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POSTNOTE

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Uncertainty in Population Projections

Population projections inform policy formulation across a wide range of areas. While short-term projections are generally reliable, longer-term figures are subject to ever greater uncertainties. This POSTnote examines the sources of these uncertainties and explores projection methods which aim to take them into account.

Overview

- Population projections inform forecasts in areas including economic growth, demand for public services and housing, and the effects of climate change.
- There are many uncertainties inherent in population projections, particularly those made over the longer term.
- Problems with baseline data mean that projections made for developing countries are subject to even greater uncertainty.
- Many past assumptions made about future trends in the UK have proved to be inaccurate. For example, future trends of life expectancy have consistently been underestimated in the UK.
- Uncertainties can be communicated using either 'high' and 'low' variants or through a probabilistic approach.

Population Projections

Population projections are used for many purposes, for example to help gauge a nation's future economic performance, or future demand for housing and public services.[1,2] At the international level they underpin many models, for example those used by the Intergovernmental Panel on Climate Change (IPCC) to gauge the effects of future global warming scenarios. However, there is a growing awareness among demographers and policymakers of the uncertainties inherent in population projections. This note discusses:

- how population projections work
- how accurate they are
- methods for handling uncertainty in projections.

How Population Projections Work

The most widely used method of population projections, and that employed by the UK's Office for National Statistics (ONS) (Box 1), is the 'cohort-component' method. It involves taking a cohort (a population in a one- or five-year age band) and projecting what it will look like in a given number of years. For example, five years from now, the 30-34 year old age group will be 35-39. During this period some would have died and some emigrated. A new group of people within this age group would have moved into the country and some have given birth. The projection is carried out for every age group, with a new 0-4 age category for new births and young migrants. The size of the future population in each age band is thus calculated. This method is also called 'deterministic' projection and the result is called the 'medium' variant ('high' and 'low' variants are discussed on page 3). To calculate this, key pieces of information are needed. The first is the 'baseline data', or the size and structure of today's population. In UK projections, such data are 'rebased' every ten years after a Census.

The second body of information concerns age-specific fertility, mortality and migration. This allows demographers to create assumptions about what we expect to happen to each cohort over the next five years. For example mortality rates among 30-34 year olds in 2007 can be calculated and it can be assumed that they will be the same in 2012.

Box 1. Key Organisations Producing Population Projections

In the UK, population projections are produced by the ONS. Sub-national projections are prepared by the devolved administrations, and local authorities produce their own population projections for planning purposes.[3] The national ONS projections are updated every two years to ensure the latest trends are included. The European statistical agency, Eurostat, publishes comparable EU-wide projections, and the United Nations publishes projections for every country in the world.[4,5] While agencies use very similar methodologies to make their projections, they make differing assumptions about future levels of fertility, mortality and migration, giving rise to different projections. For example, Eurostat's projection for the UK's total population in 2035 is 71.9 million, which is 1.3 million fewer than that projected by the ONS.[6]

Such an assumption, however, is unlikely to be true given our understanding of constantly changing mortality rates. Therefore, demographers examine recent trends both in the UK and internationally, to design a set of assumptions about what is a justifiable future outcome. Often, agencies such as the ONS will publish a justification for their assumptions.[7] These assumptions are guided by models of how populations behave over longer periods of time in relation to changes in factors such as economic development, health, social change or urbanisation. One widely used model is the 'Demographic Transition Model' (Box 2 and Figure 1).

Accuracy of Projections Made in the Past

Examining how projections based on past assumptions match up with the reality that followed can be instructive. Figure 2 shows the differences between the fertility assumptions for England made by the Government Actuary's Department/ONS in different years, and the actual total fertility rate or TFR (black line). Projections made before 2000 did not foresee that fertility would either decline or stay low. Projections made after 2000 did not foresee a sustained increase in fertility. These divergences occurred because of a series of social and economic factors which, in turn, shaped birth rates in ways that those designing the projections could not predict.

A second major component of population projections is mortality, most often measured by life expectancy at birth. As Figure 3 shows, estimates of life expectancy at birth have been consistently lower than reality, largely resulting from medical and lifestyle developments. Incorrect assumptions can impact on policy: the consistent under-estimation of future trends of life expectancy is in part responsible for today's pensions situation. However, Figure 3 also shows that over time, assumptions tend to be adjusted to take such trends into account.

A third component of changes in population size is migration. This can change and fluctuate in relation to both economic factors and political shifts in Government policy. Data regarding migration to and from the UK have frequently been described as inadequate.[8] In the UK, projected levels of net migration are based on assessments of whether recent levels are likely to be maintained. They may not reflect current policy such as the use of a points-based system for immigration control, or stated desires for an overall net decrease in migration.

Figure 4 shows the difference between total population size and previous projections. In the short- to medium-term (up to 30 years) projections are quite accurate, and have become more so over time despite the inaccurate assumptions shown in Figures 2 and 3. This is partly because the inaccuracies introduced by these assumptions tend to cancel each other out. Also, over this timeframe extrapolation based on current data or trends is less likely to introduce inaccuracies as there are fewer unknowns. For example the age structure, especially of women of reproductive age, is already known.

Box 2. The Demographic Transition Model

There are considered to be four main phases in the growth of a nation's population, starting from high fertility and mortality, followed by a period of falling mortality, then one of falling fertility, until fertility and mortality are both low and growth stabilises (Figure 1). The UK passed through these phases over the past 250 years. Based on this model it is often assumed that developing countries will follow a similar trajectory.

Recent critiques of this model argue that it does not adequately reflect the overall *decline* in population in the developed world where fertility has fallen below the 'replacement rate' of just over two children per woman.[9] The latest model employed by the UN incorporates the pattern seen in the developed world more accurately: fertility declines to below the replacement rate before rising slightly and eventually fluctuating around 2.0. There is also some criticism of the model's implicit assumption that fertility decline always follows mortality decline; in fact fertility decline has stalled in parts of the developing world.

Figure 1. The Demographic Transition model

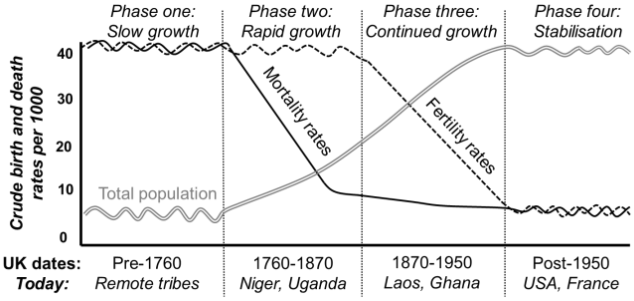
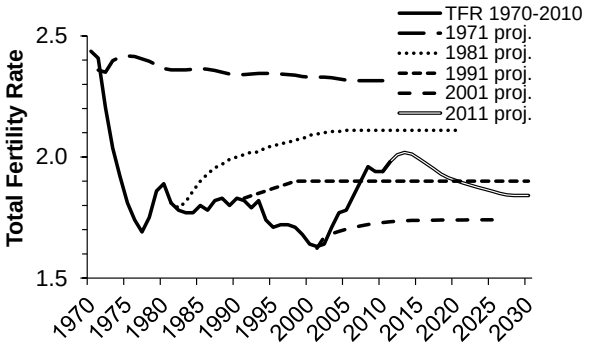


Figure 2. Past Projections of Total Fertility Rates and Actual Rates, United Kingdom [10,11]



Age-specific mortality rates can be predicted within narrow margins of uncertainty, and age-specific fertility rates can also be estimated reasonably well. In the longer term, the uncertainties inherent in these assumptions become more significant as they accumulate.

It is difficult to state with certainty what the size and structure of a given population will be beyond a generation or two. This is not only because of uncertainties over future trends in fertility, mortality and migration. It can also be due to incomplete knowledge of recent trends, or of the current population size and make-up. This is particularly the case in many developing countries (Boxes 3 and 4). Also, unforeseen events, for example due to natural disasters or conflict, can dramatically alter population size.

Figure 3. Past Projections of Female Life Expectancy at Birth and Actual Figures, United Kingdom [9,10]

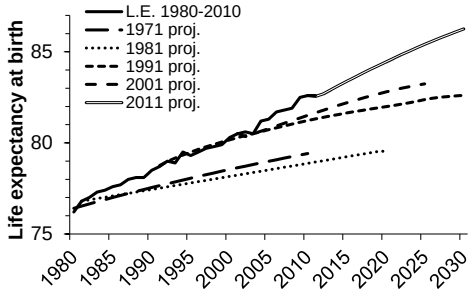
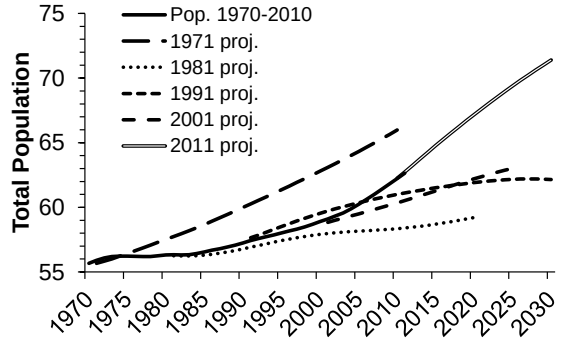


Figure 4. Past Projections of Total Population Size and Actual Figures, United Kingdom [3,9,10]



Building Uncertainty into Projections

How uncertainties are communicated in population projections could affect policy decisions based on them. Deterministic projections convey uncertainties using the 'variant' method discussed below. However, there is also an alternative method of projection known as 'probabilistic projection', which conveys uncertainty in a different way. There has been much debate over the relative merits of deterministic and probabilistic projections.

High, Medium and Low Variants

In deterministic projections, it is standard practice to present not just a 'medium' variant, but a 'high' and 'low' future based upon lower or higher values of fertility, mortality and migration. For example, for fertility in the UK, ONS produces two variants on the basis of high or low fertility levels for different age groups. Factors that are considered possible influences on these rates include the level of education and labour force participation, the costs of caring for children and fertility variations among migrant groups. Users can choose to employ different variants. The Office for Budget Responsibility, for example, uses the ONS 'low variant' for migration in their 2012 *Fiscal Sustainability Report*.[12]

Probabilistic Projection

This approach involves examining a wide body of information on patterns of population change, for example fertility rates over time and across different countries. By placing projections in this context, uncertainties in the projections are quantified and built into the model. This allows predictions about the probability of future populations falling within certain boundaries. This method is used by a small number of national and international agencies but is less widespread than the deterministic approach.

Choosing a Projection Method

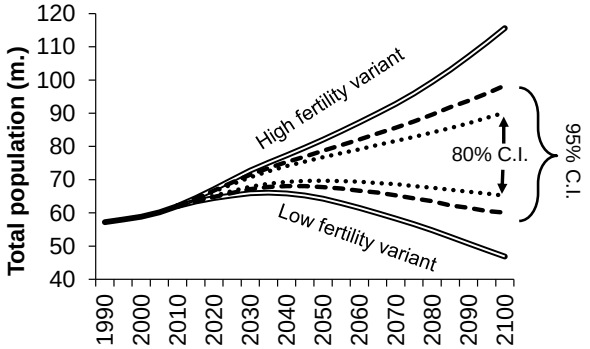
Figure 5 (over page) shows population predictions for the UK and illustrates the difference in the information conveyed using deterministic and probabilistic methods. The 'funnel' area shows the result of a probabilistic projection performed by the United Nations. The UN model says that the user can be 80% sure that the future population of the UK will lie within the area bounded by the dotted lines, and 95% sure that it will lie within the area bounded by the hashed lines. The 'high' and 'low' variants are also shown. These suggest how population would change if fertility rates varied by +/- 0.5 children from the medium variant.

One criticism of the variant approach is that that it does not explicitly provide information on the *likelihood* of different scenarios. For example as Figure 5 shows, both the high and the low variant are statistically highly unlikely. A further issue is that when fertility falls to low levels, the uncertainties associated with the low and high variants themselves can be extremely high. However, proponents argue that as long as variants are well chosen and are well explained, and represent plausible alternative scenarios, they can be valuable. Overall it is agreed that deterministic projections are useful in showing what will happen if certain trends do continue. The nearly universal adoption of family planning programmes in the developing world was in part a response to the knowledge of those projections.

Proponents of probabilistic projections argue that, if used correctly, they can allow for greater transparency in expressing uncertainty and can increase our capacity to consider the likelihood of alternative futures.[13] They can also enable differentiation between levels of uncertainty in developed countries and developing countries, while allowing comparison across countries. The latest UN population projections are presented probabilistically.[13] Madagascar and the Netherlands were countries with roughly equal size in 2010. In the Netherlands, population growth is expected to be slow, and by 2100 the UN model predicts with 95% confidence that the population will be between 13.9 and 21.2 million.[14] In Madagascar, however, population growth will be rapid and the uncertainty is far greater. By 2100 the UN model predicts with 95% confidence that its population will be between 51.8 and 194.9 million.[14] When extrapolated to the global level, the uncertainty in future global population is very large.

One criticism of probabilistic projections is that policymakers tend to look to demographers to provide them with a 'best estimate' of future population size and structure. A wide 'range' of futures is less definitive and can be less helpful. It is also pointed out that probabilistic projections are still highly dependent on the accuracy and reliability of the baseline data. Some argue that probabilistic approaches are based on our knowledge of past experiences, and do not generally factor in unknowns such as the emergence of new diseases, or sustained global crises such as the HIV/AIDS pandemic.

Figure 5. Probabilistic Population Projection for the United Kingdom Using the UN Methodology[16]



Box 4. Finding the Population and Fertility Rate of China

Undercounts in Chinese censuses have been identified as a major problem in the past. These are caused by factors such as the large levels of internal migration and the effects of family planning restrictions.[17] This affects the *baseline* assumptions.

The miscounting of children in censuses also has implications for estimates of total fertility rates in China. This can mean that projections are based upon inaccurate data. Figure 6 shows that there is significant variation between the official TFRs and those derived from other sources such as school registers and surveys. Recent research using data from the 2010 census suggests that the current TFR for China is likely to be around 1.45 – much lower than the official estimate.[15]

Managing Uncertainty in a Policy Context

It is widely agreed that policymakers need to be aware of the uncertainty inherent in population projections and of the fact that that this uncertainty is greater both in developing countries and in long-term projections. It is important to recognise that the 'medium' variant is only one future which could be affected by numerous social, economic, environmental, cultural and political developments.

A more transparent approach to the relationship between population and future trends – whether they relate to the economy, the environment and demand for resources or public services – could be gained either by employing probabilistic projections, or through a deeper understanding of the assumptions behind deterministic projections.

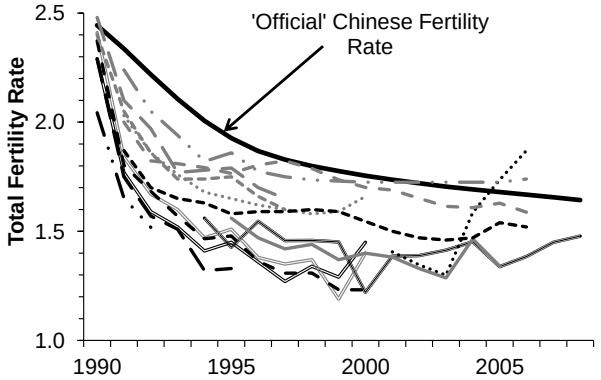
The poor quality of birth and death registration in much of the developing world presents a major obstacle to accurate population estimation and hence to projections (Box 3). A concerted global effort to improve birth and death registration systems in developing countries would go some way to improving the accuracy of population projections.

In 2010, DfID stated that 'investment will be made in stronger monitoring systems and robust evaluation and support efforts to build countries' own routine health information management systems and vital events registration'.[17]

Box 3. Projection Problems in Developing Countries

While the UK (and most other developed countries) benefit from relatively accurate baseline data and generally stable fertility and mortality rates, the same cannot be said for many developing countries. For instance, in 2007, the WHO estimated that globally, two-thirds of deaths and almost 40% of births occurring every year are not registered.[1] Most sub-Saharan African countries do not have adequate civil registration systems. They are hence unable to produce current and continuous fertility and mortality statistics, including causes of death statistics at national and sub-national levels. This means that evidence is usually gathered from representative surveys and extrapolated to the country level. Meanwhile, in many other countries, the limited availability of reliable data render the exercise extremely challenging (Box 4).

Figure 6. Uncertainty in Past Trends of Fertility in China, Comparing the Official Rate with Other Estimates[18]



While it took centuries for civil registration systems to evolve in much of Europe, countries such as Jordan, Malaysia, Sri Lanka and South Africa have shown that a combination of political will and international support can enable a functional registration system to be created within a few decades.

Endnotes

1 For more information see the work of the House of Lords Select Committee on Public Service and Demographic Change
2 OBR, 2012, *Fiscal Sustainability Report*
3 ONS, 2012, *National Population Projections, 2010-based Reference Volume: Series PP2*; The Local Government Association hosts software to support local authority projections (www.ccsr.ac.uk/popgroup)
4 Eurostat, *Population Projections Database*.
5 UN, *World Population Prospects: the 2010 Revision*.
6 ONS, *Comparison with international projections*.
7 See: ONS, 2012, *Methodology of national population projections*.
8 House of Commons Home Affairs Select Committee, *Immigration Control: Fifth Report of Session 2005–06*
9 PRB, 2004, *Population Bulletin: Transitions in World Population*.
10 GAD, 2012, *Projections Database.*
11 Shaw, 2007, Fifty years of UK National Population Projections, *Population Trends* 128, 8-23.
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18 Adapted from Gu and Cai, 2010, Fertility Prospects in China, *UN Population Division Expert Paper No. 2011/14*.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Dr Stuart Basten for researching this briefing, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Chandrika Nath.