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Non Print Items

Abstract

Population is the collective noun for a set of people inhabiting a particular territory. Demography is the set of concepts and techniques that are applied to the study of (human) populations. These techniques help measure the rates associated with the components of population change: births, deaths, and migration. The consequences of different regimes of population change for past, current, and future population structures are explored through demographic models, which are defined mathematically and applied numerically to effect measurements or predictions of change. Examples of such models are the life table and the cohort component projection model, which can be used with single populations or used in multistate versions to understand the interactions between many populations. To explain the changes measured, demographers have put forward sets of theories that describe and explain how and why regimes of population change themselves. The most important regime change over the past century is called the first demographic transition, which saw population mortality and fertility levels fall dramatically. The second demographic transition has seen the persistence of below-replacement fertility in European societies. Prolonged low fertility leads to population aging, and results in gaps in labor supply which are filled by migration, and this constitutes the third demographic transition.

We proceed to extract the essence of the demographic approach to population analysis by examining successively: definitions of population, the characteristics of population used in demographic analysis, the main formal models used in demography, the main sources of population data, the main components of change and associated indicators, models for projecting the population, the processes of population change, and their profound implications for all societies across the globe. Most demographic analysis examines countries; some demographic analysis investigates variations within the spaces of countries, particularly at regional or local government scales; a small body of work examines demographic variables at neighborhood or community scale.

Keywords

Components of change; Demographic transitions; Demography; Fertility measures; Fertility trends; International migration measures; International migration trends; Intranational migration measures; Intranational migration trends; Life table models; Migration and ageing; Mortality measures; Mortality trends; Population; Population accounting models; Population ageing; Population characteristics; Population projection models.

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A0005 # Demography

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Glossary

G0005 **Age–Time Graph** The graph used to represent the age and time properties of demographic data and model variables (also known as Lexis diagram, after one of its first developers).

G0010 **Cohort-Component Projection Model** A model for projecting population using all the components of change for age groups in a period-cohort framework.

G0015 **Components of Change** The population flows that change the population: births, deaths, and migration.

G0020 **First Demographic Transition** The shift from a regime of high fertility and mortality rates to a regime of low fertility and mortality rates.

G0025 **International Migration** Migration from one country to another. Sometimes referred to as external migration.

G0030 **Intranational Migration** Migration from one location to another within the same country. Sometimes referred to as internal migration.

G0035 **Life Expectancy** The average (expected) length of life, free of the bias of the current distribution of deaths by age, which depends in part on the age distribution of the population at risk. The period life expectancy model assumes that current age-specific mortality rates will persist through the life of the current population. In the cohort life expectancy model, the age-specific rates are projected into the future and so life expectancies computed for each birth cohort.

G0040 **Life Table** A table of rates of mortality, survival probabilities, and life expectancies based on a stationary population model.

G0045 **Long-Term Migrants** Migrants who have stayed in a destination for 12 months or more (retrospective measure) or who intend to reside at a destination for 12 months or more (prospective measure).

G0050 **Migrants** People who have migrated from an origin to a destination and survive there. Also referred to as transitions.

G0055 **Migration Distance** The average of distances between origins and destinations weighted by the size of the migration flow.

G0060 **Migration Expectancy** The expected number of migrations that a person would experience over a lifetime, allowing for mortality.

G0065 **Migrations** The number of relocations of usual residence that occur in a time interval. For any migration flow, the number of migrations (events) will exceed the number of migrants (transitions/survivors). Also referred to as movements.

Multistate Model A model for computing the life table or for projecting the population in many states (e.g., regions and educational grades) which incorporates the movements or transitions between states. G0070

Net Migration The difference between in-migration to and out-migration from a geographical unit. G0075

Population Accounts Tables for organizing population stocks and components of change for consistency checks. G0080

Population Aging The process through which the population becomes older over time. The mean age of the population rises and the share of the population that is old rises. The same process occurs within the older population. The process is a consequence of the first demographic transition and becomes even more pronounced with the second demographic transition. It may be mitigated to a partial extent by the third demographic transition. G0085

Probabilistic Projections A large set of projections of the population in which the uncertainty in future trajectories of the components of change has been handled by sampling from error distributions around those trajectories. Using the set of projections, statements can then be made about the probability that the future population will lie between an upper and a lower limit. G0090

Proximate Determinants of Fertility A set of multiplicative factors which explain the level of fertility in a population. The factors involve marriage levels, use of contraception, use of abortion, the degree of natural infertility, and the maximum potential number of children. G0095

Radix The assumed stationary number of births and deaths used in constructing life tables. Typically, 100 000 births and deaths per year are used. G0100

Replacement Fertility The level of total fertility rate (TFR) needed to ensure that the population is replaced in the long run. It depends on female mortality rates in combination with age-specific fertility rates. In the lowest-mortality countries, replacement TFR has now fallen to 2.07–2.08 children per woman, close to the minimum of *c.* 2.05 when there are no female deaths G0105 before the end of female reproductive careers and when boys make up 51% of births.

G0110 **Scenario Projection** A population projection which uses conditional assumptions (e.g., what if fertility rates were at replacement level) to explore special futures for the population.

G0115 **Second Demographic Transition** The shift to a demographic regime of below-replacement fertility rates.

G0120 **Short-Term Migrants** Migrants who have stayed in a destination between 3 and up to 12 months (retrospective measure) or who intend to reside at a destination for 3–12 months (prospective measure).

G0125 **Standardized Mortality Ratio (SMR)** The ratio of observed mortality in a population to the mortality that would have occurred if it had the same age-sex distribution as a standard population (e.g., European standard population).

G0130 **Third Demographic Transition** The shift to a regime of low fertility combined with positive net migration from other countries.

G0135 **Total Fertility Rate (TFR)** The total number of children a woman would have if she experienced the age-specific fertility rates of either a current period (period TFR) or of an estimation/projection of age-specific fertility rates for a birth cohort (cohort TFR).

G0140 **Variant Projection** A population projection which uses assumptions about one or more of the components of change that is different from the assumptions used in a central or principal projection.

G0145 **Visitors** Persons who have stayed in a destination for less than 3 months (retrospective measure) or who intend to reside at a destination for up to 3 months (prospective measure).

S0005 Definitions

P0005 People are normally counted at their usual place of residence. By usual residence is meant the place where they spend most of their nonwork time, and from which they make journeys to work, to shop, to school, to leisure, and holiday locations. The concept of usual residence is unproblematic for most of the population, but a significant minority have several places of residence, some temporary, some permanent. In many censuses, a separate record is made of people who are temporarily resident on census night, either because they are visiting or because they are working away from home. AU1

P0010 In societies where permission was needed to take up permanent residence in new places (under the Hukou registration system in China, for example), counts of the population of cities depended on whether people with temporary residence were included as well as those with permanent registrations. Many Western societies attract short-term labor migrants (e.g., United Kingdom with its large intake of labor migrants from the new European Union member states in the period 2004–07), but official population estimates only include long-term international migrants and not those who are short term. Temporary migration results in the population present fluctuating during the year, and so resident population estimates are used. As population counts and estimates play a crucial role in the computation of key demographic indicators, the user of those indicators needs to bear in mind that they are subject to a margin of error based on the uncertainty of the population stock estimate.

Population Characteristics S0010

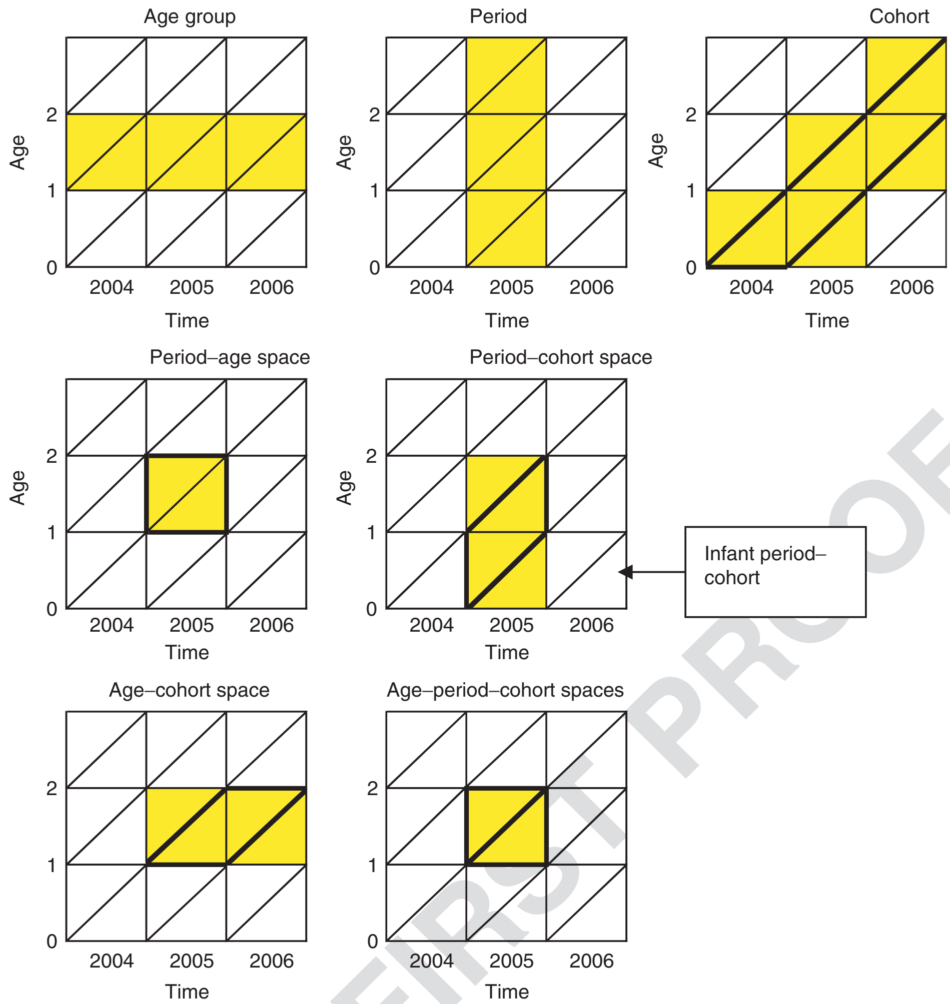
Demography studies the groups within the population that differ in their attributes and behavior. We consider the following dimensions that differentiate the population: location, sex, age, time; marital status, living arrangements, and household membership; social and economic statuses, including educational attainment, occupation, and income class; and race and ethnicity. P0015

Location, Sex, Age, and Time S0015

All populations are distinguished by location in geographical space. They are usually studied at country level where national laws and boundary controls make people's locations reasonably unambiguous. Within countries, demographic analyses are carried out for regions, local districts, and small areas. There are difficulties in comparing territorial units across countries (particularly when migration is considered) and across time because changes to administrative units are made. The European Union has made efforts, for example, to standardize territorial units across Europe in the Nomenclature of Units for Territorial Statistics (NUTS). P0020

Virtually, all demographic analysis distinguishes between the sexes both because of differences in biology and because of differences in behavior and welfare. For example, women live longer than men in virtually all countries of the world, but these differences are narrowing in the most developed nations. P0025

A crucial variable in demographic analysis is age, which is measured as the integer number of years elapsed since birth. Mortality, fertility, and migration processes vary profoundly and in different ways by age. Age interacts with the passage of time to give rise to a number of key concepts which are displayed in **Figure 1**, which consists of a set of age–time graphs. The top row of graphs illustrates the concepts of age group (persons with the same ages), period (an interval of time), and cohort (persons with the same birth year who proceed together through age–time space). We can place within the age– P0030



F0005 **Figure 1** The age–time framework at the heart of demographic analysis.
AU2

time graph both demographic events (births, deaths, and migrations), which occur at a point in time to persons of an exact age, and demographic transitions (changes of status measured at two time or two age points, such as survival or being a migrant). There are four schemata for capturing demographic events/transitions (shown in the bottom block of four graphs): period–age (e.g., deaths in a calendar year to persons aged 80 at death), age–cohort (e.g., survivors from one birthday in 1 year to the next birthday in the following year), period–cohort (survivors of one age group at the start of the year to the next age group at the end of the year) and age–period–cohort (e.g., births to mothers born in year by age at maternity and year of birth). The age–cohort schema is used in the life table model. The period–cohort schema is used in the cohort-component population projection model. The age–period–cohort schema is used to record demographic events where year of birth and age of event are both recorded. Data from this schema can be reassembled for use in either life tables or projection models. The period–age schema is used when year of birth has not been recorded for the demographic event and some assumptions are needed in order to use these data in demographic models.

Marital Status, Living Arrangements, and Household Structure S0020 AU3

P0035 A second set of population attributes which affect demographic processes concern small groups: couples, families (living together), and households (person sharing the same living accommodation). These units take economic (e.g., consumption) and social (e.g., childrearing) decisions together (at least in part). Marital status includes the states of being single, married (first married, remarried), separated (married but living apart), and divorced. In many societies, cohabitation by couples outside of marriage has become important, though the living arrangement may lead to marriage. In the future, social and demographic surveys may need also to count same-sex unions where these are recognized.

S0025 Social and Economic Status: Education, Occupation, and Income Class

P0040 Although social and economic attributes are the focus of social geography rather than demography, demographic analysis has been usefully applied to the growth of populations by educational grade. Projections of the world's population by educational attainment under varying scenarios demonstrate the enormous future importance of the educated labor force of China and India, for example.

S0030 Race and Ethnicity

P0045 Through past and present international migration, national populations, particularly in the developed world, are becoming more diverse in their racial and ethnic composition. The main focus of social research has been on integration/segregation of new groups within national societies, but demographers are now tracking the changing composition of national populations using a variety of projection techniques. Europe's population will become less 'European' and more 'foreign origin' and mixed in ethnicity over the next 50 years. AU4

S0035 Demographic Models

P0050 To understand how and why population sizes, compositions, and distributions change, we use models of the processes of population change. Although simplified from complex reality, demographic models are powerful tools for understanding population change.

S0040 Models of the Components of Population Change

P0055 Populations of the same territory at two points in time are connected by the following 'components of change' relationships:

$$P^{t+n} = P^t + N^t + M^t \qquad [1]$$

where P^{t+n} is the population at time $t+n$ years, P^t is the population at time t, N^t is the natural increase of the population in the time interval t, $t+n$, and M^t is the net balance of in- and out-migration. Natural increase is the surplus of births over deaths in a population, and the net migration balance is the difference between in- and out-migration streams. So it is useful to break down the change components further into:

$$P^{t+n} = P^t + B^t - D^t + M^t_{\text{in}} - M^t_{\text{out}} \qquad [2]$$

where B^t, D^t, M^t_{in}, and M^t_{out} are, respectively, births, deaths, in-migrations, and out-migrations in the time interval starting at time t. However, it is normally important to decompose the migration streams into those internal to a country from those crossing international boundaries, because the data sources may be different and because international migration is influenced by explicit policy measures, whereas internal migration is only indirectly and weakly affected. So the third version of the 'components of change' equation is AU5

$$P^{t+n} = P^t + B^t - D^t + M^t_{\text{in}} - M^t_{\text{out}} + I^t - E^t \qquad [3]$$

where M_{in} and M_{out} refer only to internal migration and I to immigration and E to emigration. **Table 1** shows a components table for one ethnic population, White males, in the UK region of Yorkshire and the Humber in the 2001–02 (mid-year to mid-year interval), decomposed by a single year of age. Each row of the table records what happens in a period–cohort, labeled by the start and finish ages in the table. The first row refers to the infant period–cohort, with a start stock of births and a finish stock of population aged 0. For a single population,

T0005 AU6 **Table 1** An example of the components of population change for period–cohorts, Yorkshire and the Humber region, UK, 2001–02, White males[a]

Start age	*Population 2001*	*Deaths*	*Out-migration*	*Emigration*	*In-migration*	*Immigration*	*Population 2002*	*Finish age*
Births	24 814	147	805	106	864	105	24 724	0
0	24 338	23	691	92	742	91	24 365	1
1	25 175	11	609	94	653	93	25 208	2
2	26 358	8	559	86	600	85	26 391	3
3	26 829	6	518	85	556	84	26 860	4
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
98	123	42	2	0	2	0	81	99
99	107	41	1	0	3	0	68	100
100 +	142	142	0	0	0	0	0	101 +
Sum	2 274 520	27 056	38 451	7786	41 256	7707	2 250 190	
Population	2 249 706							

[a] Each row contains the stocks and flows for one period-cohort. The sum of the Population 2001 column is the combination of the 2001 population and births in 2001–02.

From WHO (2007). *WHO Statistical Information System*. Online at: http://www.who.int/research/en/.

the components of change account completely for population flows into and out of the population.

S0045 ## Population Accounting Models

P0060 When many populations that interact (e.g., a set of regions within a country) are considered together we can expand the components into a population accounts table. **Table 2** shows how this is done for the components defined as demographic events by explicating representing the rest of a country and the rest of the world as system states. Very similar accounts can be defined using transition information, which is convenient when migration data derive from retrospective questions in a census or national survey. Such population accounts implicitly underpin multistate population models, widely used in population projection. The multistate framework has the key advantage of linking the population changes in one region or country to those in other regions or countries from which it receives its migrants. The accounting framework has the key advantage of forcing the user to achieve consistency between start and finish population stocks and component flows.

S0050 ## Life Table Models/Stationary Population Models

P0065 One of the most widely used demographic models is that of the life table used not only by national and international statistical agencies to monitor the health of populations but also by the actuarial profession and insurance industry to compute the funds needed to support population groups (firm employees and members of life assurance funds). Life table models are designed to remove from mortality analysis the effects of varying births to a population and the effect of the current age structure on cruder measures. So the life table model adopts a hypothetical population in which deaths and births are equal. **Table 3** presents an abridged life table for Australia using 2005 mortality data for persons. To the hypothetical stationary population are added 100 000 babies each year (row 1, column 4) and the total population is just over 8.1 millions (row 1, column 7). Most demographic texts give accounts of how the variables set out in **Table 3** columns are computed. Mortality rates, ${}_nM_x$, are computed by dividing observed death counts by period–age by a mid-interval or average population in the age group. Mortality probabilities, ${}_nq_x$, are computed from mortality rates using simple assumptions to convert to age-cohorts. The complement of these probabilities, the survival probabilities, are applied to the life table radix, 100 000, to compute survivors, ${}_nl_x$, and to compute nonsurvivors, ${}_nd_x$. Life years lived in an interval, ${}_nL_x$, are a sum of the survivors at the end of the interval, l_{x+n}, plus the nonsurvivors, ${}_nd_x$, weighted by the length of the age interval, n multiplied by the fraction spent alive, ${}_na_x$. The total life years beyond age x, T_x, are a sum of the life years lived from the oldest to age x. Life expectancy, e_x, is the ratio of T_x to the survivors to age x, l_x.

Full accounts of the life table model equations are provided in the main demographic texts. Here we comment on features of the life table which are neglected in conventional descriptions. P0070

Although most life table models list six equations connecting the life table variables as laid out in **Table 3**, life expectancies beyond age x can be expressed in one sum of products equation as a function of the age intervals, n, life fractions in age intervals, ${}_na_x$, and P0075

T0010 AU7 **Table 2** Population accounts for a two-region system, White males, ages 1–2

		End state in interval t, t+n				
		Region (1)	*Rest of the country (2)*	*Rest of the world*	*Deaths*	*Totals*
Start state in interval t, $t+n$	*Region (1)*	R^1	M^{12}	E^1	D^1	P^{1t}
	Rest of country (2)	M^{21}	R^2	E^2	D^2	P^{2t}
	Rest of world	I^1	I^2	0	0	I^*
	Totals	P^{1t+n}	P^{2t+n}	E^*	D^*	T
	Period–cohort: age 1 to age 2	*End state in 2000–01*				
		Yorkshire and the Humber	*Rest of UK*	*Rest of world*	*Deaths*	*Totals*
Start state in 2000–01	Yorkshire and the Humber	24 461	609	94	11	25 175
	Rest of UK	653				
	Rest of world	93		0	0	
	Totals	25 208				

Notes: R^1 = accounting residual for region 1 = $P^{1t} - M^{12} - E^1 - D^1$ etc.

T0015 **Table 3** Abridged life table for Australia, 2005, persons

Ages (x)	*Age interval (n)*	*Years alive* (${}_na_x$)	*Mortality rate*	*Mortality probability*	*Cohort numbers surviving*	*Cohort numbers dying*	*Life years*	*Total life years*	*Life expectancy*	*Survivorship probability*	*Ages at start*	*Ages at end*
			Period–age (${}_nM_x$)	*Age–cohort* (${}_nq_x$)	*Exact age* (l_x)	*Age–cohort* (${}_nd_x$)	*Age–cohort* (${}_nL_x$)	*Sum of age cohorts* (T_x)	*Exact age* (e_x)	*Period–cohort* (${}_nS_x$)		
0	1	0.1	0.00 511	0.00 509	100 000	509	99 542	8 141 182	81.4	0.99 455	Birth	0–4
1	4	0.4	0.00 024	0.00 096	99 491	96	397 735	8 041 640	80.8	0.99 912	0–4	5–9
5	5	0.5	0.00 011	0.00 055	99 395	54	496 841	7 643 905	76.9	0.99 947	5–9	10–14
10	5	0.5	0.00 010	0.00 051	99 341	50	496 579	7 147 064	71.9	0.99 885	10–14	15–19
15	5	0.5	0.00 036	0.00 180	99 291	178	496 008	6 650 485	67.0	0.99 768	15–19	20–24
20	5	0.5	0.00 057	0.00 285	99 112	282	494 856	6 154 477	62.1	0.99 700	20–24	25–29
25	5	0.5	0.00 063	0.00 315	98 830	311	493 371	5 659 621	57.3	0.99 655	25–29	30–34
30	5	0.5	0.00 075	0.00 375	98 519	369	491 670	5 166 249	52.4	0.99 583	30–34	35–39
35	5	0.5	0.00 092	0.00 459	98 149	450	489 621	4 674 580	47.6	0.99 439	35–39	40–44
40	5	0.5	0.00 133	0.00 663	97 699	648	486 876	4 184 958	42.8	0.99 192	40–44	45–49
45	5	0.5	0.00 192	0.00 954	97 051	926	482 941	3 698 082	38.1	0.98 821	45–49	50–54
50	5	0.5	0.00 283	0.01 407	96 125	1352	477 245	3 215 141	33.4	0.98 238	50–54	55–59
55	5	0.5	0.00 429	0.02 121	94 773	2011	468 838	2 737 896	28.9	0.97 217	55–59	60–64
60	5	0.5	0.00 704	0.03 458	92 762	3208	455 791	2 269 058	24.5	0.95 512	60–64	65–69
65	5	0.5	0.01 143	0.05 555	89 554	4975	435 335	1 813 267	20.2	0.92 775	65–69	70–74
70	5	0.5	0.01 883	0.08 993	84 580	7607	403 882	1 377 932	16.3	0.88 094	70–74	75–79
75	5	0.5	0.03 268	0.15 107	76 973	11 628	355 795	974 050	12.7	0.80 189	75–79	80–84
80	5	0.5	0.05 806	0.25 352	65 345	16 566	285 308	618 255	9.5	0.68 341	80–84	85–89
85	5	0.5	0.10 034	0.40 107	48 779	19 564	194 983	332 947	6.8	0.49 715	85–89	90–94
90	5	0.4	0.16 897	0.56 065	29 215	16 379	96 936	137 964	4.7	0.33 547	90–94	95–99
95	5	0.3	0.27 815	0.70 471	12 835	9045	32 519	41 028	3.2	0.20 739	95 +	100 +
100	2.25	0.45	0.44 543	1.00 000	3790	3790	8509	8509	2.2			

Adapted from WHO (2007). *WHO Statistical Information System*. Online at: http://www.who.int/research/en/

mortality rates, ${}_nM_x$:

$$e_x = \sum_{k=x}^{k=z} \left\{ n_n a_x \prod_{y=0}^{y=k} [1 - ({}_nM_x/(1 -_n a_{xn} M_x))] \right\} \qquad [4]$$

where z is the last age beyond which all survivors are assumed to die, k, x, and y are age indices. It is thus possible to compute life expectancies or any other life table variable without necessarily constructing the full life table, though presenting the intermediate computations in life table form is advisable.

P0080 Life tables involve explicit assumptions about the fraction of an age interval spent alive by persons who die. This variable is labeled ${}_na_x$ and is reported in the third column of the table. For most age intervals, an assumption of 0.5 is fine, but for the first and second intervals it is better to substitute fractions based on a study of the detailed distribution of deaths by smaller age intervals. This leads to an adoption of 0.1 for the interval birth to age 0, 0.4 for the interval age 1 to age 5, 0.4 for the interval age 90–95, and 0.3 for the interval 95–100. The life spent beyond age 100 is computed as the reciprocal of the mortality rate and the fraction is computed for a 5-year interval. More precise estimates based on empirical information about the distributions of deaths within age intervals can be made, but do not make much difference to the computed expectations of life.

P0085 It is important when computing life tables for most countries to adopt at least 100 as the highest age, as more and more people survive to that advanced age. In many countries, national statistics are already prepared for much higher ages (e.g., to 120). Under 2005 mortality conditions shown in **Table 3**, 50% of Australians will survive to 84.6 years. On only mildly optimistic assumptions about continuing declines in mortality rates (2% per year), it is likely that more than half the 2006 birth cohort in the UK will still be alive at age 100. The implications of this trend for society will be profound.

P0090 The column titled 'survivorship probability' is not usually included in published life tables. Period–cohort survival probabilities are computed as L_{x+n} divided by L_x, where L is interpreted as the number in the stationary population of the life table. These probabilities can be used directly in cohort survival calculations in population projection models.

P0095 Australia's life table represents one of the most advanced in the world: better life expectancies are found only in Japan and Iceland. It should be stressed that these life expectancies are period specific. Cohort expectancies are likely to be considerably higher, although they will depend on forecasts of mortality into the future.

The Cohort-Component Model for Projecting the Population S0055

One of demography's main contributions to societal planning is to provide projections of the future population. A population projection is a future trajectory of the population and its constituent groups based on particular assumptions about the drivers of change, mortality, fertility, and migration. There are thus as many projections as there are sets of plausible assumptions. P0100

The main device used for population projection is the cohort-component model, an expansion of the component model, adding age in period–cohort form. This is conveniently organized in the following sequence of equations in single region form. P0105

For all period–cohorts from $x=0$ to $x=z$ (the last) and recognizing populations by gender, g, the components of change equation is P0110

$$P_{xg}^{t+n} = P_{xg}^{t} - D_{xg}^{t} + M_{\text{in},xg}^{t} - M_{\text{out},xg}^{t} + I_{xg}^{t} - E_{xg}^{t} \qquad [5]$$

with a parallel equation for the infant period–cohort (from birth to age 0)

$$P_{-1g}^{t+n} = B_{-1g}^{t} - D_{-1g}^{t} + M_{\text{in},-1g}^{t} - M_{\text{out},-1g}^{t} + I_{-1g}^{t} - E_{-1g}^{t} \qquad [6]$$

This formulation assumes that people remain in the same period–cohort in a time interval, so we need to add an equation to transfer them to the next period–cohort at the start of the next time interval: P0115

$$P_{x+ng}^{t+n}(\text{next}) = P_{xg}^{t+n}(\text{current}) \qquad [7]$$

with the necessary addition of the end populations for the last, open-ended age group

$$P_{xg}^{t+n}(\text{next}) = P_{x-ng}^{t+n}(\text{current}) + P_{xg}^{t+n}(\textit{current}) \qquad [8]$$

The cohort-component model also requires that the age and time intervals be equal in length (and preferably single years of age and annual time intervals). P0120

The equations above are simply accounting identities which must be turned into model equations for use in projection. Occurrence–exposure rates are computed as the ratio of demographic events to the population at risk for a unit time interval. A simple assumption, used frequently, for the population at risk is that it is a linear average of the start and end populations in an interval. Using d to represent mortality rates, e emigration rates, o out-migrations rates (to the rest of a country), M_{in} to represent in-migration flows (from the rest of a country), and n the age/time interval, the projection equation for the end of interval population of gender g in the period– P0125 cohort that starts in age x is projected as

$$P_{xg}^{t+n} = P_{xg}^{t}\left[1 - n\tfrac{1}{2}\left(d_{xg}^{t} + e_{xg}^{t} + o_{xg}^{t}\right)\right] / \left[1 + n\tfrac{1}{2}\left(d_{xg}^{t} + e_{xg}^{t} + o_{xg}^{t}\right)\right] + M_{\mathrm{in},xg}^{t} / \left[1 + n\tfrac{1}{2}\left(d_{xg}^{t} + e_{xg}^{t} + o_{xg}^{t}\right)\right] + I_{\mathrm{in},xg}^{t} / \left[1 + n\tfrac{1}{2}\left(d_{xg}^{t} + e_{xg}^{t} + o_{xg}^{t}\right)\right] \quad [9]$$

P0130 Once the population that exists at the start of the interval has been survived forward to end of the interval, newborns can be projected and assigned a gender:

$$B_{x}^{t} = u_{g} \times n \times f_{x}^{t} \times \tfrac{1}{2}\left(P_{xf}^{t} + P_{xf}^{t+n}\right) \quad [10]$$

where u_g is the proportion of births that are of gender g (male, female) and f_x are the period–age fertility rates. Equation [9] is then used for the infant period–cohort with births rather than start population to survive and migrate newborns in the interval.

P0135 This schema for computing the cohort-component model avoids the need for iteration and can be easily generalized from a single region to many regions, converting the scalar equations into matrix equations.

S0060 The Multistate Demographic Model

P0140 American demographer Andrei Rogers and colleagues developed the life table and cohort-component models to handle many populations simultaneously. Populations of particular ‘states’ (e.g., regions) are the result of the flows from and to all the other states in the system being studied. The populations of states are therefore dependent on the populations of all other states: out-migrations from a region are in-migrations to other regions. It took some time for full agreement to be reached on the exact specification of the multiregional demographic model (in its life table or projection forms), because different operational realizations were needed, depending on the nature of the migration flow data available in any applied context. If migration data derive from retrospective questions in censuses, surveys, or linked registers, then a transition form of the multistate model is appropriate; if migration data derive from population or administrative registers which record flows as events, then a movement form of the model is needed. But the only real difference between these approaches is the way the input multistate transition probabilities are computed. Once computed, the models are identical.

P0145 The single-region cohort-component model has been generalized thus:

$$p_{xg}^{t+n} = \left[1 - n\tfrac{1}{2}\left(M_{xg}^{t}\right)\right]\left[1 + n\tfrac{1}{2}\left(M_{xg}^{t}\right)\right]^{-1} p_{xg}^{t} + \left[1 + n\tfrac{1}{2}\left(M_{xg}^{t}\right)\right]^{-1} i_{xg}^{t} \quad [11]$$

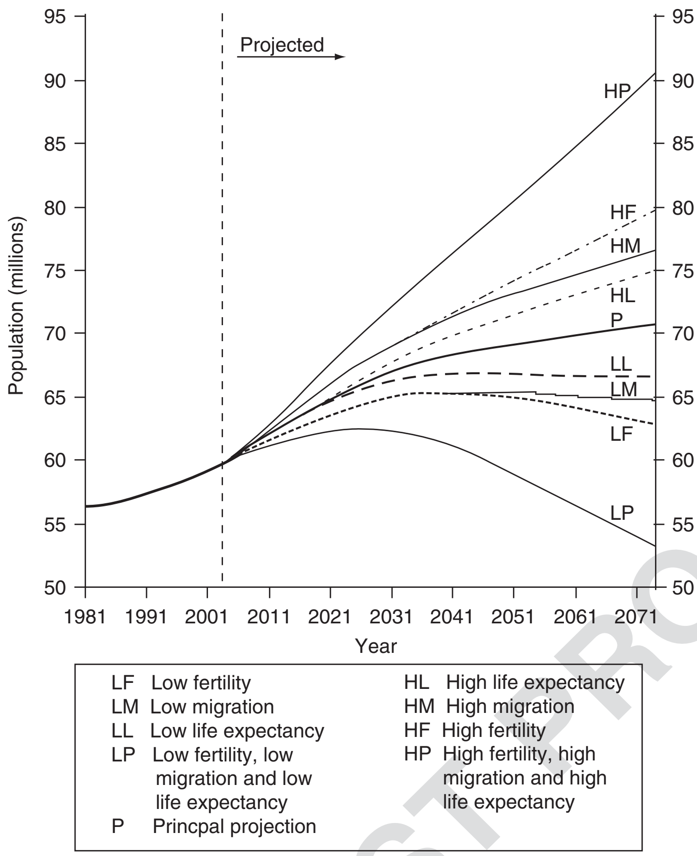
where p_{xg}^{t+n} is the column vector of regional populations for gender g and period–cohort x at the end of the time interval, p_{xg}^{t} is the equivalent for start of time interval populations, i_{xg}^{t} is the column vector of immigration to regions in the time interval and M_{xg}^{t} is a matrix containing the negative of mortality and emigration rates in the principal diagonal and region-to-region migration rates in the off-diagonal cells. The other parts of the single-region model can be similarly generalized to many regions in matrix form. Of course, this brief account of the multistate demographic model cannot provide readers with more than the basic idea, and they will need to pursue a sustained reading course to build a full understanding. Multistate methods are widely employed by national statistical offices in their regional and local populations. They are also used by regional authorities to project their local populations and by Lutz and colleagues to project sets of world regions and countries. Ways of reducing the number of variables in the multistate model have been explored through substituting functions for the component rate age schedules or through representing the full origin–destination–age–sex array of migration rates with simpler models. Software (LIPRO) for implementing the multistate projection model is available from the Netherlands Interdisciplinary Demographic Institute (NIDI).

Other Models for Projecting the Population S0065

The models discussed so far are based on the average behavior or experiences of population groups and the number of states through which the population flows is limited to the main demographic variables, location, sex, and age in combination with marital status, ethnic status, labor force status, or education status. We may wish to examine the full interplay of these variables on population dynamics, but face the problem of rapidly expanding numbers of variables and the difficulties of estimating transitions between states. P0150

So researchers have adopted a different model structure in which the lives of individuals are represented and then assigned events or transitions by sampling from a distribution of event rates or transition probabilities. Multistate and micro-simulation projection models are closely related, and have advantages and disadvantages which suit each to particular applications. Many important cross-sectional micro-simulation models have been constructed in order to study the impact of economic policy changes on households, but relatively fewer dynamic models have been built, because of paucity of good transition data. P0155

We now briefly discuss the way projection models have been used, examining, first, variant projections and, second, probabilistic projections, both attempts to capture and report the uncertainty inherent in projections. P0160



F0010 **Figure 2** Population of the United Kingdom according to principal and variant 2004-based projections, 1981–2074. ONS and GAD (2006). *National population projections: 2004-based*. Series PP2, No. 25. London: Palgrave-Macmillan for the Office for National Statistics, Figure 9.5. Online at: http://www.statistics.gov.uk/.

S0070 ## Variant Projections

P0165 The projection considered most likely is termed the ‘principal’ and alternatives are labeled ‘variants’. A common scheme for preparing variant projections involves deciding on high, medium, and low assumptions for each of the three components (or four if migration is split into its internal and international streams). This then generates a schema of some 27 variants (three assumptions for each of three components). **Figure 2** displays the principal 2004-based projection for the United Kingdom plus eight variant projections. It is also common to carry out particular ‘what if’ or scenario projections to achieve additional understanding of the future population. For example, a projection that assumed no international migration would be compared with the principal projection to assess the impact of the international migration assumptions on the future population.

S0075 ## Probabilistic Projections

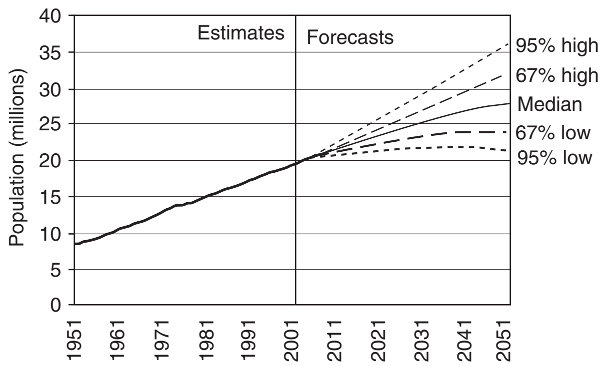
P0170 In the past 15 years several demographers have argued that users want to know what probability can be placed on a particular range of future populations or what the probability that a population will reach a particular level. A group led by Lutz at the International Institute of Applied Systems Analysis has pioneered techniques for producing probabilistic projections. The essence of the method is to estimate the error distribution in key component parameters (e.g., total fertility rate) and to sample from these distributions year by year in the future. Each set of parameters is used to project the population into the future, and from the full set of hundreds of projections run a probability distribution of outcomes can be constructed. **Figure 3** shows such an outcome for Australia. The median projection for Australia sees the population growing from 20.0 millions in 2001 to 28.0 millions in 2051. Around this median are the uncertainty distributions of population: around two-thirds of outcomes will lie between 24.4 and 31.8 millions, while there is a 95% probability that the 2051 Australian population will lie between 21.1 and 36.0 millions.

Main Components of Change and Associated Indicators S0080

Much effort has been expended by demographers to describe, explain, and forecast the main drivers of P0175 population change. We consider some features of this effort, with some discussion of sources of data and of the important relationship of each component with age.

S0085 Mortality Measures and Trends

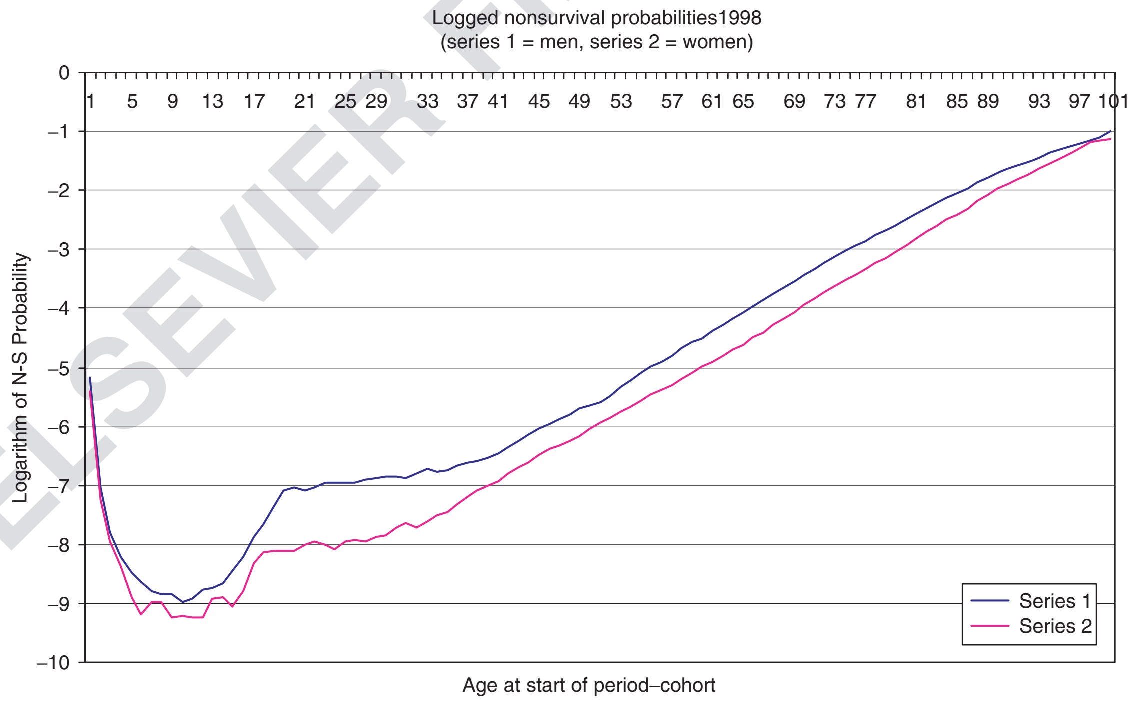
P0180 To measure the mortality level experienced by a population, good statistics on deaths and population are needed. In most developed countries, deaths must be legally registered with cause(s) of death recorded by a physician. In countries with less-developed vital registers, survey methods are used that ask households about deaths of members. This was the method used to estimate the very high death rate that occurred in Iraq in the 2003–06 period after the invasion of the country by American and coalition forces, though the method of sampling households has been challenged.



F0015 **Figure 3** The probability distribution of Australia's future population. Wilson, T. and Bell, M. (2004). Australia's uncertain demographic future. *Demographic Research* 11(8), 195–234. Online at: http://www.demographic-research.org/Volumes/Vol11/8/, Figure 12.

Register or survey deaths combined with population estimates are used to compute age-specific mortality rates. **Table 3** displays such a set of rates for Australia in 2005. The relationship between mortality and age has the general form shown in **Figure 4** (for the United Kingdom in 1998). Rates for the very young are high (because of infectious disease and malnutrition in poor countries, and because of malformations at birth in richer countries) and then decline quickly to a base level between ages 5 and 10. From age 10, mortality rates rise steadily in a straight line on the semilog graph, indicating exponential increase with age. The smoothness of the rise is interrupted between ages 15 and 25 by above trend mortality rates, mainly associated with accidents and violence. Populations differ in the level of this rate–age curve. In **Figure 4** we can see that female mortality rates are lower than male, except before age 5 and after age 95 when they are nearly the same. P0185

Using age-specific mortality rates, it is usual to compute standardized mortality rates which filter out the effect of the age structure of a population on the level of mortality. For comparison of mortality rates across subnational areas within a country, standardized mortality P0190



F0020 **Figure 4** Mortality probabilities by age, United Kingdom, 1998. Computed by the author from data on deaths and population published by the Office for National Statistics and other UK national statistical offices.

ratios (SMRs) are used in which the mortality experience of a local population is compared with that of the country which are given the value of 100. Areas with worse than the national average mortality SMRs are above 100; areas with better than average mortality experience have SMRs below 100.

P0195 Life tables, discussed earlier in this article, provide the best means of comparing the mortality of different populations. Where it is difficult to make good estimates of the age-specific mortality rates that are the key input to the life table model, then recourse can be had to collections of model life tables. These use common patterns of the mortality–age relationship and generate life tables for a set of given life expectancies (20, 25, … , 80, 85). However, the World Health Organization has developed an extensive library of country life tables, and there is now less need to use model life tables.

P0200 Mortality trends have in the past six decades, in general, moved steadily downward, resulting in steady and sustained rises in life expectancies in most countries. For developed countries, the rate of improvement in life expectancy has been about 2 years per decade with higher rates of change in fast-developing countries in Asia. However, there are notable exceptions such as the post-Soviet transition countries which experienced a decline in life expectancy as a result of economic hardship. Most Central and East European countries are now experiencing improving life chances. The other countries which have experienced declines in the last two decades have been sub-Saharan countries, such as Botswana or Zimbabwe, which have been affected by the HIV/AIDS epidemic or severe economic crises.

P0205 There is a vigorous debate about the future of life expectancy, which most international and national projections assume will continue to improve, at least in the short run. On the one hand, 160 years of historical records analyzed by demographers Vaupel and Oeppen tell us that the best national life expectancies have improved at 0.20–0.25 of a year per year, with the implication that projection assumptions should, in any one country, adopt a similar linked trajectory. On the other hand, Olshansky and colleagues emphasize the threat of increasing obesity to this record of continuous improvement. This debate about longevity has considerable relevance for economic and social policies, particularly for the provision of pensions, health, and social care for the elderly.

S0090

Fertility Measures and Trends

P0210 To measure the fertility level experienced by a population, good statistics on births and population are needed. In most developed countries, births must be legally registered by the parents. In countries with less-developed vital registers, survey methods are used that ask household about past births of mothers. From these data are computed crude birth rates (births/population), general fertility rates (births/females age 15–44), and age-specific fertility rates or ASFRs (births to mothers by age/females by age). ASFRs are multiplied by the relevant age interval (usually single years) and summed to yield the total fertility rate (TFR) for a population. The TFR is a synthetic indicator of women's fertility: it is a prediction of the number of children that a woman would have if she experienced the current period ASFRs. Cohort TFRs substitute actual (past) or predicted (future) fertility rates to arrive at a better indicator of what might happen but require a long time series of ASFRs or a projection of them.

P0215 A version of the TFR which allows for the effect of female mortality between age 0 and 45 is the net reproduction rate (NRR), which is the number of daughters a woman would have by the end of her reproductive life. When NRR is 1, then the population replaces itself, generation by generation. Because computing the NRR means that the female life table must be computed first, researchers interested in the level of fertility in relation to replacement use the concept of the replacement TFR, commonly specified as 2.1 children. The replacement TFR varies between world regions and countries because female mortality varies. In the least developed regions in 1995–2000, 2.75 children were needed to guarantee that one daughter is alive at the end of the reproductive lifetime. The replacement TFR for England and Wales has been recently computed to be 2.07 in 2001, close to the minimum of about 2.05.

P0220 Trends in fertility in recent decades have been predominantly downward or, if low levels have already been achieved, fluctuating around those low levels. In developing countries, the fertility transition is part of the first demographic transition to smaller families consequent on industrialization, urbanization, the introduction of universal education, and a shift in the balance of childrearing costs/benefits. The downward shift has been promoted by family planning programs and the development of new effective methods of contraception (the contraceptive pill, the intrauterine device, etc.). An influential framework called proximate determinants of fertility has been developed by Bongaarts and colleagues for understanding the level of fertility in countries in transition.

P0225 Developed countries saw low fertility in the Great Depression years of the 1930s and the war years of the early 1940s, followed by fertility booms in the quarter-century after 1945. Since 1970, most European, North American, and East Asian populations have seen fertility decline to below replacement, as women's independence has grown through labor market entry, educational advancement, and female control over conception, combined with the demise of the traditional child-centered family and the rise of individualism. This fertility shift has been termed the second demographic transition. One of the factors underpinning continuing below-replacement fertility in developed countries has been the postponement of births to older ages: mean age at first birth is now in the 25–29 age group, and in many countries the peak fertility rate has shifted into the 30–34 age group. But if postponement finishes, then fertility decline stops. In 2000–06, half of European countries experienced small increases in TFR, while half experienced small declines. These data have been interpreted as showing two fertility regimes in Europe: northern countries from Finland to France where TFRs are around 1.8 and have risen a little since 2000, and Southern, Central, and Eastern Europe where TFRs are below 1.5 where there are both small increases and decreases. A suggested determinant of this pattern is the degree of support for early childcare and reentry into the labor market after childbirth provided by the state, institutions, and the market to mothers.

S0095 International Migration Measures and Trends

P0230 International migration is the movement of people across international borders for the purpose of settlement. International migrants change their usual place of residence from one country to another. The United Nations suggests that the degree of permanence of the migration should be measured over a 12-month period, so that shorter stays in another country are not classified as permanent international migration. When passengers arrive in a country, they are asked whether they intend to stay for less than 3 months, classifying them as visitors; for between 3 months and 12 months, classifying them as short-term migrants; or for 12 months or more, classifying them as long-term migrants. This is a prospective measurement of migration. Alternatively, people can be surveyed at their current place of residence and asked where they were living 12 months ago. If the answer is another country, then they are classified as international migrants. This is a retrospective measurement of migration. It is also possible to measure international migration by asking migrants leaving a country to register their departure and to ask a question about migration of those new registering in countries which maintain a comprehensive population register.

P0235 All measurements of international migration are fraught with error and disagreement. Those expressing an intention to stay for more than 12 months may return home before the year has ended, while visitors may decide to apply for permanent residence after arrival. Short-term migrants may become long term and vice versa. People leaving a country frequently fail to register their departures, and in many cases they are not departing from one permanent residence but moving between one residence and another on a seasonal or periodic basis. Poulain and colleagues have documented the statistical systems used to record international migration between European states, and present a matrix of migration flows between EU member states, from both receiving and sending country statistics. Most cells have at least one entry, though there are a few empty cells. The discrepancies between the two views can be very large: in 2002 Germany reported 78 739 people migrating to Poland, while Poland reported only 2335 arriving! In general, immigration statistics are considered more trustworthy as immigrants normally have to fill in a form on entry or to obtain work, education, or healthcare. To arrive at a reasonable estimate of the migration flows between European countries, Raymer had to design an ingenious and elaborate algorithm to make best use of the available data. There is also error introduced as a result of failure to count illegal migrants.

Flows within Europe, though large, are not the largest P0240
international migrations in Europe, which involve migrations from and to the world outside Europe. In recent years, both Spain and Italy have received very large flows of migrants from abroad, 2004 of 610 000 and 558 000 net migrants, respectively, compared with 204 000 into the United Kingdom, 105 000 into France, and only 82 000 into Germany, according to statistics assembled by the Vienna Institute of Demography.

A team led by Kupiszewski at the Central European P0245
Forum for Migration and Population Research has recently carried out explorations of the future population of 27 European countries under different international migration scenarios. They show that under no plausible scenario of net gains from international migration will there be much alleviation of the effects of population aging on old-age dependency. The projection model interestingly divides the international migration flows into two sets, those between the 27 countries which are modeled as part of a multistate population projection, and the net immigration flows from outside Europe which will make the biggest impact on the future population. In effect, what was formerly international migration within Europe has become very similar to domestic or intranational migration.

When we move from a European to a world canvas, it P0250
becomes even more difficult to paint a reliable picture of international migration flows. One attempt to do so is by Dorling and colleagues in their Worldmapper project. They have assembled statistics on the populations in each country born abroad which yields a lifetime immigration estimate, and then used that information to reconstruct the distribution of those foreign populations by origin country to yield a lifetime emigration estimate. Subtraction emigration from immigration produces a net international migration estimate based on foreign population stocks. When we compute those net balances for 200 countries, expressed as percentage of the resident population, and plot them against median male earnings,

T0020 **Table 4** Comparable measures of internal migration, Australia and Britain

Measure	*Australia*			*Britain*		
	1980–81	*1995–96*	*1995–96*	*1980–81*	*1990–91*	*1990–91*
Migration expectancy (moves per lifetime)						
Males	10.7	12.8		6.4	6.2	
Females	11.1	13.6		6.7	6.5	
Median distance moved (km)		Inter-zone	All moves		Inter-zone	All moves
38 city regions		248	41			
65 Time Consistent Statistical Districts		178	41			
67 counties					94	28
459 districts					34	6

Adapted from Bell, M., Blake, M., Boyle, P. *et al.* (2002). Cross-national comparison of internal migration: issues and measures. *Journal of the Royal Statistical Society A* 165(3), 435–464.

we find a moderate positive correlation ($r = 0.28$) between balance and the income variable, indicating that the higher a country's per capita income the more likely it is that the balance of migration will be inward.

P0255 Because of difficulties in measuring international migration in a comparable way, most work has focused on immigrant populations, and the ways in which they interact with and integrate with host populations and into sources of conflict and lack of cohesion.

S0100 Intranational (Internal) Migration Measures and Trends

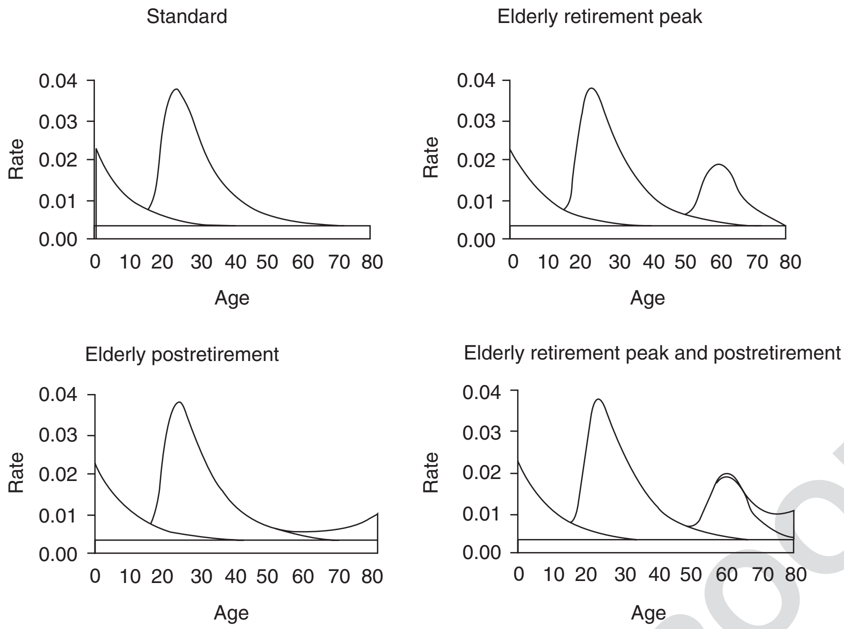
P0260 Intranational is defined as changes of usual residence within countries. Some researchers have distinguished between local mobility and longer-distance migration because of the different mix of motivations at the two scales, but, in practice, is difficult to compartmentalize what is a continuously varying phenomenon.

P0265 Migration levels and intensities vary with the spatial scale of measurement: the more territorial units there are the greater the level of migration, when migration is defined as a border crossing. This makes it difficult to construct comparable measures of migration between countries, except for migration at the smallest scales of all residential moves. Long, an American demographer, has established that the new countries of North America and Australasia have much higher internal migration levels than European countries. Courgeau, a French demographer, proposed a simple linear model of the relationship between migration intensity and the logarithm of the number of spatial units used in migration measurement be used to compare internal migration between countries, but the idea has not found favor. A full audit of measures that can be used to compare internal migration across countries has been undertaken by Bell and colleagues. They recommended adoption of measures capturing four dimensions of internal migration: migration intensities, migration distances, migration connectivity, and migration effects or impacts. Their discussion is illustrated by a rigorous comparison of migration in Britain and Australia using comparable measures. **Table 4** reports on migration expectancy and on median distance moved in Australia and Britain, showing Australians to be twice as migratory as the British and migrating over twice as far. However, this measurement agenda has yet to be adopted by any international statistical agency.

Most applied work that compares internal migration between countries has focused on the structure and patterns using net migration, one of the impact measures. For example, a study of internal migration in ten European countries in the 1980s and 1990s identified whether internal migration was contributing to urbanization or to counter-urbanization. P0270

The relationship of migration intensity and age has been studied and modeled extensively by Rogers and collaborators over several decades. They have developed a family of models, based on combining exponential functions, which describe the schedule of migration intensities plotted against age. **Figure 5** illustrates the ways that these can be assembled. All four versions contain the single negative exponential decline during the childhood ages and the double exponential that represents rising and then falling mobility of labor market entry, career moves, followed by a settled occupation. Some migration-intensity/age schedules exhibit an elderly retirement peak (another double exponential), when couples relocate after exit from the labor force. This type of schedule is found in migration flows from metropolitan centers to regions of retirement living. More common are schedules with a single positive exponential after retirement, reflecting migrations triggered by loss of spouse/partner or increasing infirmity. P0275

Because migration consists of a move from an origin to a destination over intervening space, a large number of spatial interaction models of migration have been developed that seek to explain the intensity of migration in terms of a set of origin variables, a set of destination variables, and measures of the cost of crossing the space between origin and destination. There have been a huge number of the determinants of migration flows between P0280



F0025 **Figure 5** The four main families of multi-exponential model migration schedules. Raymer, J. and Rogers, A. (2006). Applying Model Migration Schedules to Represent Age-Specific Migration Flows. *Working Paper, Population Program POP 2006–03*, Institute of Behavioral Science, University of Colorado at Boulder, Figure 1. Online at: http://www.colorado.edu/ibs/pubs/pop/pop2006-0003.pdf.

sending and receiving regions within countries, using a variety of statistical models of migration. A recent analysis of UK migration constructed models for 98 origins/destinations and 14 age–sex groups and used more than 40 potential explanatory variables.

S0105 Processes of Population Change and Their Implications

P0285 This article concludes with the study of population through the lens of demography by putting the different components of change together to see what major changes have occurred or are occurring to populations in different parts of the world.

S0110 The Demographic Transitions

P0290 Over the past century and a half, national populations have experienced a shift in their demographic regimes from high fertility, high mortality, and low and uncertain growth to low fertility and low mortality, and uncertain growth through an intermediate phase (transition) of fertility decline and mortality decrease. This is the first demographic transition. Because mortality decline preceded fertility decline and often proceeded more quickly, the result was high natural increase and rapid population growth. The demographic transition, its course in different continents and epochs, and its drivers and causes are extensively discussed in demographic texts. What is less explored is the way the demographic transition has favorable economic impacts because of the increasing concentration of the population in the working ages (fewer children, relatively, and more surviving into later working ages). Bloom and Williamson have argued convincingly that an important factor explaining the extraordinary growth performance in East and Southeast Asia in the past 30 years has been this concentration of the population in the productive ages. In the current and next two decades, East Asia will lose this advantage as its population ages beyond the working years.

Europe's fertility decline did not stop at replacement fertility level but moved into much lower fertility territory after 1970. This is the second demographic transition. By 1985, virtually all European countries had fertility levels below 2.1 children per woman and low fertility has persisted since then. A range of explanations have been advanced to explain this new demographic regime: these include shifts to new philosophies of individualism and careers over family for women, women's freedom to control their own fertility through the contraceptive pill, the increase in female labor force participation (and opportunity cost of children), increased female incomes and therefore independence, the decline of marriage and the rise of cohabitation, the renewed rise in childlessness, women's increased participation in higher education, and the failure of the state and market P0295 to provide enough early childcare support (to make possible both work and children for women). Interestingly, fertility intentions (in an ideal world) seem not to have shifted in surveys from a modal choice of two children.

P0300 Persistence of low fertility over several decades leads to reduced entries to the labor force and so to shortages of workers. In many European countries, this has led to renewed immigration by foreign workers and their families, which over time will begin to change the composition of the population, particularly if the immigrants have, at least initially, higher fertility than the native population. This is the third demographic transition. Coleman has documented this process for a number of European countries, and gathered together evidence on projection of European country populations distinguished by foreigner/citizen or ethnicity. This shows substantial changes in nationality or ethnicity composition of country populations taking place, with more anticipated in the next half-century, although the shifts are dependent on the immigration policies in place. This population replacement process is also occurring in North America and Australasia.

S0115 The Aging of the World's Population

P0305 The most important consequence of the demographic transitions is population aging. Population aging is the process that results in higher average ages and higher shares of the population being old. The threshold age used by the United Nations for defining the old age population is 60 years. Population aging occurs because smaller new birth cohorts are born into populations as a result of fertility decline and because more people survive to older ages with lower mortality rates. Migration redistributes both younger and older populations, and so affects the degree of aging of countries and subnational regions and localities. The United Nations report on World Population Aging makes several critical observations: (1) that population aging has been a new phenomenon of the twentieth century and will be even more pronounced in the twenty-first century; (2) that aging affects virtually all countries in all continents, whether rich and poor; (3) that the pace of aging for many countries in East and Southeast Asia will be more rapid than that experienced by countries in Europe and North America, because their fertility decline in the demographic transition has been so much faster in the past 40 years; (4) that it is highly unlikely that the process will be reversed, given that it occurs under virtually all plausible future scenarios for demographic change; and (5) that aging will have profound social and economic implications for human societies.

Migration and Aging S0120

National policy makers and employers now often ask whether the effects of aging on the labor supply and on the support available for retired workers can be mitigated by accepting immigrants from other countries. This is called the replacement migration question, and was explored in an influential report by the United Nations. The migration assumptions in population projections for eight developed countries far into the aging process were adjusted to achieve particular outcomes in terms of age structure. These scenario projections showed that to achieve, for example, a long-run, constant old-age-dependency ratio, would require immigration at completely unprecedented and unrealistic levels. The same exercise was carried out for 27 European countries by the Central European Forum for Migration Research using a projection model that handled migration in a more sophisticated fashion. Again the results were that international migration into European countries could make a small impact in slowing aging, but to achieve a stable level of the old age ratio or the old age share would require huge migration flows, which were demographically, let alone politically, infeasible. P0310 AU8

Aging poses huge challenges for societies affecting pension and social security systems, demand for healthcare and the needs of the infirm elderly for family, social, and state support. Decisions need to be taken about ages of entitlement to state and occupational pensions and the length of working life, the relative responsibilities of individuals, families, and younger generations for support for older people. New intergenerational contracts will be needed. But population aging should be seen as an enormous success for the societies experiencing it and one that can be coped with through new fair arrangements and through continued growth in economic productivity. The knowledge of demographic trends past and future, such as outlined in this article, provide policymakers with long lead times for taking appropriate action. P0315

See also: Census geography (00814); Emigration (00816); Immigration (00819); Migration (00821); Population Geography (00823).

Further Reading

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