Session IV:
Projecting the level and pattern of fertility

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Population Estimates and Projections Section

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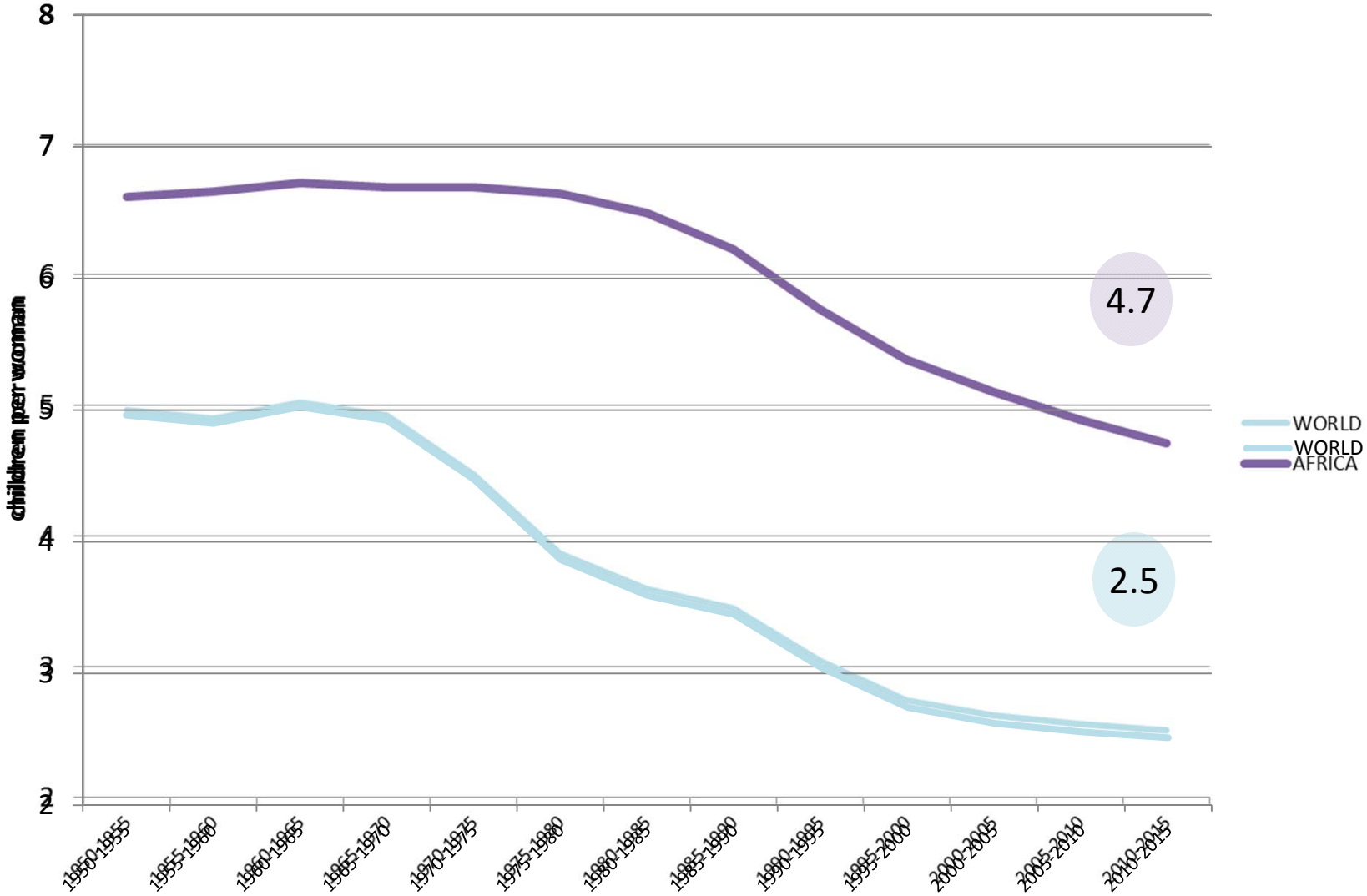
Outline

I. Projecting the level of fertility:
   a. Overview
   b. Establishing the baseline of fertility
   c. The United Nations models
   d. The US Bureau of Census model

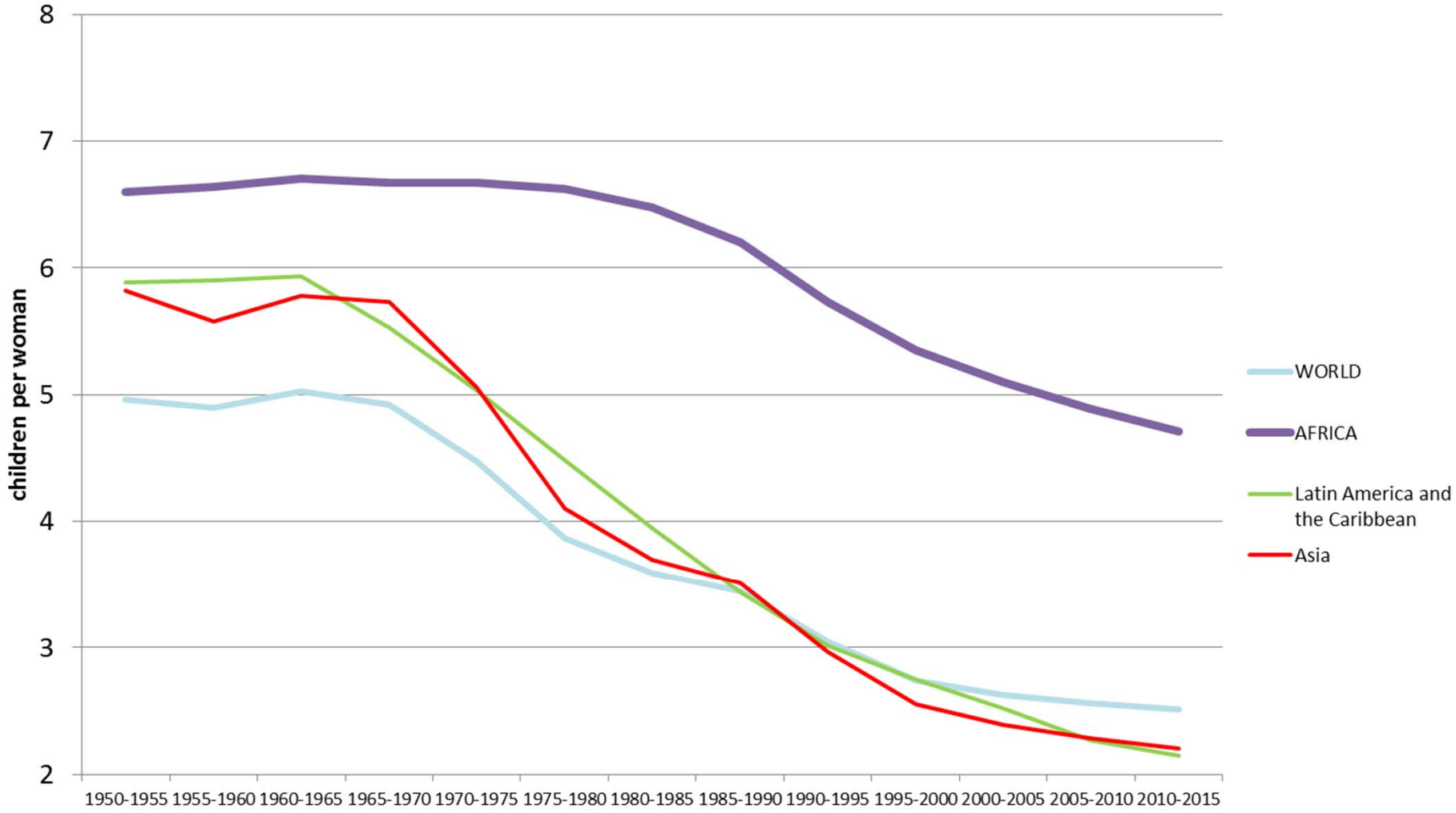
II. Projecting the age pattern of fertility:
   a. Overview
   b. Establishing the baseline of age patterns
   c. Projection options

Projecting the level of fertility:
a. Overview

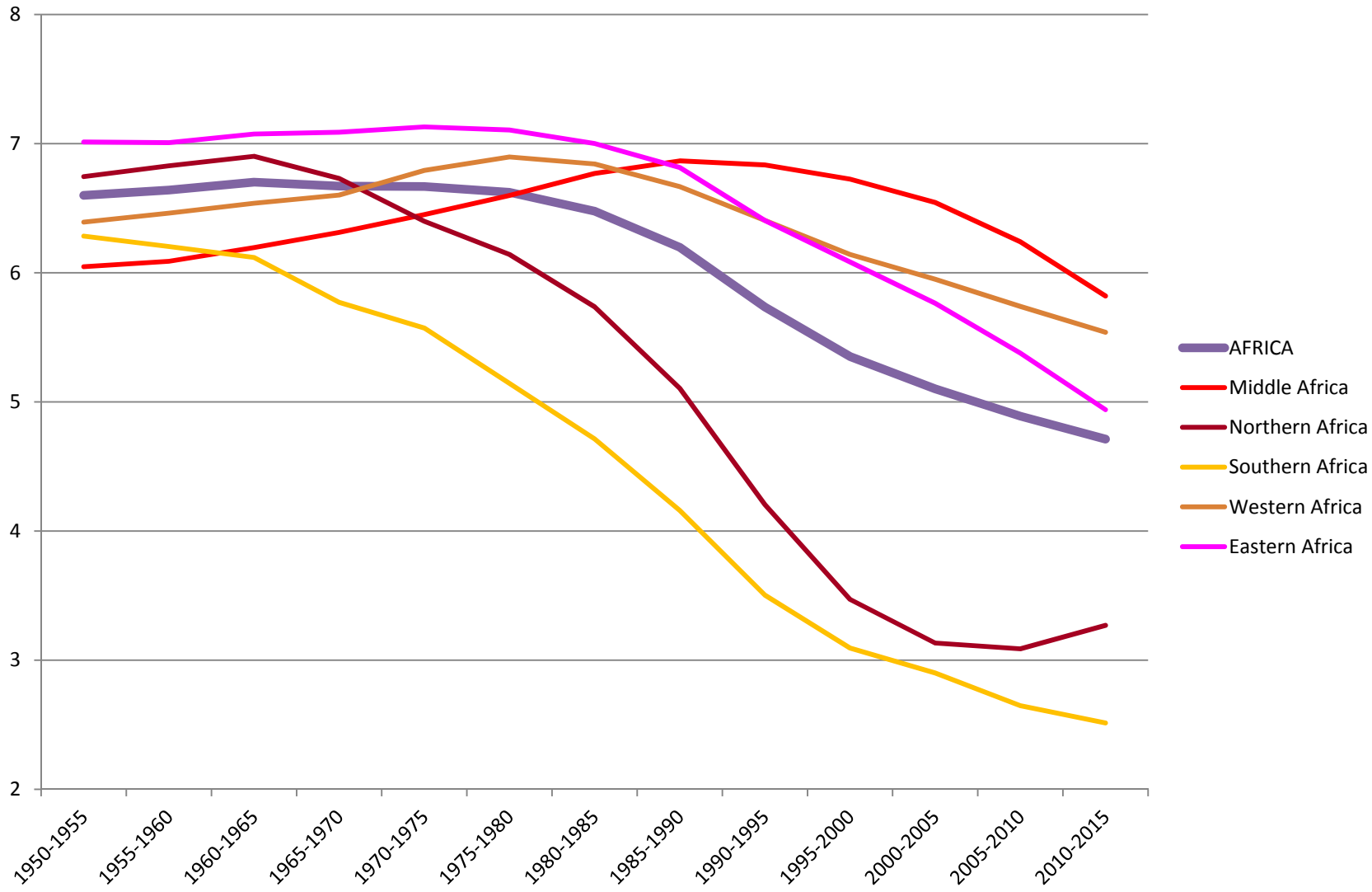
Total Fertility
1950-2015 estimates



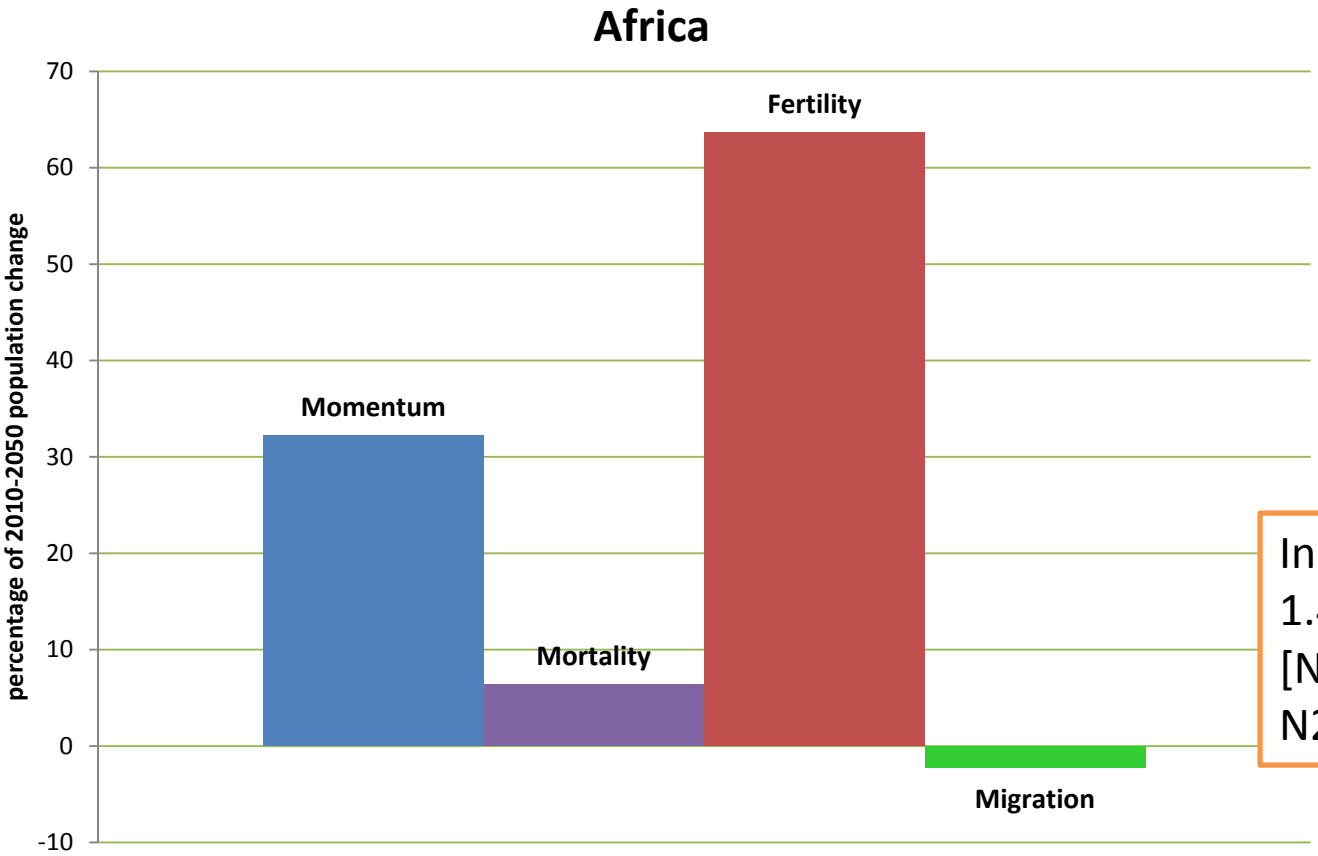
Total Fertility
1950-2015 estimates



Total Fertility
1950-2015 estimates



In many countries, fertility is the most important factor influencing future population growth. In Africa, for example, it has been estimated that fertility will be responsible for around 64 % of the population growth between 2010 and 2050



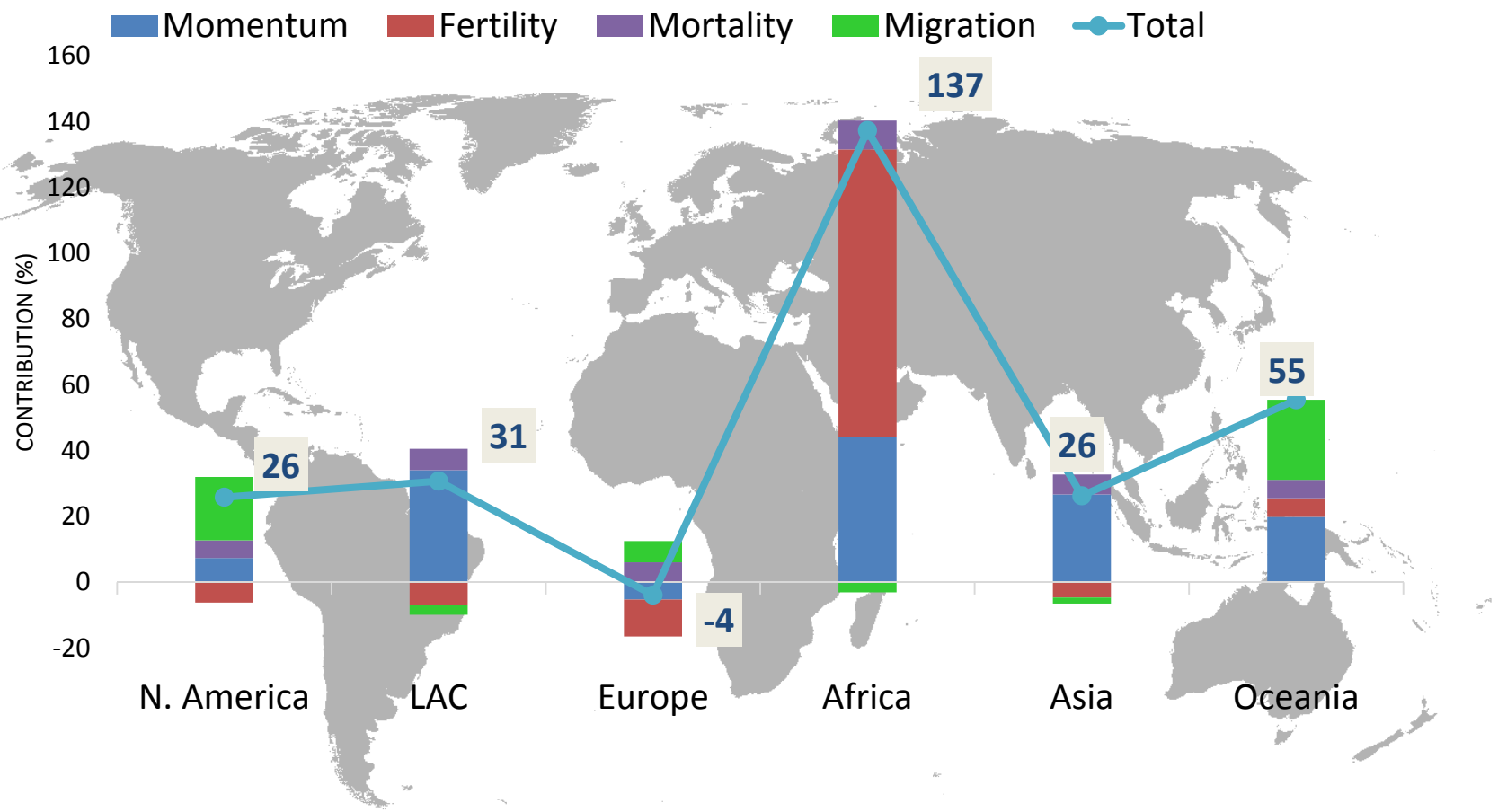
Contribution of demographic components to 2010-2050 population growth in Africa (per cent) (United Nations projections)

Increase 2010-2050 = 1.4 billion
[N2010 = ~ 1.05 billion
N2050= ~ 2.5 billion]

United Nations, Department of Economic and Social Affairs, Population Division (2015). Demographic Components of Future Population Growth: 2015 Revision

Contribution of demographic components to 2010-2050 population growth

as percentage of population in 2010

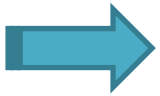


Fertility levels and trends depend largely on social and cultural factors, such as social norms on reproduction and contraception, individuals' desired family size, access to family planning, etc.

- 1. Observe and interpret past trends carefully ⇉ 2. make assumptions about future trends

Three steps:

1. Observe recent levels and trends
2. Compare recent trends with similar ones from the past (in the same or other populations)
3. Make inferences as to a plausible course of fertility development



Pay attention to recent irregularities:

- Check for data issues
- Fluctuations
- Exceptions (temporary postponement of marriage, wars, etc.)

Assumptions about fertility projections

Examples:

“An increase in fertility is assumed [from 2013]. Greater increases are assumed during the first 5-year periods, until reaching very small increase at the end of the projection period. TFR increases from 1.71 to 1.96 over the span of the projection” [35 years]. Cuba (2015)

“The national estimated Total Fertility Rate (TFR) of 3.9 children per woman (…) was assumed to decline linearly to 2.4 to 2041”. Namibia (2014)

“Fertility has declined (…) though the levels and hence the magnitude of the decline may be debatable (…). Officially published and re-estimation figures suggest that the fertility decline between 2001 and 2011 appeared to be less steep than during the period 1980-2001. It was therefore assumed in all the scenarios that total fertility rate will continue to decline slowly during the period 2011 to 2016 at the same magnitude of the decline in 2001-2011 (…). … it was assumed that total fertility will stabilise during the period 2016-2026 at the level in 2016.”. Botswana (2015)

Projecting the level of fertility:
b. Establishing the baseline of fertility

To measure the level of fertility we compute the:

Total Fertility Rate (TFR)

- *TFR* is independent of the effect of the age structure.
- *TFR* gives the number of births that women give birth to.
- *TFR* is the standard way to compare fertility levels across countries and time.

$$TFR = \sum_{x=15-19}^{45-49} ASFR \cdot 5$$

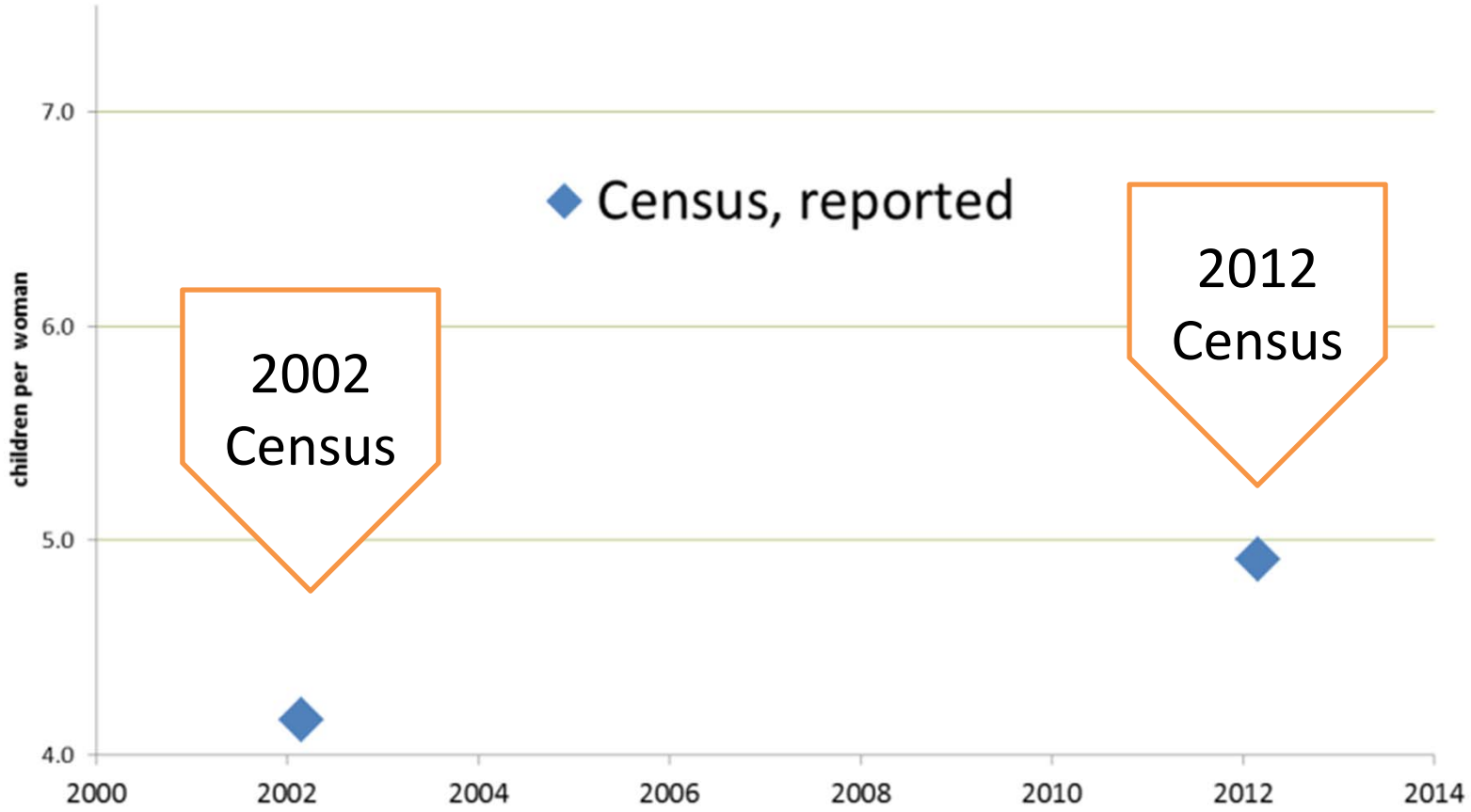
Interpretation

The number of children a woman ***would have if*** she lived from age 15 to age 50 and experienced the ASFRs of the period in question throughout her reproductive life.

> An example of a synthetic cohort > a measure of period fertility

May be subject to the *tempo* effect: a change in the timing of births produces an apparent and temporary change in fertility level

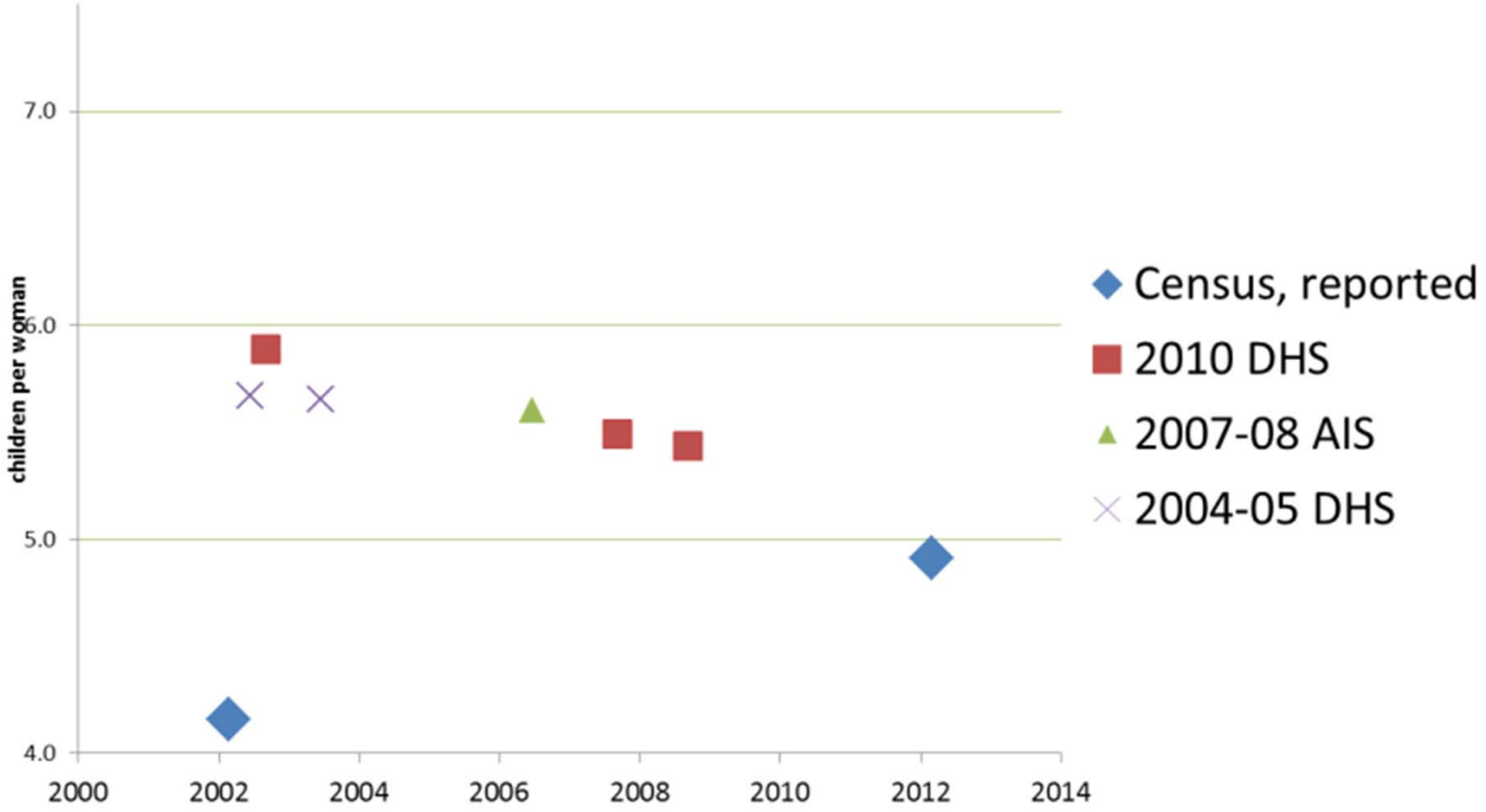
Direct estimates of TFR (census reported), 2002 and 2012



Establishing a 2012.5 baseline for fertility projection - example

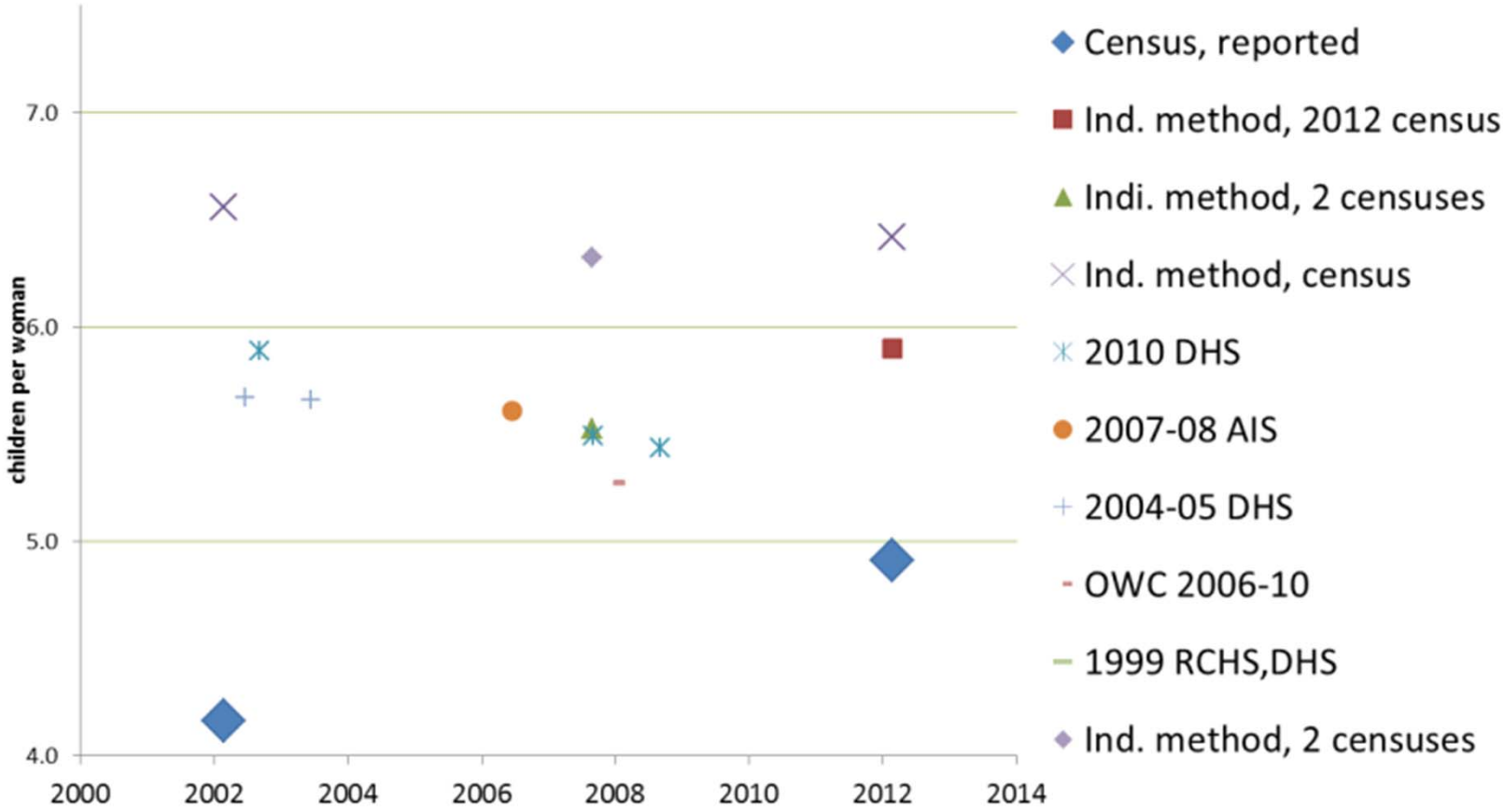
Caution! Quality assessment needed

Direct estimates of TFR (census, surveys), 2002 to 2012



Caution! Quality assessment needed

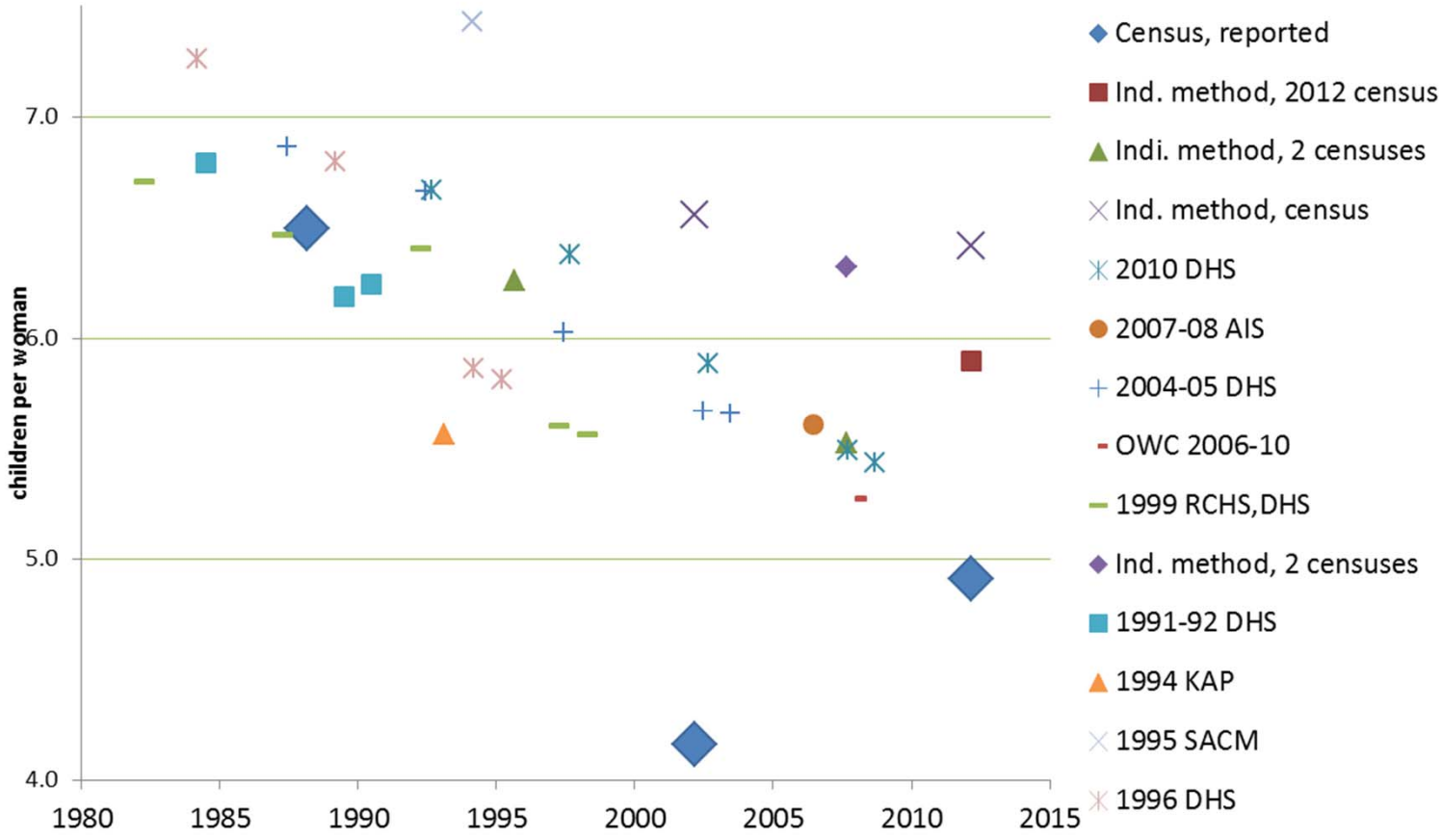
Direct & indirect estimates of TFR (census, surveys), 2000-2015



Based on national report

Caution! Quality assessment needed

Direct and indirect estimates of TFR, 1980-2012



Based on national report

Caution! Quality assessment needed

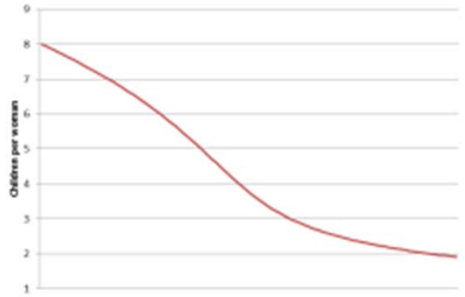
Projecting the level of fertility:
c. The United Nations models

- Two models of fertility projection:
  - **High and Medium-fertility countries**: until 2015 had had no or an incipient fertility decline (high) or fertility has been declining but were still above 2.1 children per woman in 2010-2015
  - Low-fertility countries: total fertility is at or below 2.1 children per woman in 2010-2015.

- Fertility projected through a transition from high to low levels
- Fertility modelling approach used in *World Population Prospects: the 2008 Revision* for high- and medium-fertility countries

- Uses a double-logistic function (similar model as for mortality).
- Not the level itself, but the rates of change are modeled.
- Incorporates the observation that during the demographic transition, fertility first changed slowly, then decline accelerated and finally decelerated.

2-phase process modeled by 2 logistic functions
(one approaching an upper limit, and second one approaching a lower limit)



2-phase process modelled by 2 logistic functions
(one approaching an upper limit, and second one approaching a lower limit)

- Sum of two 3-parameters logistic growth pulses for annual declines in TFR

  General pattern:

$$annual\ decline\,(TF) = \frac{k_1}{1+\exp[-\frac{Ln(81)}{\Delta t_1}(TF - t_{m1})]} + \frac{k_2}{1+\exp[-\frac{Ln(81)}{\Delta t_2}(TF - t_{m2})]}$$

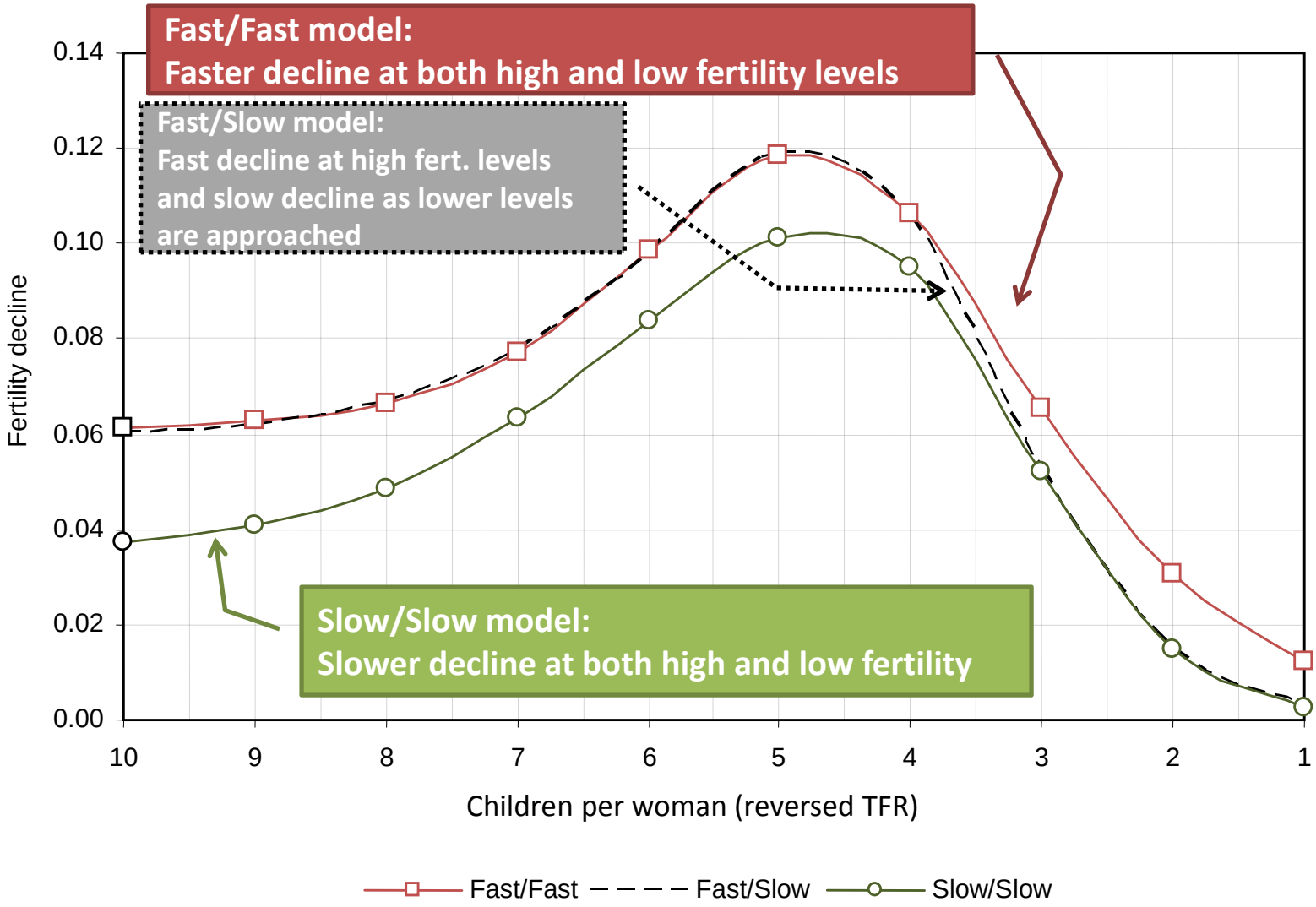
$\boldsymbol{\Delta TF}$

Projecting the level of fertility: c. The UN models

- We model variations of the **general pattern,** associated with differences in pace of fertility decline at the beginning and at the end of the fertility transition.
- We create groups based on similar trends of pairs of level of fertility and fertility declines, which results in…
- **Three models of fertility decline: *Slow/Slow, Fast/Slow, Fast/Fast.***
- The parameters of the two logistic functions vary across models:

Parameter	*Slow/Slow*	*Fast/Slow*	*Fast/Fast*
k_1	-0.112730	-0.160976	-0.252160
Δt_1	5.027900	4.341125	4.014580
t_{m1}	5.768830	5.064407	5.166560
k_2	0.147540	0.220137	0.312840
Δt_2	2.754150	3.022537	4.316520
t_{m2}	3.211780	3.523051	3.941380

- 3 Models of fertility decline:



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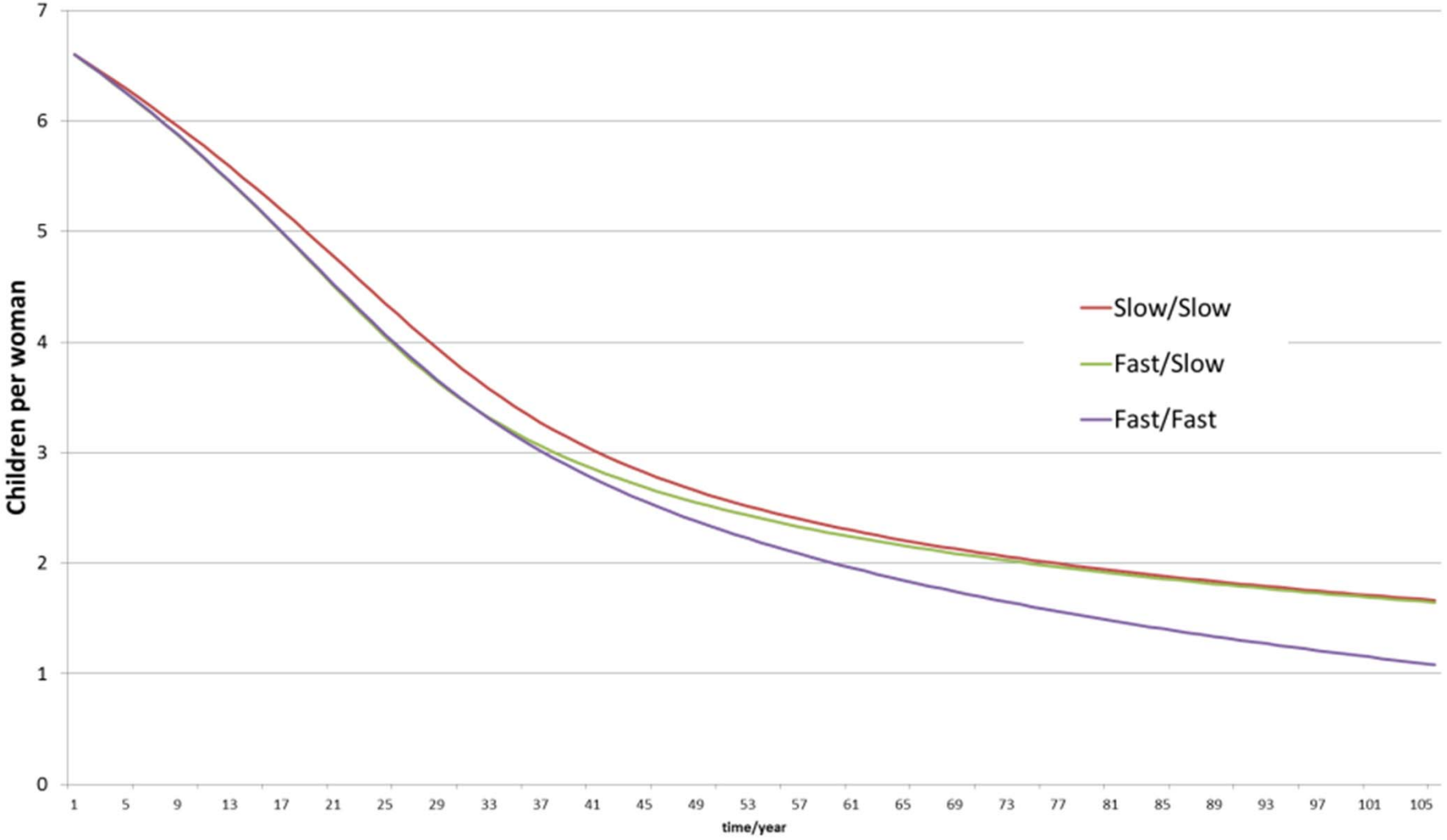
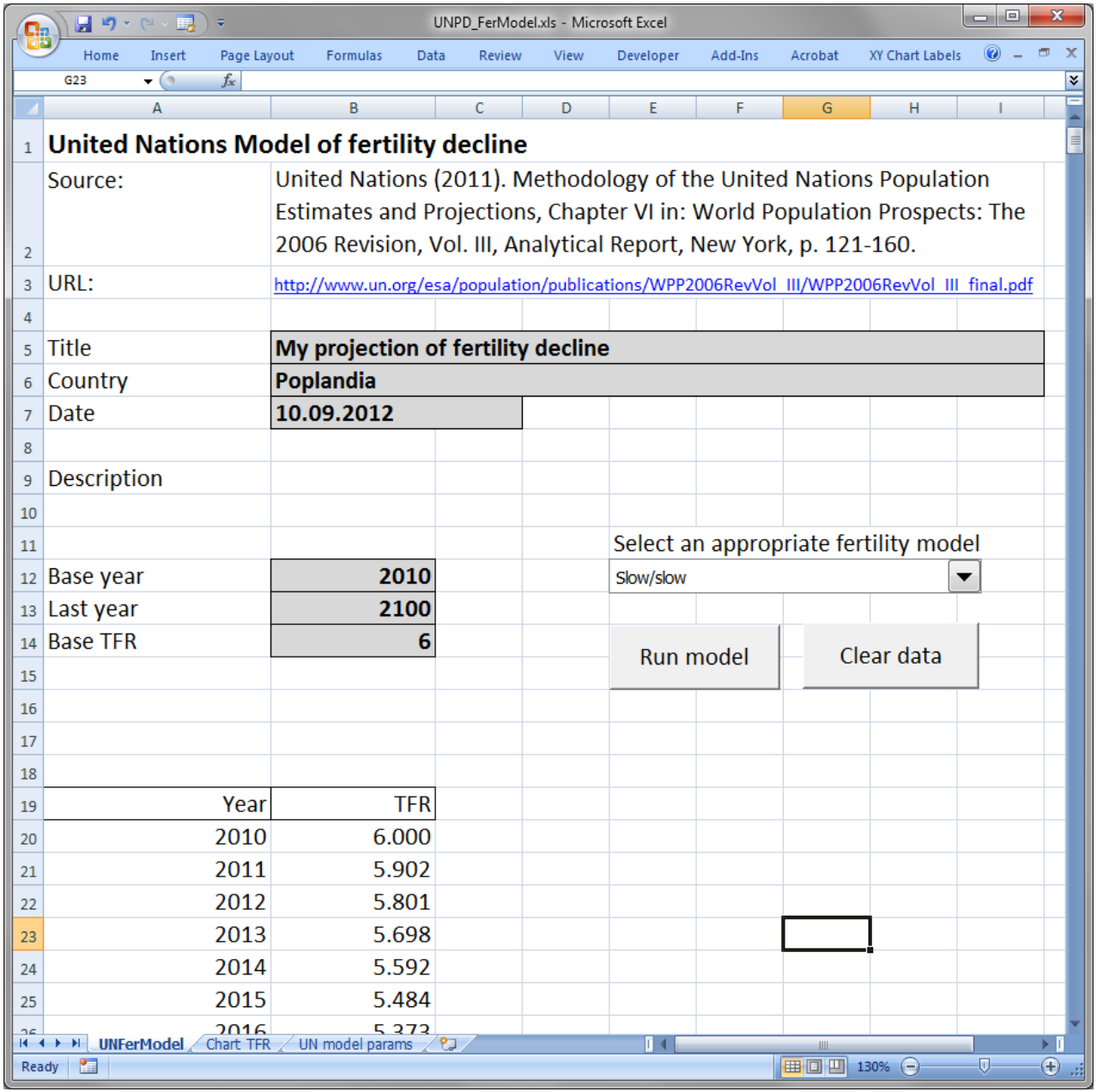




Tool to use the three models of fertility decline:

UNPD_FerModel.xls

Projecting the level of fertility:
d. The US Bureau of Census model

- Interpolates and extrapolates Total Fertility rates: **TFRLGST.xls**

- Fits a logistic function to 2 to 17 TFRs representing past trends, given an upper and a lower asymptotes. >>
  - Input data

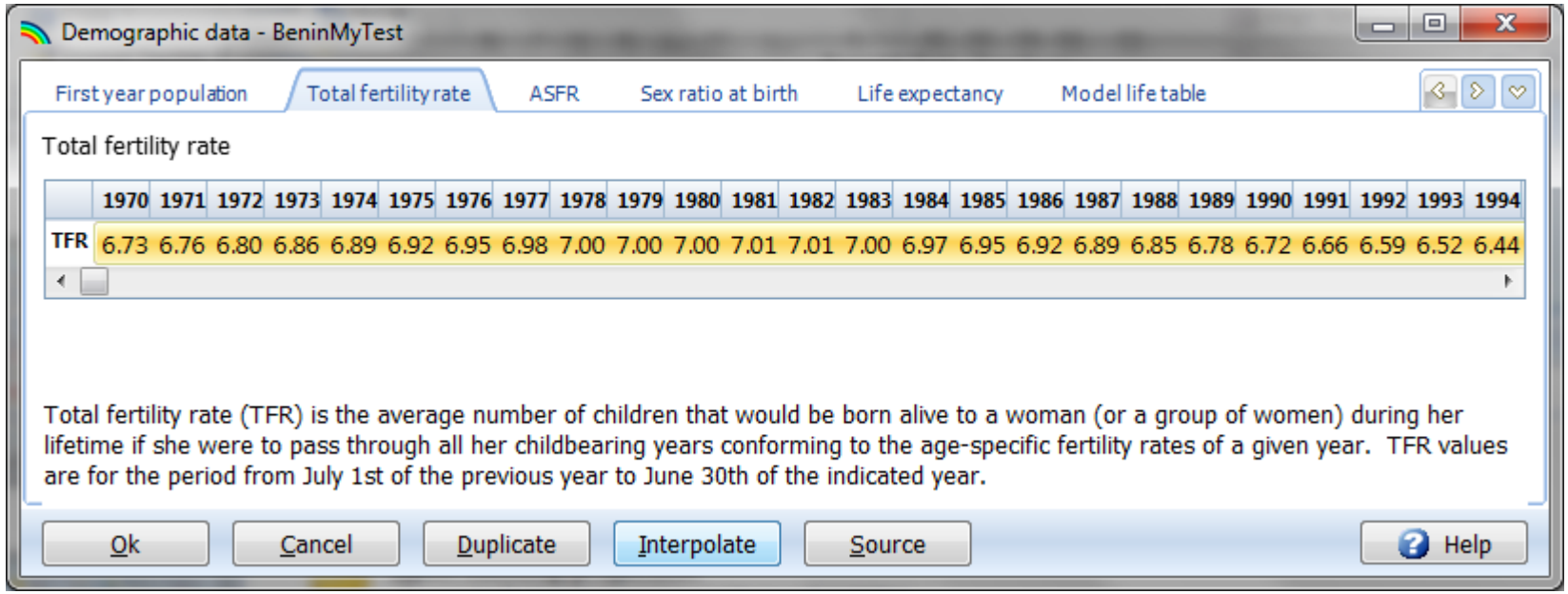
Microsoft Excel - TFRLGST_AFG.xls [Compatibility Mode]

	A	B	C	D	E	F	G	H
1	Table							
2	Afghanistan							
3	Interpolation and Extrapolation of the Total Fertility Rate							
4	Using a Logistic Function.							
5	----------	----------	---	----------	----------	---	----------	----------
6	Item/							
7	year	Value		Year	TFR		Year	TFR
8	----------	----------		----------	----------		----------	----------
9	Asymptotes:			2004.50	7.21		2004.50	7.21
10				2005.50	6.99		2009.50	5.71
11	Lower	3.00		2006.50	6.72		2014.50	4.04
12	Upper	8.00		2007.50	6.42		2019.50	3.27
13				2008.50	6.08		2024.50	3.06
14	Initial TFR's			2009.50	5.71		2029.50	3.01
15				2010.50	5.33		2034.50	3.00
16	1998.00	7.88		2011.50	4.96		2039.50	3.00
17	2003.00	7.39		2012.50	4.62		2044.50	3.00
18	2008.00	6.33		2013.50	4.31		2049.50	3.00
19				2014.50	4.04		2054.50	3.00
20				2015.50	3.81		2059.50	3.00
21				2016.50	3.63		2064.50	3.00
22				2017.50	3.48		2069.50	3.00
23				2018.50	3.36		2074.50	3.00
24				2019.50	3.27		2079.50	3.00
25				2020.50	3.21		2084.50	3.00
26				2021.50	3.15		2089.50	3.00
27				2022.50	3.11		2094.50	3.00
28				2023.50	3.09		2099.50	3.00
29				2024.50	3.06		2104.50	3.00
30				2025.50	3.05		2109.50	3.00
31				2026.50	3.03		2114.50	3.00
32				2027.50	3.03		2119.50	3.00
33	----------	----------		2028.50	3.02		2124.50	3.00
34				2029.50	3.01		2129.50	3.00
35				2030.50	3.01		2134.50	3.00
36				2031.50	3.01		2139.50	3.00
37	Beginning date for			2032.50	3.01		2144.50	3.00
38	results:	2004.50		2033.50	3.00		2149.50	3.00
39	----------	----------	---	----------	----------	---	----------	----------
40	TFR - Total fertility rate.							
41	Source:							
42								

Tool to use the logistic curve given for fertility decline an upper and lower asymptotes :

TFRLGST.xls

Preparing the input for Spectrum

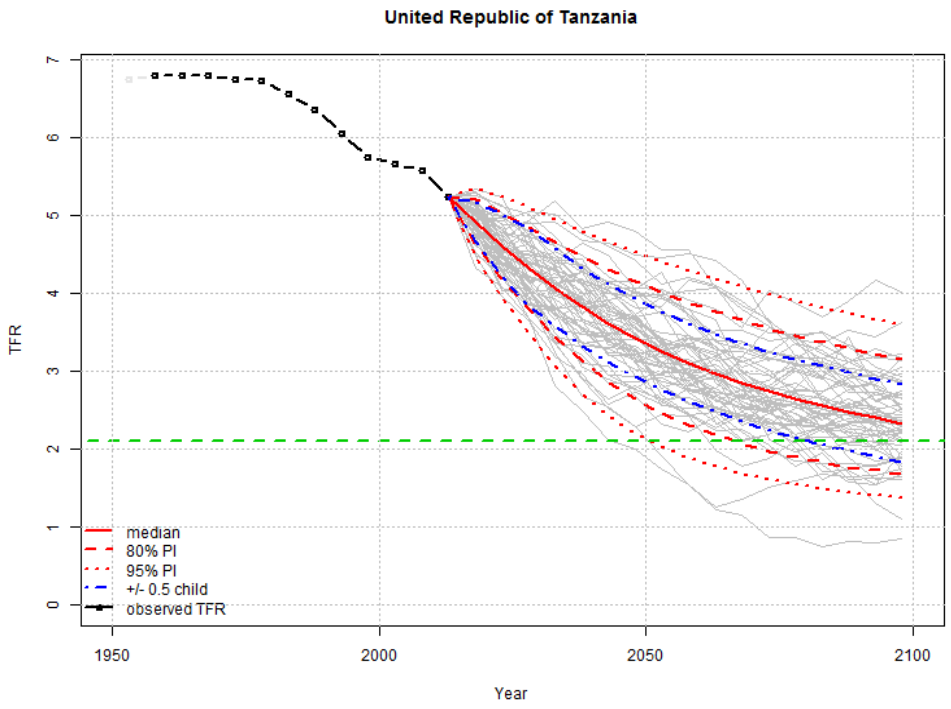


The UNPD models and simple interpolation methods are easy "ready-to-go" projection tools. However, these tools may not reflect accurately some of the recently trends observed in the African region, or the expected future trends in the fertility transition of African countries.

Country-specific models and alternative approaches to global fertility projection have been developed, but their complexity (with regards to methodology, data requirement, etc.) make their implementation challenging.

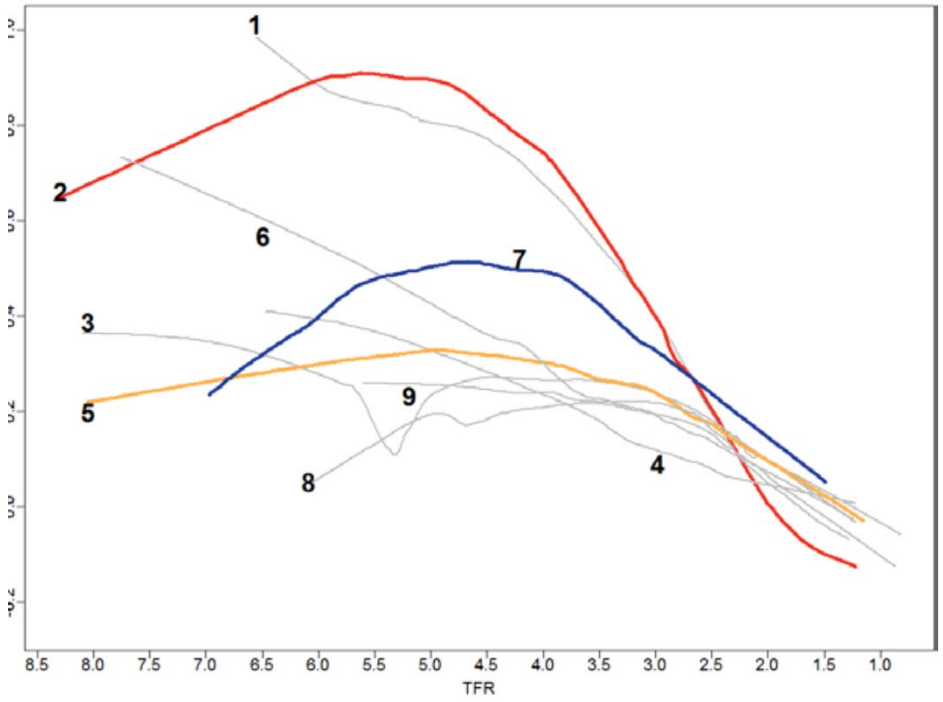
Alternative approaches to fertility projections (work in progress):

Illustration of probabilistic fertility projection based on Bayesian Hierarchical Modeling (a small selection of the probabilistic trajectories are shown)



Based on World Population Prospects: the 2015 revision

Illustration of nine clusters showing distinct patterns of pace of decline (data from 130 counties, over 60 years)



Based on World Population Prospects: the 2012 revision

Source: Gerland, P. et al (2015) Demography is not destiny: Probabilistic scenarios of future fertility change in Sub-Saharan Africa

Outline

I. Projecting the level of fertility:
   a. Overview
   b. Establishing the baseline of fertility
   c. The United Nations models
   d. The US Bureau of Census model

II. Projecting the age pattern of fertility:
   a. Overview
   b. Establishing the baseline of age patterns
   c. Projection options

Projecting the age pattern of fertility: a. Overview

To measure the age pattern (or schedules) of fertility we compute:

Age-Specific Fertility Rates (ASFRs)

- ASFRs measure the annual number of births to women of a specified age or age group per 1,000 women in that age group

$$ASFR_{x,x+n} = {}_nF_x = \frac{{}_nB_x}{{}_nW_x}$$

- Where ${}_nB_x$ refer to births to women age x to x+n (usually 5-year age groups covering the age range 15-49), during a given period, and ${}_nW_x$ refers to the mid-period population of women age x to x+n.

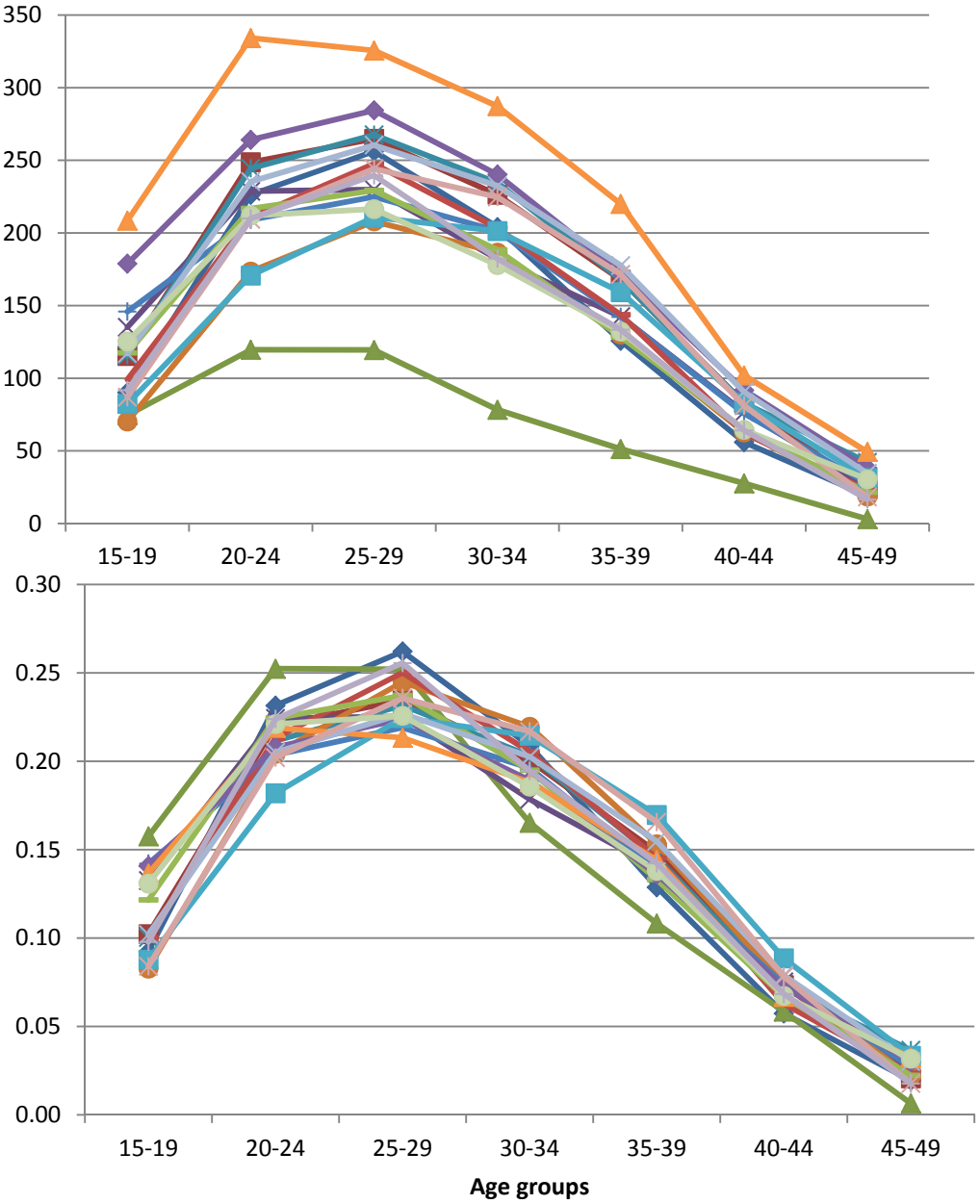
- Dividing each ASFR by the sum of all across the childbearing ages, we obtain:

Proportionate Age-Specific Fertility Rates (PASFRs)

- The sum of PASFRs = 1 (or 100)

An Excel template is available in the "**PASFRs MAC**" sheet of your exercise file

Projecting the age pattern of fertility: a. Overview - ASFRs and PASFRs



2010-2015 ASFRs

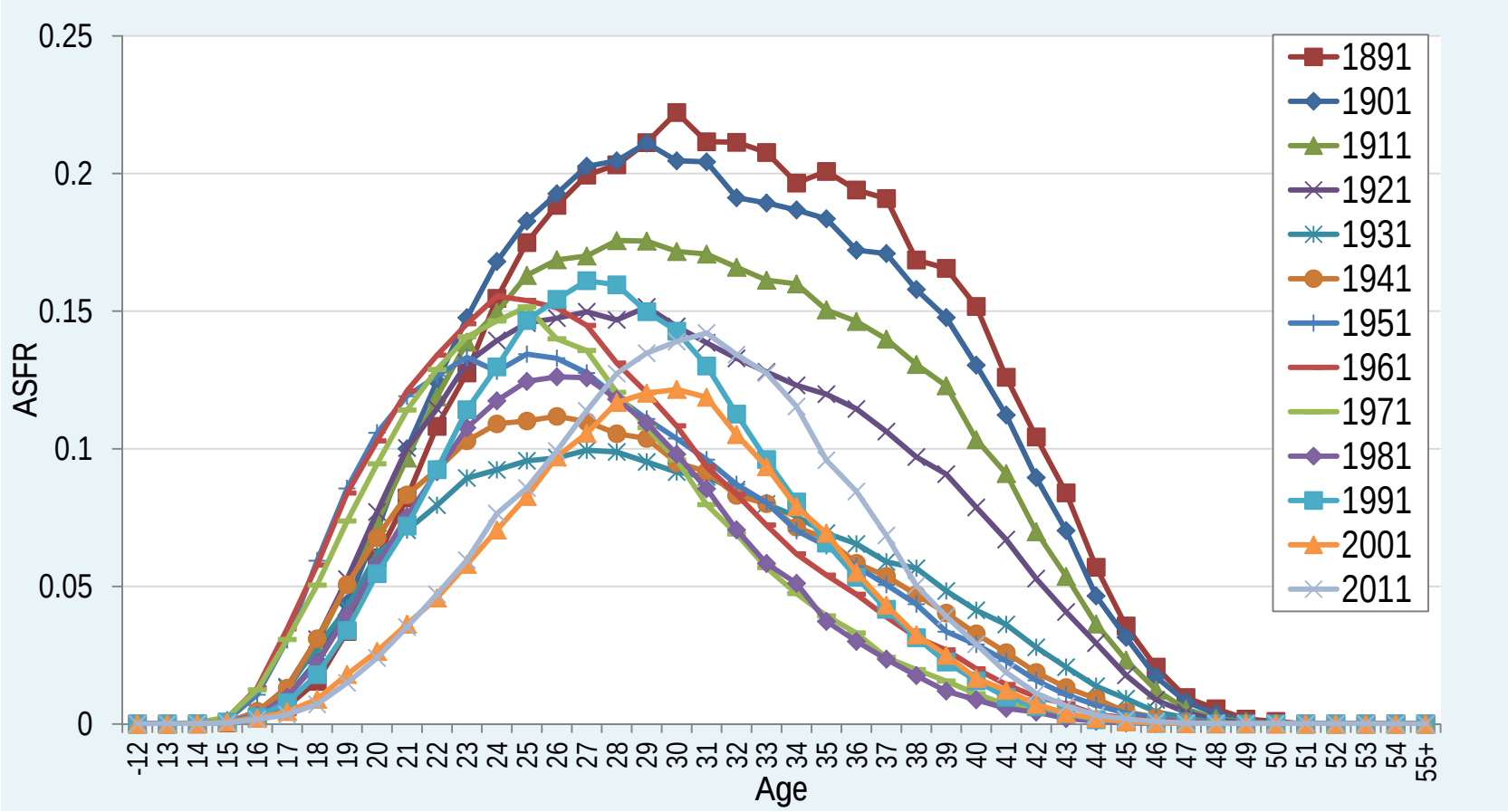
West African countries

- Benin
- Burkina Faso
- Cabo Verde
- Côte d'Ivoire
- Gambia
- Ghana
- Guinea
- Guinea-Bissau
- Liberia
- Mali
- Mauritania
- Niger
- Nigeria
- Senegal
- Sierra Leone
- Togo

2010-2015 PASFRs

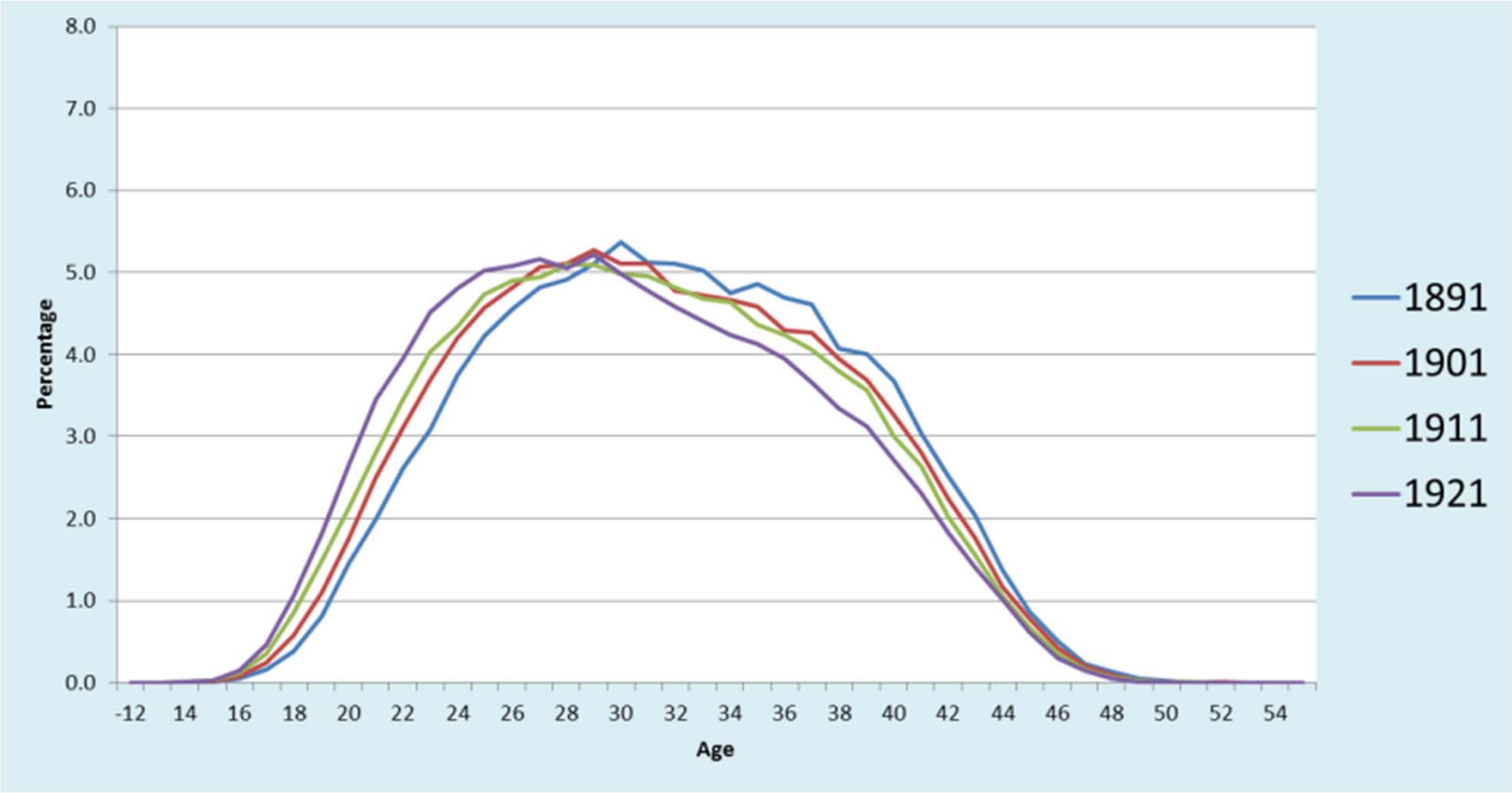
Source: World Population Prospects: the 2015 Revision

Age-Specific Fertility Rates (*ASFR*s) – Sweden, 1891-2011



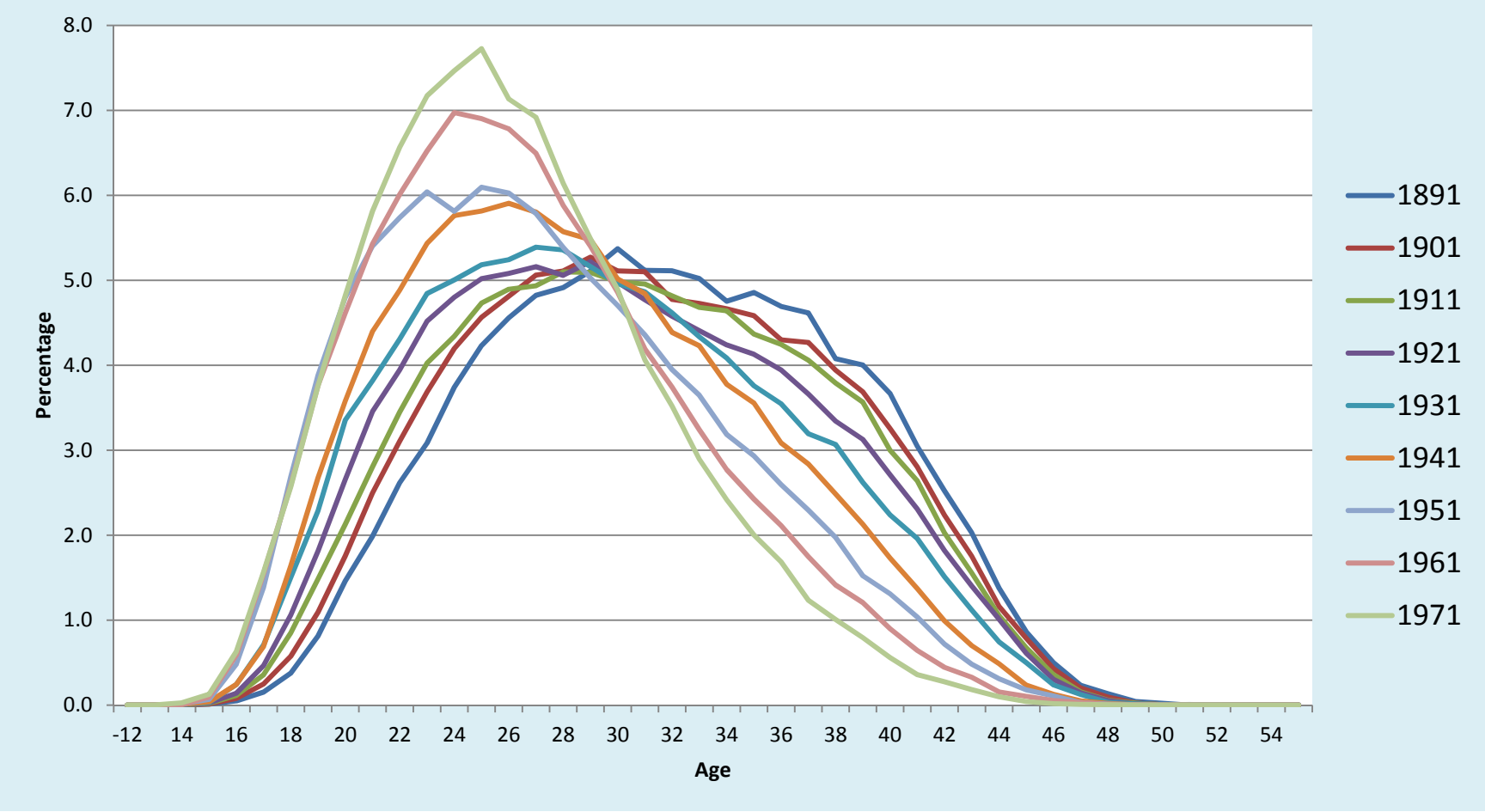
Source: Human Fertility Database

Proportionate Age-Specific Fertility Rates (*PASFR*s) – Sweden



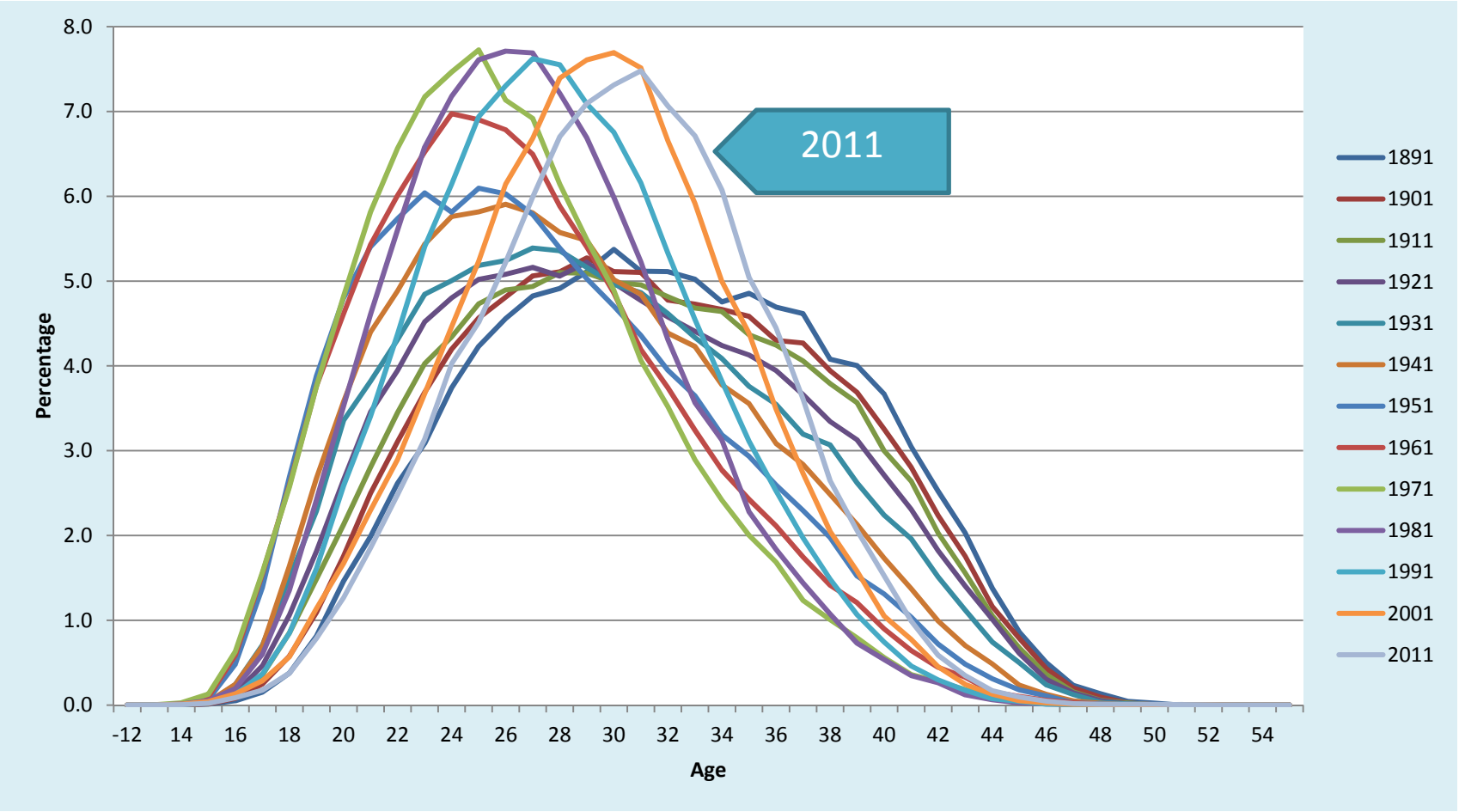
Source: Human Fertility Database

Proportionate Age-Specific Fertility Rates (*PASFR*s) – Sweden



Source: Human Fertility Database

Proportionate Age-Specific Fertility Rates (*PASFR*s) – Sweden



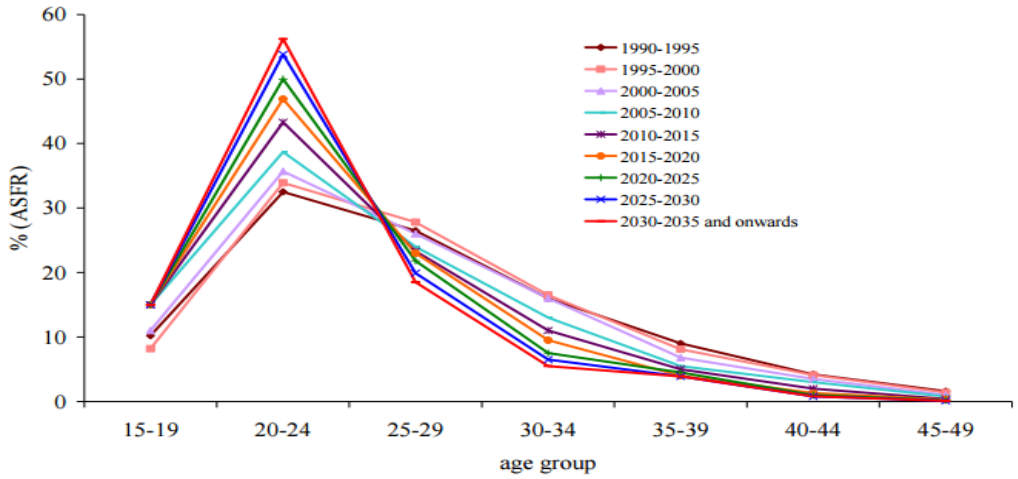
Source: Human Fertility Database

Projecting the age pattern of fertility: a. Overview - ASFRs and PASFRs

Source: Matthews et al. (2009), "Does early childbearing and a sterilization-focused family planning programme in India fuel population growth", Demographic Research, vol. 20 art. 28, pp. 693-720.

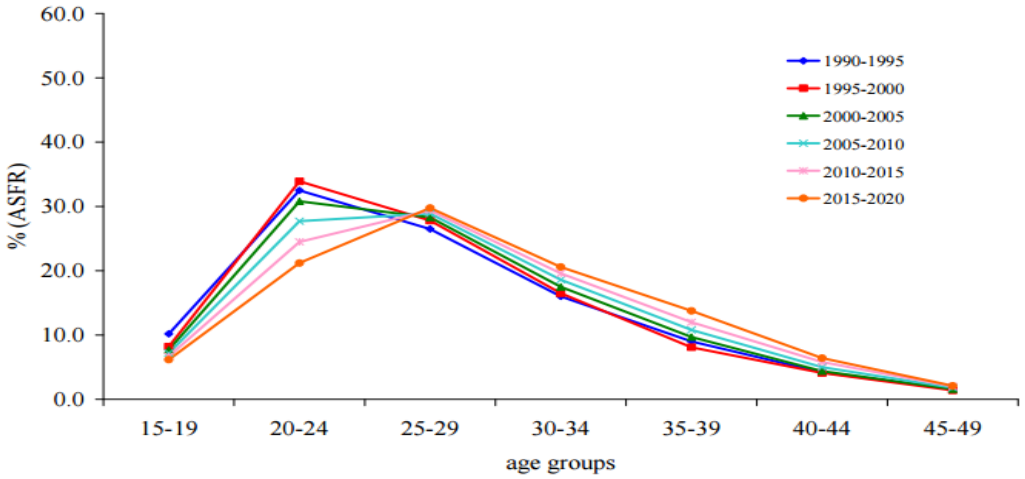
Early age patterns of fertility

Figure 4a: Assumptions for early childbearing pattern



Late age patterns of fertility

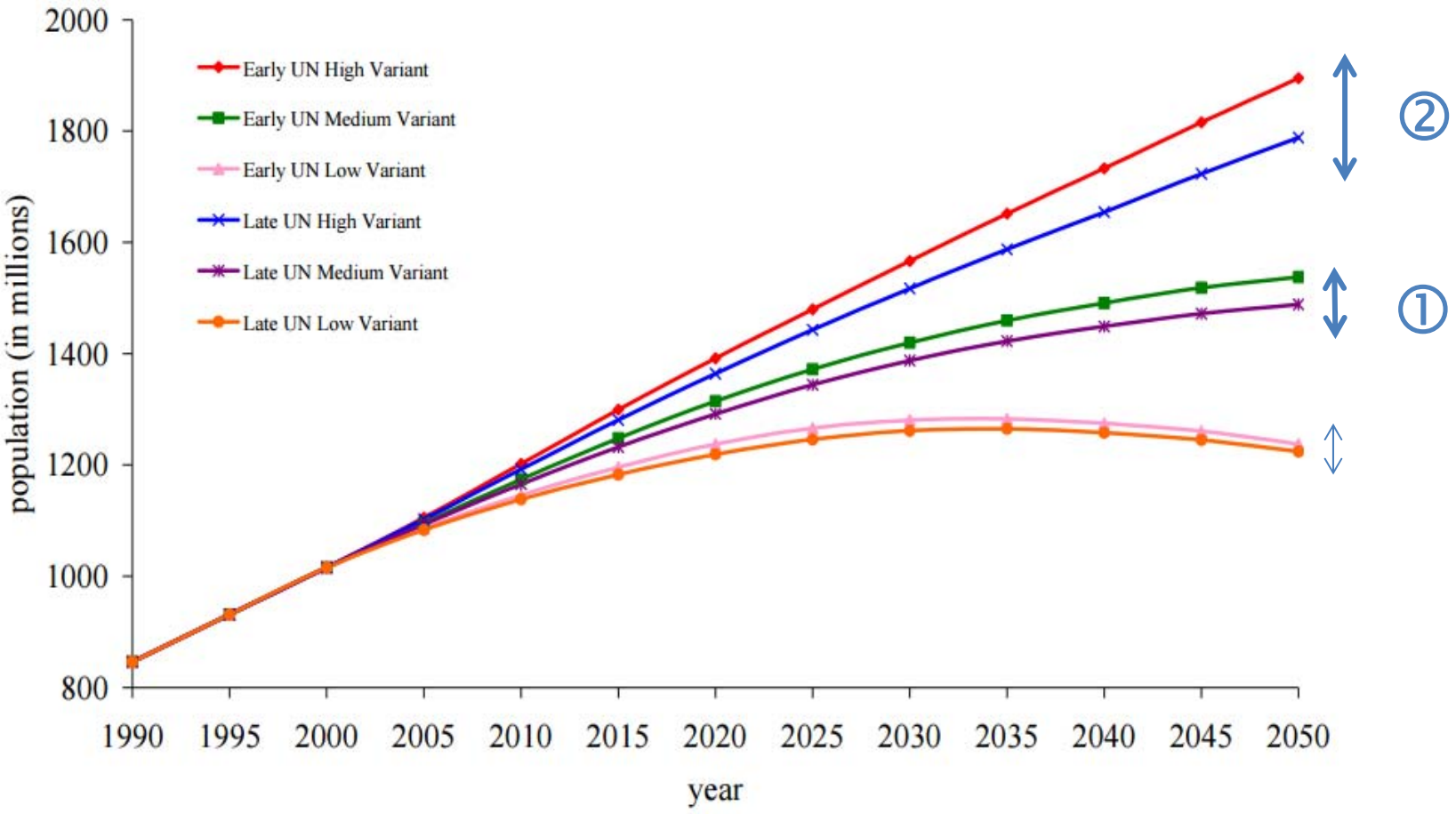
Figure 4b: Assumptions for late childbearing pattern



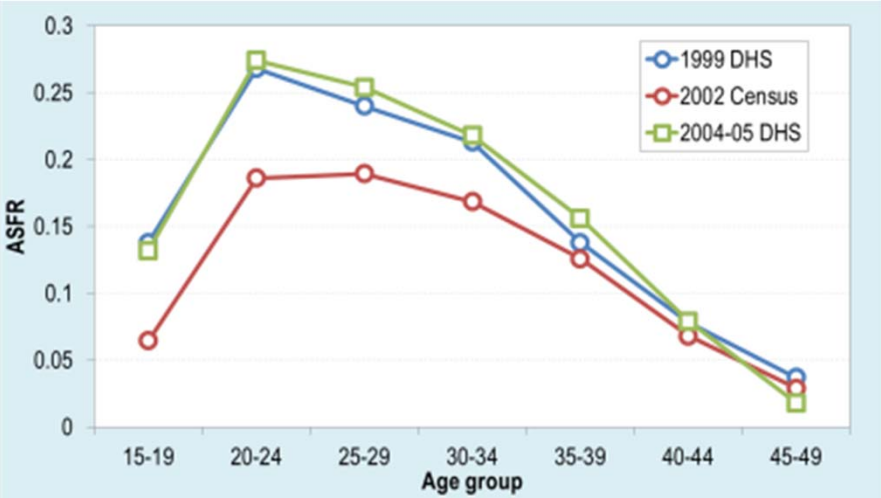
Projecting the age pattern of fertility: a. Overview - ASFRs and PASFRs

Matthews et al. (2009), "Does early childbearing and a sterilization-focused family planning programme in India fuel population growth", Demographic Research, vol. 20 art. 28, pp. 693-720.

Figure 5: Projected population of India based on early and late childbearing patterns, 1990–2050

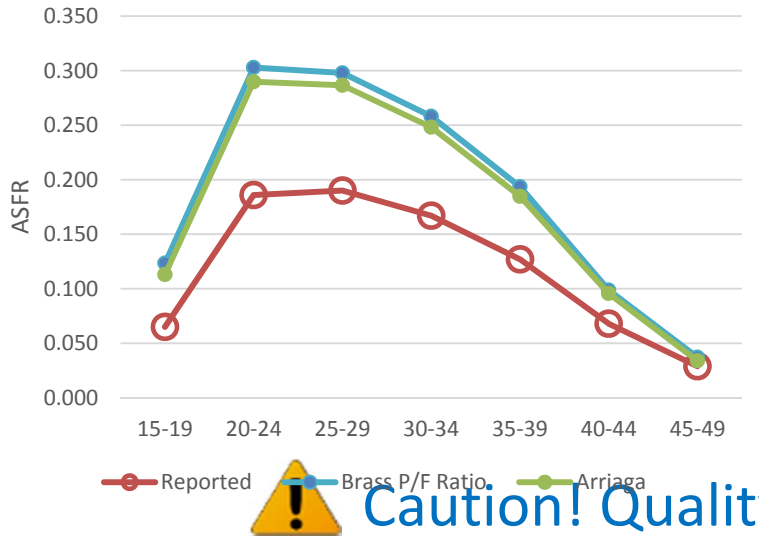


Direct and indirect estimates of ASFRs – different sources



2002 ASFRs estimates

Age group	1999 DHS	2002 Census	2004-04 DHS
15 - 19	0.138	0.064	0.132
20 - 24	0.268	0.186	0.274
25 - 29	0.240	0.189	0.254
30 - 34	0.213	0.168	0.218
35 - 39	0.138	0.126	0.156
40 - 44	0.078	0.068	0.079
45 - 49	0.037	0.029	0.018
TFR	**5.6**	**4.2**	**5.7**



	Reported	2002 census Brass P/F Ratio	Arriaga
15-19	0.065	0.123	0.113
20-24	0.186	0.303	0.290
25-29	0.190	0.298	0.287
30-34	0.167	0.258	0.248
35-39	0.127	0.194	0.185
40-44	0.068	0.099	0.096
45-49	0.029	0.037	0.034
TFR	**4.16**	**6.56**	**6.26**

Caution! Quality assessment needed

Example of quality assessment of ASFRs based on recent births data from Malawi

Age Specific Fertility Rate (ASFR)

$$nFx = \frac{nBx}{nWx}$$

nBx =Births to women age x to x+n during period

nWx =Mid-period population of women age x to x+n

Are births be classified by age of mother at birth of her child or by age of mother at the survey/census date?

If not known, assume the latter, almost universally, in censuses, data are classified by age of mother at time of census. In this case, ASFRs are shifted by ½ year as mothers were ½ year younger at the time of birth.

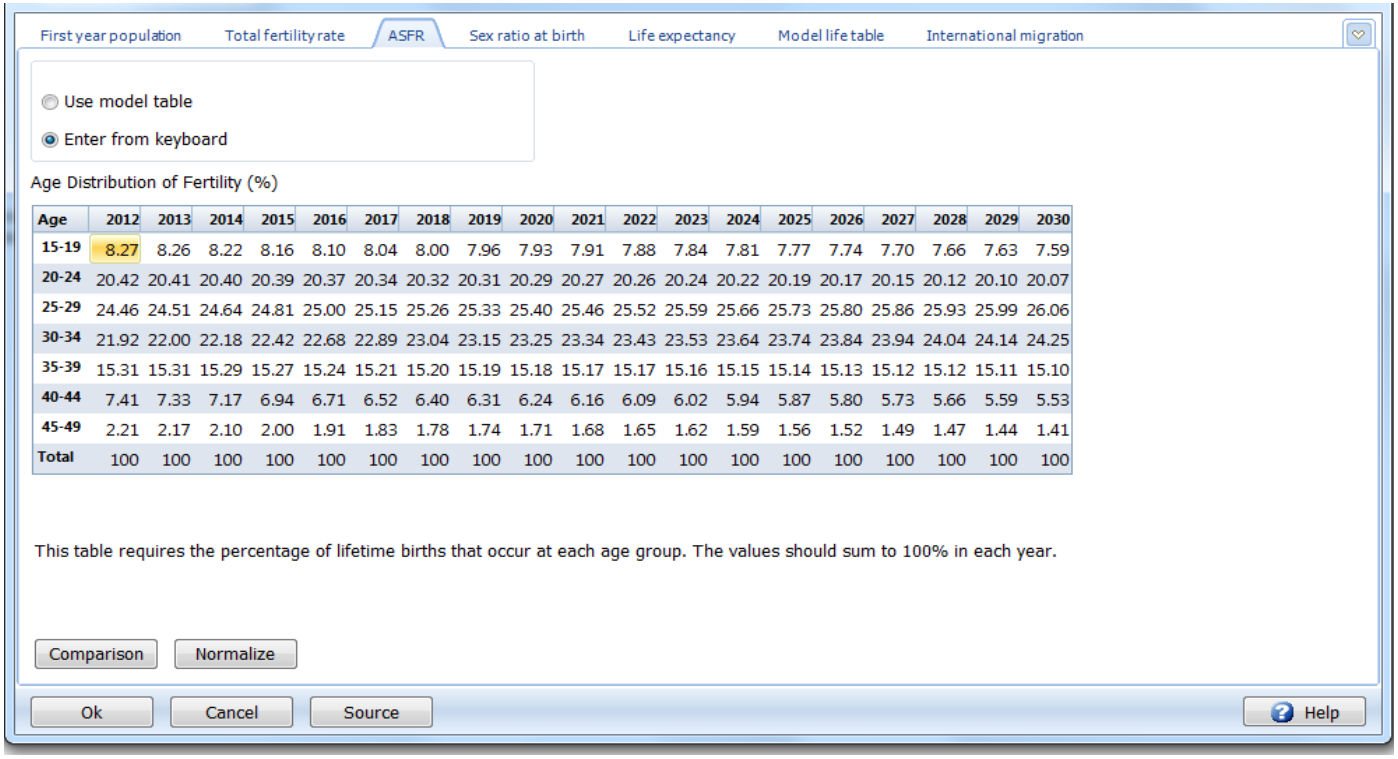
Malawi, census June 2008

Age group	Births in 12 months preceding census	Total women in age group	ASFR
14.5 – 19.5	70,737	699,155	0.10117
19.5 – 24.5	169,406	596,363	0.28407
24.5 – 29.5	130,331	539,482	0.24159
29.5 – 34.5	79,232	517,345	0.15315
34.5 – 39.5	43,747	374,526	0.11681
39.5 – 44.5	15,956	276,264	0.05776
44.5 – 49.5	5,599	224,100	0.02498

Caution! Quality assessment needed

Projecting the age pattern of fertility: c. Projection options

- Since we have projected levels of fertility, we will use PASFRs (not ASFRs) to project age patterns.
- In Spectum, PASFRs are expressed in percentages (the sum of PASFRs = 100)
- Two options are available:
  1) "Use model table"
  2) "Enter from keyboard": User-defined projections



Age	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
15-19	8.27	8.26	8.22	8.16	8.10	8.04	8.00	7.96	7.93	7.91	7.88	7.84	7.81	7.77	7.74	7.70	7.66	7.63	7.59
20-24	20.42	20.41	20.40	20.39	20.37	20.34	20.32	20.31	20.29	20.27	20.26	20.24	20.22	20.19	20.17	20.15	20.12	20.10	20.07
25-29	24.46	24.51	24.64	24.81	25.00	25.15	25.26	25.33	25.40	25.46	25.52	25.59	25.66	25.73	25.80	25.86	25.93	25.99	26.06
30-34	21.92	22.00	22.18	22.42	22.68	22.89	23.04	23.15	23.25	23.34	23.43	23.53	23.64	23.74	23.84	23.94	24.04	24.14	24.25
35-39	15.31	15.31	15.29	15.27	15.24	15.21	15.20	15.19	15.18	15.17	15.17	15.16	15.15	15.14	15.13	15.12	15.12	15.11	15.10
40-44	7.41	7.33	7.17	6.94	6.71	6.52	6.40	6.31	6.24	6.16	6.09	6.02	5.94	5.87	5.80	5.73	5.66	5.59	5.53
45-49	2.21	2.17	2.10	2.00	1.91	1.83	1.78	1.74	1.71	1.68	1.65	1.62	1.59	1.56	1.52	1.49	1.47	1.44	1.41
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

- **Option 1:** User-defined projection using Spectrum interpolation function.

  We need a base year pattern and a target pattern.

- **Option 2:** User-defined patterns using models from the Excel template **ASFRPATT.xls**

  Finds age patterns of fertility for a given level of fertility, based on typical age-specific fertility patterns.

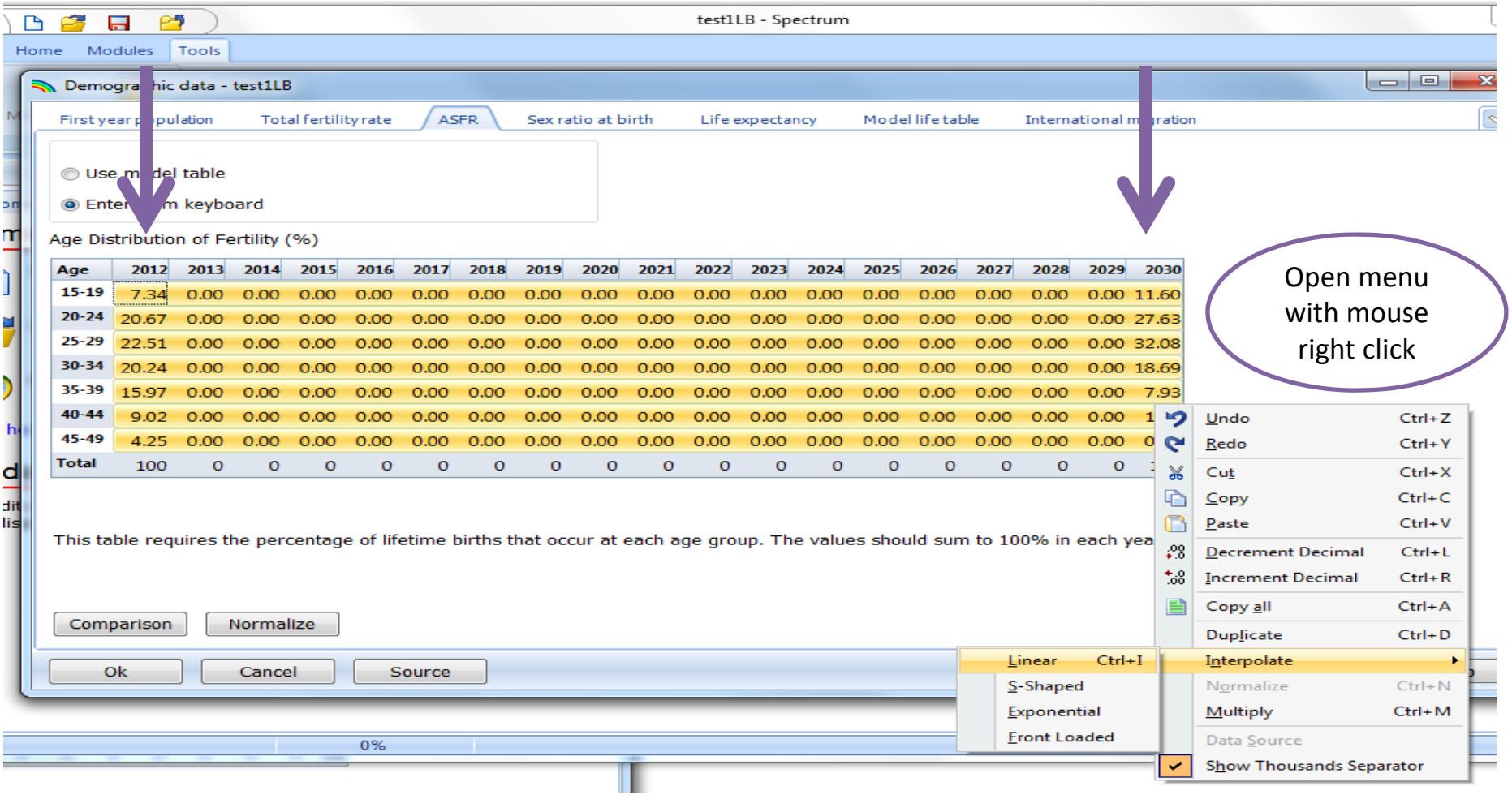
- **Option 3:** User-defined patterns using models from the Excel template **UNPD_ASFR.xlsm**

  Characteristic empirical age patterns of fertility are used as a basis for projections.

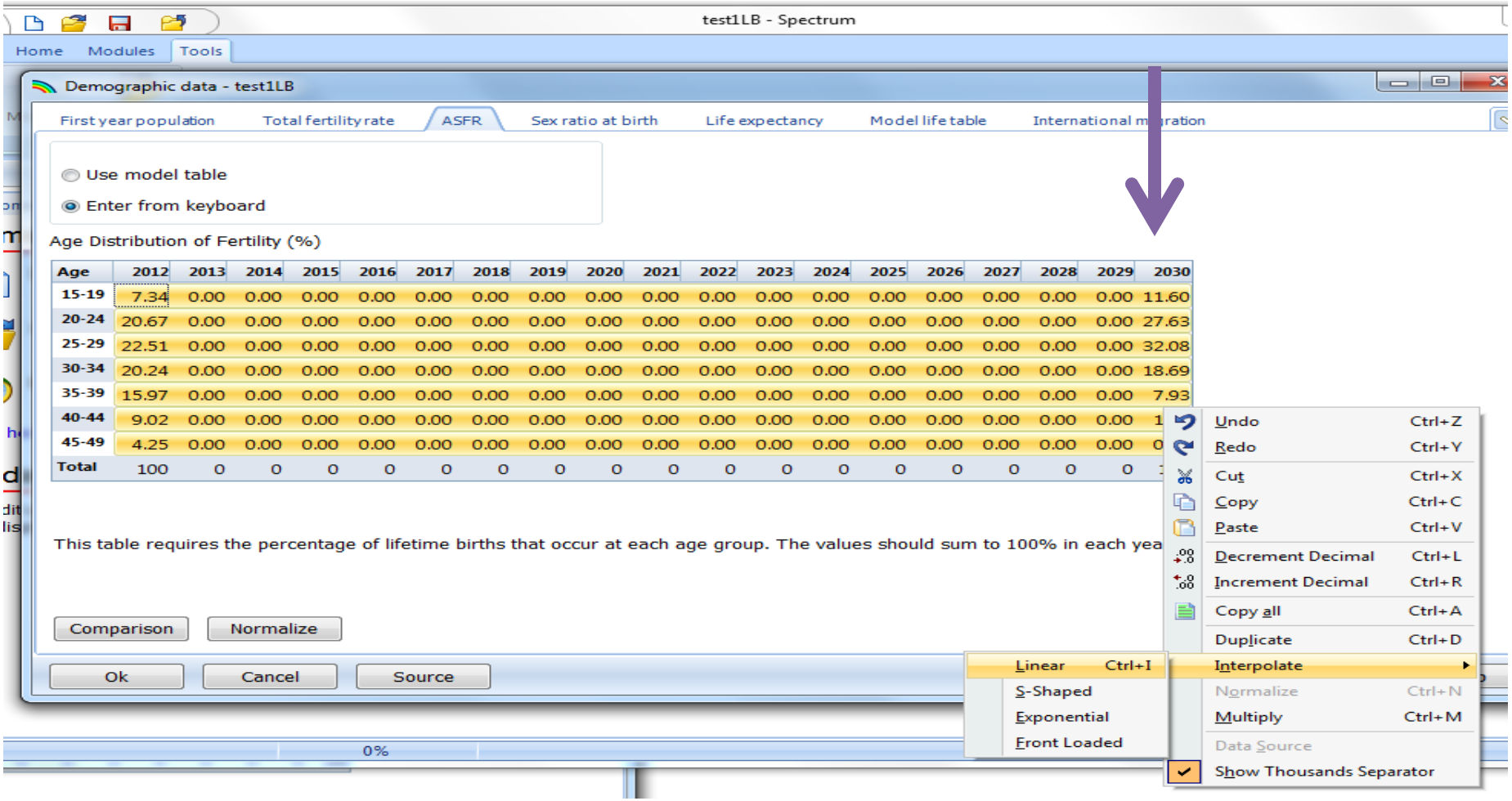
- **Option 4 (caution is recommended):** "Use model table" from Spectrum software

- **Option 1:** User defined projection using Spectrum interpolation function.

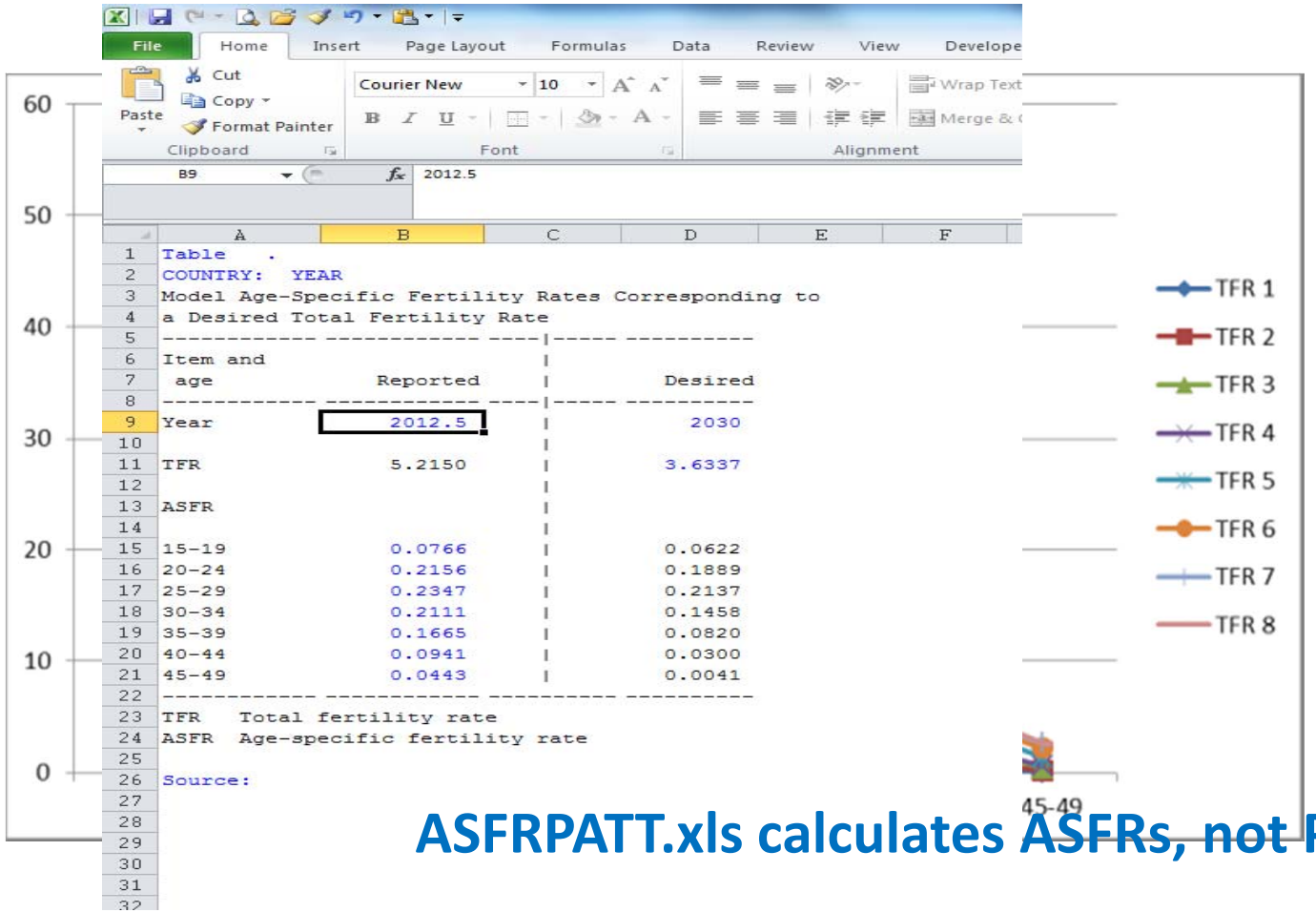
We need a base year pattern and a target pattern.



- **Option 1:** How do we define a **target pattern?**



- **Option 2:** Use Excel template **ASFRPATT.xls**
- Finds age patterns of fertility for a given level of fertility, based on typical age-specific fertility patterns.

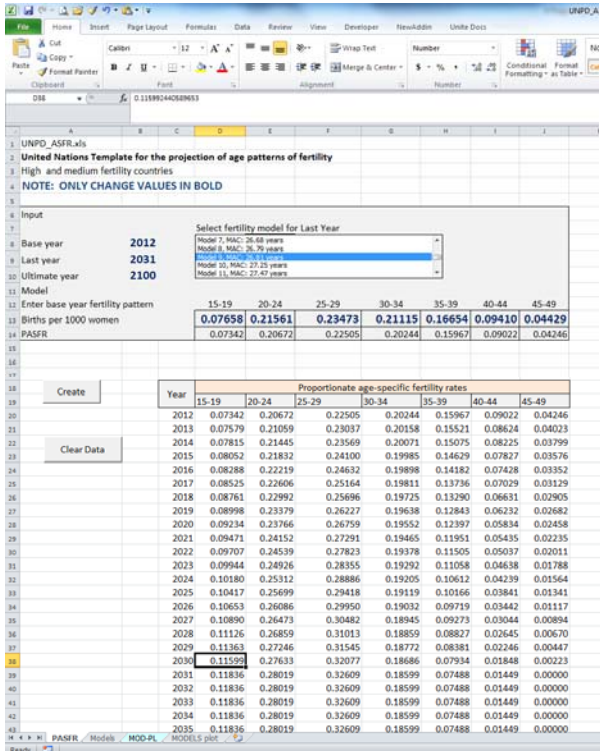


	A	B	C	D	E	F
1	Table .					
2	COUNTRY: YEAR					
3	Model Age-Specific Fertility Rates Corresponding to					
4	a Desired Total Fertility Rate					
5	---------- ---------- ----|----- ----------					
6	Item and					
7	age	Reported		Desired		
8	---------- ---------- ----|----- ----------					
9	Year	2012.5		2030		
10						
11	TFR	5.2150		3.6337		
12						
13	ASFR					
14						
15	15-19	0.0766		0.0622		
16	20-24	0.2156		0.1889		
17	25-29	0.2347		0.2137		
18	30-34	0.2111		0.1458		
19	35-39	0.1665		0.0820		
20	40-44	0.0941		0.0300		
21	45-49	0.0443		0.0041		
22	---------- ---------- ---------- ----------					
23	TFR Total fertility rate					
24	ASFR Age-specific fertility rate					
25						
26	Source:					
27						
28						
29						
30						
31						
32						

ASFRPATT.xls calculates ASFRs, not PASFRs!

o **Option 3:** Use Excel template **UNPD_ASFR.xls**

- Uses characteristic age-patterns of fertility associated with select levels of fertility
- The model generates a series of age patterns by interpolating between a base pattern and a target pattern.
- The template allows for extending the target pattern beyond the last year (target year) by keeping it constant.
- Model age patterns of fertility are presented as PASFRs, indexed by the *mean age at childbirth (MAC)*



Mean age at childbirth (MAC):

The sum of ASFRs weighted by the mid-point of each group, divided by the sum or ASFRs

$$MAC = \sum_a x_a f_a \Big/ \sum_a f_a$$

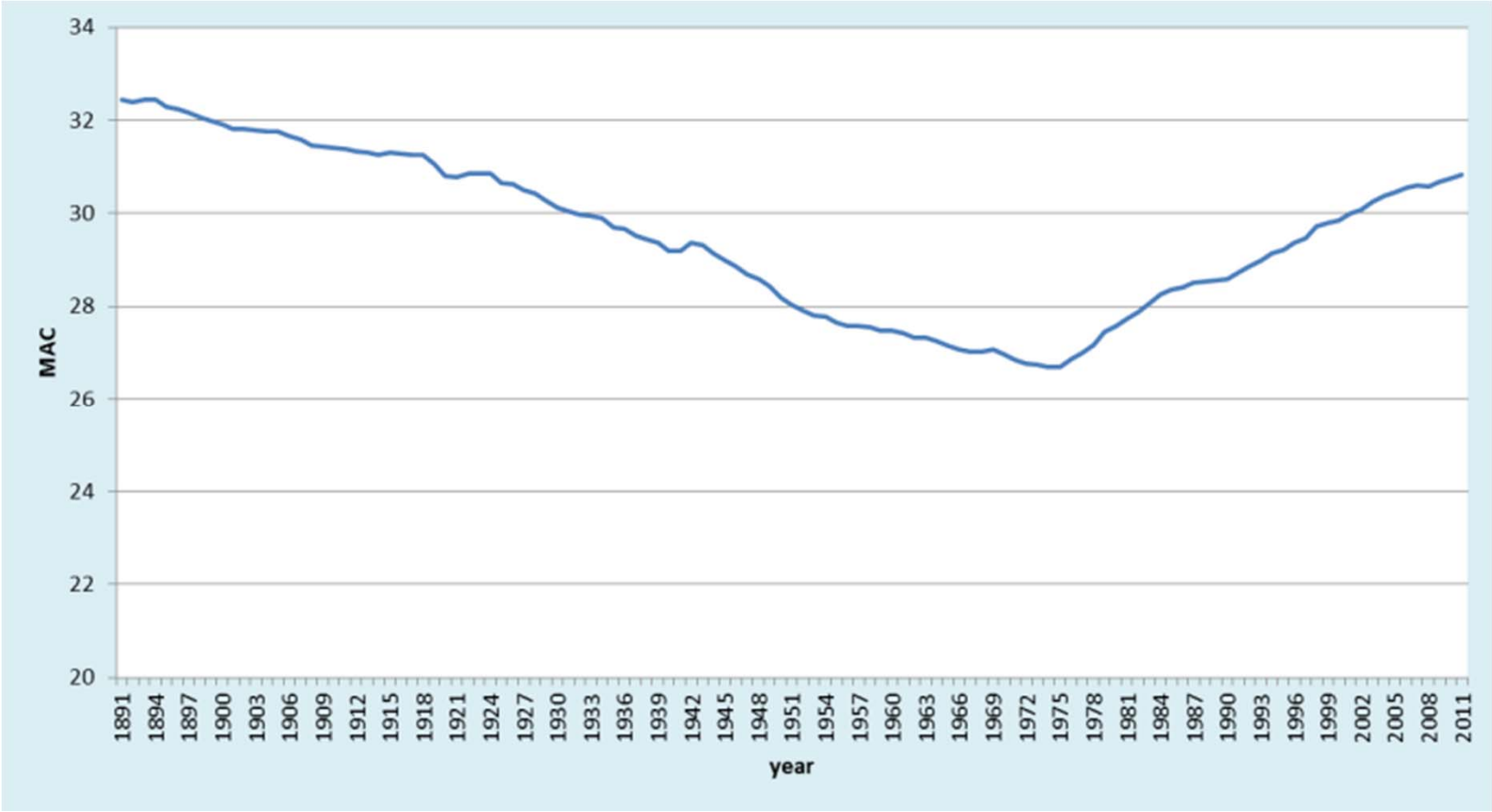
where $\boldsymbol{x_a}$ is the mid-point of each age interval (17.5, 22.5, … 47.5) and $\boldsymbol{f_a}$ ais the ASFR for women in age group $\boldsymbol{a}$

Interpretation

The mean age of mothers at the birth of their children, under the assumption that women are subject through age 50 to the ASFRs observed in a given year.

An Excel template is available in the "**PASFRs MAC**" sheet of your exercise file

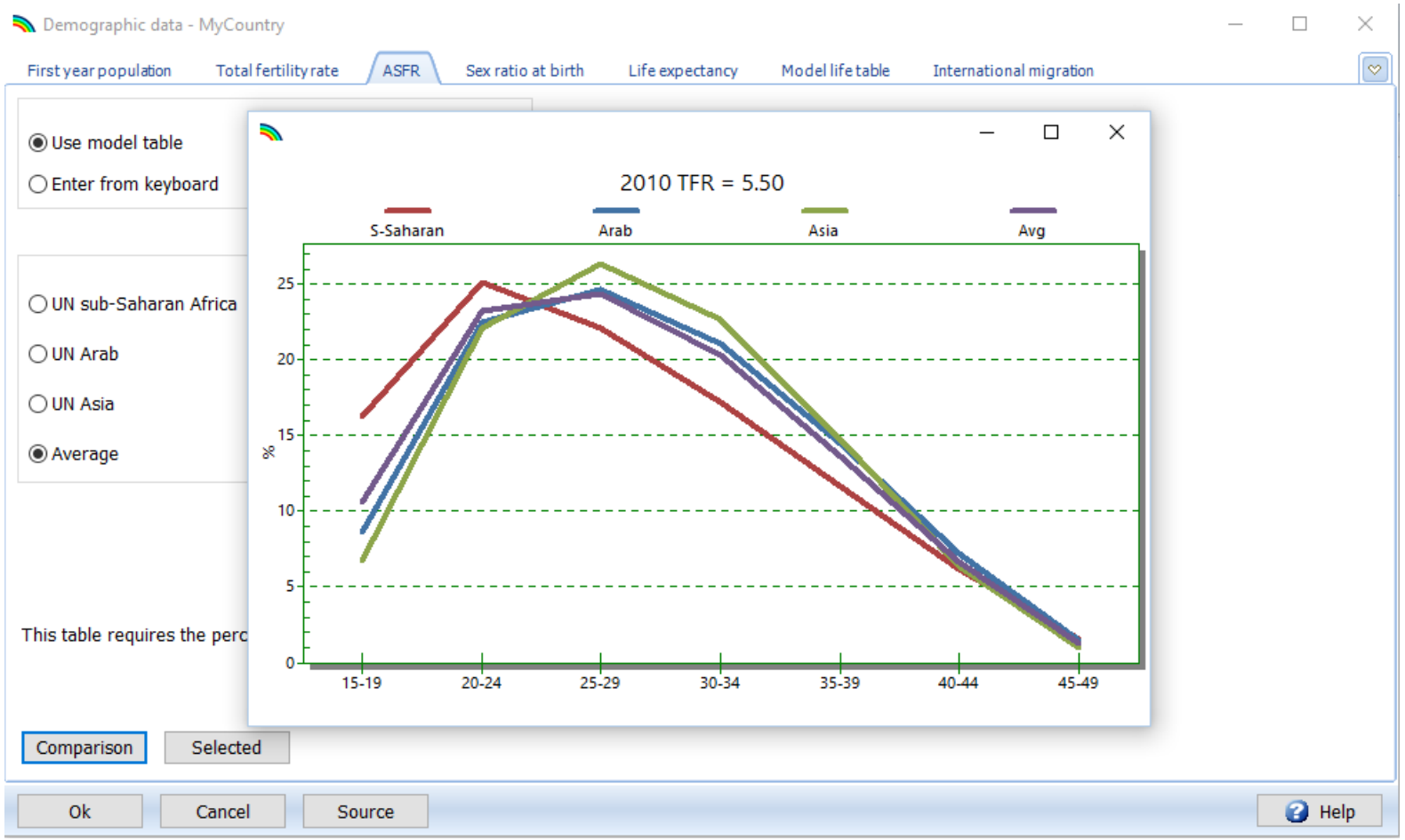
Mean age at childbirth (MAC): – Sweden, 1891-2011



Source: Human Fertility Database

- **Option 4: (caution is recommended):** "Use model table" from Spectrum software

3 regional models and one average model are provided.



Thank you

Questions?

>> until 11 March:

>> After 11 March: sawyerc@un.org
bassarsky@un.org