentée par Bernard Bru et Pierre Crépel. Paris: INED/PUF.

Courgeau, D., (1982). Premiers migrants, migrants secondaires et retours (France 1968-1975). *Population*, *37*, 1189-1193.

Courgeau, D. (1987). Constitution de la famille et urbanisation. *Population*, *42*, 57-82 ((1989). Family Formation and Urbanization. *Population: An English Selection*, *1*, 123-146).

Courgeau, D. (1991). Perspectives avec migrations. *Population*, *46*, 1513-1530.

Courgeau, D. (1999a). L'enquête " Triple biographie : familiale, professionnelle et migratoire ". In Groupe de réflexion sur l'approche biographique *Biographies d'enquêtes,* Collection: Méthodes et savoirs (pp..59-74). Paris: PUF diffusion/INED,

Courgeau, D. (1999b). De l'intétêt des analyses multi-niveaux pour l'explication en démographie. In D. Tabutin, C. Gourbin, G. Masuy-Strobant, & B. Schoumaker (Eds.) *Théories, paradigmes et courants explicatifs en démographie*, *Chaire Quetelet 1997* (pp. 93-116), Louvain-la-Neuve: Academia-Bruylant/L'Harmattan.

Courgeau, D. (2000). Réflexions sur la causalité en sciences sociales. *Recherches et prévisions*, *60*, 49-60.

Courgeau, D. (2002). Vers une analyse biographique multiniveau, In Christine M. (Ed.) *Actes des Journées de Méthodologie Statistique* (pp. 375-394). Paris: INSEE méthodes 101.

Courgeau, D. (2001). Individus et contextes dans l'analyse des comportements selon l'approche multiniveau. In G. Caselli, J. Vallin, G. Wunsch (Eds.) *Démographie: analyse et synthèse. I La dynamique des populations* (pp. 519-536). Paris: Editions de l'INED.

Courgeau, D., & Baccaïni, B. (1997). Analyse multi-niveaux en sciences sociales. In Courgeau (Ed.) *Nouvelles approches méthodologiques en sciences sociales* (pp. 831-864), *Population, 52*, ((1998), Multilevel analysis in the social sciences, in Courgeau (Ed.) *New methodological approaches in the social sciences* (pp. 39-71)*, Population : an English Selection, 10*).

Courgeau, D., & Lelièvre, E. (1985). Nuptialité et agriculture. *Population*, *41*, 303-326.

Courgeau, D., & Lelièvre E. (1989). *Analyse démographique des biographies*, Paris: Éditions de l'INED.

Courgeau, D., & Lelièvre, E. (1992). *Event history analysis in demography.* Oxford: Clarendon Press.

Courgeau, D., & Lelièvre, E. (1996). Changement de paradigme en démographie. *Population*, *51*, 645-654 ((1997). Changing paradigm in demography. *Population: an English Selection*, 9, 1-10).

Cox, D. (1972). Regression models and life tables (with discussion). *Journal of the Royal Statistical Society*, *B34*, 269-276.

Cribier, F., & Kych, A. (1999). Un ensemble d'enquêtes auprès de deux cohortes de retraités parisiens. In Groupe de réflexion sur l'approche biographique : *Biographies d'enquêtes*, *Méthodes et savoirs* (pp. 75-103). Paris: PUF diffusion/INED,.

Davis, K. (1945). The world demographic transition. *Annals of the American Academy of Political and Social science*, *237*, 1-11.

Delaporte, P. (1941). *Evolution de la mortalité en Europe depuis les origines des statistiques de l'état civil.* Paris.

Dellacherie, C. (1980). Un survol de l'intégrale stochastique. *Stochastic Processes Applications*, *10*, 115-144.

Dellacherie, C., & Meyer, P.A. (1980) *Probabilités et potentiels: théorie des martingales.* Paris: Hermann.

Deparcieux, A. (1746). *Essai sur les probabilités de la durée de la vie humaine.* Paris: Guérin frères.

Duchêne, J., Wunsch, G., & Vilquin, E. (Eds.). (1989). *L'explication en sciences sociales: la recherche des causes en démographie*. Bruxelles: Éditions Ciaco.

Dupâquier, J. (1985). Le mémoire de Jean de Witt sur la valeur des rentes viagères. *Annales de démographie historique*, 355-394.

Dupâquier, J. (1996). *L'invention de la table de mortalité.* Paris: PUF.

Dupâquier, J. & Dupâquier, M. (1985). *L'histoire de la démographie.* Paris: Librairie Académique Perrin.

Durkheim, E. (1930). *Le suicide.* Paris: PUF (original work published 1897).

Durkheim, E. (1937). *Les règles de la méthode sociologique.* Paris: PUF (original work published 1895).

Easterlin, R.A. (1961). The American baby-boom in historical perspective. *American Economic Review*, *51*, 860-911.

Easterlin, R.A., & Crimmins, E.N. (1985). *The fertility revolution: A demand-supply analysis.* Chicago: University of Chicago Press.

Euler, L. (1760). Recherches générales sur la mortalité et la multiplication du genre humain, *Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Berlin*, *VII*, 144-175.

Filloux, J.C. (2001). *Epistémologie, éthique et sciences de l'éducation.* Paris: L'Harmattan.

Firebaugh, G. (1978). A rule for inferring individual-level relationships from aggregate data. *American Sociological Review*, *43*, 557-572.

Franck, R. (Ed.). (1994). *Faut-il chercher aux causes une raison? L'explication dans les sciences humaines.* Paris-Lyon: Librairie Philosophique Vrin.

Goldstein, H. (1995). *Multilevel statistical models.* London: Arnold.

Graunt, J. (1662). *Natural and political observations upon the bills of mortality... of the city of London.* Tho. Roycroft: London ((1977) *Observations naturelles et politiques*, translated by Vilquin E., Paris: INED).

Greenland, S. (2000). Principles of multilevel modelling. *International Journal of epidemiology*, *29*,. 158-167.

Greenland, S. (1998). Hierarchical regression. In K. Rothman and S. Greenland (Eds.), *Modern Epidemiology* (pp. 427-432), Lippincott-Raven.

Guillard, A. (1855). *Éléments de statistique humaine ou démographie comparée.* Paris: Guillaumin.

Halley, E. (1693). An estimate of the degrees of the mortality of mankind drawn from curious tables of the births and funerals at the city of Breslaw. *Philosophical Transactions*, *XVII*, 596-610.

Henry, L. (1959). D'un problème fondamental d'analyse démographique. *Population*, *13*, 9-32.

Henry, L. (1966). Analyse et mesure des phénomènes démographiques par cohorte. *Population*, *20*, 465-482.

Henry, L. (1972). *Démographie: Analyse et modèles.* Paris: Larousse.

Hoem, J. (1985). Weighting, misclassification and other issues in the analysis of survey samples of life histories. In Heckman and Singer (Eds.), *Longitudinal analysis of labour market data* (pp. 249-293). Cambridge: Cambridge University Press.

van Imhoff, E., & Keilman, N. (2000). On the quantum and tempo of fertility: comment. *Population and Development Review*, *26*, 549-553.

Jones, K. (1997). Multilevel approaches to modelling contextuality: from nuisance to substance in the analysis of voting behaviour. In G.P. Westert and R.N. Verhoeff (Eds.), *Places and people: multilevel modelling in geographical research* (pp.19-43). Utrecht: Nederlandse Geografische studies 227.

Keiding, N. (1999). Event history analysis and inference from observational epidemiology. *Statistics in Medicine*, *18*, 2353-2363.

Keilman, N. (1986). Analysing nuptiality:The multidimensional method and the French school. In *Population and family in the low fertility countries* (pp. 91-113). Den Haag/Brussels: Nidi/CBGS publicaties 16.

Keilman, N. (2001). La translation démographique: les indicateurs du moment aux indicateurs de génération et réciproquement. In G. Caselli, J. Vallin, & G. Wunsch (Eds.), *Démographie: Analyse te synthèse. I La dynamique des populations* (pp. 359-378). Paris: Ined.

Körösi, J. (1896). An estimate of the degrees of legitimate natality as derived from a table of natality compiled by the author from his observations made at Budapest. *Philosophical Transactions, (Royal Society of London), series B, 186*, 781-875.

Krieger, N. (2000). Epidemiology and social sciences: towards a critical reengagement in the 21st century. *Epidemiologic Reviews*, *22*, 155-163.

Kuhn, T.S. (1972). *La structure des révolutions scientifiques.* Paris: Flamarion.

Lancaster, T. (1990). *The econometric analysis of transition data.* Cambridge: Cambridge University Press,.

Landry, A. (1982). Les trois théories principales de la population. In A. Landry, *La révolution démographique.* Paris: Ined (original work published 1909).

Landry, A. (1945). *Traité de démographie.* Paris: Payot.

Lazarsfeld, P.-F., & Menzel, H. (1961). On the relation between individual and collective properties. In Etzioni (Ed.), *Complex organizations* (pp. 422-440). New York: Holt, Reinhart, and Winston.

Lee, P.M. (1997). *Bayesian statistics. An introduction.* Second edition. London: Arnold.

Lelièvre, E. (1987). Activité professionnelle etfécondité: les choix et les déterminations des femmes françaises entre 1930 et 1960. *Cahiers Québéquois de Démographie*, *16*, 207-236.

Lelièvre, E., Bonvalet, C., & Bry, X. (1997). Analyse biographique des groupes. Les avancées d'une recherche en cours. In D. Courgeau (Ed.), *Nouvelles approches méthodologiques en sciences sociales*, *Population*, *52*, 803-830 ((1998), Event history analysis of groups. The findings of an on-going project. In Courgeau (Ed.), *New methodological approaches in the social sciences, Population: an English Selection*, *10*, 11-37).

Lesthaeghe, R. (1983). A century of demographic and cultural change in Western Europe: An exploration of underlying dimensions. *Population and Development Review*, *9*, 411-435.

Loriaux, M. (1989). L'analyse contextuelle: renouveau théorique ou impasse méthodologique. In J. Duchêne, G. Wunsch, E. Vilquin (Eds.), *L'explication en sciences sociales. La recherche des causes en démographie*, *Chaire Quetelet '87* (pp. 333-368). Bruxelles: Ciaco Editeur.

Lotka, A. (1939). *Théorie analytique des associations biologiques*, *Deuxième partie.* Paris: Hermann et Cie.

Lyberg, I. (1983). The effect of sampling and nonresponse on estimates of transitions intensities: some empirical results from the 1981 Swedish Fertility Survey. *Stockholm Research Reports in Demography*, *14*.

Mason, K. O. (1997). Explaining fertility transitions. *Demography*, *34*, 443-454.

Mason, W.M., Wong, G.W., & Entwistle, B. (1983). Contextual analysis through the multilevel linear model. In S. Leinhart (ed.),.*Sociological Methodology 1983-1984* (pp. 72-103). San Francisco: Jossey-Bass.

Matalon, B. (1967). Epistémologie des probabilités. In Piaget J. (Ed.), *Logique et connaissance scientifique* (pp. 526-553). Paris: Éditions Gallimard.

Menken, J., & Trussel, J. (1981). Proportional hazards life table models: An illustrative analysis of socio-demographic influences on marriage dissolution in the United States. *Demography*, *18*, 181-200.

Moheau, J.-B. (1994). *Recherches et considérations sur la population de la France.* Paris: Editions de l'Institut National d'Etudes Démographiques (original work published 1778).

Morgenstern, H. (1998). Multilevel analyses and design. In K. Rothman and S. Greenland (Eds.), *Modern Epidemiology* (pp. 478-480). Philadelphia: Lippincott-Raven.

Notestein, F. (1945). Population - The long view. In Schulz (Ed.) , *Food in the world*, Chicago: University of Chicago Press.

Pascal, B. (1986). Traité du triangle arithmétique. In Edwards A.W.F. (Ed.), *Pascal arithmetic triangle.* London: Charles Griffin, (original work published 1651).

Petty, W. (1690). *Political arithmetick.* London: Robert Clavel & Hen. Mortlock. Retrieved February 6, 2003, from: http://socserv2.socsci.mcmaster.ca/~econ/ugcm/3113/petty/poliarith.html.

Piaget, J. (Ed.). (1967). *Logique et connaissance scientifique.* Paris: Éditions Gallimard.

Popper, K. R. (1973). *La logique de la découverte scientifique.* Paris: Éditions Payot (original work published 1935).

Poulain, M., Riandey, B., & Firdion, J.M. (1991). Enquête biographique et registre belge de population: une confrontation des données. *Population*, *46*, 65-88 ((1992) Data from a life history survey and the Belgian Population Register: a comparison, *Population: An English Selection*, *4*, 77-96).

Pressat, R. (1966). *Principes d'analyse.* Paris: Éditions de l'INED.

Puig, J. P. (1981). La migration régionale de la population active. *Annales de l'INSEE*, *44*, 41-79.

Quetelet, A. (1997). *Physique sociale ou essai sur le développement des facultés de l'homme.* Bruxelles: Académie Royale de Belgique (original work published 1869).

Robinson, W. S. (1950). Ecological correlations and the behavior of individuals. *American Sociological Review*, *15*, 351-357.

Rogers, A. (1973). The multiregional life table. *The Journal of Mathematical Sociology*, *3*, 127-137.

Roussel, L. (1971). La nuptialité en France. Précocité et intensité suivant les régions et les catégories socio-professionnelles. *Population*, *26*, 1029-1056.

Ryder, N. B. (1965). The cohort as a concept in the study of social change. *American Sociological Review*, *30*, 843-861.

Sadler, M.T. (1830). *The law of population: a treatise, in six books, in disproof of the superfecundity of human beings, and developing the real principle of their increase.* London.

Schoen, R., & Nelson, V.E. (1974). Marriage, divorce, and mortality: a life table analysis. *Demography*, *11*, 267-290.

Schultz, T.W. (1973). New economic approaches to fertility: Proceedings of a Conference, June 8-9, 1972. *Journal of political economy*, *81*, (2, Part II).

Schweder, T. (1970). Composable Markov processes. *Journal of Applied Probabilities*, *7*, 400-410.

Singleton, M. (1999). Les sens et les non-sens d'un nominalisme démographique. In D.Tabutin, C. Gourbin, G. Masuy-Strobant, & B. Schoumaker (Eds.), *Théories, paradigmes et courants explicatifs en démographie*, *Chaire Quetelet 1997* (pp.15-39). Louvain-la-Neuve / Paris: Academia-Bruylant / L'Harmattan.

Suppes, P. (1981). *Logique du probable.* Paris: Flamarion.

Süssmilch, J.P. (1979). *L'Ordre Divin dans les changements du genre humain*, translated by Hecht J. INED: Paris, (original work published 1741).

Travers, R. (1969). *An introduction to educational research.* New York: Mac Millan.

Tuma, N. B., & Hannan, M. T. (1984). *Social dynamics. Models and methods.* Orlando, Florida: Academic Press.

Wachter, K.W., & Lee, R.D. (1989). US births and limit cycle models. *Demography*, *26*, 99-115.

Willekens, F.J. (1999). The life course: models and analysis. In L. van Vissen, & P. Dykstra (Eds.), *Population issues. An interdisciplinary review* (pp. 23-52). New York: Kluwer Academic / Plenum Publishers.

Willekens, F.J. (2001). Theoretical and technical orientations towards longitudinal research in the social sciences. *Canadian Studies in Population*, Special issue on longitudinal methodology, *28*, 189-217.

Wong, G., & Mason, W.M. (1985). The hierarchical logistic regression model for multilevel analysis. *Journal of the American Statistical Association*, *80*, 513-524.

Wunsch, G. (1988). *Causal theory and causal modelling.* Leuven: Leuven University Press.

Zelinsky, W. (1971). The hypothesis of the mobility transition. *Geographical Review*, *61*, 219-249.