

Global population projections by the United Nations

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Brief history

- The United Nations has produced 24 sets of population projections since 1951
- Early projections were for the world or large regions only
- Beginning in 1968, the UN began making projections for individual countries
- The latest set, the 2015 Revision, includes projections from 2015 to 2100 for 201 countries or areas

Highlights of 2015 Revision

- Continued growth of the global population:
7.3B 2015 -> 8.5B 2013 -> 9.7B 2050 -> 11.2B 2100
- Future growth concentrated in Africa. For 2015-2050:
+2.4B world, +1.3B Africa, +0.9B Asia, ..., -0.03B Europe
- Shifts in rankings among most populous countries:
India to overtake China in 2022
Nigeria to overtake USA by 2050
- Considerable demographic diversity:
High fertility / rapid growth / younger populations
Low fertility / slow growth / older populations
- Rapid reductions in child mortality in last 10-15 years
Reduced gap between LDCs and rest of the world

UN projection methods

- Calculations using a cohort-component approach
- Assumptions about future trends of fertility and mortality are:
 - Derived primarily from past trends for a given country
 - Also informed by theories of demographic change and the historical experience of other countries
- Alternative future trends have traditionally been described using variants and scenarios
- NEW: Alternative future trends are now also depicted using a probabilistic model

Terminology

- Levels and trends in human fertility and mortality can be described using a variety of measures. Two of the most common measures are key components of the projection model used by the United Nations:
 - The **total fertility rate**, or **TFR**, is expressed as the number of births per woman over her lifetime. It equals the sum of age-specific fertility rates for a given time period and thus represents the average number of births that women would bear if the intensity of childbearing throughout their lives matched the current age-specific rates.
 - **Life expectancy at birth**, or e_0 , is expressed as the average duration of life in a population. It equals the mean of a hypothetical distribution of ages at death, if a cohort of individuals were to experience throughout life the age-specific death rates of the period in question.

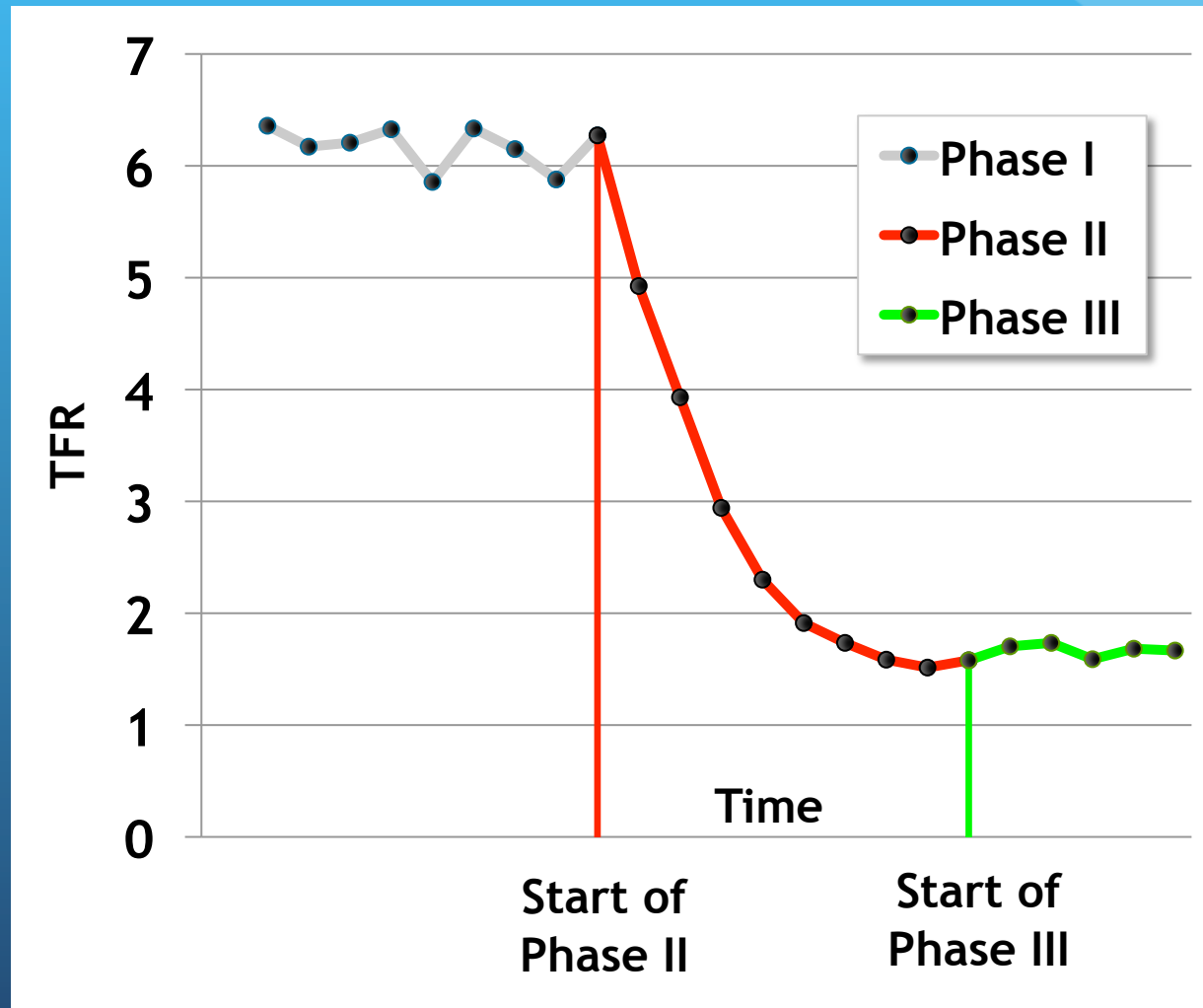
Using historical experience

- UN projections of fertility and mortality are guided by historical trends in those same variables
- Regularities in historical trends have led to theories of demographic change, which give structure to the projection model
- The model is calibrated for each country using an estimation procedure that combines the country's data with that of other countries:
 - Giving most weight to data from that country, if such data are plentiful
 - Giving more weight to data from other countries, if no or little data are available

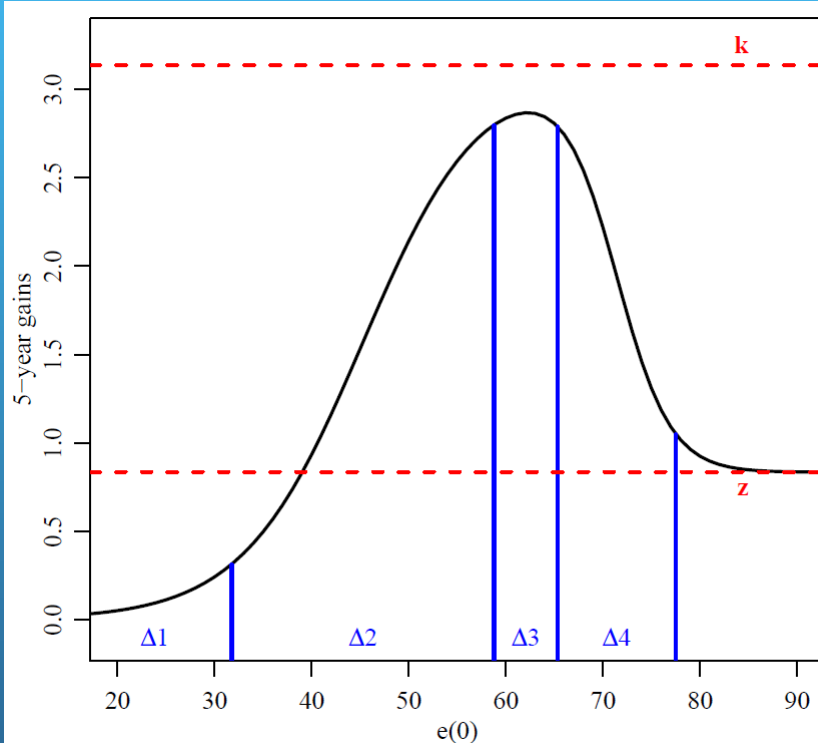
Theory → Model structure

- Theories of the demographic transition share certain common points about the historical decline of fertility and mortality, which are reflected in the structure of the UN's projection model
- For fertility, there is a transition from high to low values of the TFR (below 2.0), typically followed by fluctuations and a modest recovery
- For mortality, the increase of life expectancy at birth follows an S-curve (slow-rapid-slow change), which remains positive and roughly linear in the final phase

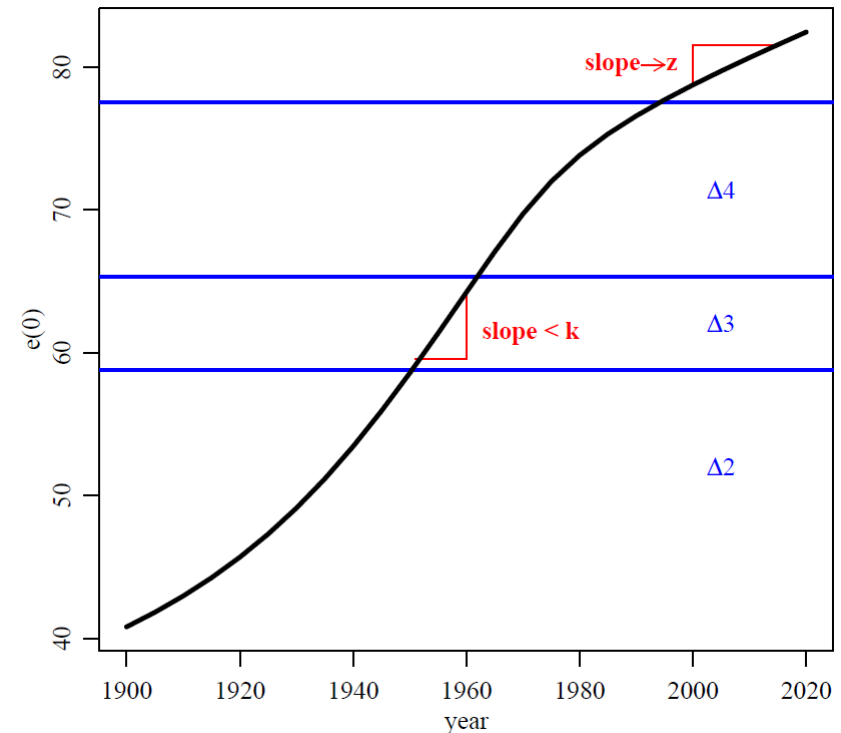
Three phases of TFR trend: Pre-decline, decline, post-decline



Model of historical trend in life expectancy at birth



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



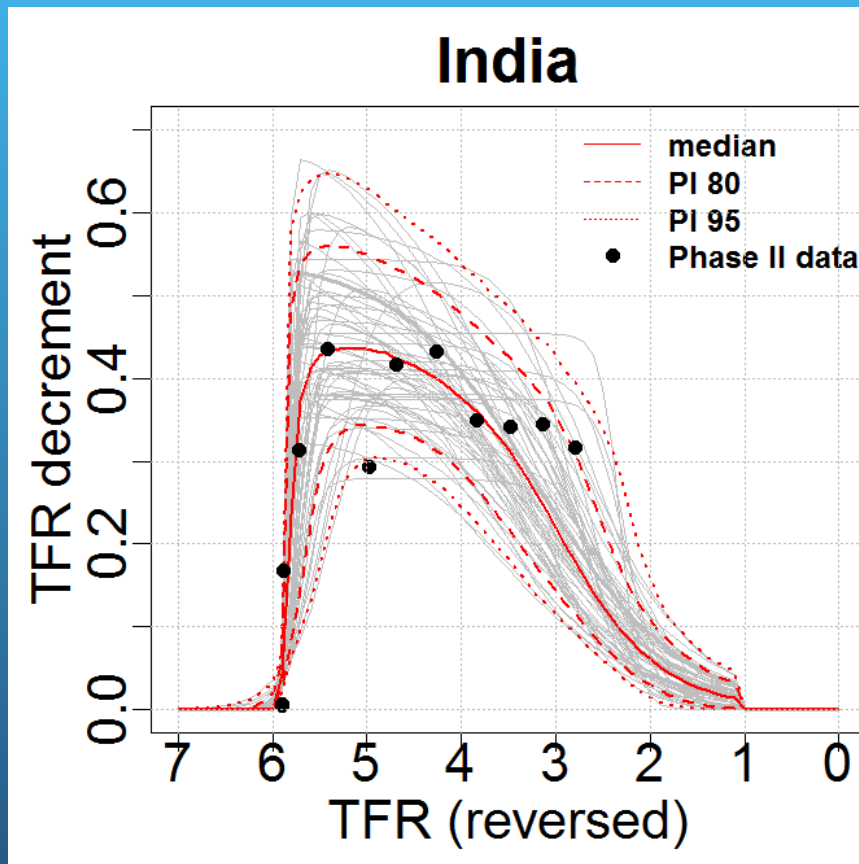
Trend in life expectancy at birth with slope determined by double-logistic function

Fertility decline model: Phase II

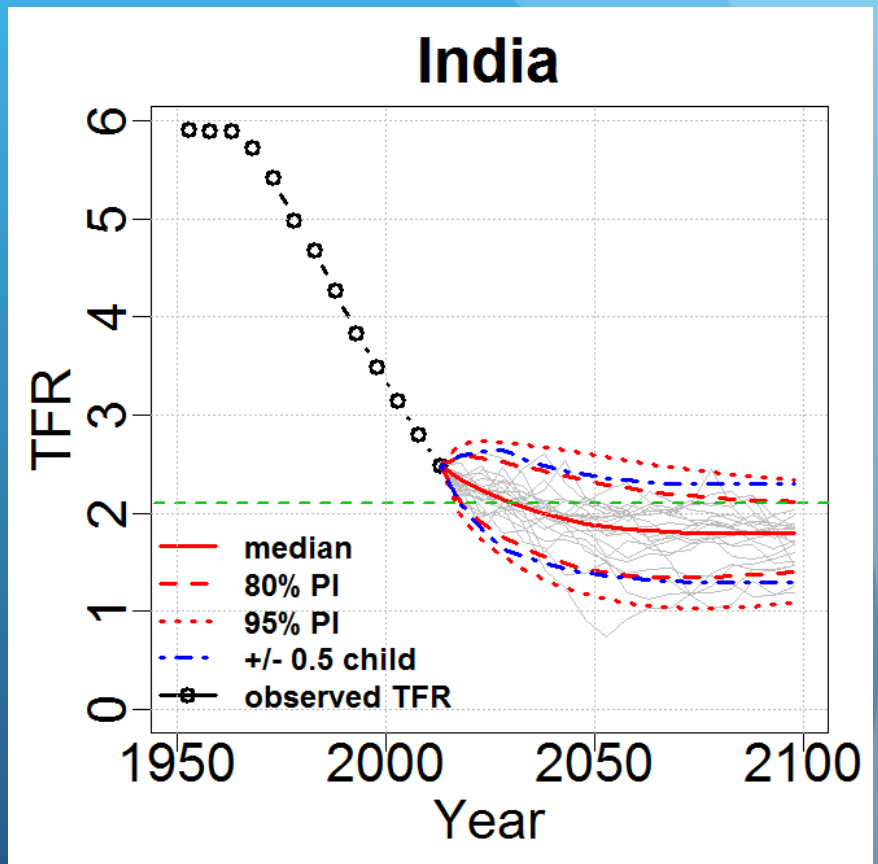
- Rate of TFR decline depends on level of TFR
 - Peak rate of decline around TFR=5
 - Slower decline for TFR > 5 or TFR < 5
- Rate of decline in the TFR, as a function of its current level, is modeled using a double-logistic function, which has an inverted U-shape
- Bayesian hierarchical model used to estimate model for the world and for each country
- In addition, standard time series methods are used to project future trends

Fertility projection for India

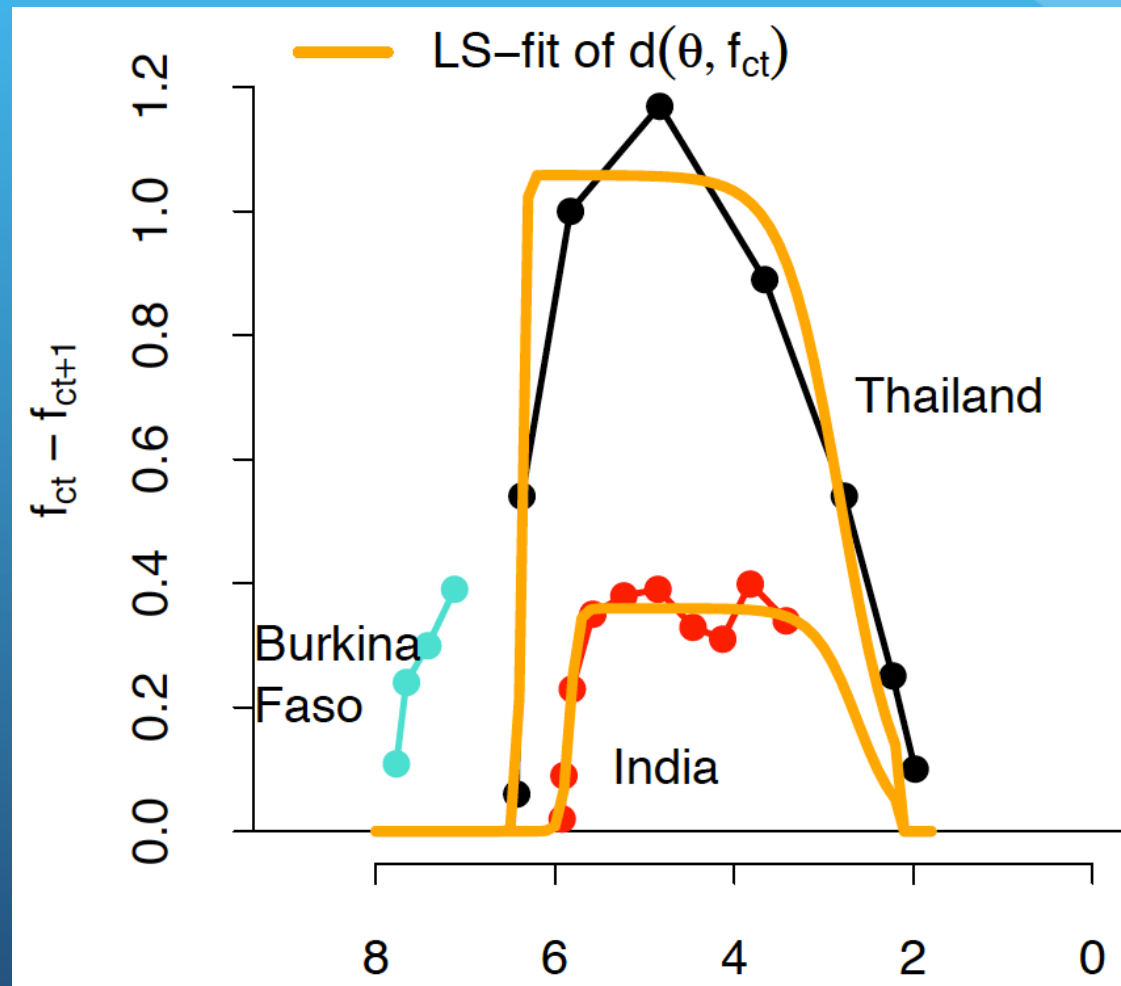
TFR decline function



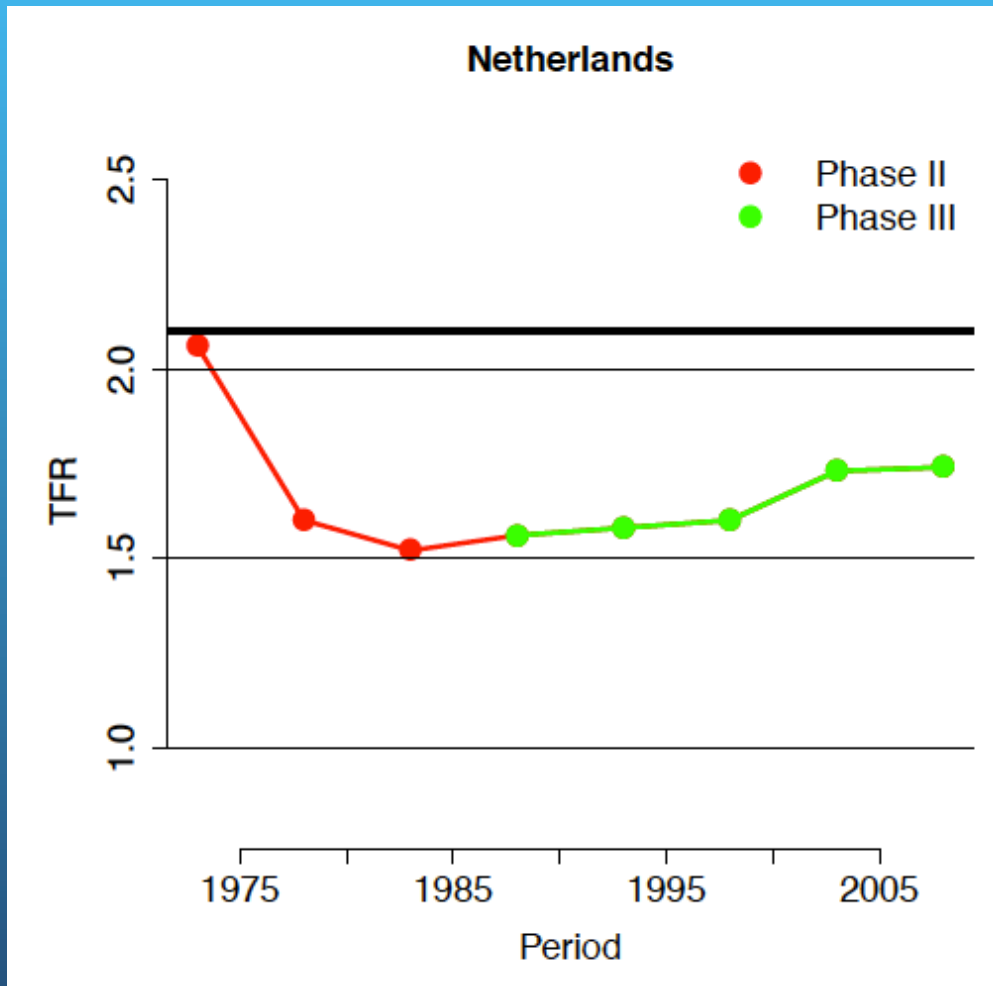
Probabilistic TFR projections



Country-specific estimates of double-logistic TFR decline function



Post-transition low-fertility rebound: Phase III



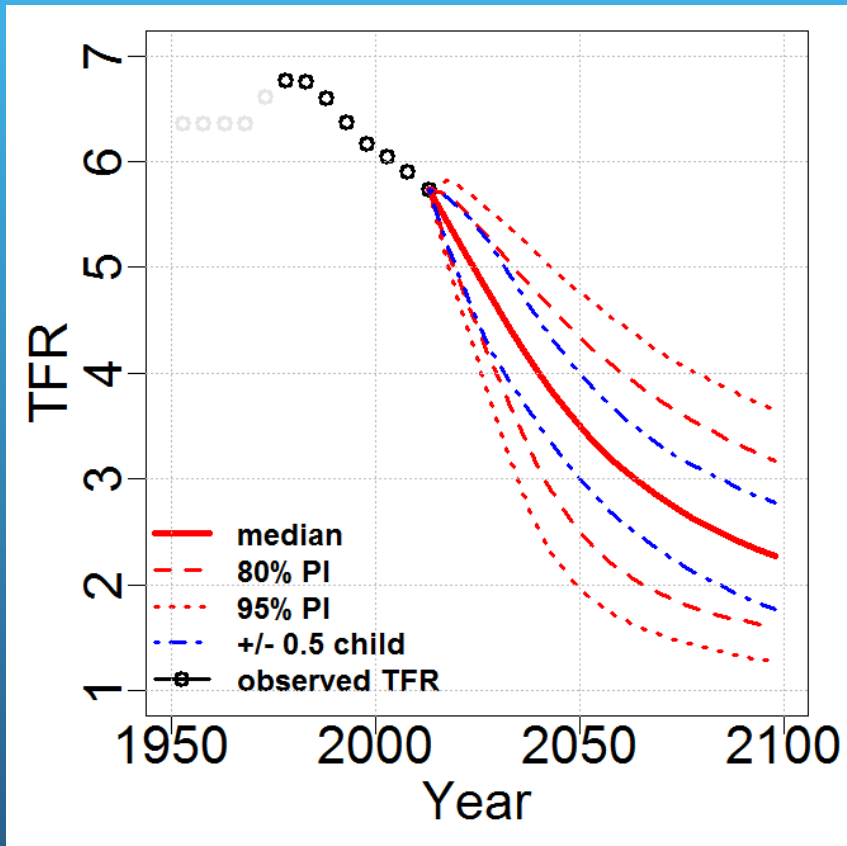
- Start of Phase III defined by two earliest consecutive 5-year increases when $TFR < 2$
- Has been observed in 38 countries or areas: 29 in Europe, 7 in Asia (China, Hong Kong, Macao, Japan, Republic of Korea, Singapore, Viet Nam) plus USA and Barbados

Future trends are uncertain

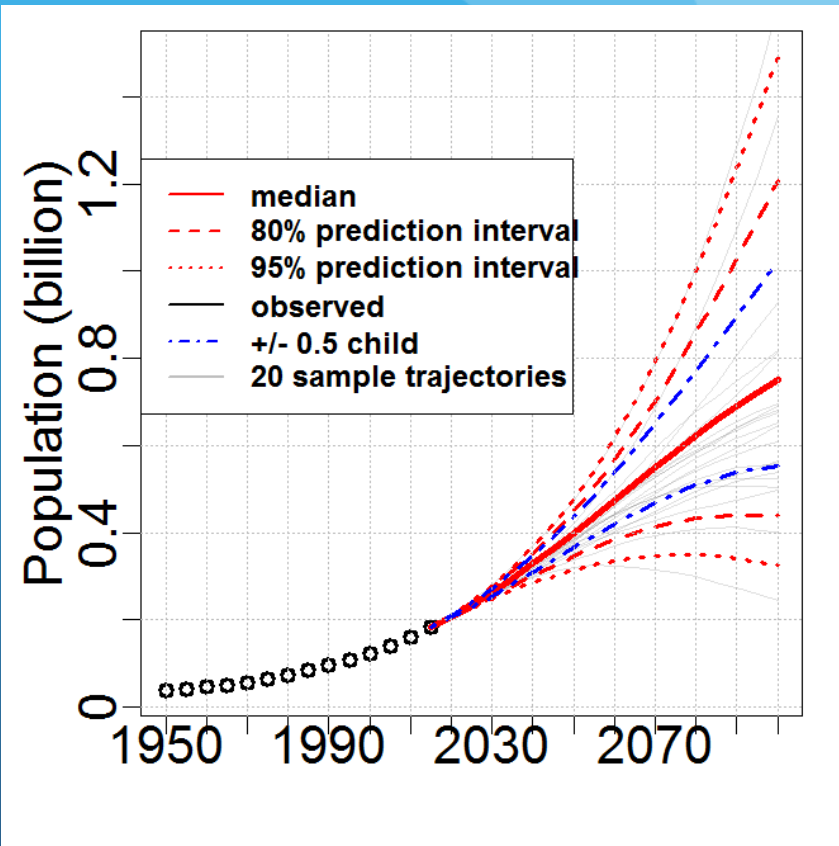
- Traditionally, UN projections have included several variants or scenarios:
 - Variants describe future trends produced by varying key assumptions (e.g. fertility), illustrating sensitivity of results
 - Scenarios describe hypothetical future trajectories, illustrating core concepts such as population momentum
- Bayesian hierarchical model of past trends, combined with time series model of future trends, yields probabilistic depiction of plausible future outcomes

Nigeria

Total fertility rate

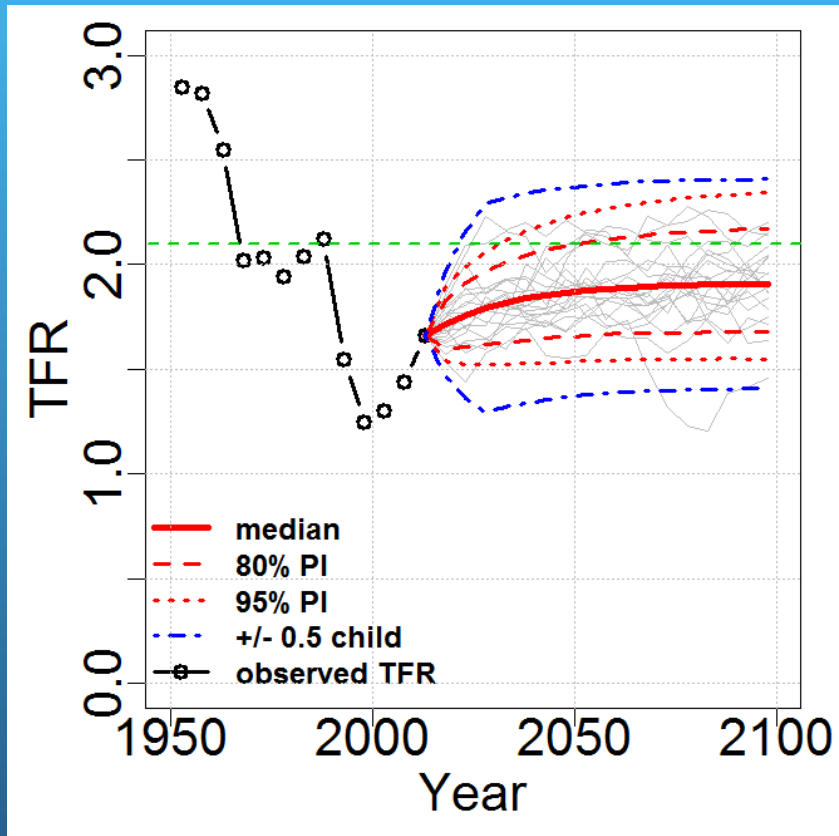


Total population

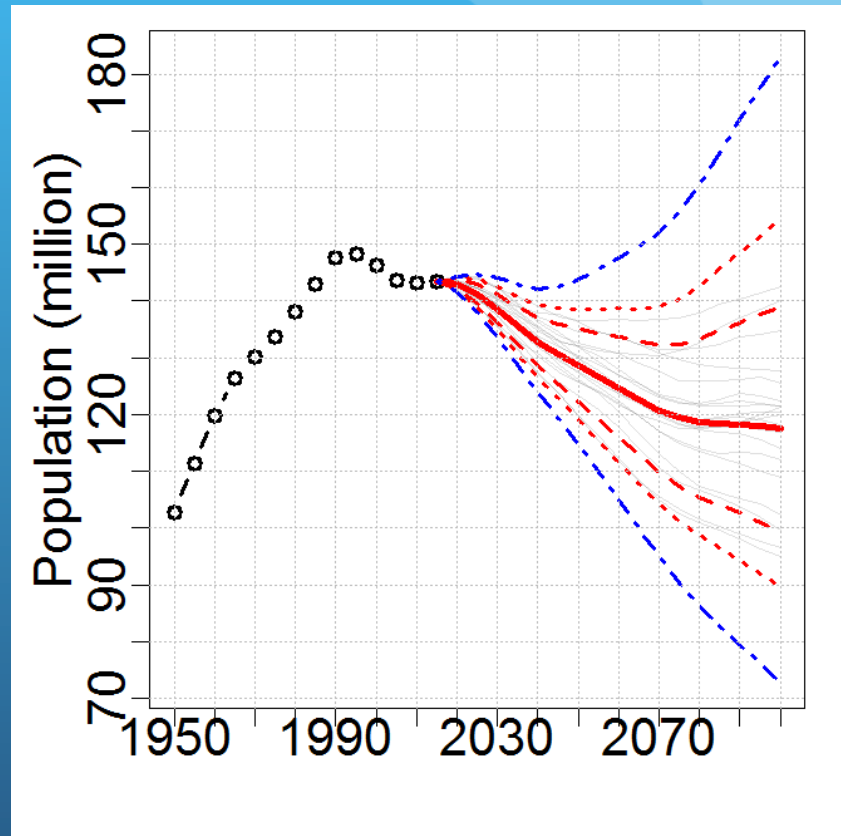


Russian Federation

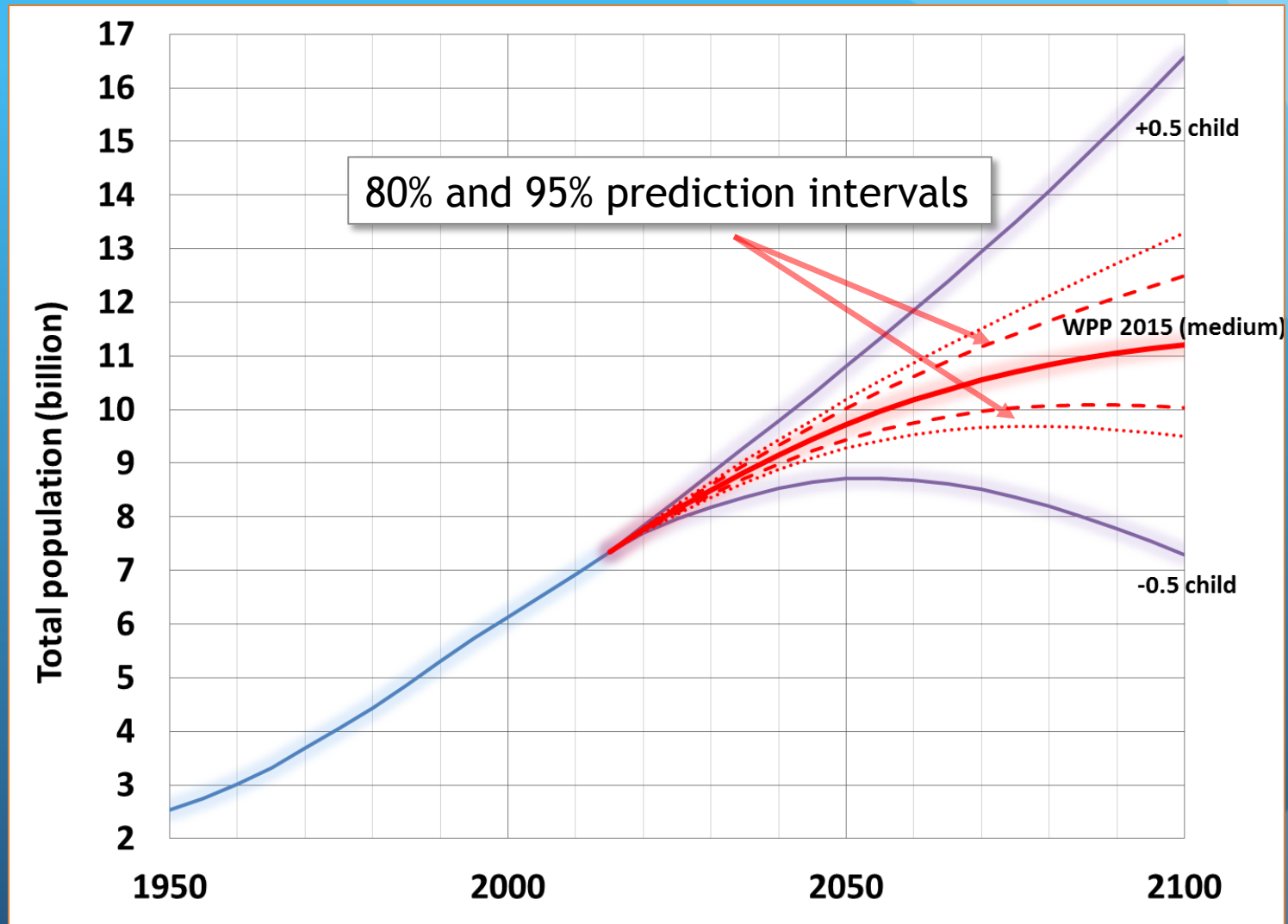
Total fertility rate



Total population



World population projections



Source: United Nations, *World Population Prospects: The 2015 Revision*, 2015

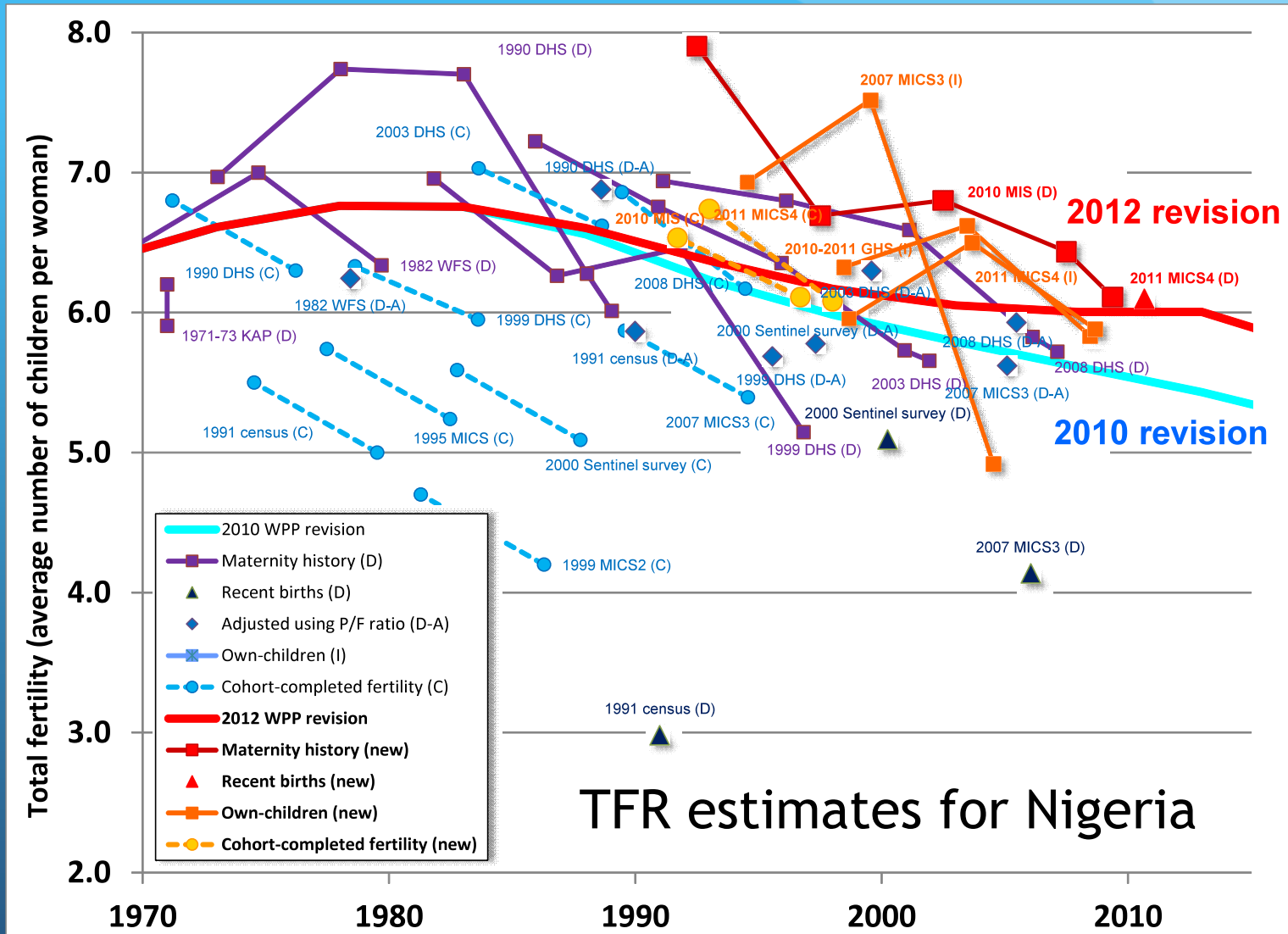
What have we learned?

- UN fertility variants (+/- half child):
 - Overstate the “uncertainty” of future trends at the global level, and also for some low-fertility countries (TFR < 2)
 - Understate the “uncertainty” of future trends for high-fertility countries (TFR > 3)
- World population growth
 - 95% prediction interval for 2050: 9.3 - 10.2 billion
 - 95% prediction interval for 2100: 9.5 - 13.3 billion
 - Population stabilization unlikely in this century, but not impossible (probability ~23%)

Additional sources of uncertainty

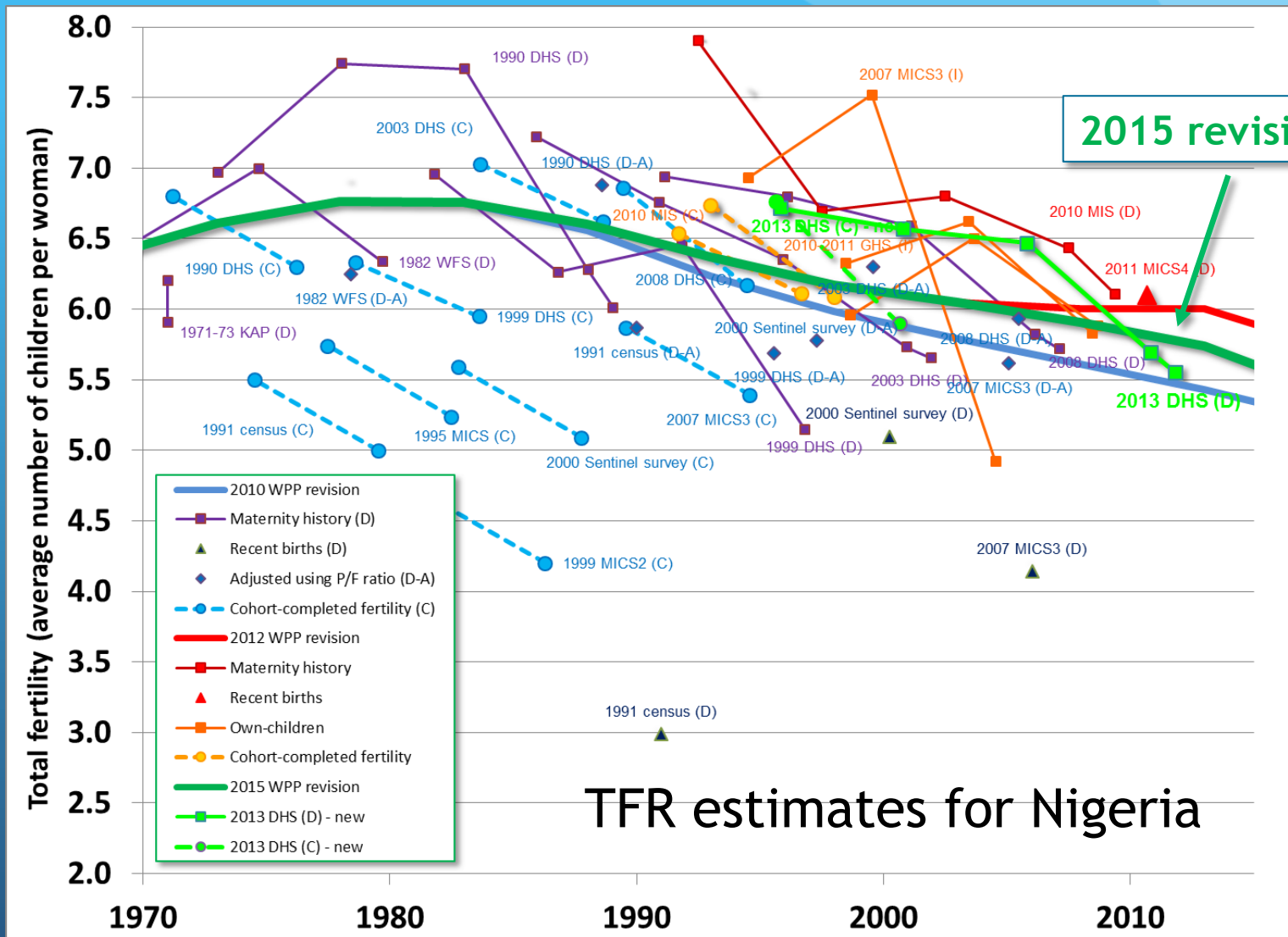
- Baseline population and current levels of fertility, mortality and migration
- Model specification (e.g., asymptotic rate of increase in e_0)
- Future age patterns of fertility and mortality
- Future path of the HIV/AIDS epidemic
- Future sex ratios at birth
- Future trends in international migration

Uncertainty about the past and present



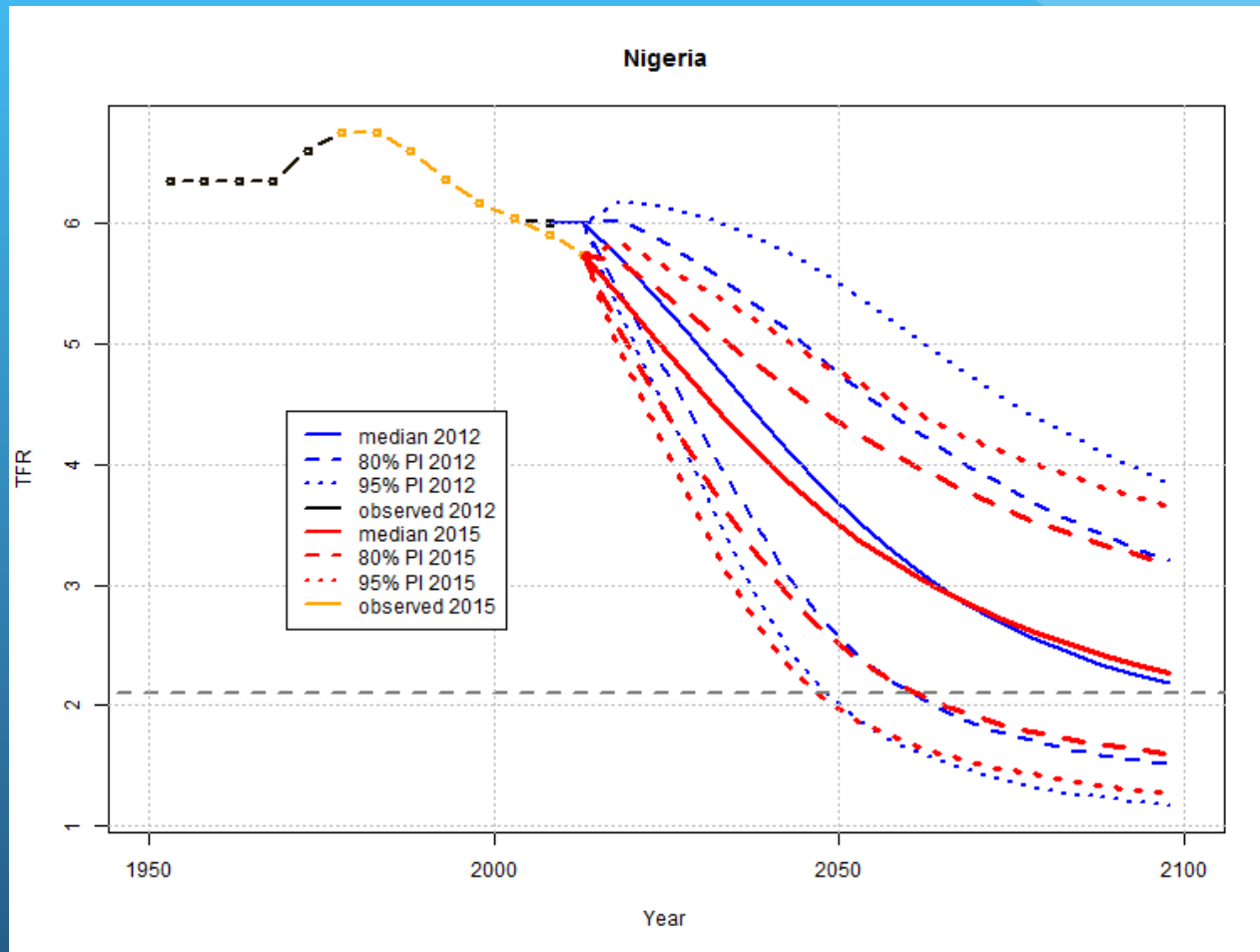
Source: United Nations, *World Population Prospects: The 2012 Revision - Methodology*, 2014

Uncertainty about the past and present



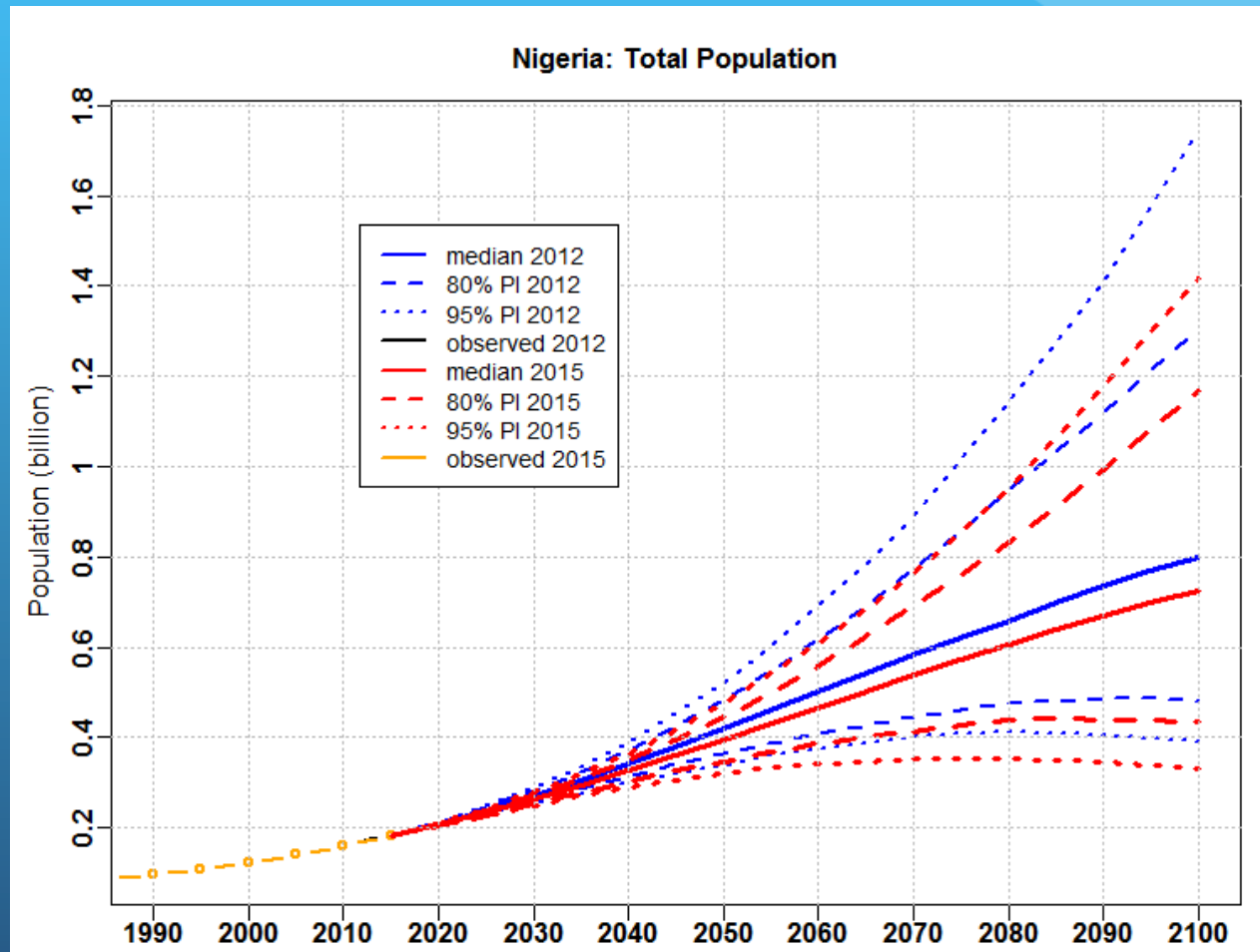
Source: United Nations, *World Population Prospects: The 2015 Revision*

Implication of revised estimates for projection of fertility



Source: United Nations, *World Population Prospects: The 2015 Revision*

Implication of revised fertility for projection of population



Source: United Nations, *World Population Prospects: The 2015 Revision*

Summary

- Population projections by the United Nations are derived from models of future trends in the demographic components of change, in particular fertility and mortality
- UN projection models have a strong basis in demographic theory; for each country, the models are calibrated using data from the country itself and, especially when data are sparse, from other countries as well
- Uncertainty of the UN population projections is reflected in traditional variants and scenarios; the two latest revisions have also employed a new method based on the Bayesian hierarchical model to derive probabilistic statements about plausible future trends
- Work on the probabilistic assessment of uncertainty is ongoing and could benefit from further efforts to incorporate additional sources of projection uncertainty, including that which derives from the uncertainty of current estimates

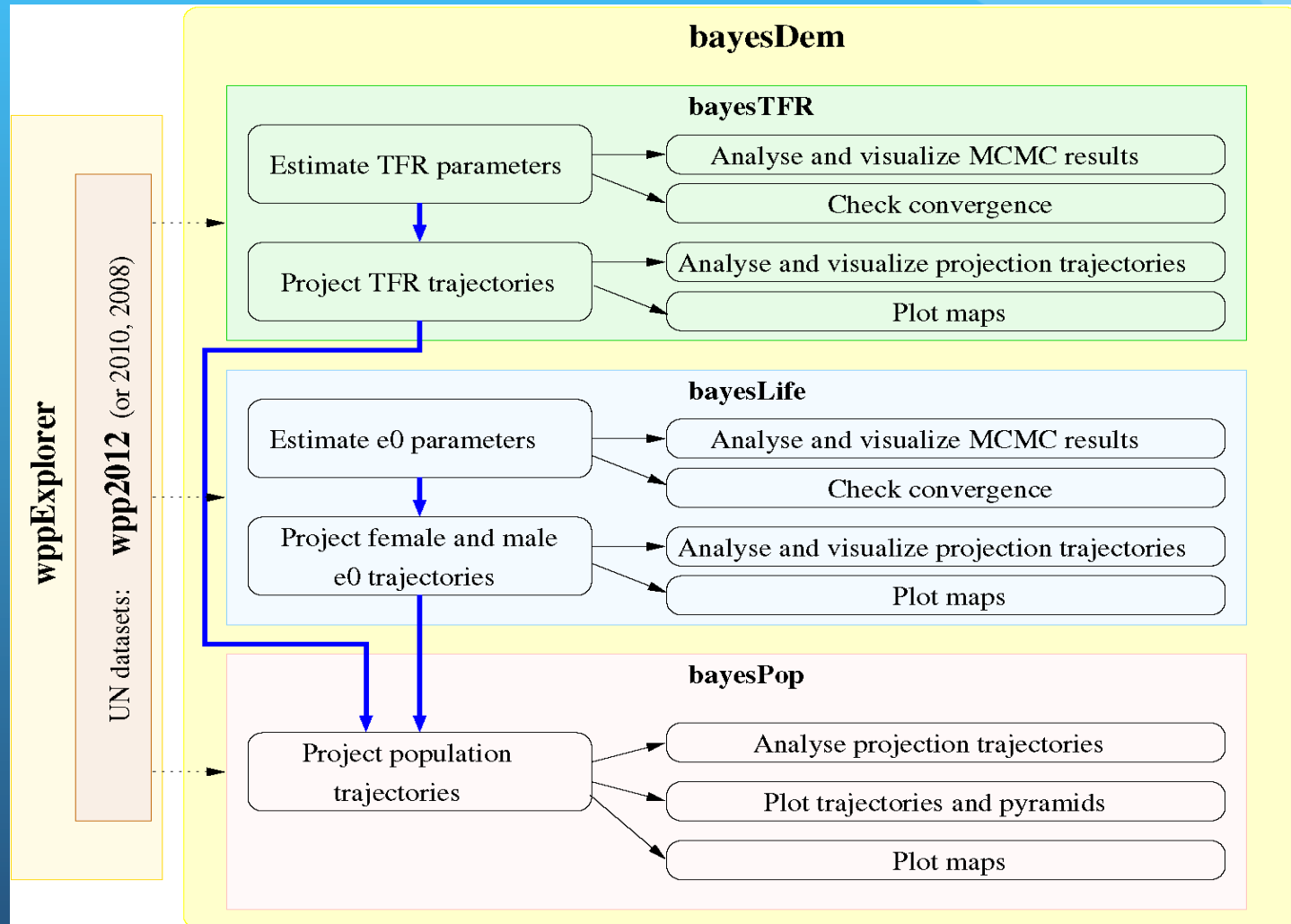
Acknowledgements

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- The probabilistic projections are the product of ongoing research and collaboration between the UN Population Division and Professor Adrian Raftery (Department of Statistics, University of Washington) and his team of students and collaborators working on the BayesPop Project, including Leontine Alkema, Jennifer Chunn, Bailey Fosdick, Nevena Lalic, Jon Azose and Hana Ševčíková

R packages: Free, open source, and available at <http://cran.r-project.org>

- Probabilistic projections of total fertility rate: **bayesTFR**
- Probabilistic projections of life expectancy at birth: **bayesLife**
- Probabilistic population projections: **bayesPop**
- Graphical user interface: **bayesDem**, **wppExplorer**
- UN datasets: **wpp2015 (forthcoming)**, **wpp2012**, **wpp2010**, **wpp2008**

R packages: A roadmap



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