Overview of Demographic Concepts and Methods

United Nations Statistics Division
Outline

1. What is demography
2. Meaning of “population”
3. Population change and components of population growth
4. Demographic transition
5. Data sources
6. Demographic measurements
7. Direct and indirect techniques
What is demography?

Literally translated from the Greek, 'demography' means 'description of the people’

One definition among many:

“Demography is the study of the size, territorial distribution, and composition of population, changes therein, and the components of such changes, which may be identified as natality, mortality, territorial movement (migration), and social mobility (change of status).” (Duncan & Hauser 1972)

>>The study of population processes
Meaning of “population”

1. Collection of persons alive at a specified point in time who meet certain criteria
   
   Examples:
   - The “population of India on April 1, 1995,”
   - The "population of American black females in the Northeast on June 1, 1900”

2. Kind of collectivity that persists through time even though its members are continuously changing through attrition and accession. Thus, "the population of India" may refer to the aggregate of persons who have ever been alive in the area we define as India and possibly even to those yet to be born there. The collectivity persists even though a virtually complete turnover of its members occurs at least once each century.

Source: Preston et al. (2001)
Demographic analysis

- Focuses on this enduring collectivity studying changes in its size, growth rates, and composition.

- Emphasis is on understanding aggregate processes, but demography is also attentive to the implications of those processes for individuals.

- Many of the indexes used in demography (life expectancy at birth, total fertility rate) translate aggregate-level processes into statements about the demographic circumstances faced by an average or randomly-chosen individual.

Source: Preston et al. (2001: 1-2)
World population growth through history

Source: McFalls 2007: 25
# World population growth through history

<table>
<thead>
<tr>
<th>World population</th>
<th>When?</th>
<th>How long?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 billion</td>
<td>1800</td>
<td>All of human history</td>
</tr>
<tr>
<td>2 billion</td>
<td>1930</td>
<td>130 years</td>
</tr>
<tr>
<td>3 billion</td>
<td>1960</td>
<td>30 years</td>
</tr>
<tr>
<td>4 billion</td>
<td>1975</td>
<td>15 years</td>
</tr>
<tr>
<td>5 billion</td>
<td>1987</td>
<td>12 years</td>
</tr>
<tr>
<td>6 billion</td>
<td>1999</td>
<td>12 years</td>
</tr>
<tr>
<td>7 billion</td>
<td>2013</td>
<td>14 years</td>
</tr>
</tbody>
</table>

...  

Source: McFalls 2007: 25
World population growth 1950-2050

Source: UNPD (2013)
### World population clock, 2014

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>More developed countries</th>
<th>Less developed countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
<td>7,238,184,000</td>
<td>1,248,958,000</td>
<td>5,989,225,000</td>
</tr>
<tr>
<td><strong>Natural increase per</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>86,582,000</td>
<td>1,466,000</td>
<td>85,115,000</td>
</tr>
<tr>
<td>Month</td>
<td>7,215,167</td>
<td>122,167</td>
<td>7,092,917</td>
</tr>
<tr>
<td>Week</td>
<td>1,665,038</td>
<td>28,192</td>
<td>1,636,827</td>
</tr>
<tr>
<td>Day</td>
<td>237,211</td>
<td>4,016</td>
<td>233,192</td>
</tr>
<tr>
<td>Hour</td>
<td>9,884</td>
<td>167</td>
<td>9,716</td>
</tr>
<tr>
<td>Minute</td>
<td>165</td>
<td>3</td>
<td>162</td>
</tr>
<tr>
<td>Second</td>
<td>2.7</td>
<td>0.0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

*Source: Haub & Kaneda (2014)*
How to understand these changes?
What are the components of population growth?
Components of population growth

\[ P_t = P_0 + (B - D) + (I - E) \]

- Population at time \( t \)
- Population at time 0
- Natural increase (Births – Deaths)
- Net migration (Immigration – Emigration) (arrivals – departures)
Components of population growth

Population growth can occur only if:

1. Natural increase is positive
   \[ B > D \Rightarrow B \text{ increases or } D \text{ declines} \]

   and/or

2. Net migration is positive
   \[ I > E \Rightarrow I \text{ increases or } E \text{ declines} \]

In history, the first case is more important to understand the impressive population growth

>> Demographic transition
Demographic Transition

- One of demography’s main theoretical preoccupation in 20th century
- More a generalization from observed trends than a theory
- Descriptive and pedagogic value
- Many patterns of transition, with different timing and explanations

>> Movement of death and birth rates in a society, from a situation where both are high (in the pre-transition stage) to one where both are low (in the post-transition stage).

>> Transition is the interval between these two stages during which the population increases oftentimes rapidly, as births exceed deaths.
Classic stages of demographic transition

Before the start:
- Mortality decline: life was short, but births were many, growth was slow and the population was young.
- Fertility decline: population growth remains high at the beginning but falls near 0 at the end of the stage.

At the end of the DT:
- Birth and death rates are close again. Low population growth with fluctuations.

Source: McFalls 2007: 27
Growth rate over the demographic transition

Stage 1  Stage 2  Stage 3  Stage 4

Adapted from Bloom et al. 2003: 31
250 years of demographic transition in Norway

Data source: Moving average computed from Rowland (2003)
Demographic transition across the globe  
(Data source: UNPD 2013)

WORLD

- Crude Birth Rate
- Crude Death Rate

More Developed Regions

Less Developed Regions
(excluding least developed)

Least Developed Regions

Demographic transition in Asia  \textit{(Data source: UNPD 2013)}
STAGE 2: With declining mortality, the population becomes younger because more children survive.
STAGE 3: Fertility decline reduces the proportion of children. Successive generations become similar in size (parents = children).
STAGE 4: With continuing fertility decline, the relative number of children reduces and the older population becomes more important (high life expectancy).
Diversity of population pyramids, 3 different stages

**Rapid Growth**
Ethiopia

**Age**
- 100+
- 95-99
- 90-94
- 85-89
- 80-84
- 75-79
- 70-74
- 65-69
- 60-64
- 55-59
- 50-54
- 45-49
- 40-44
- 35-39
- 30-34
- 25-29
- 20-24
- 15-19
- 10-14
- 5-9
- 0-4

**Slow Growth**
United States

**Birth Year**
- Before 1906
- 1906-1910
- 1911-1915
- 1916-1920
- 1921-1925
- 1926-1930
- 1931-1935
- 1936-1940
- 1941-1945
- 1946-1950
- 1951-1955
- 1956-1960
- 1961-1965
- 1966-1970
- 1971-1975
- 1976-1980
- 1981-1985
- 1986-1990
- 1991-1995
- 1996-2000
- 2001-2005

**Decrease**
Italy

**Source:** McFalls 2007: 19

United Nations Workshop on Evaluation and Analysis of Census Data
Nay Pyi Taw, Myanmar, 1–12 December 2014
Components of population growth

\[ P_t = P_0 + (B - D) + (I - E) \]

Each component of population growth (population, births, deaths, migration) need to be estimated from empirical data

>> Data sources
Data sources

Main sources
- Census
- Vital registration
- Sample surveys

Some other sources
- Population register
- Demographic Surveillance System (DSS)
Data sources – Census

"The total process of collecting, compiling, evaluating, analysing, and publishing or otherwise disseminating demographic, economic and social data pertaining to all persons in a country or in a well-delineated part of a country at a specified time.” (United Nations 2008)

> **Total process**
  Not sufficient to simply collect and collate information in a census, but also analyze, publish and disseminate the data.

> **Demographic, economic and social data**
  To collect more than just a simple headcount of the population

> **Universality**
  To enumerate all people in a population

> **Simultaneity**
  To produce a snapshot of the population at a point in time
Data sources – Census

- The oldest, most demanding, and most important source of demographic information >> many demographic methods developed for census data
- Among the most complex and massive peacetime exercises a nation undertakes
- Requires the mapping the entire country, mobilizing and training an army of enumerators, conducting a massive public campaign, canvassing all households, collecting individual information, compiling vast amounts of completed questionnaires, and analysing and disseminating the data
Data sources – Census

- (Recommended) to be conducted once per decade
- UN Principles and Recommendations (>> 3rd revision forthcoming)
- 2010 World Population and Housing Census Programme (UNSD)
  - 19 countries have not conducted a census (slight improvement compared to 26 during the 2000-round)


> Micro samples available for 79 countries (258 censuses) at IPUMS International (Integrated Public Use Microdata Series): https://international.ipums.org/international/
General overview – 2010 round of censuses

Number of countries/areas that conducted, plan to conduct and did not schedule a population and housing census in the 2010 round, by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Conducted</th>
<th>Planned</th>
<th>Did Not Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td>19</td>
</tr>
</tbody>
</table>
### Enumeration used in 2010 round of censuses

<table>
<thead>
<tr>
<th>Method</th>
<th>Total countries</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>126</td>
<td>100</td>
</tr>
<tr>
<td>Face-to-face interview, paper questionnaire</td>
<td>94</td>
<td>75</td>
</tr>
<tr>
<td>Face-to-face interview, electronic questionnaire</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Telephone</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Self-enumeration, paper questionnaire, collected by enumerators</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>Self-enumeration, paper questionnaire, return by mail</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Self-enumeration, internet</td>
<td>33</td>
<td>26</td>
</tr>
<tr>
<td>Register-based enumeration</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Pre-existing administrative records</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* The sum of the categories exceeds 100% as countries were asked to provide answers as to all the methods they applied.
Data sources – Census (De facto vs. De jure)

De facto (Latin, for ‘in actual fact’)
The population is enumerated where it is found, regardless of the respondent’s usual place of residence.

De jure (Latin for ‘in law’)
The respondent is enumerated at their usual place of residence, regardless of where they stayed on the census date.

In highly mobile populations, or populations subject to extensive seasonal migration (e.g. crop-pickers), De facto and De jure data may give widely divergent results

Source: IUSSP & UNFPA (n.d.)
## Data sources – Census

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>The coverage aims to be universal</td>
<td>The size and complexity of the exercise means that the content and quality control efforts may be limited</td>
</tr>
<tr>
<td>Census provides sampling frame for subsequent surveys and studies</td>
<td>Due to high costs, census is conducted only every ten years</td>
</tr>
<tr>
<td>The census can serve as a useful tool for ‘nation-building’, by involving the entire population</td>
<td>Some delay between data collection and release of results (typically, between 18 months to two years) meaning that the census only offers a snapshot of the population at some point in the past</td>
</tr>
<tr>
<td>Census data avoids the sampling errors that can occur with sample data</td>
<td>Risks that census being politicised – either by groups who feel that they might be systematically undercounted by the exercise, or by parties with a vested interest in seeking to ensure that their group’s population is found to be larger than that of other groups</td>
</tr>
<tr>
<td>Censuses provide data for small areas, such as districts and counties, which is vital for the planning of services</td>
<td></td>
</tr>
</tbody>
</table>

*Source: IUSSP & UNFPA (n.d.)*
Data sources – Vital registration system

- The second main source for demographers
- Collect information on individuals when (or shortly) after they experience the vital events (birth, marriage, death, (sometimes) migration)
- In almost all developed countries, registration of births, deaths, and marriages is compulsory
- Vital data collected are tabulated totals from individual records
- Sometimes more extensive information collected (e.g. statistics for birth could include sex, birth weight, place of birth…)
- Despite progress, civil registration systems still deficient in many countries

  For example, only 60% of the 230 countries and areas register at least 90% of births occurred in the country. While for death registration, only 47% of the countries and areas have at least 90% coverage. (UNSD 2012)
Data sources – Sample surveys

- More and more important as statistical science has developed
- Collect vital statistics where the official registration system is inadequate or nonexistent and for intercensal period
- Collect supplementary demographic and other data, where it is not feasible to collect the same from the population census
- Since the 1970s, coordinated demographic surveys have been taken around the world through the World Fertility Survey (WFS), the Demographic and Health Surveys (DHS), the Multiple Indicator Cluster Surveys (MICS), or other national types of survey

> DHS micro datasets available online at: [www.dhsprogram.com](http://www.dhsprogram.com)
> MICS micro datasets available online at: [http://www.childinfo.org/mics.html](http://www.childinfo.org/mics.html)
Data sources – Some other sources

Population register

>> If country has a system of continuous registration it is possible to maintain a separate card for each individual from the time of his birth (or immigration) to his death (or emigration) and to continually update the record by recording such additional registration data as marriage, divorce, birth of children, etc.

Demographic Surveillance System (DSS)

>> DSS monitors demographic and health characteristics of a population living in a well-defined geographic area. A baseline census is followed by regular update of key demographic events (birth, death, migration, marriage…) and health events
Demographic measurements (rate, ratio, proportion)

Rate
The most widely used comparative measures of population change ideally, demographic rates show ideally the relationship between the number of demographic events (numerator) and the population at risk of experiencing them (denominator) in a specific period of time.

\[
Rate = \frac{Number \ of \ Demographic \ Events}{Population \ at \ Risk \ during \ specific \ period \ of \ time}
\]

\[
Rate = \frac{Number \ of \ Occurrences}{Number \ of \ Person-years \ Lived}
\]
Demographic measurements (rate, ratio, proportion)

Rate

- When studying the relative incidence of births, deaths, marriages, migration and other vital events, it is apparent that the number of these events depends on the interval of time chosen (usually one year).

- A common method of comparing the incidence of births in several countries is to calculate for each country the number of births during one year per 1,000 persons in the population of that country at the middle of the year. The result is called a rate, in this case a rate per 1,000 per year.

  >> Mid-year population calculated as the mean or average of the population at the start and end of the year
Demographic measurements – Rate, examples

Crude Birth Rate and Crude Death Rate

>> Example in Excel
A note on approximation of person-years

When population increase linearly, the estimate of person-years lived using the mid-period population times period length will be accurate because the overestimate for the first half-period is exactly offset by the underestimate for the second half-period, i.e., the two triangles have equal areas.

When population follows an exponential growth pattern, the two shaded surfaces have different areas and the mid-year approximation will underestimate person-years lived during the period.

Source: Preston et al. (2001: 16)
Demographic measurements (rate, ratio, proportion)

**Ratio**
- The size of a number relative to another convenient number
- When the population at risk is unavailable
- Denominators for ratios selected depending on the available data and ease of understanding
- Example: sex ratio
  - the number of men per hundred women
  - (men/women * 100)
Demographic measurements (rate, ratio, proportion)

Proportion
- A ratio in which the denominator includes the numerator
- Decimal fraction (between 0 and 1)

Percentage
- A proportion multiplied by 100
- Easier to read/interpret
### Demographic measurements – Example

<table>
<thead>
<tr>
<th></th>
<th>Number (in thous.)</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinhalese</td>
<td>11,053</td>
<td>0.744</td>
<td>74.4</td>
</tr>
<tr>
<td>Tamil</td>
<td>2,652</td>
<td>0.179</td>
<td>17.9</td>
</tr>
<tr>
<td>Ceylon Moor</td>
<td>1,026</td>
<td>0.069</td>
<td>6.9</td>
</tr>
<tr>
<td>Others</td>
<td>117</td>
<td>0.008</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14,848</td>
<td><strong>1.000</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*Source: Pollard et al. (1990)*
### Demographic measurements – Example

<table>
<thead>
<tr>
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<td><strong>1.000</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

In 1984, 15.5 births per 1,000 population per year were observed in Australia. 

Rate

Source: Pollard et al. (1990)
Demographic measurements - Probability

- The ratio of the number of demographic events to the *initial population at risk* of experiencing them in a fixed period of time
- In demography, probabilities are always based on the *initial population*
- For example, probability of dying at age 100 is based on the number of people who celebrated their 100th birthdays (initial population)

\[
Probability = \frac{\text{Number of Occurrences}}{\text{Number of Preceding Events or Trials}}
\]

- Since each occurrence in the numerator (e.g., divorce) must be preceded by an event in the denominator (marriage), the number of occurrences cannot exceed the number of preceding events

>> a probability cannot exceed one and, since we are only dealing with positive quantities, probabilities cannot be negative

*Source: Preston et al. (2001: 19)*
Demographic measurements - Probability

- Populations do not have probabilities except insofar as they pertain to **cohorts** that are included in the population.

- Although we could count the number of marriages in a population during some calendar year and the number of divorces during that year, the two numbers combined do not give a sensible estimate of the probability of divorce because they don't apply to the same cohort. If we happened to choose a year in a small population where no one married but there was a divorce, our population's probability of divorce \( q^D \) would be \( 1/0 = \infty \) (infinity), *an obviously absurd outcome*.

- Only when we count the events pertaining to the **cohort** at risk of the event we can properly define a probability

*Source: Preston et al. (2001: 19)*
Demographic measurements - Cohort

- Cohort is the aggregate of all units that experience a particular demographic event during a specific time interval.
- As for a population, a cohort always has some specific geographic referent whether it is explicit or implicit.
- A cohort usually consists of people, but it may also consist of entities (e.g., marriages) formed by a demographic event.
- The cohort is usually identified verbally both by the event itself and by the time period in which it is experienced.
- Birth cohort = most used >> Persons born during the same period will pass through life together.
- Examples:
  - "US birth cohort of 1942" = all persons born as US citizens in calendar year 1942
  - "French marriage cohort of 1990" = all marriages contracted in France during the calendar year 1990

Source: Preston et al. (2001)
Demographic measurements – Cohort

Main limitation of working with cohort is that for computing cohort rates and probabilities requires complete information on each individual until he or she has died (or at least has ceased to be "at risk” of the event of interest)

For mortality, need to wait until the last person of a birth cohort passes away in order to compute mortality indicators

For fertility, need to wait until the last woman of a birth cohort reaches the end of her childbearing ages

>> Demographers have developed the artifact of the synthetic cohort

- Synthetic cohort mixes the experiences of persons from different (birth) cohorts in order to compute demographic indicators

Source: Preston et al. (2001)
Example: Period Fertility vs. Cohort Fertility

Source: IUSSP & UNFPA (n.d.)
Example: Period Fertility vs. Cohort Fertility

Source: IUSSP & UNFPA (n.d.)
Example: Period Fertility vs. Cohort Fertility

The period TFR can be calculated in 1965 and would be current for that period.

The cohort TFR (CFS) cannot be calculated until 2000 and would be “centred” on 1975 – the mean age of childbearing.

*Source: IUSSP & UNFPA (n.d.)*
Direct and indirect techniques

“In a perfect world, data would always be complete, accurate, current, pertinent, and unambiguous. In the real world, data are generally flawed on some or all of these dimensions”

(Feeney 2003: 190)
Direct and indirect techniques

Direct techniques require reliable and comprehensive information on population, births, deaths… usually from censuses and registration systems.

But, in most parts of the world, vital registration is incomplete and censuses usually suffer from underenumeration and other defects.

Many of the standard direct methods of demographic estimation that can be used in a “perfect world” cannot be applied successfully to the majority of the world population.

Starting in the 1960s, development of estimation methods for use with deficient and incomplete demographic data (William Brass (1921-1999) and associates).

>> Indirect demographic estimation
Direct and indirect techniques

**Indirect techniques**

Use available information and/or assumption (through the use of models) to infer the levels and trends of demographic change

Example:

- Levels and trends in child mortality can be estimated by answers to the question on the number of children ever born and children surviving by age of women
- Adult mortality can be estimated using answers on the question on parental survival or on siblings survival
- Fertility can be estimated using the population structure by single age and sex
Indirect techniques – Main references


Available in PDF: http://demographicestimation.iussp.org/content/get-pdf-book-website
Indirect techniques – Main packages

**MORTPAK** – The United Nations software package for demographic measurement, available online:

**Excel templates** provided with each chapter of Moultrie et al. (2013), available online:
http://demographicestimation.iussp.org/
Direct and indirect techniques

“The problem of estimating demographic measures from incomplete data is a challenging one, one for which there is no universal answer and one which therefore requires in the demographer the qualities of resourcefulness and imagination.”

(Pollard et al. 1990: 164)
References


Thank you

Questions/comments?

>> until 12 December:

>> After 12 December: spoorenberg@un.org