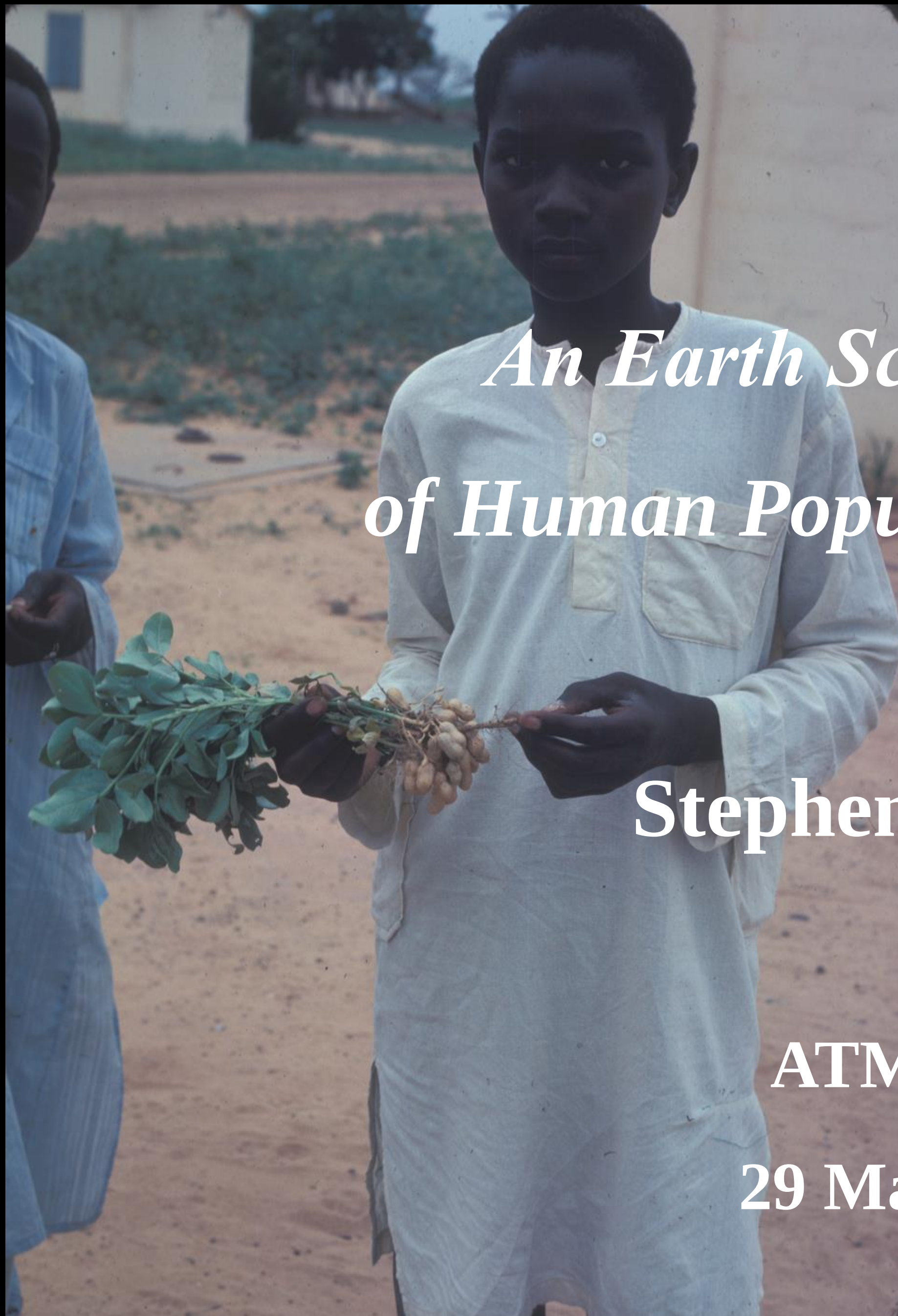


An Earth Scientist's View of Human Population Dynamics

Stephen Warren

ATMS 211

29 May 2019

Human Population: relevance to climate change

Forcing of climate change:

predicting emissions of greenhouse gases

Impacts of climate change:

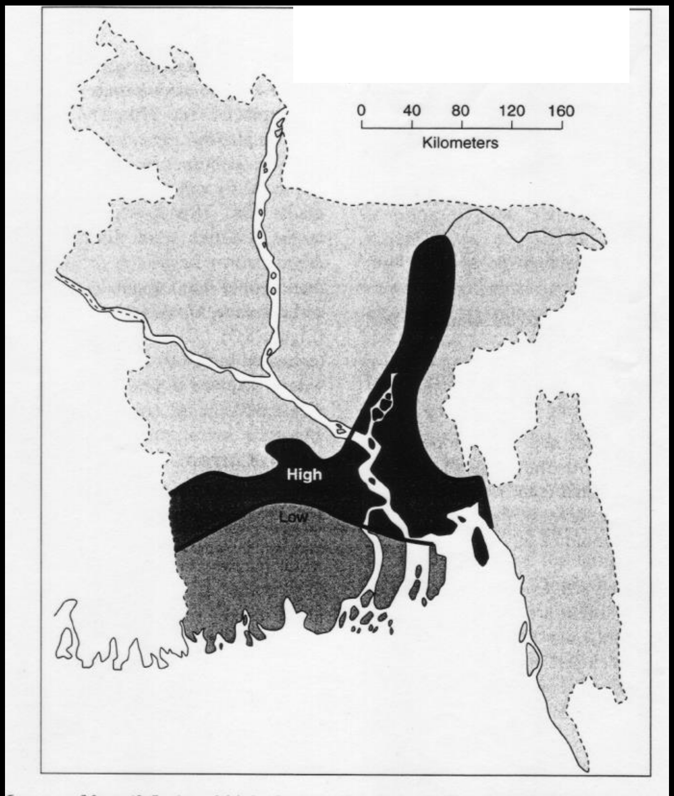
sea-level rise

Bangladesh

80 million in 1975

160 million in 2015

200 million in 2050?



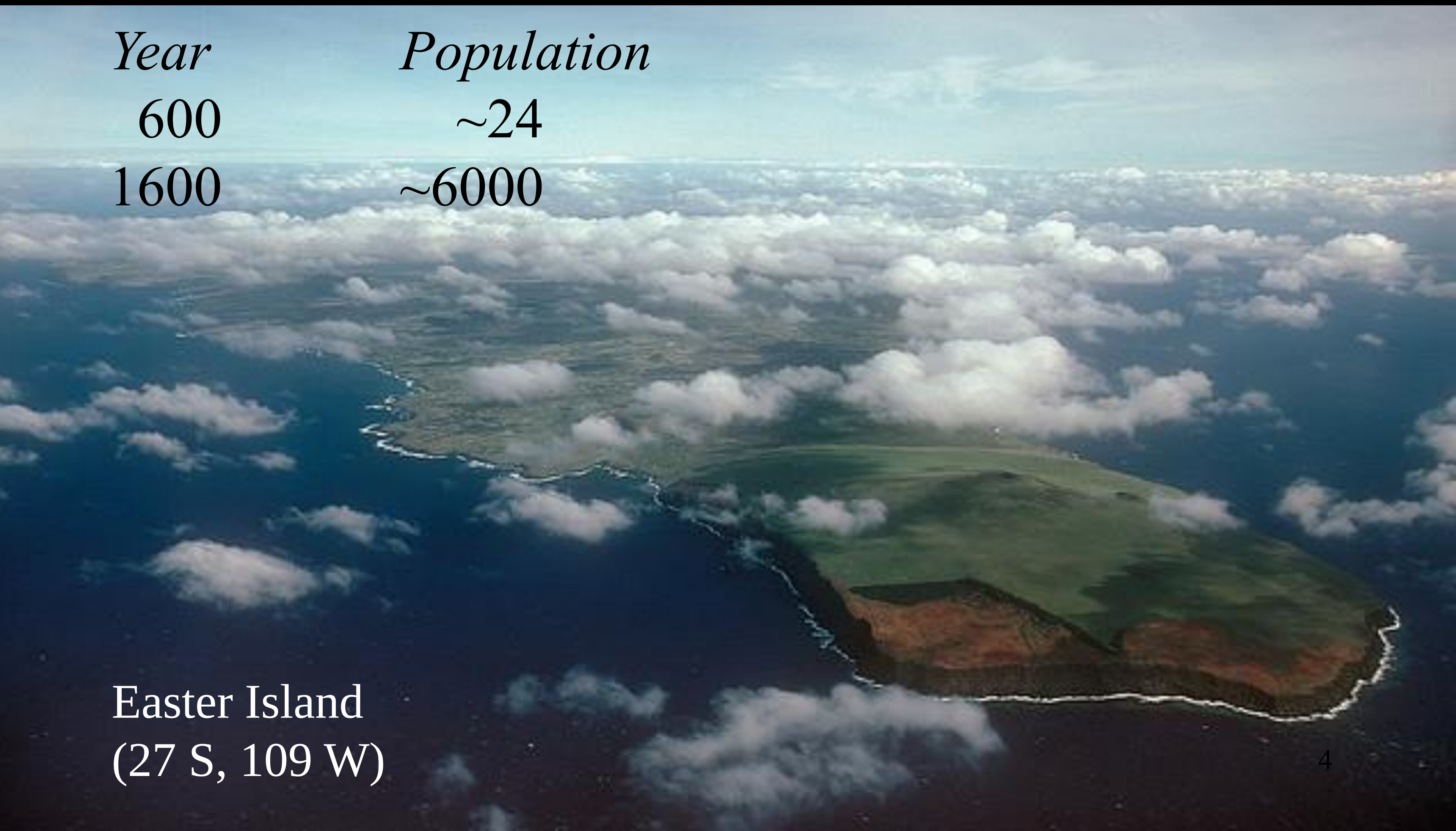
Impact of low (0.5 m) and high (3 m) sea-level rise in Bangladesh (From Broadus

1. ***Test your intuition about population growth***

Exponential growth or exponential decay results when the change in a quantity is proportional to the quantity itself.

Populations of animals, plants, or bacteria, are capable of growing exponentially because the number of offspring is proportional to the current population.

Relation of fertility rate to growth rate: the example of Easter Island



Year	*Population*
600	~24
1600	~6000

Easter Island
(27 S, 109 W)

Relation of fertility rate to growth rate: the example of Easter Island

Year	*Population*
600	~24
1600	~6000

Make a guess: how many children (that reached reproductive age) did each couple produce, on average, during those 1000 years? Write down your guess.

(Assume a generation time of 25 years.)

Easter Island

The increase is a factor 6000/24, or 250, or 2^8.

The population doubled 8 times.

24
48
96
192
384
768
1536
3072
6144

Easter Island

The increase is a factor 6000/24, or 250, or 2^8.

The population doubled 8 times.

8 doublings in 1000 years, so the doubling time is 125 years or 5 generations.

Population doubles in 5 generations, so in one generation it increases by the fifth root of 2, or 1.15.

$1.15 \times 1.15 \times 1.15 \times 1.15 \times 1.15 = 2$
The population grows by 15% in one generation, requiring $2 \times 1.15 = 2.3$ children per woman.

It's useful to memorize some powers of 2:

$2^1 = 2$	$2^6 = 64$
$2^2 = 4$	$2^7 = 128$
$2^3 = 8$	$2^8 = 256$
$2^4 = 16$	$2^9 = 512$
$2^5 = 32$	$2^{10} = 1024$ (i.e., very close to 1000)

So:

10 doublings is a factor of one thousand (10^3);
20 doublings is a factor of one million (10^6);
30 doublings is a factor of one billion (10^9).
40 doublings is a factor of one trillion (10^{12}).

Population in year 600	Total fertility rate	Doubling time (years)	Number of doublings	Population in year 1600
24	4	25	40	24 trillion
24	2.3	125	8	6000
24	2.0	--	0	24

Recent population history

World population doubled in 40 years
3.0 billion in 1960
6.0 billion in 2000

U.S. population doubled in 56 years
150 million in 1950
300 million in 2006

A doubling of world population in 40 years:
is this unusual?

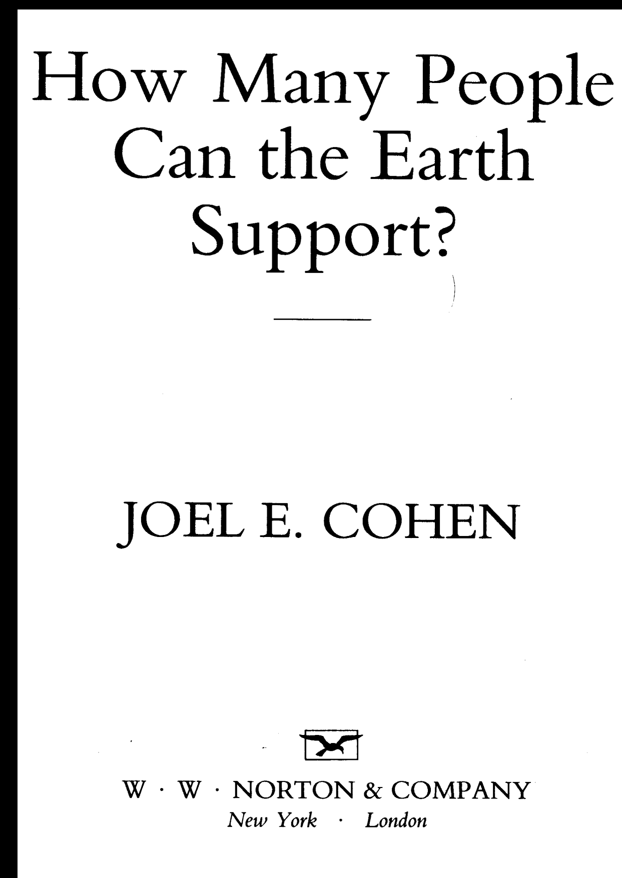
In previous centuries, did doubling take longer than 40 years?

32 doublings to grow from 2 people to 6 billion people

At 40 years per doubling, $32 \times 40 = 1280$ years

Cohen (1995):
"Within the lifetime of some people now alive, world population has tripled; within the lifetime of everyone over 40 years old, it has doubled – yet never before the last half of the twentieth century had world population doubled within the life span of any human."

1945 2.4 billion
2019 7.7 billion


How Many People Can the Earth Support?

JOEL E. COHEN

W · W · NORTON & COMPANY
New York · London

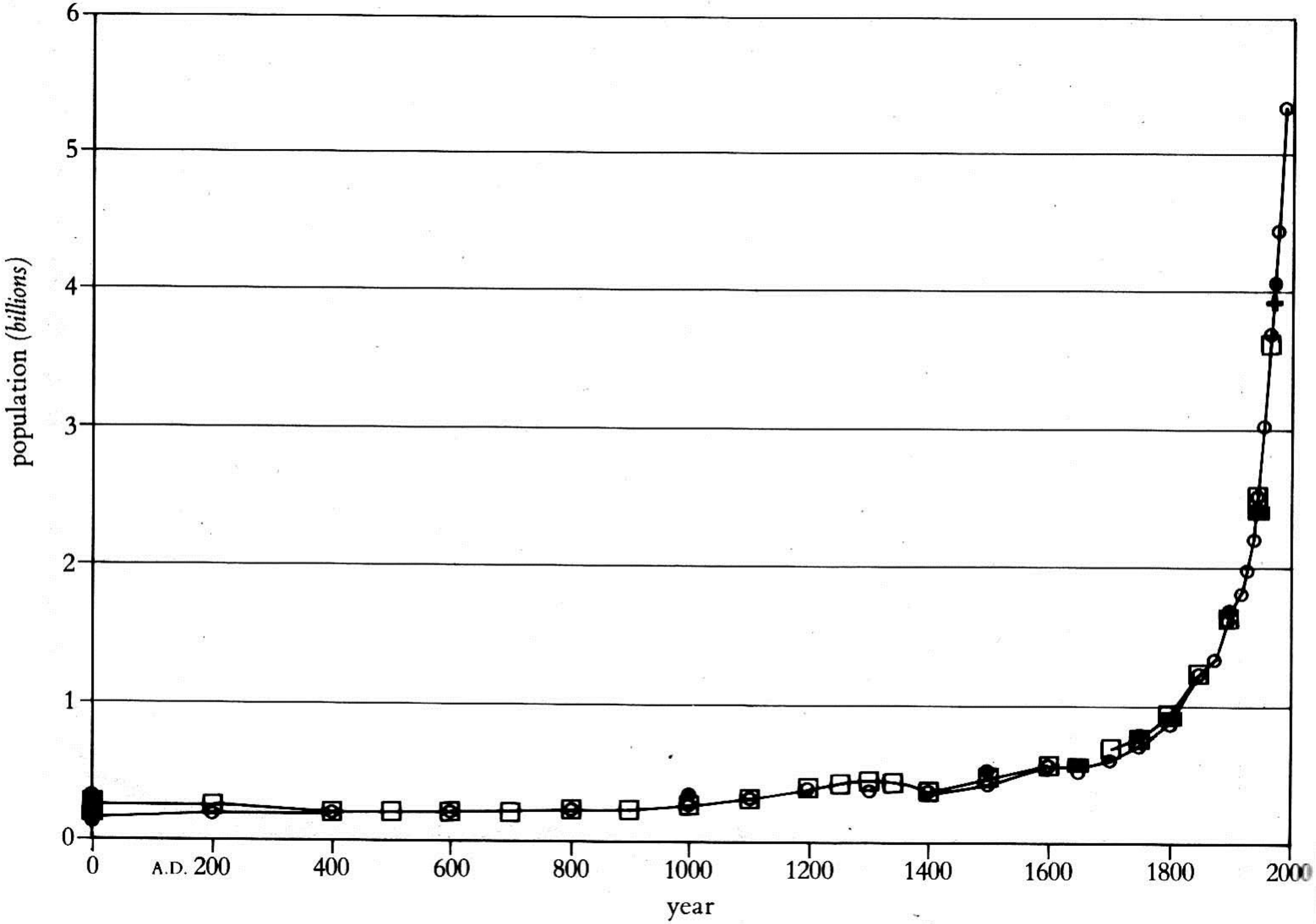


FIGURE 5.3 Estimated human population from A.D. 1 to the present. Different symbols represent estimates from different sources. SOURCE OF DATA: Appendix 2

Cohen
1995

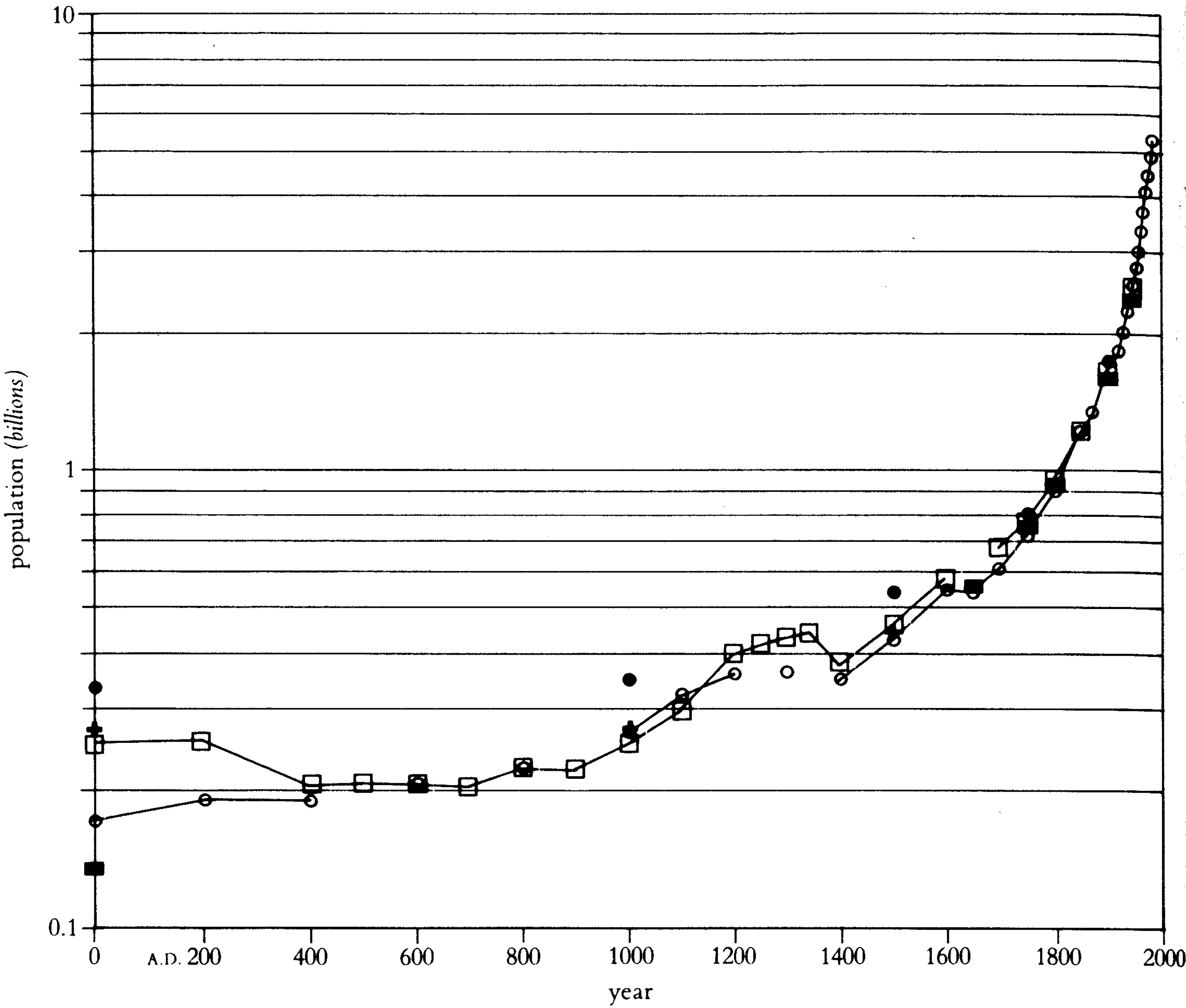
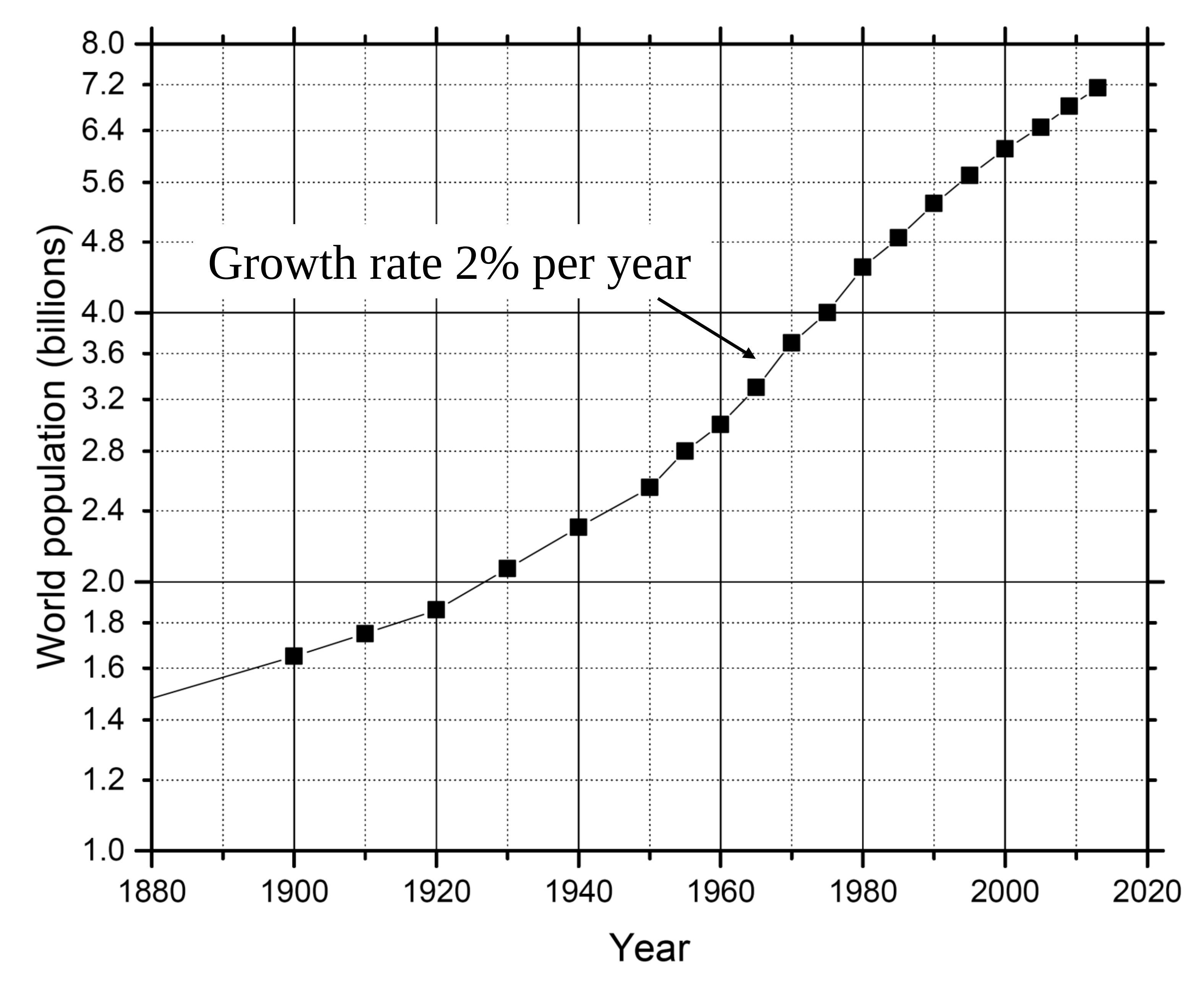
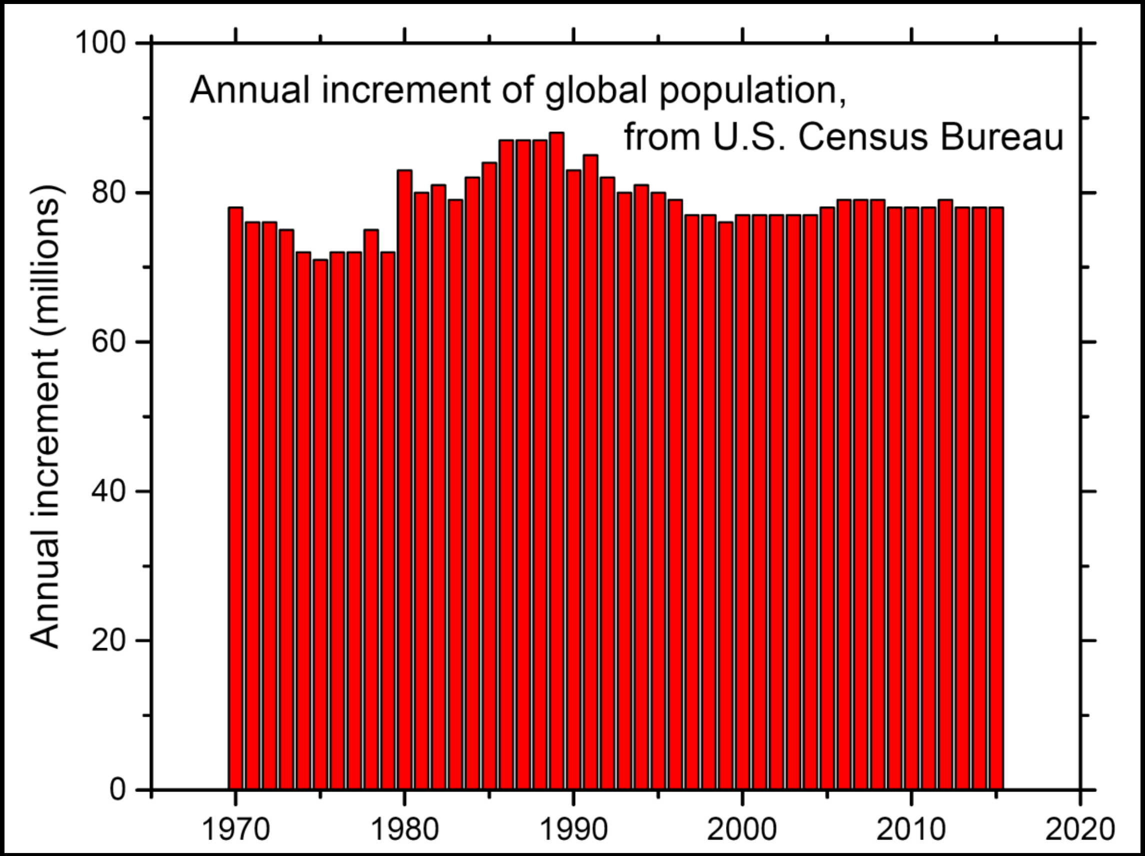


FIGURE 5.12 World population history for the last two millennia, with population plotted on a logarithmic scale. Different symbols represent estimates from different sources. SOURCE OF DATA: Appendix 2

Cohen 1995



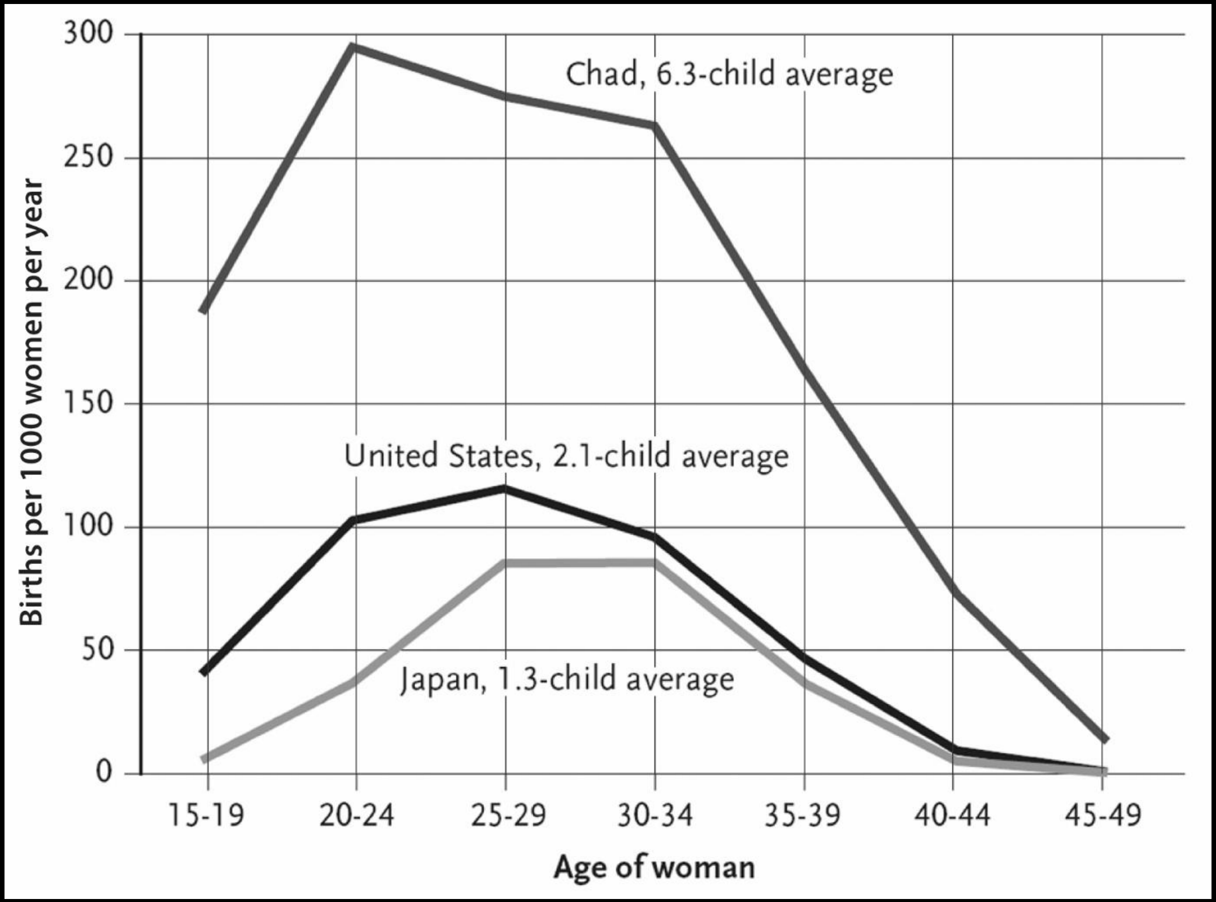
Growth rate 2% per year
World population (billions)
8.0
7.2
6.4
5.6
4.8
4.0
3.6
3.2
2.8
2.4
2.0
1.8
1.6
1.4
1.2
1.0
1880
1900
1920
1940
1960
1980
2000
2020
Year



For the last 45 years, the annual increase of world population has been steady at ~80 million (i.e., steady growth rather than exponential growth), because the growth rate is dropping.

140 million births - 60 million deaths = 80 million net per year

Year	World Population (billions)	Growth rate (percent per year)	People added per year (millions)
1977	4.3	1.9	82
1994	5.6	1.5	82
2004	6.4	1.3	82



Age-specific fertility rates;

total fertility rates *(TFR)*.

Total fertility rate *(TFR)*: *The average number of children a woman produces during her lifetime, using the current rates for each age-cohort.*

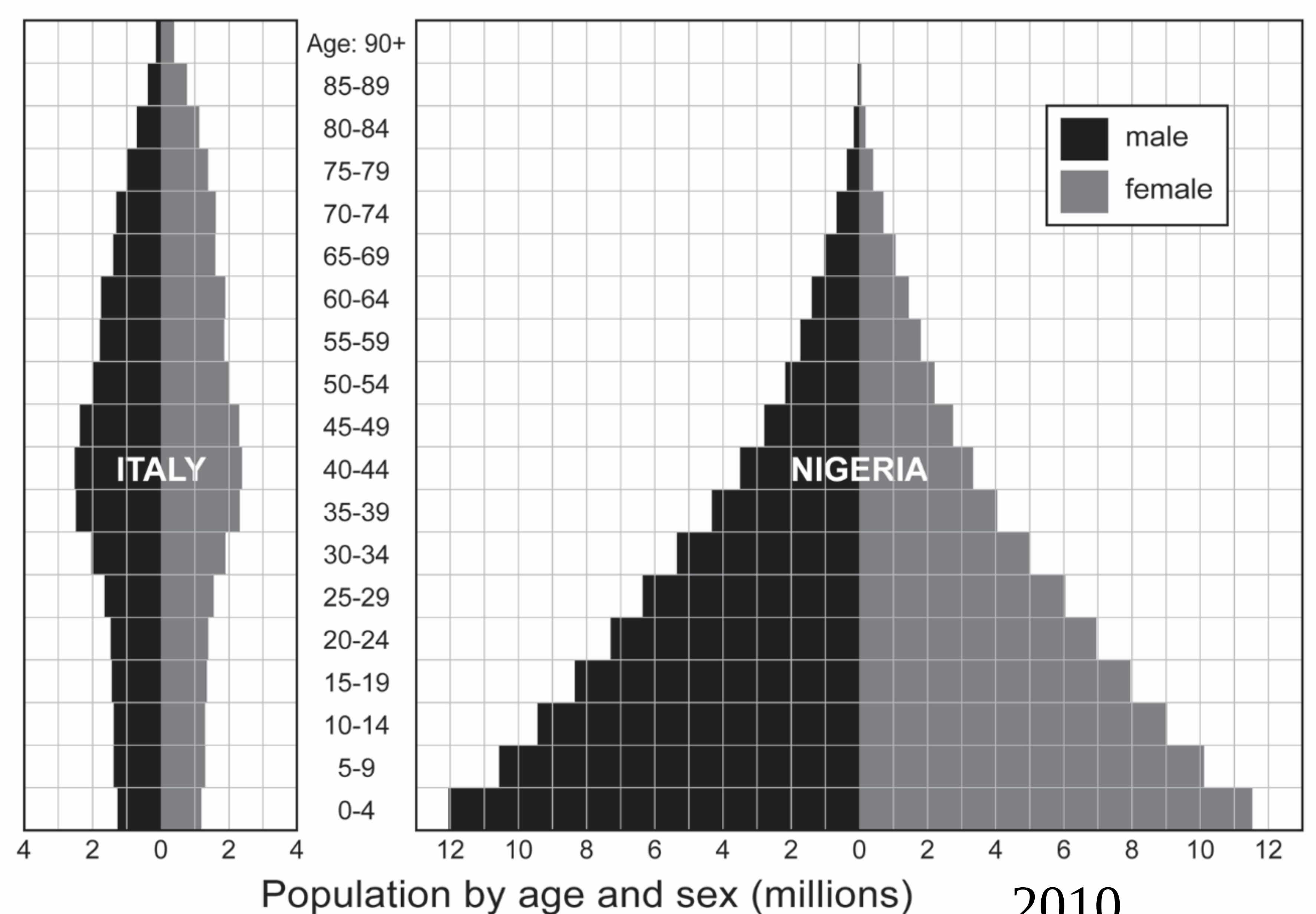
Highest *TFR*s are in Africa, 6-8 children per woman (cpw)
(e.g. Niger, Angola, Congo).

Lowest *TFR*s are in Eastern Europe and East Asia, 1.2 cpw
(e.g. Poland, Greece, Taiwan, Singapore).

Replacement-level fertility *(RLF)*: The fertility rate needed to keep the population stable.

If children do not die before reproductive age,
$RLF = 2.0$ children per woman (cpw).
In countries with low child-mortality,
$RLF \approx 2.1$ cpw (or 2.06)

Age structure of populations: "population pyramids"



2010

Examples to illustrate
(a) the relation of total fertility rate to doubling time (or halving time)
(b) population "momentum"

Consider a little community of 80 people in the year 1600, consisting (for mathematical simplicity) of only four "cohorts", spaced 25 years apart, and equal numbers of males and females. [Your "cohort" is all the people born the same year you were born.] They all live past age 75 but they all die before reaching 100. Children are born when their parents are 25 years old.

Example 1. Each couple has two children, so the next generation (cohort) has the same population as their generation. [Each age group has 10 couples; each couple has 2 children.]

Year:	*1600*	
Age 75	20	Grandparents
Age 50	20	Parents
Age 25	20	Young adults
Age 0	20	Newborns
Total:	80	

Example 1. Each couple has two children, so the next generation (cohort) has the same population as their generation. [Each age group has 10 couples; each couple has 2 children.] Here are snapshots of the age-composition of the population at 25-year intervals.

Year:	*1600*	*1625*	*1650*	*1675*	
Age 75	20	20	20	20	
Age 50	20	20	20	20	
Age 25	20	20	20	20	
Age 0	20	20	20	20	(newborns)
Total:	80	80	80	80	

Example 1. Each couple has two children, so the next generation (cohort) has the same population as their generation. [Each age group has 10 couples; each couple has 2 children.] Here are snapshots of the age-composition of the population at 25-year intervals.

Year:	*1600*	*1625*	*1650*	*1675*	
Age 75	20	20	20	20	
Age 50	20	20	20	20	
Age 25	20	20	20	20	
Age 0	20	20	20	20	(newborns)
Total:	80	80	80	80	

The population is stable with a "total fertility rate" (number of children a woman has in her lifetime) of 2.0 children per woman (cpw): TFR = 2 *cpw*.

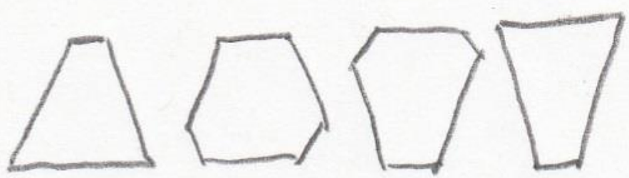
Example 2. Four children per couple.

Year:	1600	1625	1650	1675
Age 75	20	40	80	160
Age 50	40	80	160	320
Age 25	80	160	320	640
Age 0	160	320	640	1280
Total	300	600	1200	2400

After 25 years (one generation) the population at each age has doubled, so the total population has doubled. So if TFR = 4 *cpw*, the doubling time is one generation.

Example 3. In 1675 this community decides it's getting overcrowded, so they institute a one-child policy: TFR = 1 *cpw*. The population will eventually decline, but only after a transition period of 3 generations.

Year:	*1675*	*1700*	*1725*	*1750*	*1775*	*1800*	*1825*
Age 75	160	320	640	1280	640	320	160
Age 50	320	640	1280	640	320	160	80
Age 25	640	1280	640	320	160	80	40
Age 0	1280	640	320	160	80	40	20
Total	2400	2880	2880	2400	1200	600	300



The population continues to grow at first ("population momentum"); meanwhile the shape of the pyramid changes. After three generations the pyramid is inverted. After the fourth generation the population finally starts to decline, and thereafter shows a *halving time* of one generation.

If the *TFR*, the generation time, and the life expectancy are constant, and if the children do not die before reproductive age:

If TFR = 4, population doubles in one generation.

If *TFR* = 2, population stays constant.

If *TFR* = 1, population halves in one generation.

Philippines

The population doubled about every 28 years.

	population (millions)
1900	7
1928	13
1957	26
1986	51
2014	100

United States

The population doubled about every 25 years.

	population (millions)
1800	5
1820	10
1845	20
1871	40
1900	76

Population history of the United States

Census Year	*Population (millions)*	*Percent increase since previous census*
2010	309	10
2000	281	13
1990	249	10
1980	227	11
1970	203	13
1960	179	18
1950	151	14
1940	132	7
1930	123	16
1920	106	15
1910	92	21
1900	76	21
1890	63	26
1880	50	30
1870	39	23
1860	31	36
1850	23	36
1840	17	33
1830	13	34
1820	10	33
1810	7	36
1800	5	35
1790	4	

The low growth rate from 1930 to 1940 was during the economic depression; people may choose to have fewer children if they're unable to support them. This is also happening now in Russia.

The high growth rates from 1790 to 1890 coincide with opening of the "frontier“; colonization of the continent by Europeans and their descendants.

Population density

Region	*Area (millions of km²)*	*Population in 2014 (millions)*	*Population density (people per km²)*
Earth (land)	155	7238	47
Bangladesh	0.144	158	1100
Rwanda	0.026	11	420
Netherlands	0.042	17	400
France	0.544	64	120
USA	9.37	318	34
Canada	10.0	36	4
Manhattan Island	80 km^2	1.5	20,000
Hong Kong (city)	~75 km^2	~5	60,000

Note that countries in Western Europe (Netherlands, France) are about ten times as dense as the U.S., and that the U.S. is ten times as dense as Canada. Note also that high-density cities (New York, Hong Kong) are about 1000 times the global average and yet those cities are livable. Thus physical crowding is not likely to set a limit to human population; other limits to growth will probably be encountered before crowding becomes intolerable.

United Nations Population Division

	World population in 1980
Predicted in 1951	3.3 billion
Actual (1980)	4.4 billion

ST/ESA/SER.A/236

Department of Economic and Social Affairs
Population Division

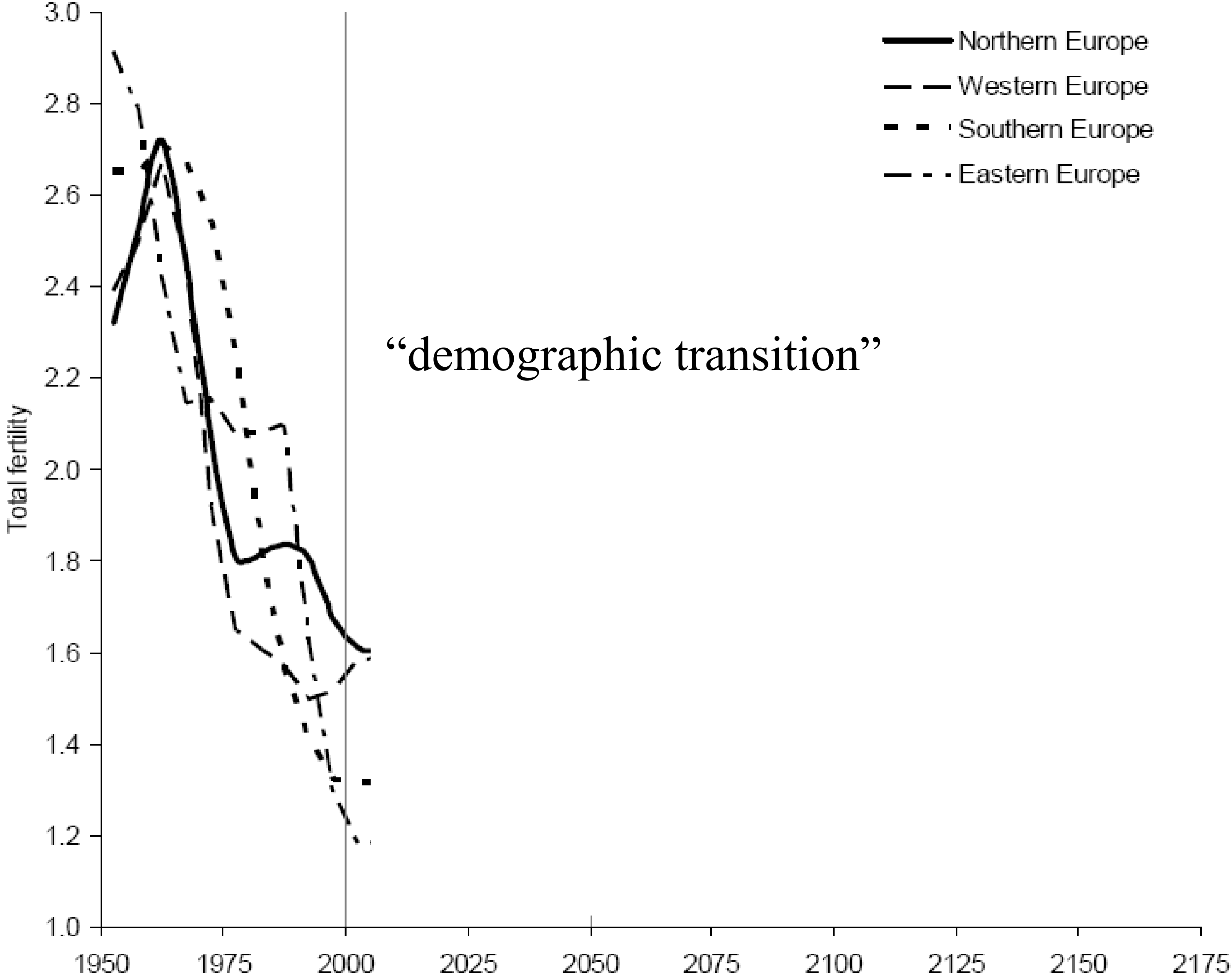
WORLD POPULATION TO 2300

United Nations
New York, 2004

United Nations
Population Division
(2004)

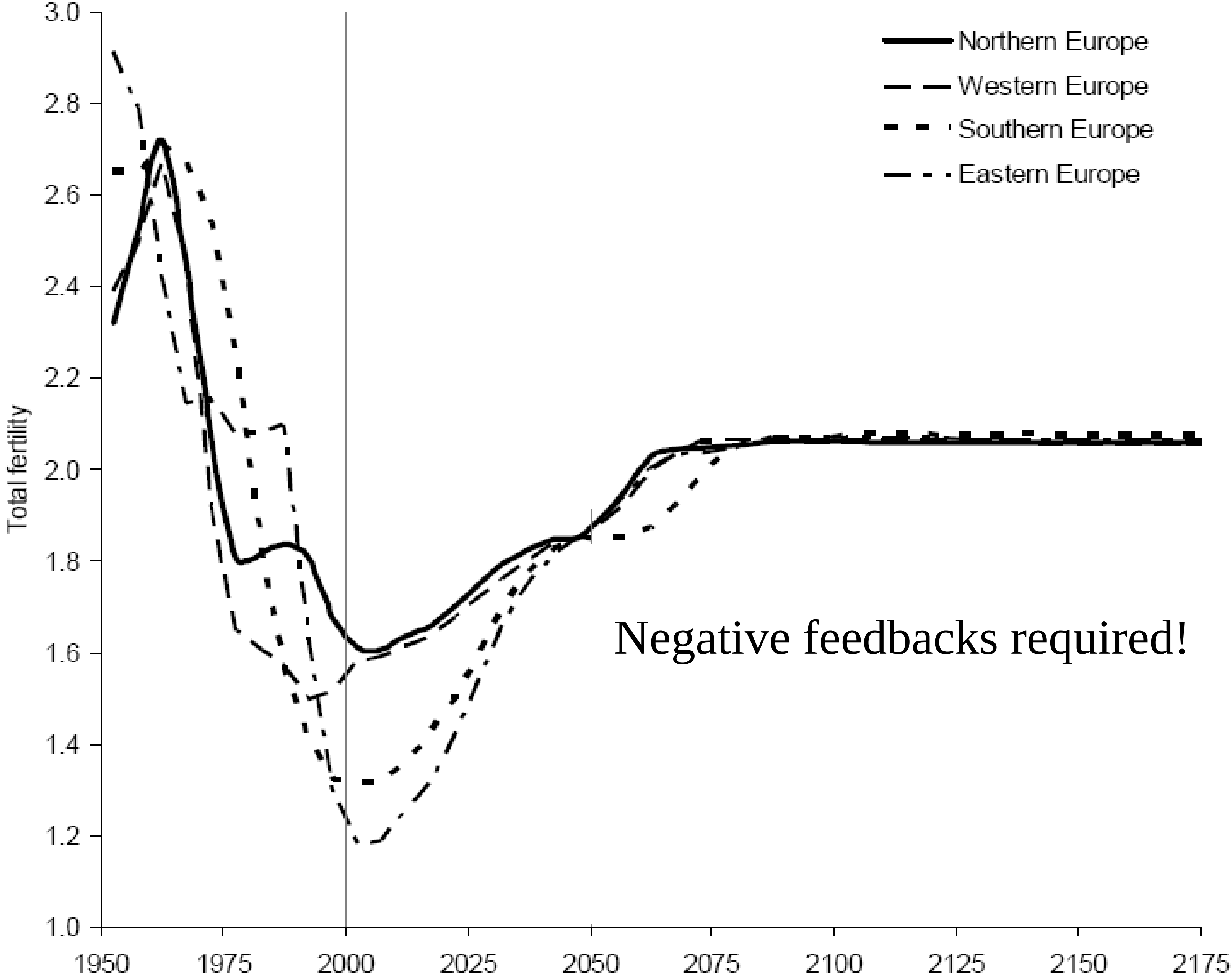
240 pages

Figure 37. Total fertility, European regions: 1950-2175



“demographic transition”

Figure 37. Total fertility, European regions: 1950-2175



Negative feedbacks required!

Replacement-Level Fertility:
The Implausible Endpoint of the Demographic Transition

PAUL DEMENY

Demeny (1997)

Yet neither policy-makers nor the informed public seem to grasp the point that there is no magic force that guarantees stability of fertility behaviour once replacement level is reached. The received wisdom on the course of fertility envisages progress—spontaneous or socially engineered—towards replacement level, followed by stasis, at a total fertility rate (TFR) of, roughly, 2.1. That, in turn, would lead to population stabilization,

Figure 41. Total fertility in Niger and Latvia, estimates and three scenarios: 1950-2300

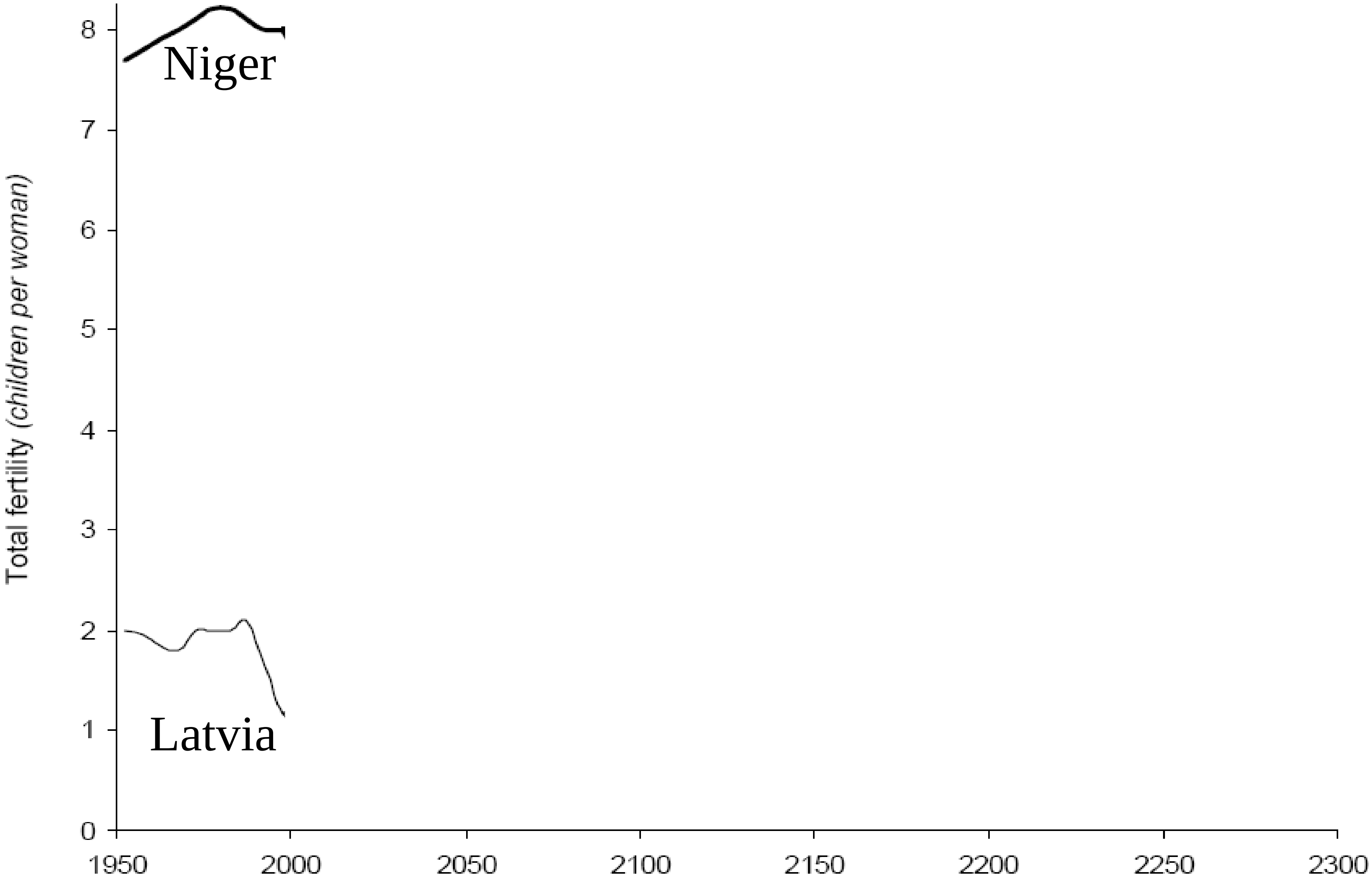
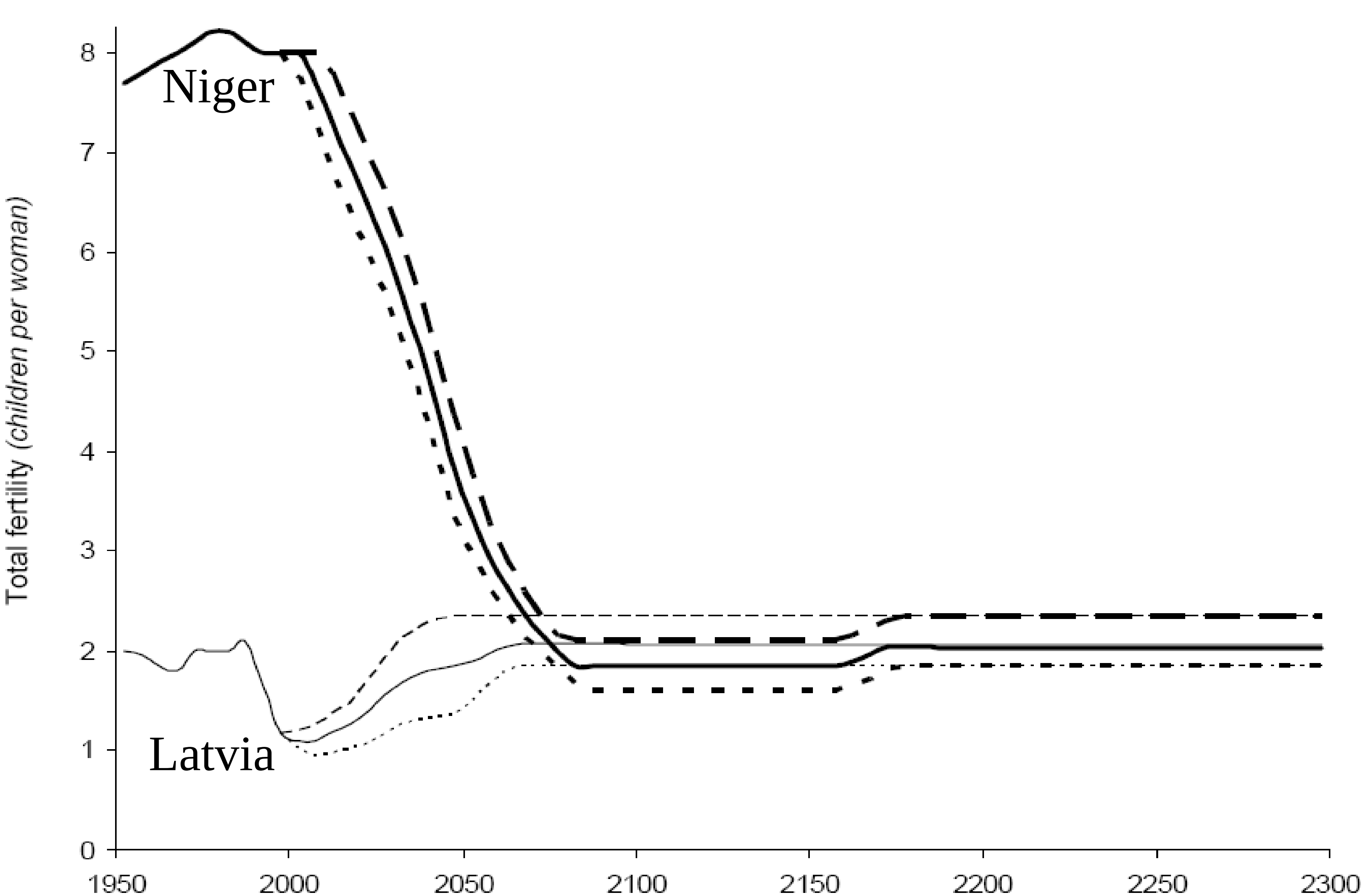


Figure 41. Total fertility in Niger and Latvia, estimates and three scenarios: 1950-2300



Logic of the UN report *World Population to 2300*:

(1) Replacement-level fertility is 2.1 cpw. (fact)

(2) Stability of population is desirable (assertion)

(3) *Therefore:*

All nations will converge to $TFR = 2.1$

Wishful thinking

Bayesian probabilistic population projections for all countries

Adrian E. Raftery[a,1], Nan Li[b], Hana Ševčíková[c], Patrick Gerland[b], and Gerhard K. Heilig[b]

[a]Departments of Statistics and Sociology, University of Washington, Seattle, WA 98195-4322; [b]Population Division, Department of Economic and Social Affairs, 2, United Nations Plaza DC2-1984, United Nations, New York, NY 10017; and [c]Center for Statistics and the Social Sciences, University of Washington, Seattle, WA 98195-4320

This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected in 2009.

Contributed by Adrian Raftery, July 5, 2012 (sent for review January 28, 2012)

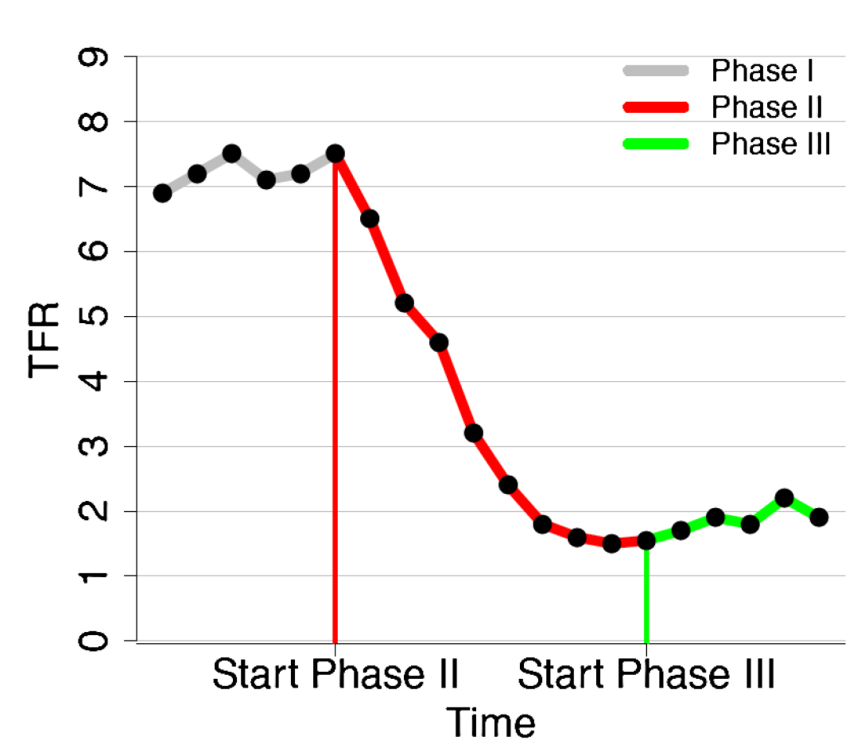
Our method assumes that TFR in a country will eventually fluctuate around an equilibrium value, taken here to be the approximate replacement level of 2.1.

The equilibrium value of 2.1 is set by expert judgment since there are not yet enough data to estimate it from observations.

PNAS | **August 28, 2012** | vol. 109 | no. 35 | **13915–13921**

Bayesian Population Projections for the United Nations

Adrian E. Raftery, Leontine Alkema and Patrick Gerland

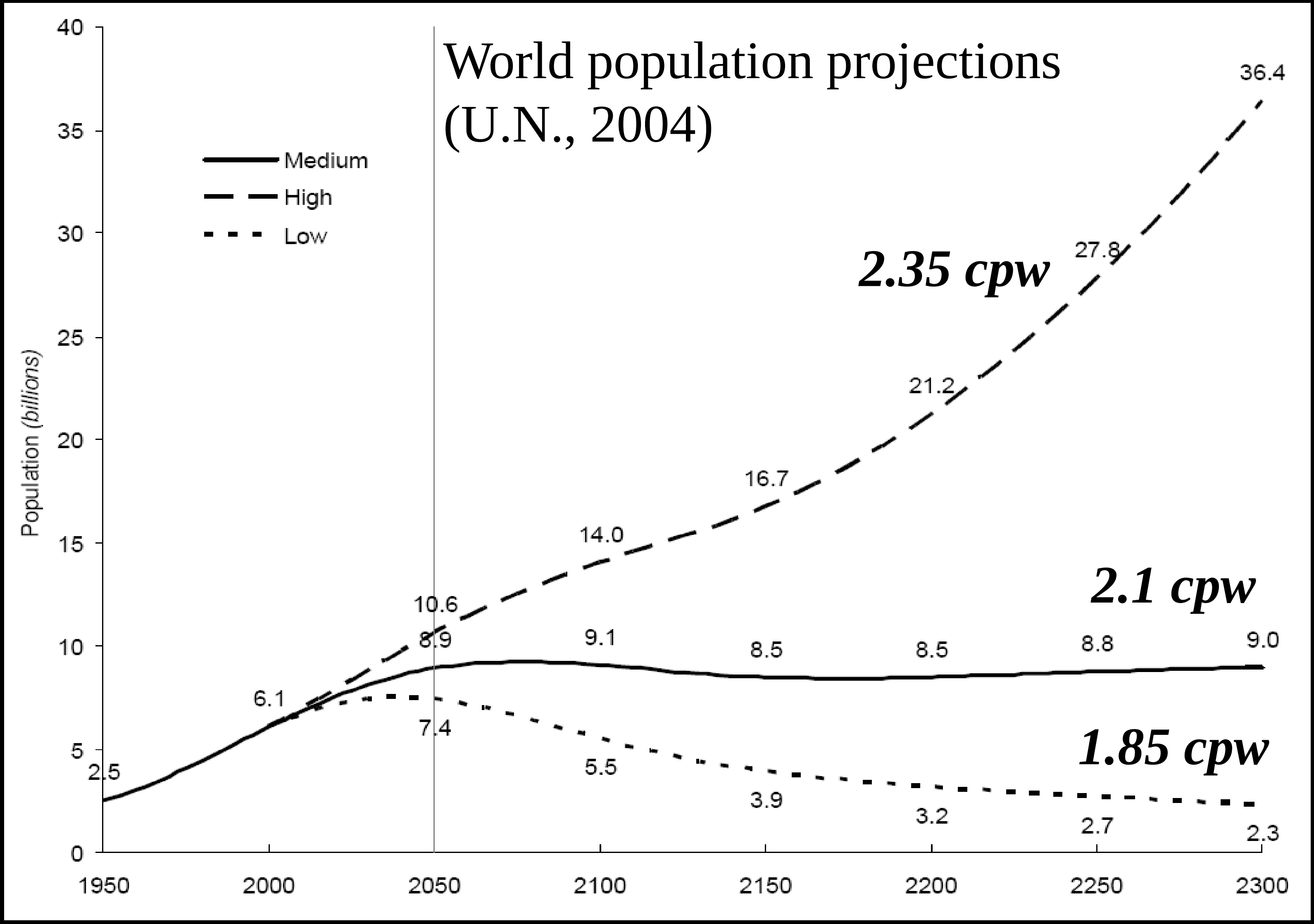


Statistical Science
2014, Vol. 29, No. 1, 58–68

To model this, we used a single first-order autoregressive model with long-term mean μ equal to the approximate replacement fertility level of $\boxed{2.1}$ for all countries in Phase III, namely,

2.1 children per woman

Why is this assumption so persistent?



To avoid disaster, keep *TFR* at 2.1!   Avoiding disaster is admirable, but avoiding disaster by wishful thinking . . . ?

SCIENCE

10 OCTOBER 2014 • VOL 346

WORLD POPULATION

World population stabilization unlikely this century

Patrick Gerland,[1*†] Adrian E. Raftery,[2*†] Hana Ševčíková,[3] Nan Li,[1] Danan Gu,[1] Thomas Spoorenberg,[1] Leontine Alkema,[4] Bailey K. Fosdick,[5] Jennifer Chunn,[6] Nevena Lalic,[7] Guiomar Bay,[8] Thomas Buettner,[9‡] Gerhard K. Heilig,[9‡] John Wilmoth[1]

To model this, we used a single first-order autoregressive model with long-term mean μ equal to the approximate replacement fertility level of $\boxed{2.1}$ for all countries in Phase III, namely,

SCIENCE

31 OCTOBER 2014 • VOL 346

Population growth: Peak probability

IN THEIR REPORT "World population stabilization unlikely this century" (10 October, p. 234; published online 18 September), P. Gerland *et al.* used a United Nations (UN) 2012 assessment to support their claim that the population will not peak this century, despite our earlier work indicating that it will (*1–3*).

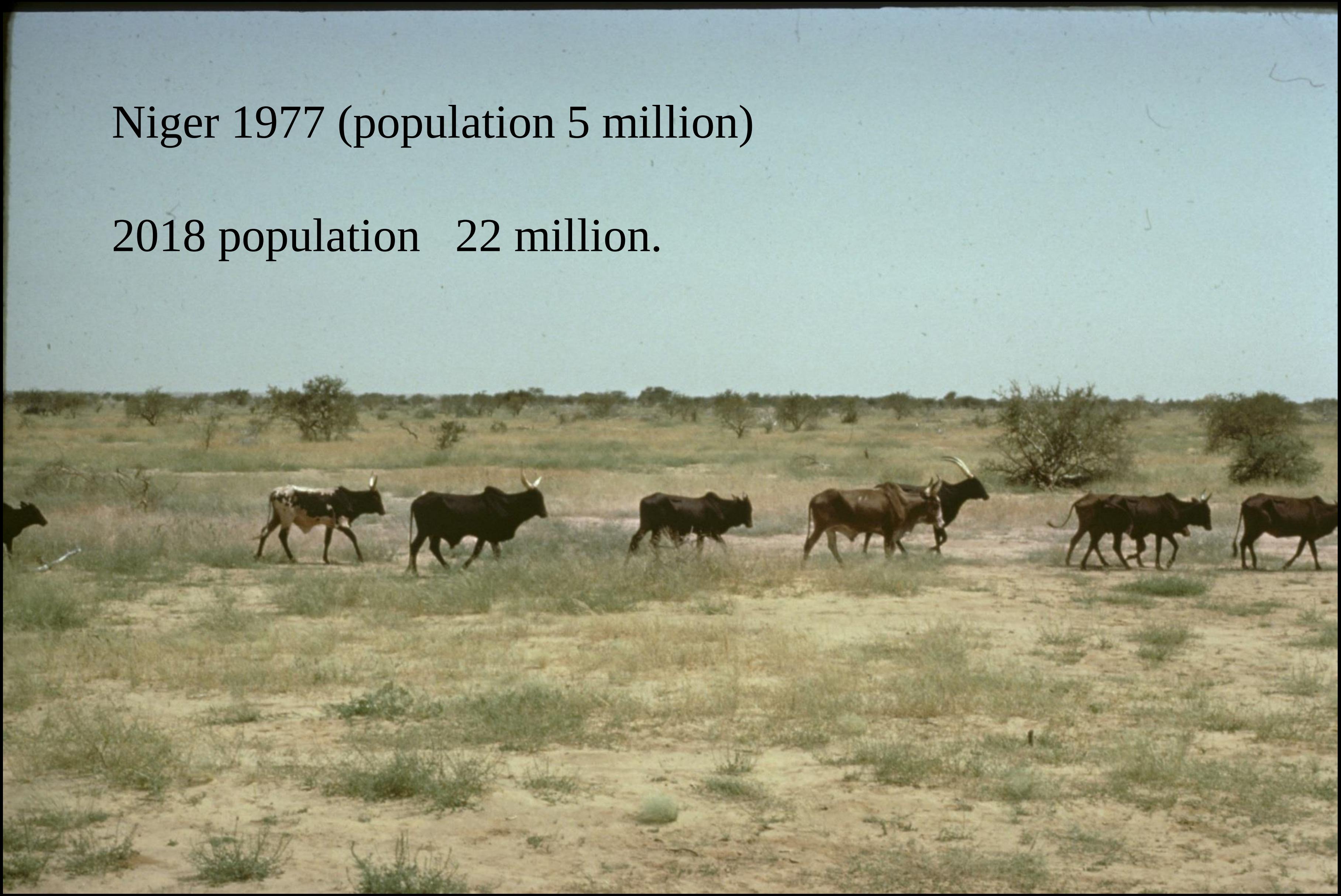
Wolfgang Lutz,* William Butz, Samir KC, Warren Sanderson, Sergei Scherbov

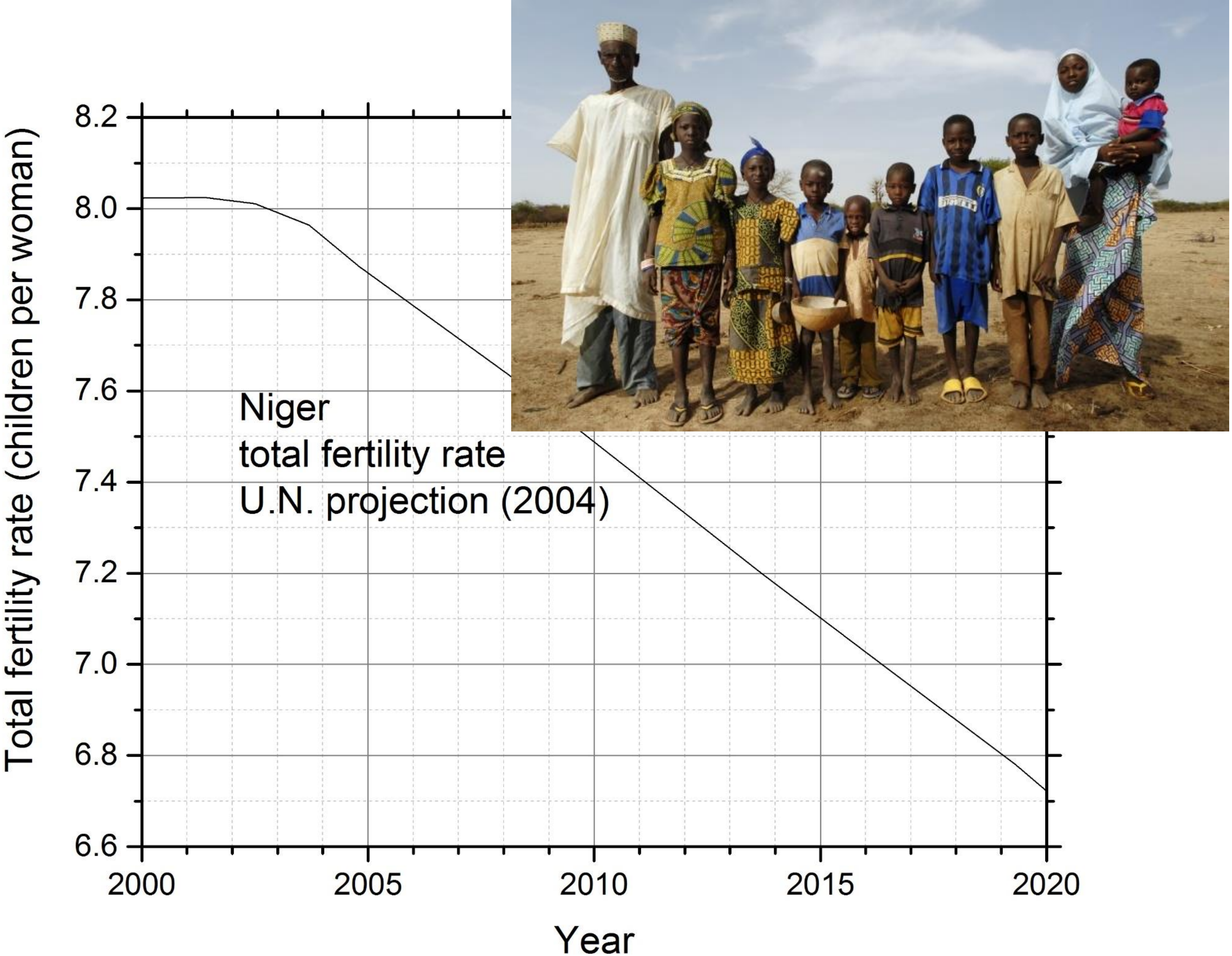
World Population Program, International Institute for Applied Systems Analysis (IIASA), A-2361 Laxenburg, Austria.

Beyond 2030–2035, fertility was assumed to reach an average level of between 1.7 and 2.1 children per woman by 2080, with the specific value depending on population density in 2030 (the high the density, the lower the fertility). The 90 per cent range around that value was set at 1.0 children. The

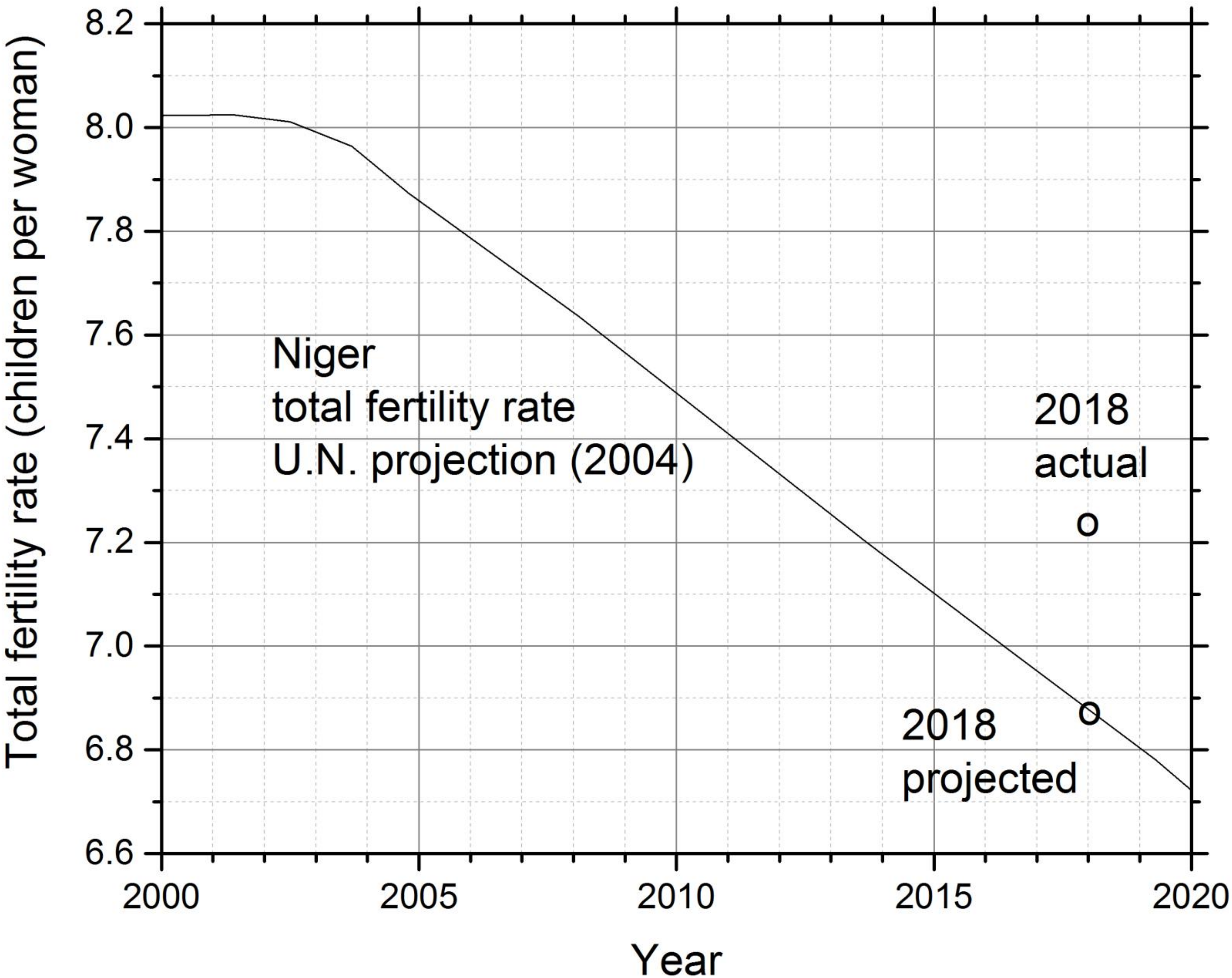
UN Children's clinic. Zinder, Niger, 1977

Agadez market, Niger, 1977


Niger 1977 (population 5 million)
2018 population 22 million.



Niger
total fertility rate
U.N. projection (2004)
Total fertility rate (children per woman)
Year
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
2000
2005
2010
2015
2020



Niger
total fertility rate
U.N. projection (2004)
2018
actual
2018
projected
Total fertility rate (children per woman)
Year
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
2000
2005
2010
2015
2020

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Stall in fertility decline in Eastern African countries: regional analysis of patterns, determinants and implications

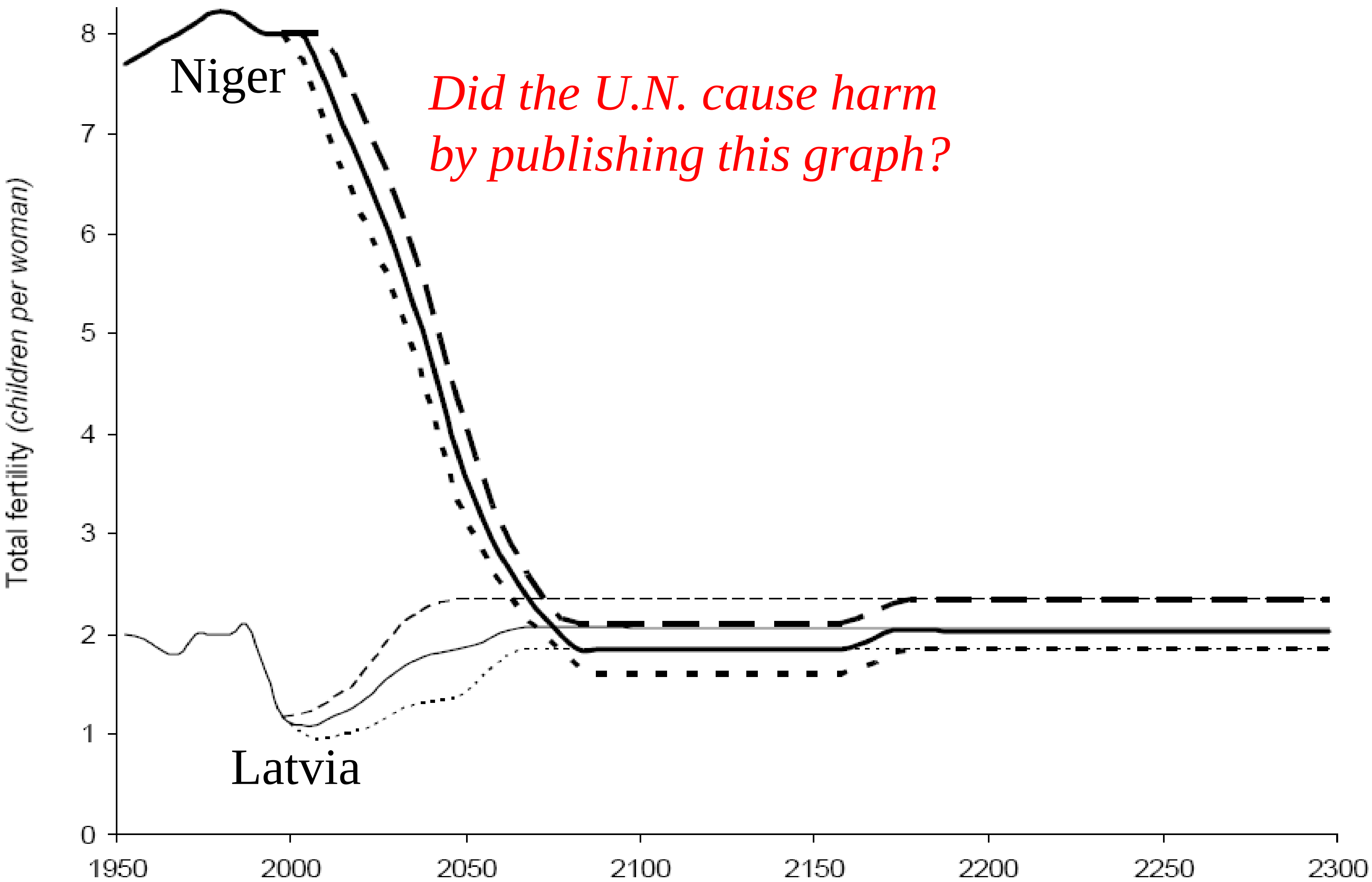
Alex C. Ezeh, Blessing U. Mberu and Jacques O. Emina

Phil. Trans. R. Soc. B 2009 **364**, 2991-3007

caused by

"decline in international development assistance for family planning"

Figure 41. Total fertility in Niger and Latvia, estimates and three scenarios: 1950-2300



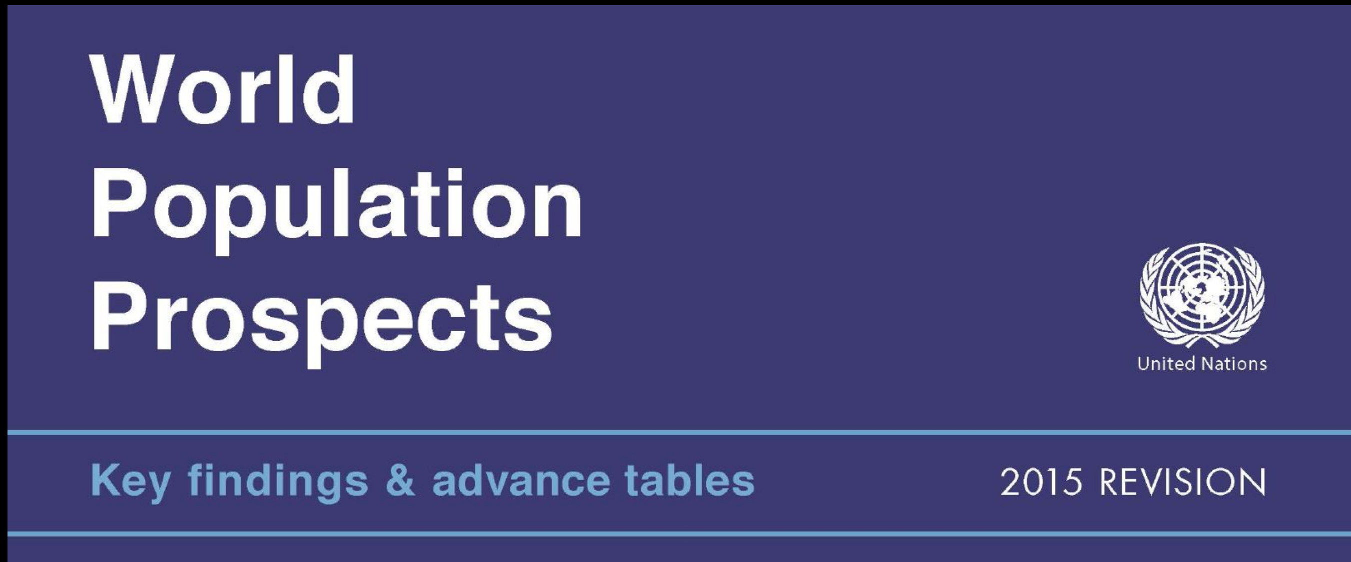
Economic & Social Affairs

World Population Prospects

United Nations

Key findings & advance tables

2015 REVISION



Niger

Year	2015	2030	2050	2100
Total fertility rate (cpw)	7.6	6.7	4.9	2.5
population (millions)	20	36	72	209
life expectancy at birth (years)	61	66	71	77
under-5 mortality (per 1000 births)	104	60	30	12

Slow down population growth

Within a decade, women everywhere should have access to quality contraceptive services, argues **John Bongaarts**.

"unmet need"

unsatisfied demand for contraception. About 74 million unplanned pregnancies occur each year in the developing world (39% of annual developing-world pregnancies). About half of these end in induced abortions[4].

Slow down population growth

Within a decade, women everywhere should have access to quality contraceptive services, argues **John Bongaarts**.

Still, only 1% of all overseas development assistance (ODA) is now allocated to family planning[10]. This amount is inadequate; in too many countries, programmes remain weak and political commitment is lacking.

The proportion of ODA allocated to family planning should be raised to 2% and developing-countries governments should expand their funding by an equivalent proportion. Such a doubling of funding will be more than repaid by savings in other sectors such as education and health care in future years.

GUTTMACHER INSTITUTE

Fact Sheet

March 2016

Unintended Pregnancy in the United States

In the United States, 45% of pregnancies are unintended.

Mistimed 27%
Unwanted 18%
Total unintended 27+18=45%

Unintended pregnancies result in birth (60%) or abortion (40%).

Reproduction and the carbon legacies of individuals

Paul A. Murtaugh[a,*], Michael G. Schlax[b]

Family-planning is the most effective way for Americans to reduce their CO_2 emissions.

Global Environmental Change 19 (2009) 14–20

Reproduction and the carbon legacies of individuals

Paul A. Murtaugh [a,*], Michael G. Schlax [b]

A B S T R A C T

Much attention has been paid to the ways that people's home energy use, travel, food choices and other routine activities affect their emissions of carbon dioxide and, ultimately, their contributions to global warming. However, the reproductive choices of an individual are rarely incorporated into calculations of his personal impact on the environment. Here we estimate the extra emissions of fossil carbon dioxide that an average individual causes when he or she chooses to have children. The summed emissions of a person's descendants, weighted by their relatedness to him, may far exceed the lifetime emissions produced by the original parent. Under current conditions in the United States, for example, each child adds about 9441 metric tons of carbon dioxide to the carbon legacy of an average female, which is 5.7 times her lifetime emissions. A person's reproductive choices must be considered along with his day-to-day activities when assessing his ultimate impact on the global environment.

(assuming your child will have 1.85 children)

Global Environmental Change 19 (2009) 14–20

Murtaugh and Schlax (2009)

Table 3

For the United States, lifetime emissions of CO_2 that are saved by different actions, based on the EPA's Personal Emissions Calculator (U.S. Environmental Protection Agency, 2007), and average emissions caused by having one additional child, from Table 2. Totals were obtained by multiplying the EPA's annual figures by 80, the current life expectancy of a female in the United States.

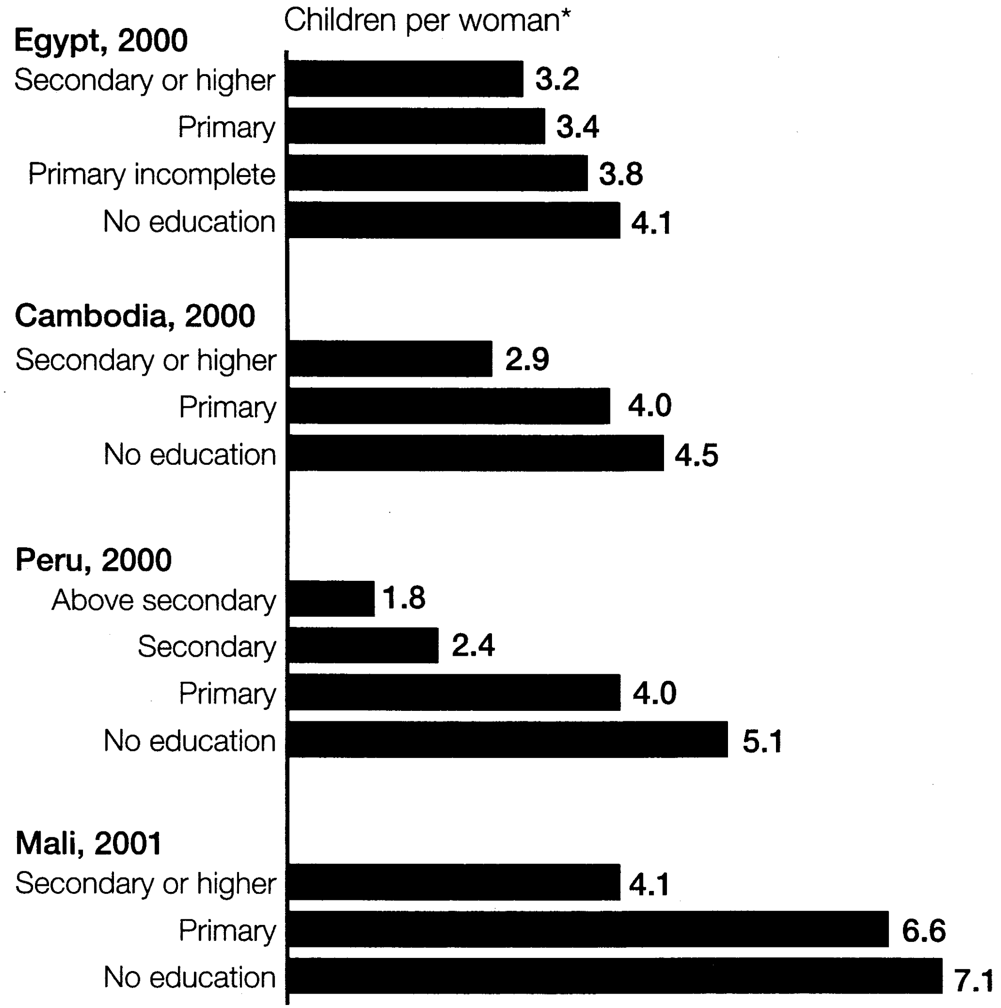
Action	CO_2 saved (metric tons [a])
Increase car's fuel economy from 20 to 30 mpg	148
Reduce miles driven from 231 to 155 per week	147
Replace single-glazed windows with energy-efficient windows	121
Replace ten 75-w incandescent bulbs with 25-w energy-efficient lights	36
Replace old refrigerator with energy-efficient model	19
Recycle newspaper, magazines, glass, plastic, aluminum, and steel cans	17
Reduce number of children by one	
Constant-emission scenario	9,441
Optimistic scenario	562
Pessimistic scenario	12,730

Birth rates have been dropping.

What causes birth rates to drop?

Figure 8

Fertility by Mother's Education Level in Selected Countries, Around 2000



*Average number of children that a woman would have under prevailing age-specific birth rates.

Sources: ORC Macro, country final reports, Demographic and Health Surveys, available online at www.measuredhs.org.

How to reduce the birth rate in high-fertility countries?

Fertility rate correlates inversely with affluence and education of girls.

The causality goes in both directions. Countries with fewer children to support are able to invest more in the education of those children.

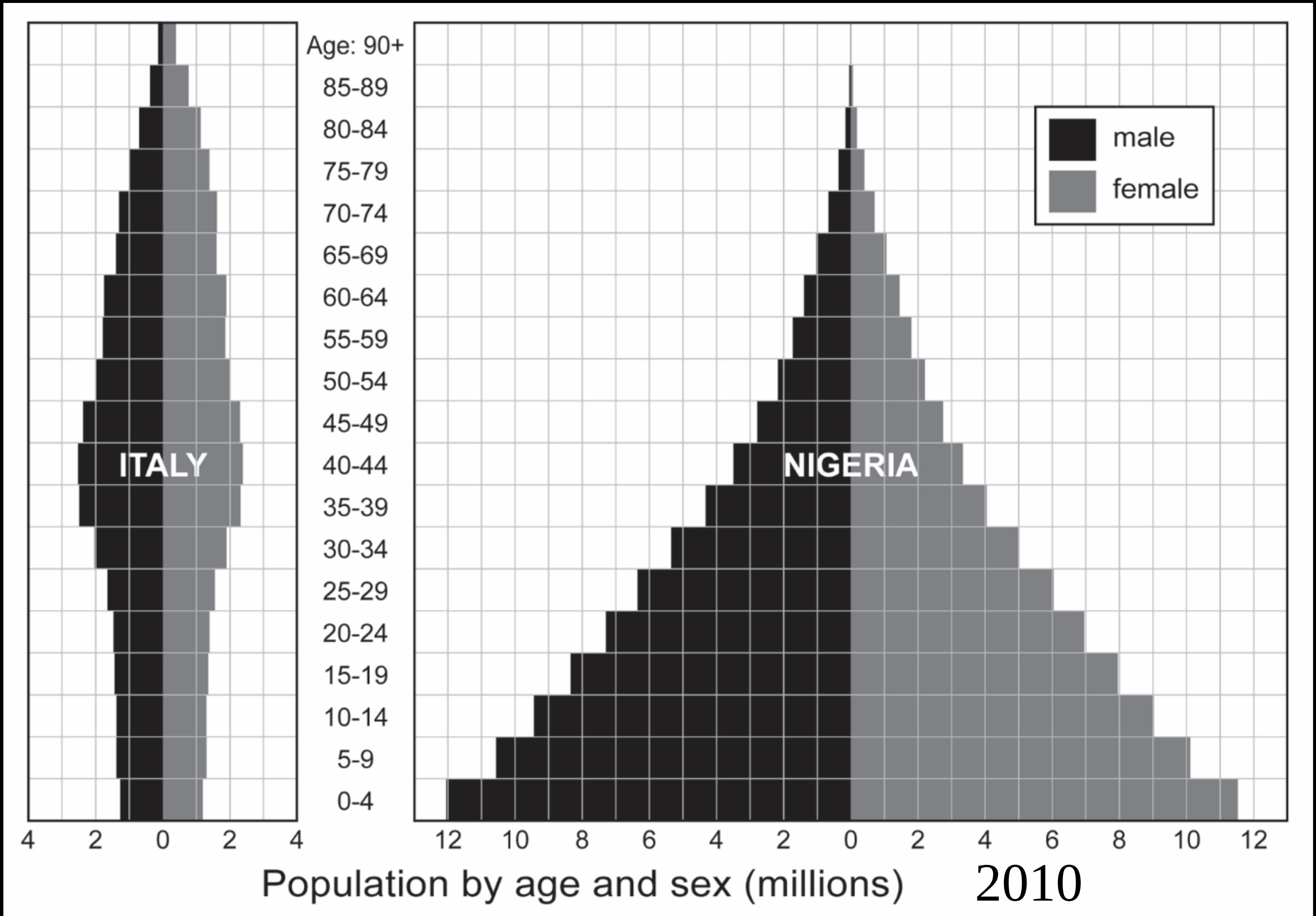
Lutz, 2011: "Under conditions of high population growth, the increase in the school-age population is such that even maintaining the current school enrollment rates is an uphill battle. From a policy perspective it is most effective to try to increase female education and improve access to family planning programs at the same time."

Fertility Below Replacement Level

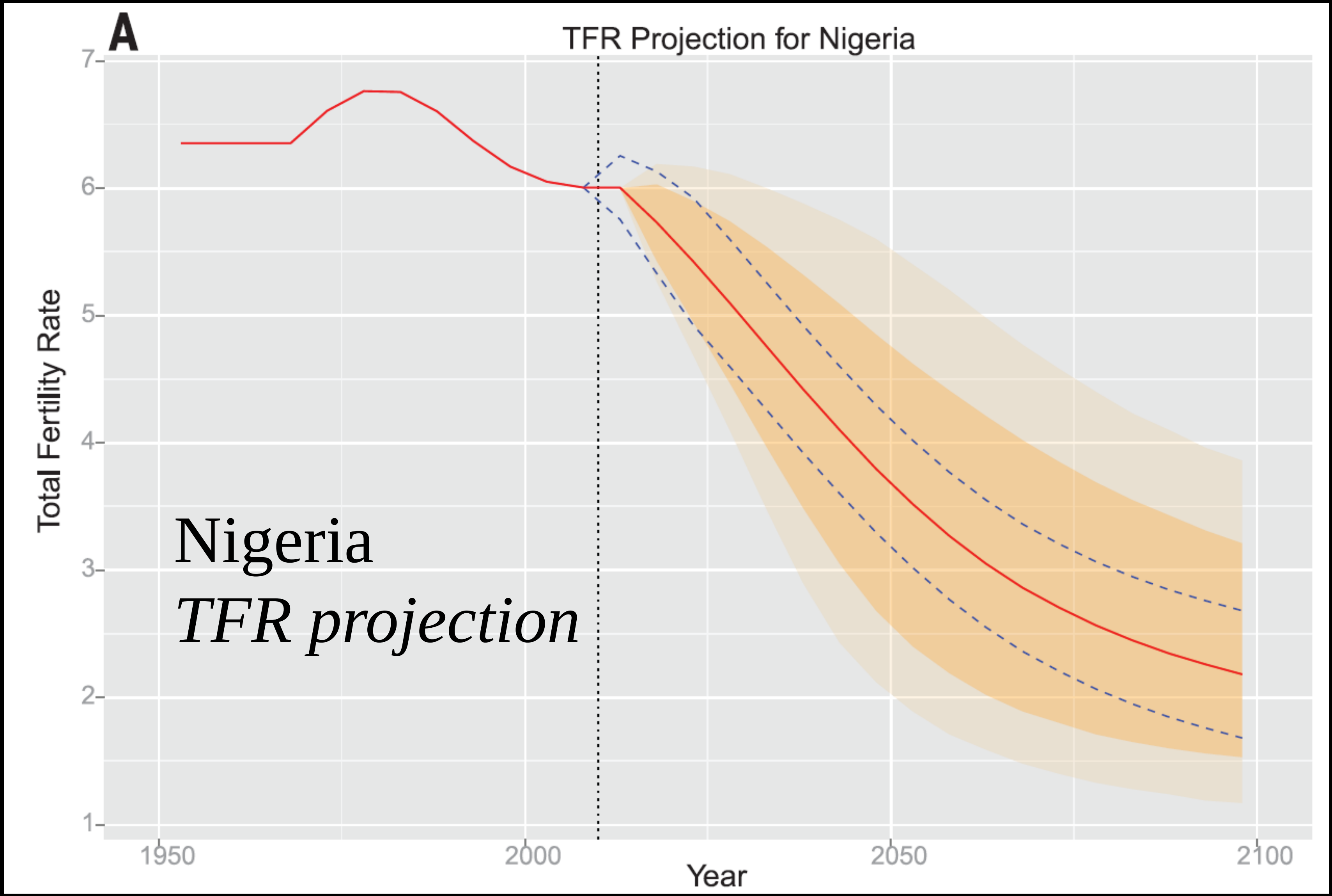
IN ASSESSING THE STATE OF THE PLANET, IT IS important to note that during late 2003 or early 2004, the human population will cross a historic, but so far largely unnoticed, threshold. Most of the world's population either already do, or soon will, live in countries or regions in which fertility is below the level of long-run replacement.

Birth rates have been dropping.

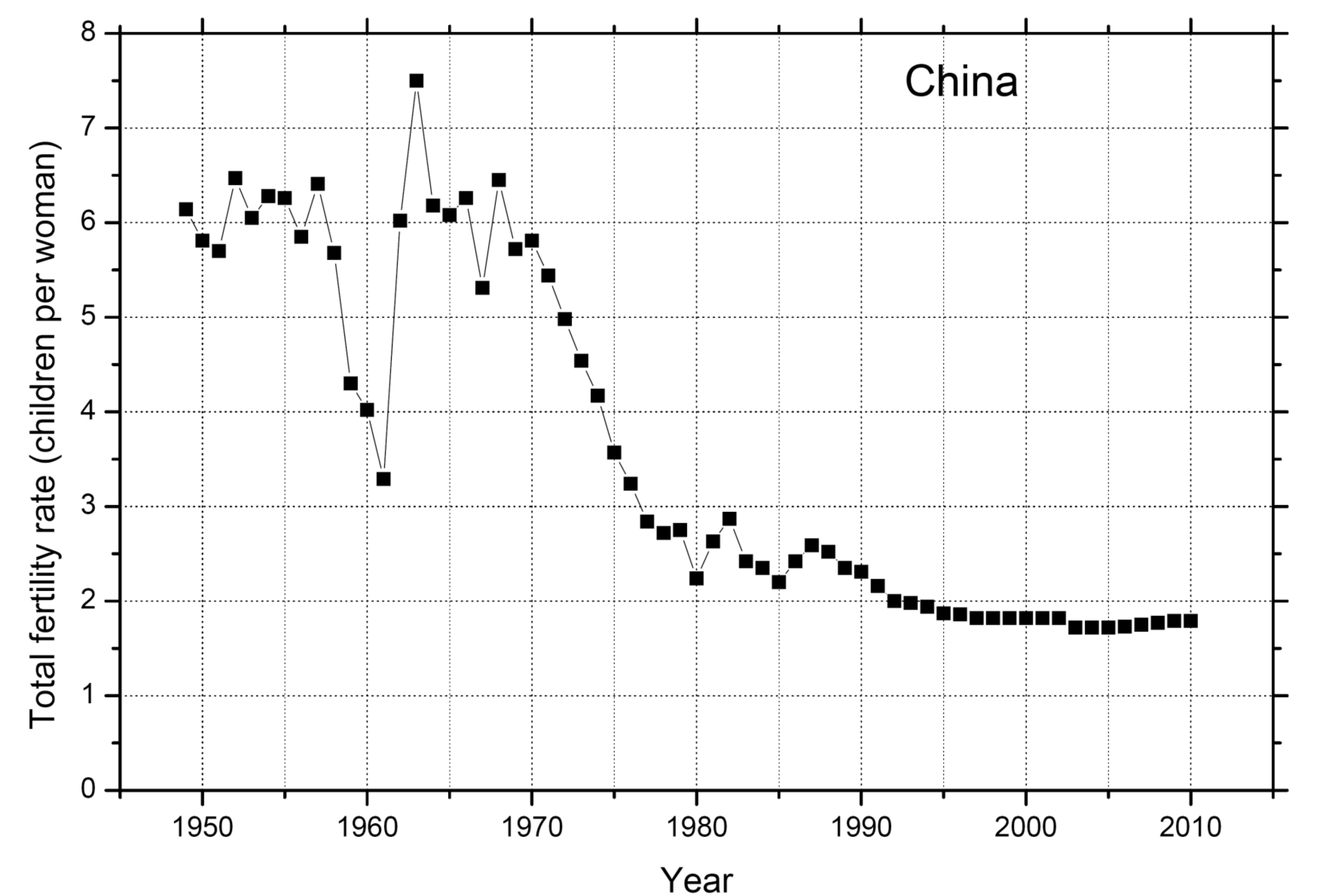
As of 2004, half of the world's population live in countries in which fertility is below replacement level. (Wilson, *Science*, 2004)

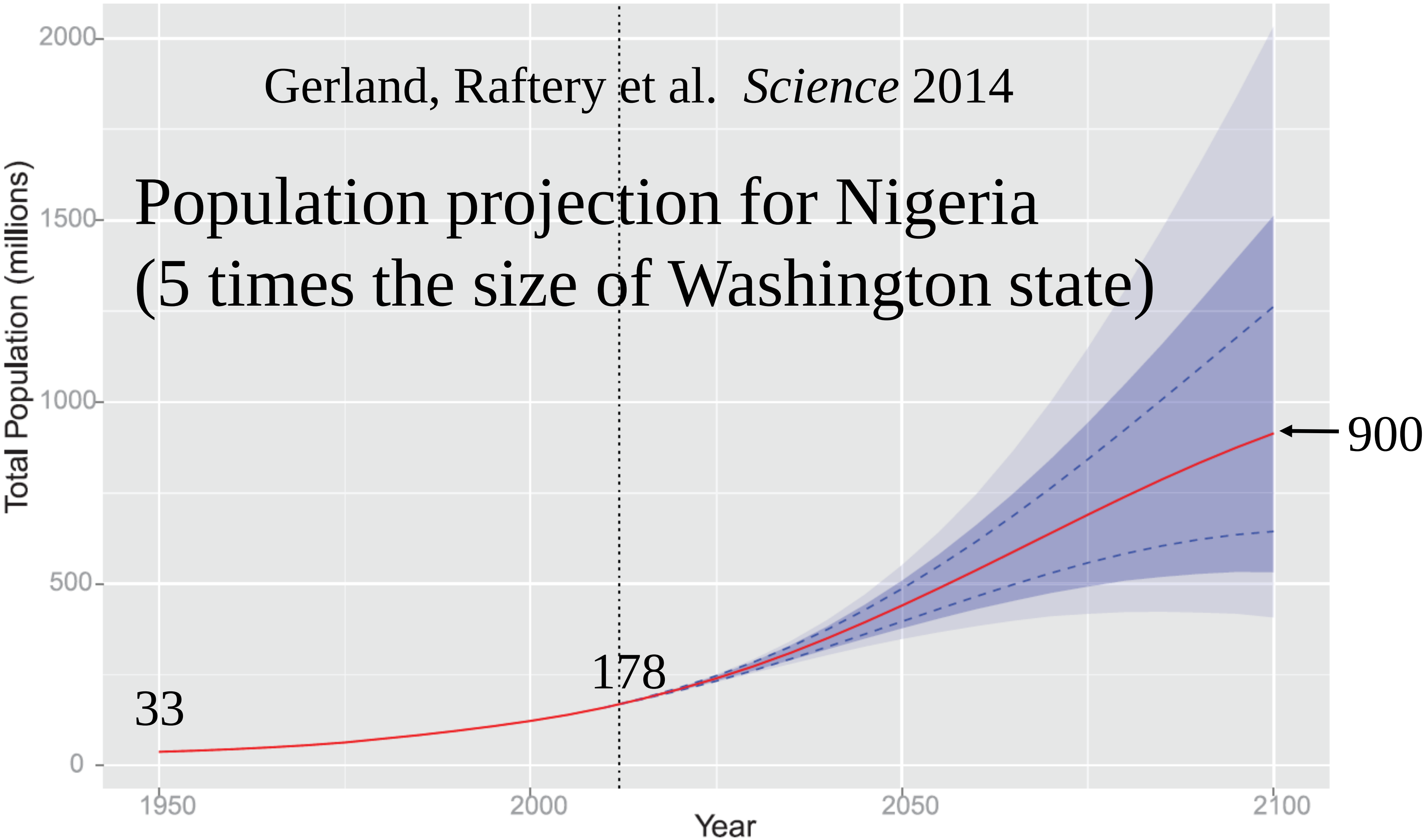


Age: 90+
85-89
80-84
75-79
70-74
65-69
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5-9
0-4
ITALY
NIGERIA
male
female
4 2 0 2 4
12 10 8 6 4 2 0 2 4 6 8 10 12
Population by age and sex (millions)
2010



Median projection of *TFR* for Nigeria reaches 2.2 in 2100.
[Gerland, Raftery et al. *Science* 2014]


China
Total fertility rate (children per woman)
Year
0
1
2
3
4
5
6
7
8
1950
1960
1970
1980
1990
2000
2010



Median projection for 2100 is 900 million.

Can Nigeria's agriculture support 900 million?

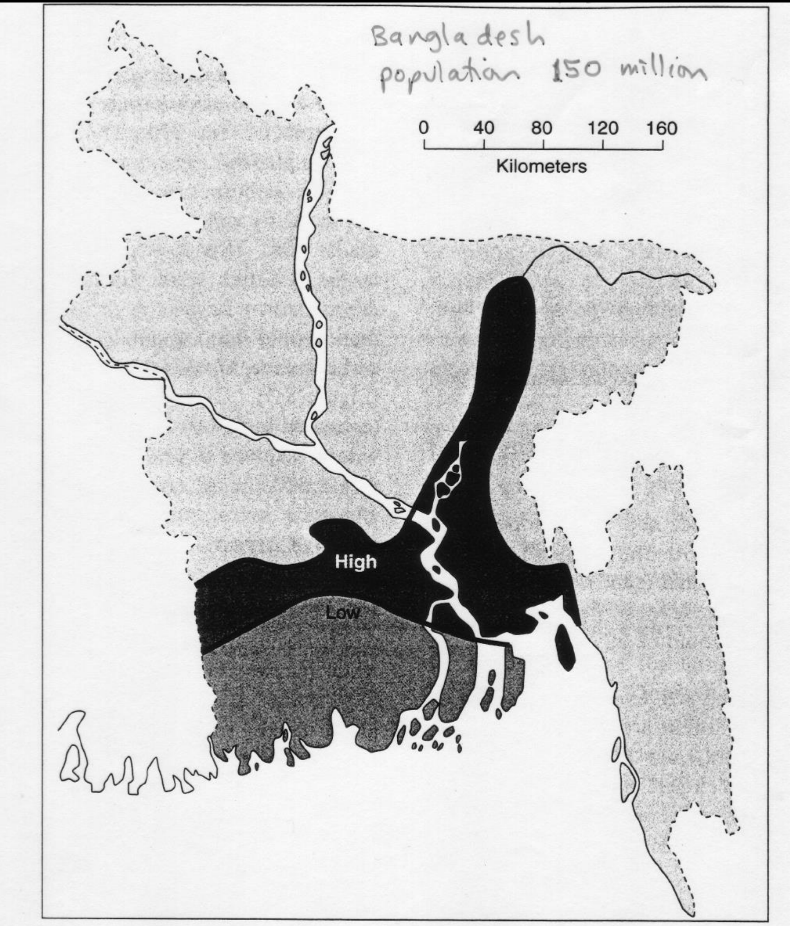
International New York Times, 2 November 2015.
"Mass migration poised to rise"

million it is as populous as Afghanistan.

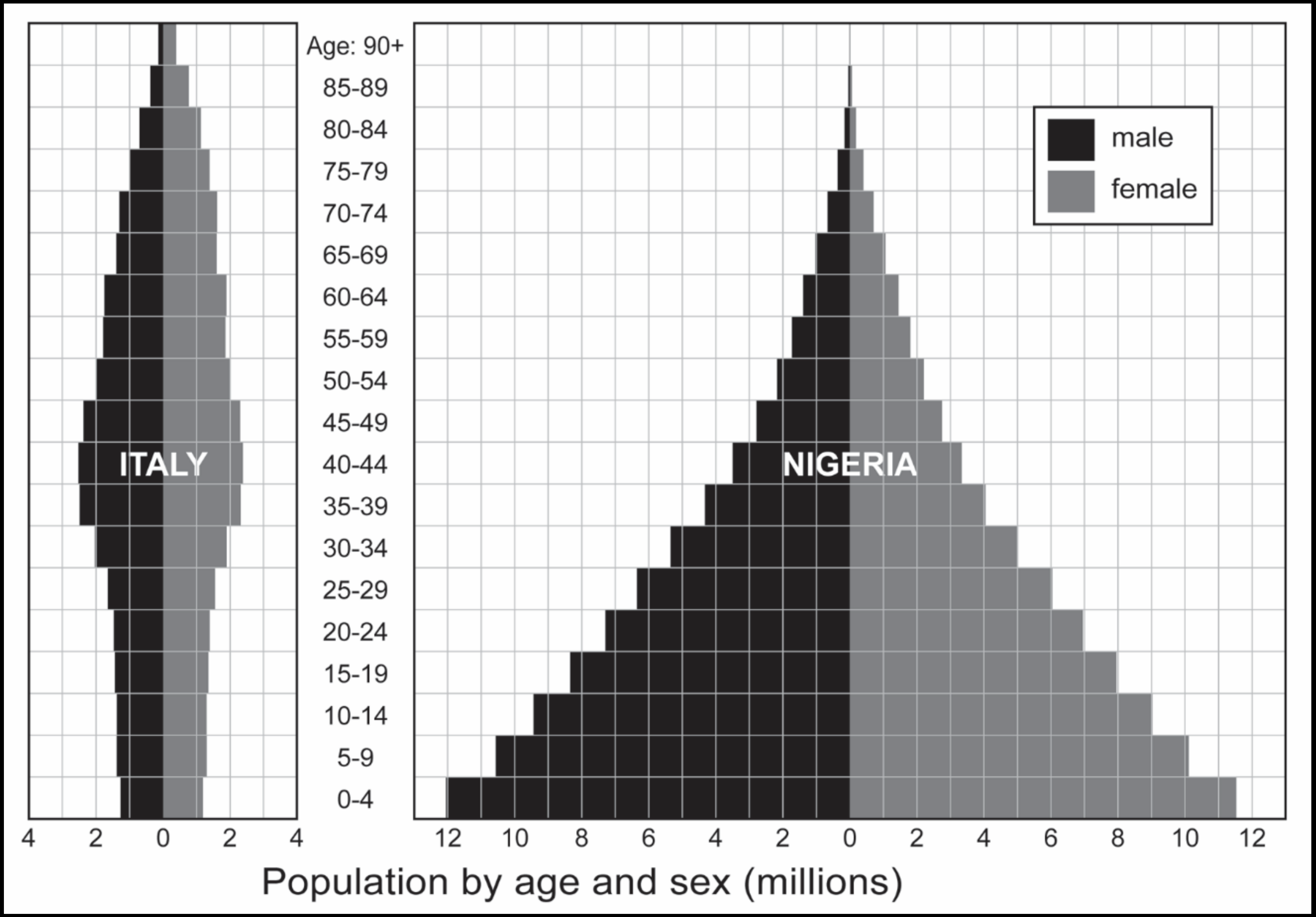
Nor is it only the Middle East and North Africa that European leaders need to consider. The Gallup Poll, based on data compiled from more than 450,000 interviews in 151 nations from 2009 to 2011, found that in Nigeria, which already has double the population of Germany, 40 percent of people would emigrate to the West if they could. And the lesson of 2015 — for them and much of the world — is that they can.

While the flow of migrants to Europe

India is building a fence on the border of Bangladesh.



Impact of low (0.5 m) and high (3 m) sea-level rise in Bangladesh (From Broadus



Countries with low fertility rates: *aging* and *shrinking*

Countries with low fertility rates:
aging and *shrinking*

LTCB International Library Trust/International House of Japan

Shrinking-Population Economics

Lessons from Japan

Matsutani Akihiko

Professor,
National Graduate Institute for Policy Studies

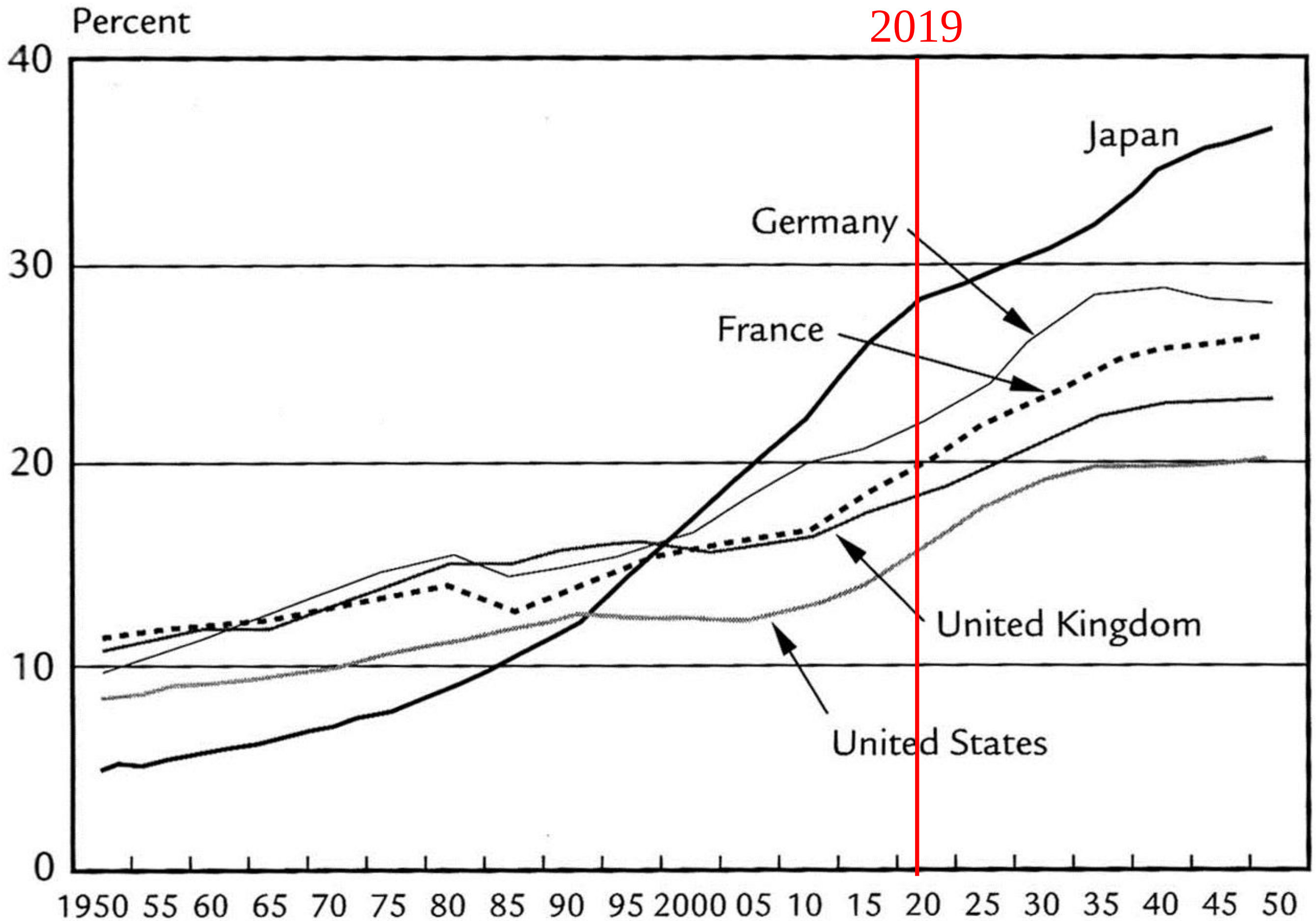
2006

201 pages

Translated by
Brian Miller

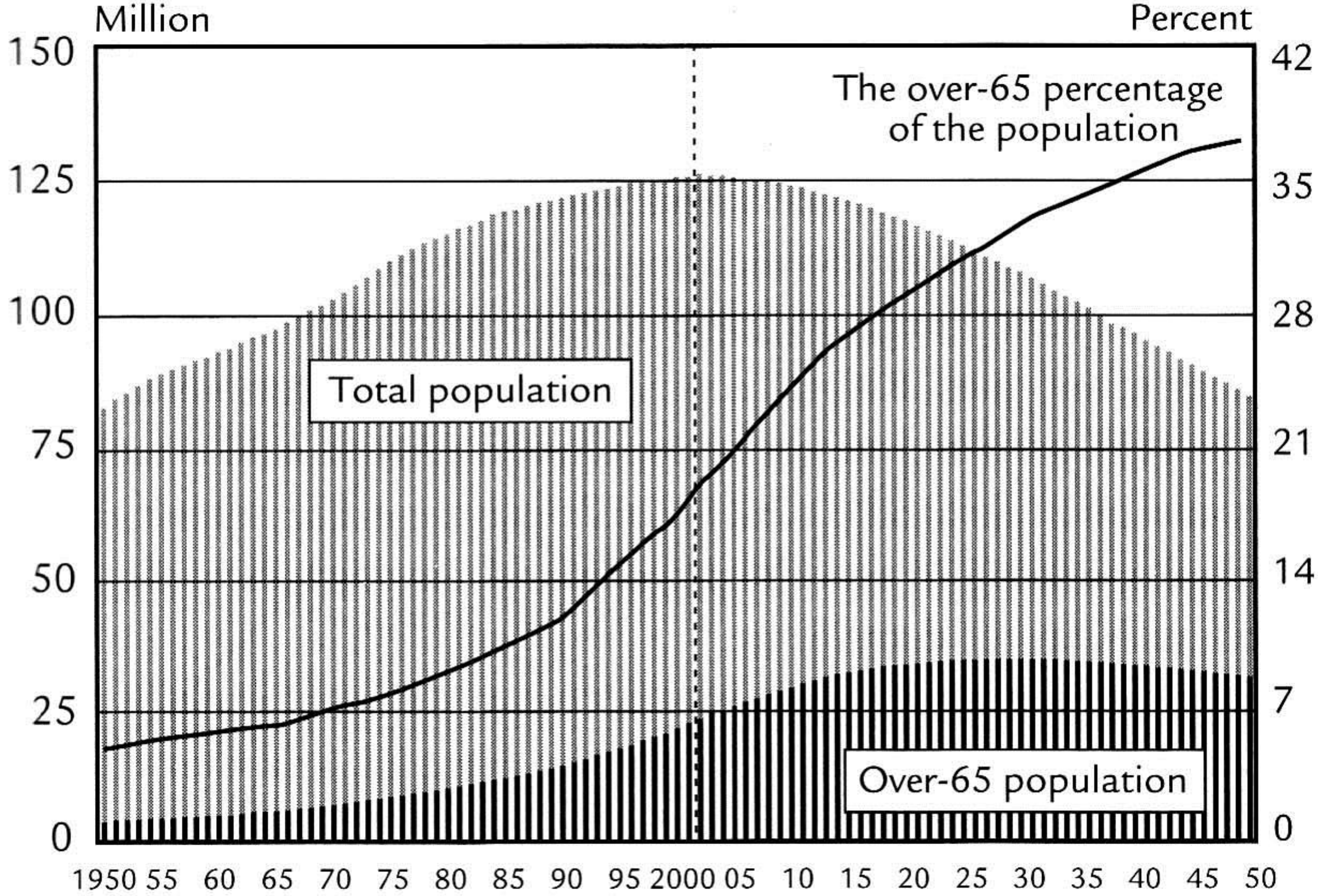
Figure 1

The Over-65 Percentage of the Population in Principal Industrialized Nations–Past, Present, and Future



Source: United Nations, *World Population Prospects 2002 Revised*

Figure 4
Over-65 Japanese



Sources: National census data published by the Statistics Bureau of Japan's Ministry of Internal Affairs and Communications for years to 2000 and projections by Fujimasa Iwao for subsequent years

ECONOMIC DEMOGRAPHY

Science, 2014

Is low fertility really a problem? Population aging, dependency, and consumption

Ronald Lee,[1*] Andrew Mason,[2,3*] members of the NTA Network†

Longer lives and fertility far below the replacement level of 2.1 births per woman are leading to rapid population aging in many countries. Many observers are concerned that aging will adversely affect public finances and standards of living. Analysis of newly available National Transfer Accounts data for 40 countries shows that fertility well above replacement would typically be most beneficial for government budgets. However, fertility near replacement would be most beneficial for standards of living when the analysis includes the effects of age structure on families as well as governments. And fertility below replacement would maximize per capita consumption when the cost of providing capital for a growing labor force is taken into account. Although low fertility will indeed challenge government programs and very low fertility undermines living standards, we find that moderately low fertility and population decline favor the broader material standard of living.

Trends in Ecology & Evolution 2018

CellPress REVIEWS

Opinion

Aging Human Populations: Good for Us, Good for the Earth

Frank Götmark,[1,*] Philip Cafaro,[2] and Jane O'Sullivan[3]

As the nations of the world grapple with the task of creating sustainable societies, ending and in some cases reversing population growth will be necessary to succeed. Yet stable or declining populations are typically reported in the media as a problem, or even a crisis, due to demographic aging. This is misguided, as economic analyses show that the costs connected with aging societies are manageable, while the economic, social, and environmental benefits of smaller populations are substantial. Earth's human-carrying capacity has been exceeded; hence, population growth must end and aging societies are unavoidable. They should be embraced as part of a just and prosperous future for people and the other species with whom we share our planet.

Highlights

Despite ongoing social and environmental crises driven by human population increase, public concern has instead focused on demographic aging as the greater challenge, even suggesting that population growth should be rekindled to combat it.

The economic and demographic literatures suggest that the problems associated with aging societies are both overstated and manageable,

Summary

For the last 45 years, world population has increased steadily by ~80 million every year, because the growth *rate* is decreasing.

Fertility rates in Africa have been declining more slowly than expected (“stalled”).

There is nothing unusual about having more than two children; it is normal for all animal species. The cause of human population growth is advances in agriculture.

Agriculture is in a race to keep up with growing population.

Recommendations for the U.N.

Instead of population projections based on optimistic assumptions of fertility and mortality,

identify *TFR* = 2.1 cpw as a *goal*, and identify policies for each country that would push *TFR* toward that goal.

Meeting the Sustainable Development Goals leads to lower world population growth

Guy J. Abel[a,b], Bilal Barakat[b], Samir KC[a,b,1], and Wolfgang Lutz[b,1]

Recommended reading:

2013

PHOTOGRAPH BY ROBERTO NEUMILLER

Costa Rica	Pakistan
Britain	Iran
Uganda	Israel
China	Japan
Philippines	India
Niger	Thailand

Let’s take a poll:
What will stop world population growth?

(a) Decrease in birth rate

voluntary
by coercion
accidental

(b) Increase in death rate

Pollution
Contagious disease
War
Depletion of resources
Lack of food

(c) The population won’t stop growing