Uses of the Human Mortality Database for demographic estimation and forecasting at the United Nations

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Background

• Population Division publishes estimates and projections by sex for all countries: population size and vital rates, 5x5 format (from July 1 to July 1) from 1950 to 2100

• World Population Prospects (WPP) series, revised every two years: since 1951 the UN has published 24 sets of population estimates and projections

• Used throughout UN system to provide the population base (denominators or multipliers); key input used for development planning, monitoring (MDGs and SDGs) and modeling (e.g., climate change)


• Upcoming: 2017 Revision, to be launched in June 2017
The Human Mortality Database, created by the University of California at Berkeley and the Max Planck Institute for Demographic Research, contains time series of national life tables for 37 countries or areas having virtually complete vital statistics and census enumerations. It also contains data on registered deaths by age and sex, registered births and enumerated populations. A uniform method was used to construct the life tables, ensuring consistency over time and across countries. The database is accessible online and is the best source on changing mortality patterns in developed countries.
Overview

HMD is used at the United Nations to:

- Inform UN estimates for HMD countries
- Validate estimates for non-HMD countries
- Develop and test new models and methods
- Inform and calibrate projection models
**Inform estimates for HMD countries:**

**World Population Prospects (WPP)**

- Global coverage: 230 countries or areas (201 with at least 90,000 inhabitants in 2015)
- 1950-2015 = estimation period
- HMD population estimates by sex and 5-year age groups, and abridged period life tables inform WPP estimates of 5x5 population and mortality estimates (populations on 1 July, and rates from 1 July in year t to 1 July in year t+5)

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Inform estimates for HMD countries: A couple of challenges

• For 13 countries or areas, HMD series start after 1950 (e.g., 1958 for Poland; 1959 for Belarus, Estonia, Latvia, Lithuania, Russia, Ukraine; 1960 for Luxembourg; 1970 for Taiwan, Province of China; 1981 for Greece; 1983 for Israel and Slovenia; 1990 for Germany)

• HMD data series not always updated for recent years

• WPP data series completed using other sources, which may reveal differences requiring adjustments (e.g., Israel for 1950-1980 above age 75, death rates show implausible trend and a low level of mortality)
Israel, women, $q_x$ trends above age 80: National data for 1950-1980, HMD for 1980-2010

Ages 80-84  
Ages 85-89  
Ages 90-94  
Ages 95-99

Source: United Nations, unpublished
Validate estimates for non-HMD countries

• Evaluate using key relationships:
  \[ q_0 \text{ vs. } q_1 \quad q_0 \text{ vs. } q_{15} \quad q_{15} \text{ vs. } e_{60} \]

• Compare observed values to historical patterns, using HMD supplemented by DSS data

• Assess plausibility of age patterns and trends over time

• Validate and/or adjust estimates using general methods and/or specialized models: smoothing, parametric models (Gompertz, etc.), empirical models (model life tables, relational models)
Infant and child mortality: HMD data and model life tables

Infant and child mortality: Spain, 1908-2009

Infant and child mortality:
Distinctive pattern in the Sahel


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Child and adult mortality: India and Sri Lanka, women

Child and adult mortality: India and Sri Lanka, men

Child and adult mortality: Bangladesh, women

Source: Unpublished UN analysis.

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Develop and test new models and methods

• Models of age patterns: model life tables, relational models

• Indirect estimation: intercensal survival, variable r method

• Vital registration data for non-HMD countries: extending the HMD toolkit
New model life table system: Log-quadratic model developed using HMD data

\[ \log( m_x ) = a_x + b_x h + c_x h^2 + v_x k + \varepsilon_x \]

Thus, there two entry parameters:

- \( h = \log( 5q_0 ) \) reflects the level of child mortality
- \( k \) reflects the level of excess adult mortality and is chosen to match \( 45q_{15} \) or other global measure of adult mortality (if available)

Log-Quadratic Model: Age Patterns

\[ \log( m_x ) = a_x + b_x h + c_x h^2 + v_x k \]

Child and Adult Mortality

Historical Data (HMD) + Log-Quadratic

Test intercensal survival method: Completeness of death registration, G7 countries, 2000-2010, using HMD data

Test variable-r method

Variable-r and adjusted survival ratios of females for selected countries

Estimates of $15q_{60}$ based on applying the extended Gompertz model to the adjusted $L_x$

<table>
<thead>
<tr>
<th>Country</th>
<th>Period</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>2000-2005</td>
<td>0.214</td>
<td>0.099</td>
</tr>
<tr>
<td>Sweden</td>
<td>1960-1965</td>
<td>0.370</td>
<td>0.292</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1991-2006</td>
<td>0.356</td>
<td>0.479</td>
</tr>
<tr>
<td>Swaziland</td>
<td>1997-2007</td>
<td>0.624</td>
<td>0.419</td>
</tr>
</tbody>
</table>


Adjustment of survival ratios for age heaping on 60 and 70 years of age (assuming similar heaping ratios at ages 60 and 70).
Vital registration data for non-HMD countries: extending the HMD toolkit

1. Collect death counts and population estimates
2. Review and standardize for differences in concepts and definitions
3. Evaluate completeness and adjust data (ages 5+), if needed
4. Use UN (IGME) estimates of $1q_0$ and $5q_0$
5. Compute life tables and interpolate/extrapolate, as needed, across age and time
6. Smooth/adjust old age mortality rates, as needed, to ensure plausible patterns over age, sex and time
Inform and calibrate projection models

- Age pattern of mortality: how to specify age-specific rates of change?
- Probabilistic projections of $e_0$: estimation and assumptions
Age-pattern of change: countries with recent data but no historical series

Example:
Estimating the age pattern of mortality decline, for a given level of life expectancy at birth (65-70 years, women)

Age-pattern of change: countries with historical data series

The Lee-Carter $b(x)$ of the 20 low-mortality HMD populations based on 1950–2010 death rates

The ultimate $b(x)$ of the 20 low-mortality HMD populations

UN probabilistic projection: India, women, $e_0$

Double-logistic gain in $e_0$ function

Probabilistic projections of $e_0$

UN probabilistic projection: Japan, women, $e_0$

Double-logistic gain in $e_0$ function

Probabilistic projections of $e_0$

Estimating the model parameters

• All parameters except the long-run asymptote can be estimated using empirical data
• Estimated using observation pairs consisting of values of $e_0$ and of changes in $e_0$ (over 5 years)
• Estimated using UN data for 1950 and later, and HMD pre-1950 data

How to determine the asymptotic limit to future gains in $e_0$?

Double-logistic function used to model rate of change in life expectancy at birth

Trend in life expectancy at birth with slope determined by double-logistic function
First approach: Calibrate according to average gain in maximum \( e_0 \)

Second approach: Calibrate according to average gain in maximum life span

Predictive distribution of change in $e_0$: India and Japan, women

Alternative assumption for asymptotic limit lies within band

Source: Unpublished graphs, prepared using bayesLife, wpp2015 and online data (see previous two slides).
Acknowledgement

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