Advances in population projection methods and their implications for the future

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Projecting the components of change

**Fertility:**
- Future trends in total fertility
- Age distribution of fertility

**Mortality:**
- Future trends in life expectancy
- Mortality rates by age and sex

**Migration:**
- Future net number of migrants
- Migrants by age and sex
PROJECTING THE FIRST COMPONENT OF CHANGE:

FERTILITY
In projecting future fertility trends one can take advantage of two things:

- The availability of a complete set of past estimates of fertility change
- The empirical existence of a “typical” pattern of fertility change as described by the demographic transition
Typical fertility trend from high to low

- **Phase I**: 1950-1955
- **Phase II**: 1960-1965 to 2000-2005
- **Phase III**: 2005-2015 to 2050-2055

*Children per woman*
Countries classified by fertility level

- **High fertility**: 18%
- **Intermediate fertility**: 40%
- **Low fertility**: 42%

*Note: The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.*
PROJECTING FERTILITY FOR COUNTRIES IN PHASE II
Fertility decrements during Phase II

Total fertility

Children per woman

Fertility decrements during Phase II
Modeled fertility decrements, Phase II

Children per woman vs. Total fertility

-0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0

0 2 4 6 8 10

Total fertility
Fertility decrements are modeled using a double logistic function with five parameters

\[ g(D, U, f_t) = \frac{-D}{1 + \exp[-2 \ln(9) * [f_t - U + 0.5 u_1]/u_1]} + \frac{D}{1 + \exp[-2 \ln(9) * [f_t - u_4 - 0.5u_3]/u_3]} \]

where \( U = u_1 + u_2 + u_3 + u_4 \)

and it represents the level at which fertility begins to decline.
Double logistic decrement function \((D=1)\)
ADDING UNCERTAINTY
Fertility is projected by using the decrements yielded by the logistic model. Uncertainty is captured by a random distortion term

\[ f_{t+1} = f_t + g(D, U, f_t) + \varepsilon_t \]

where \( \varepsilon_t \) is normally distributed and the parameters \( (D, U) \) are estimated by using a Bayesian hierarchical framework with prior distributions based on world experience or guessed and posterior distributions derived using Monte Carlo Markov chain simulation incorporating country-specific data.
Examples of decrement paths

India: Sustained decline

Malawi: Stalling decline
India: Projection of fertility

![Graph showing fertility rate projections for India with a TFR of 2.1 by 2050 and beyond.](image)
Malawi: Projection of fertility

The diagram shows the projected total fertility rate (TFR) for Malawi from 1950 to 2100. The solid black line represents the median projection, while the shaded area indicates the 80% and 95% prediction intervals. The green dashed line at TFR = 2.1 represents the replacement level fertility rate. The observed TFR is also shown by the green line, which is close to the replacement level, indicating a potential for stabilization or near replacement fertility in the future.
PROJECTING FERTILITY FOR COUNTRIES IN PHASE III
Projection for countries in Phase III

Assume TFR will fluctuate around 2.1, use an AR(1) model:

\[ f_t = f_{t-1} + (1 - \rho)(2.1 - f_{t-1}) + e_t \]

\[ e_t \sim N(0, s^2) \]

with \( \rho = \) autoregressive parameter with \(|\rho| < 1\) and \( s = \) standard deviation of the random errors
Italy: Projected fertility

![Graph showing projected fertility rates in Italy with a target of 2.1 children per woman.](image-url)

- Observed TFR, median, 80% PI, 95% PI, +/- 0.5 child.
PROJECTING THE SECOND COMPONENT OF CHANGE:

MORTALITY
Probabilistic projection of life expectancy

Raftery et al. assume that life expectancy follows a random walk with drift:

\[ e_{t+1} = e_t + g(e_t, \theta) + \varepsilon_{t+1} \]

where \( g(e_t, \theta) \) is a double logistic similar to that used in modeling fertility change and \( \varepsilon_{t+1} \) is a random error with a normal distribution.
A Bayesian hierarchical approach is used to estimate the model's parameters. This approach is used to project female life expectancy.

Male life expectancy is derived from a regression model for the female to male gap in life expectancy.
Putting it together
Malawi: Projected population in millions

- Upper 95%
- Upper 80%
- Median
- Lower 80%
- Lower 95%
- +0.5
- -0.5
India: Projected population in millions

- **Upper 95%**
- **Upper 80%**
- **Median**
- **Lower 80%**
- **Lower 95%**
- **+0.5**
- **-0.5**
### Italy: Projected population in millions

<table>
<thead>
<tr>
<th>Year</th>
<th>Lower 95%</th>
<th>Lower 80%</th>
<th>Median</th>
<th>Upper 80%</th>
<th>Upper 95%</th>
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<tbody>
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The above graph illustrates the projected population in millions for Italy from 1950 to 2100, with upper and lower 95% and 80% confidence intervals. The yellow line represents the median projection.
Some patterns emerge:

For high-fertility countries, the intervals between the high and low variants are too narrow compared to those yielded by the probabilistic projections.

For low-fertility countries, the high-low intervals are too wide.

For intermediate-fertility countries, they are about right.
Fertility trends, 1950-2100

Children per woman

- Developed
- Other developing
- Least developed

1.0
2.0
3.0
4.0
5.0
6.0
7.0

1950-1955
1960-1965
1970-1975
1980-1985
1990-1995
2000-2005
2010-2015
2020-2025
2030-2035
2040-2045
2050-2055
2060-2065
2070-2075
2080-2085
2090-2095
Least developed countries: projected fertility

- **Children per woman**
  - **Low**
  - **Medium**
  - **High**

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<th>Year Range</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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Developing countries: projected fertility

- Low
- Medium
- High

Children per woman

- 2.4
- 2.4
- 1.9
- 1.4
Developed countries: projected fertility

- Low: 1.7, 1.4
- Medium: 1.9
- High: 2.4
Annual population increments, medium variant

World: 10.8 billion in 2010

Developing

Least developed

Developed

2043: 26 million

United Nations, 2012 Revision, WPP
Projected population, medium variant

World: 10.8 billion in 2100

- Developed: 1.3
- Developing: 6.6
- Least developed: 2.9

Billions

United Nations, 2012 Revision, WPP
Projected population, high variant

World: 16.6 billion in 2100

- Developed
- Developing
- Least developed

Billions

United Nations, 2012 Revision, WPP
Median age vs. population size in different projections: least developing countries
Median age vs. population size in different population projections: developed countries
Conclusions

1. Curbing population growth in developing countries is still a challenge.
2. Least developed countries have the highest potential for growth.
3. Achieving the high variant is well within the realm of possibility for the least developed countries.
4. Even the contraction or slow growth of the rest of the world might not counterbalance that growth.
Conclusions

1. Population ageing is inevitable if the world population is not to grow excessively.
2. The medium variant offers a path where population ageing occurs at acceptable levels while population growth remains moderate.
3. The low variant would produce faster and more profound ageing.
For more information, consult:

www.unpopulation.org