Human population dynamics

Lecture 2

Future of the human population

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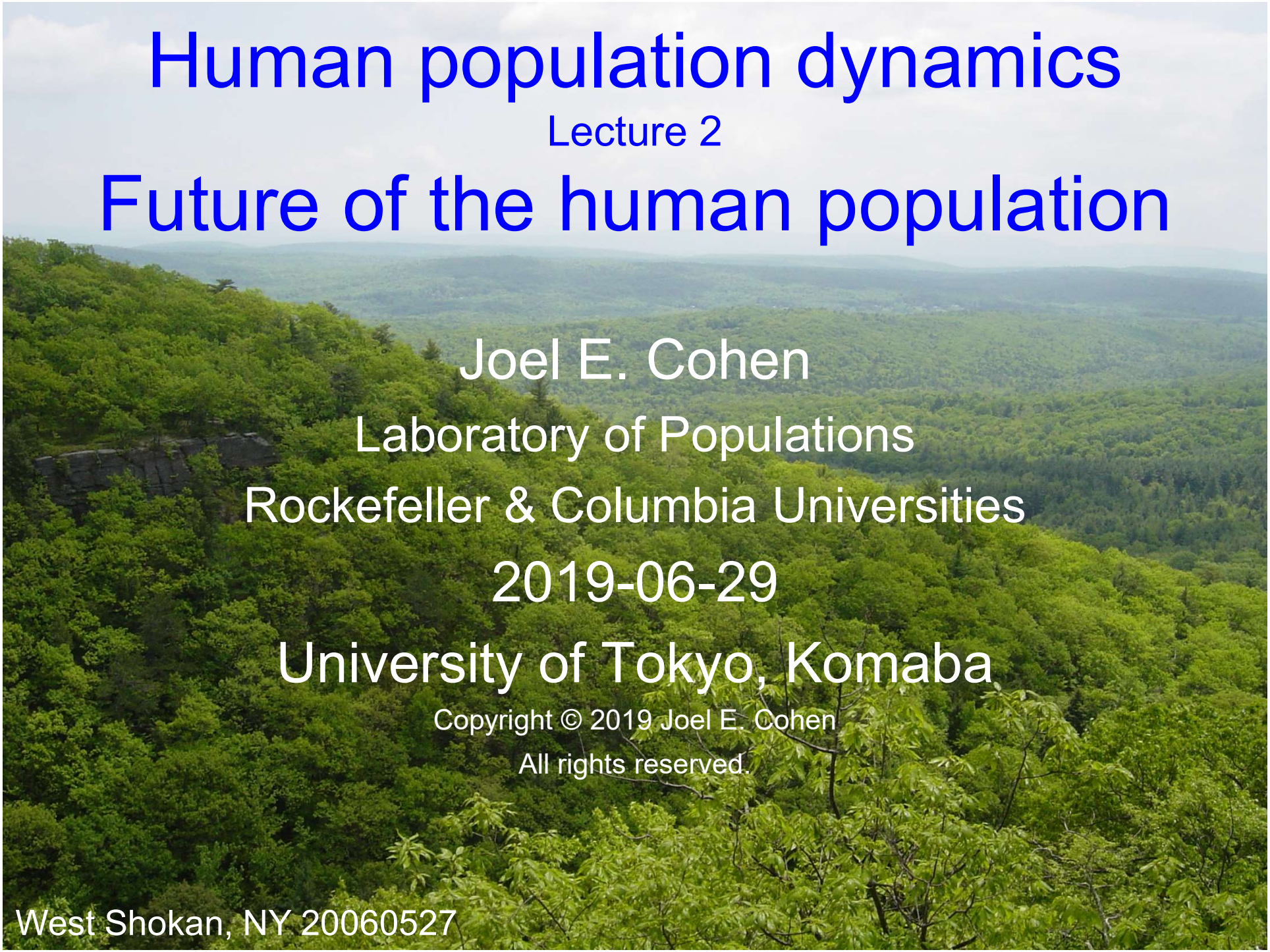
2019-06-29

University of Tokyo, Komaba



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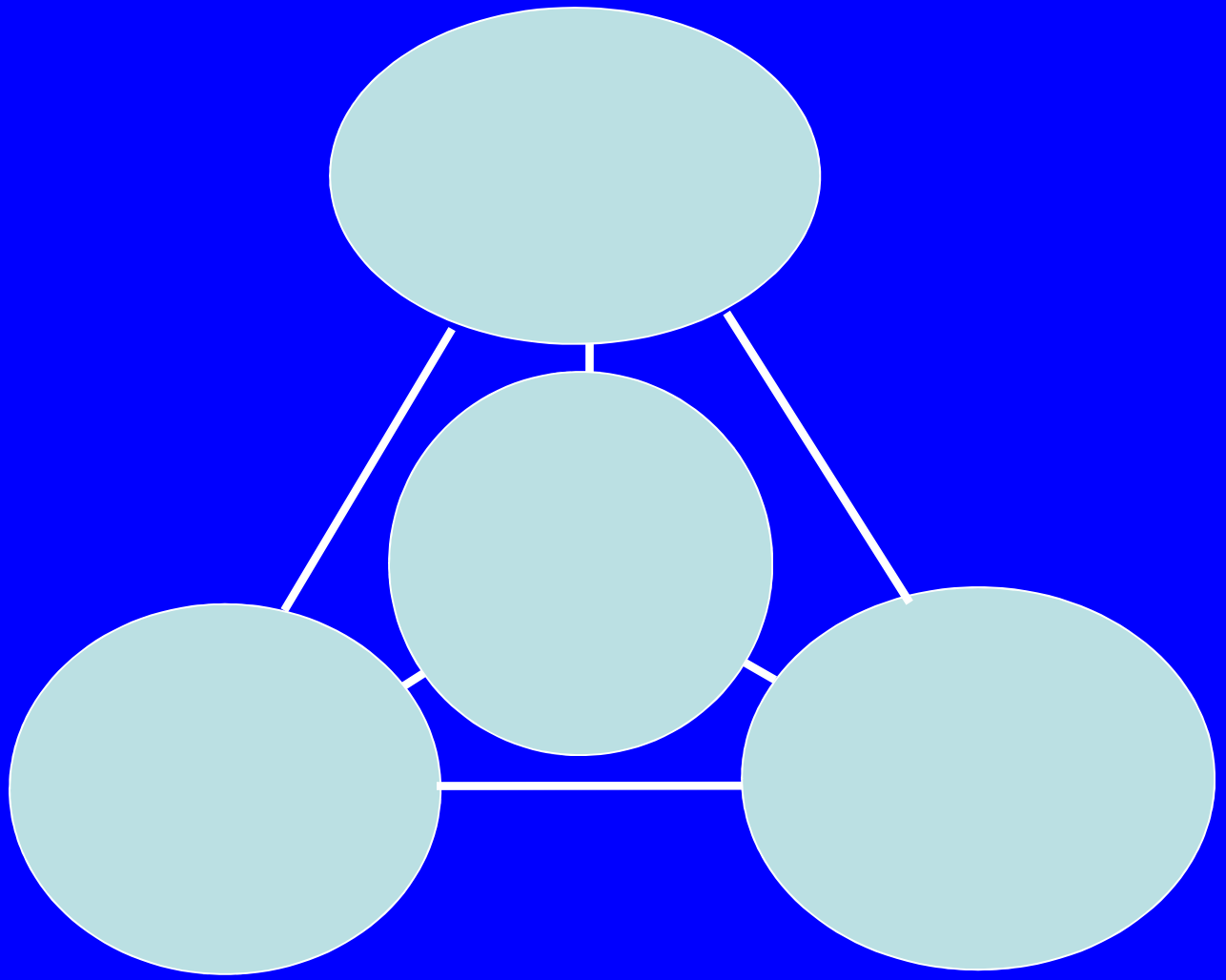
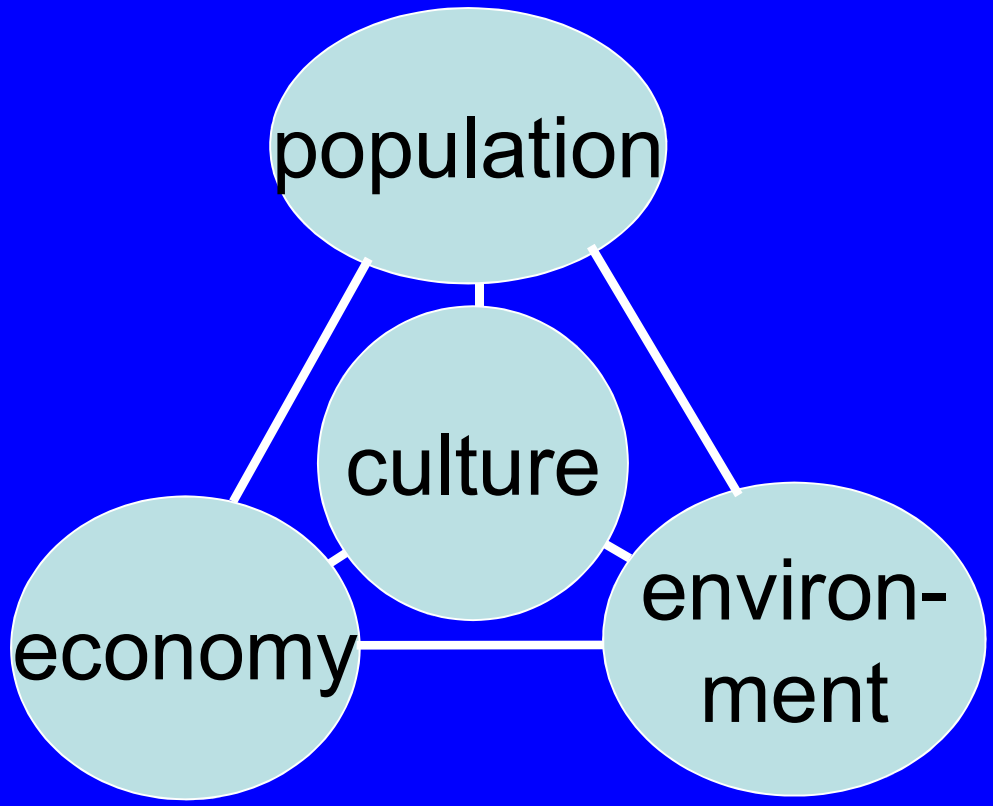
Review

Quiz



Population
Economy
Environment
Culture
interact.



Multiple choice test

1. If global population size continues to grow 1.0%/y, it will more than double by 2100. T, F
2. Global population growth is likely to end by 2100. T, F, do not know
3. Globally, most growth in urban populations comes from rural migrants to cities. T, F
4. By 2050, it is reasonable to expect as many adults 60+ as children 0-14. T, F
5. The fraction of people aged 15-64 years peaked forever around 2012. T, F


The 21st century is
demographically unlike any before.
Montpellier, France JEC

The future of human populations: Outline

Methods

Results

Methods

Core concepts

Projection vs prediction

Time horizon: short-term vs long-term

Expert judgment vs statistical models vs policy

Projection versus prediction

Projection: statement about attributes of future population conditional on explicit assumptions, without asserting these assumptions will hold true.

Example: if global population grows at 1%/year, it will double in size in ~69 years.

Prediction: unconditional statement about attributes of future population (including likelihood of different trajectories)

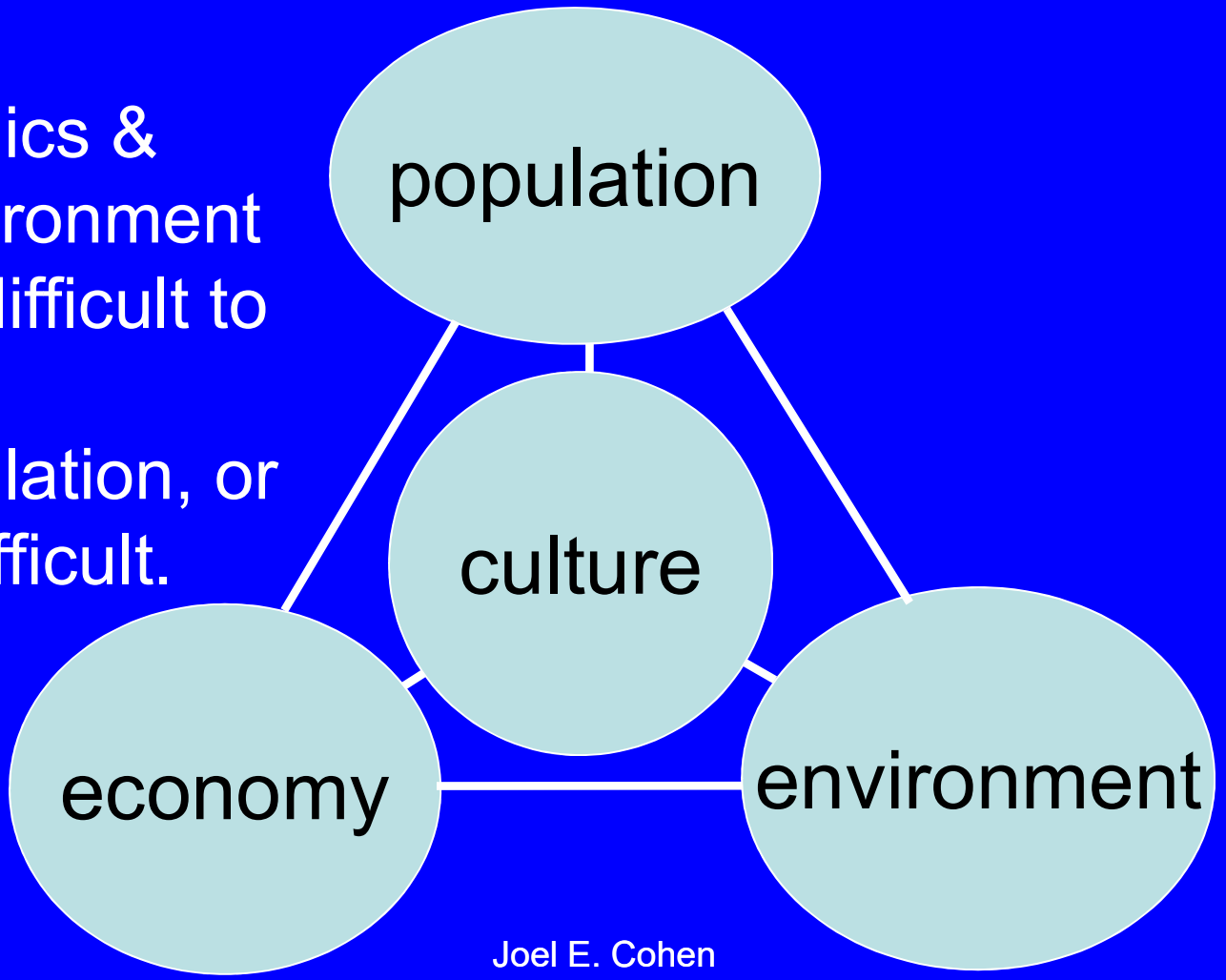
Example: global population will double in 21st century.

Journalists & the public ignore this distinction.

Fundamental difficulty in predicting future:

Population interacts with economics, the environment & culture.

Culture, economics & the environment are as difficult to predict as population, or more difficult.



Time horizon: short-term demographic future is 15 years.

Everyone who will be 15+ years old 15 years from now is alive now.

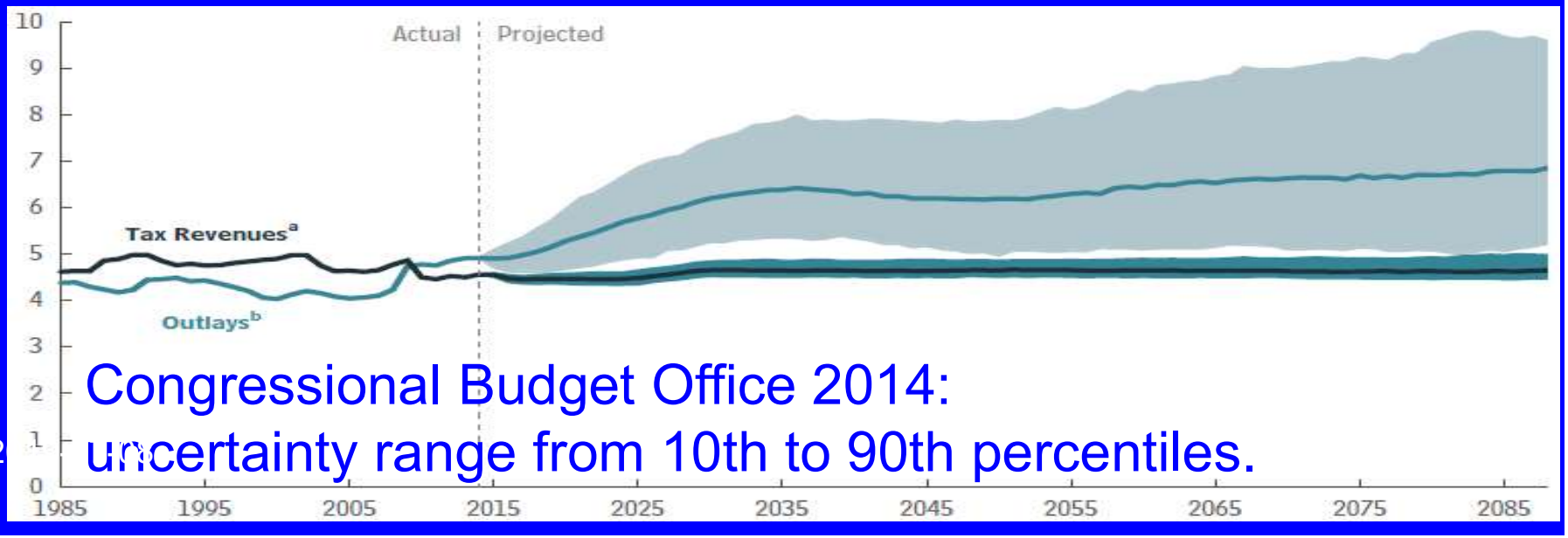
Mothers of almost all births during the next 15 years are alive now.

Prediction is plausible.

Time horizon: long-term demographic future is 85 years.

Only people who will be 81+ in 2100 are alive in 2019. Very few mothers of births 2060-2100 are alive in 2019.

Projected Social Security tax revenues & outlays under unchanged legislation in the United States



Congressional Budget Office 2014: uncertainty range from 10th to 90th percentiles.

UN projections span 2015-2100.

Forecasting quantitative details of fertility, mortality, & migration beyond 2060 is largely guesswork.

Berber girl, Atlas mountains, Morocco, 2009, JEC photo

Expert judgment vs statistical models vs policy

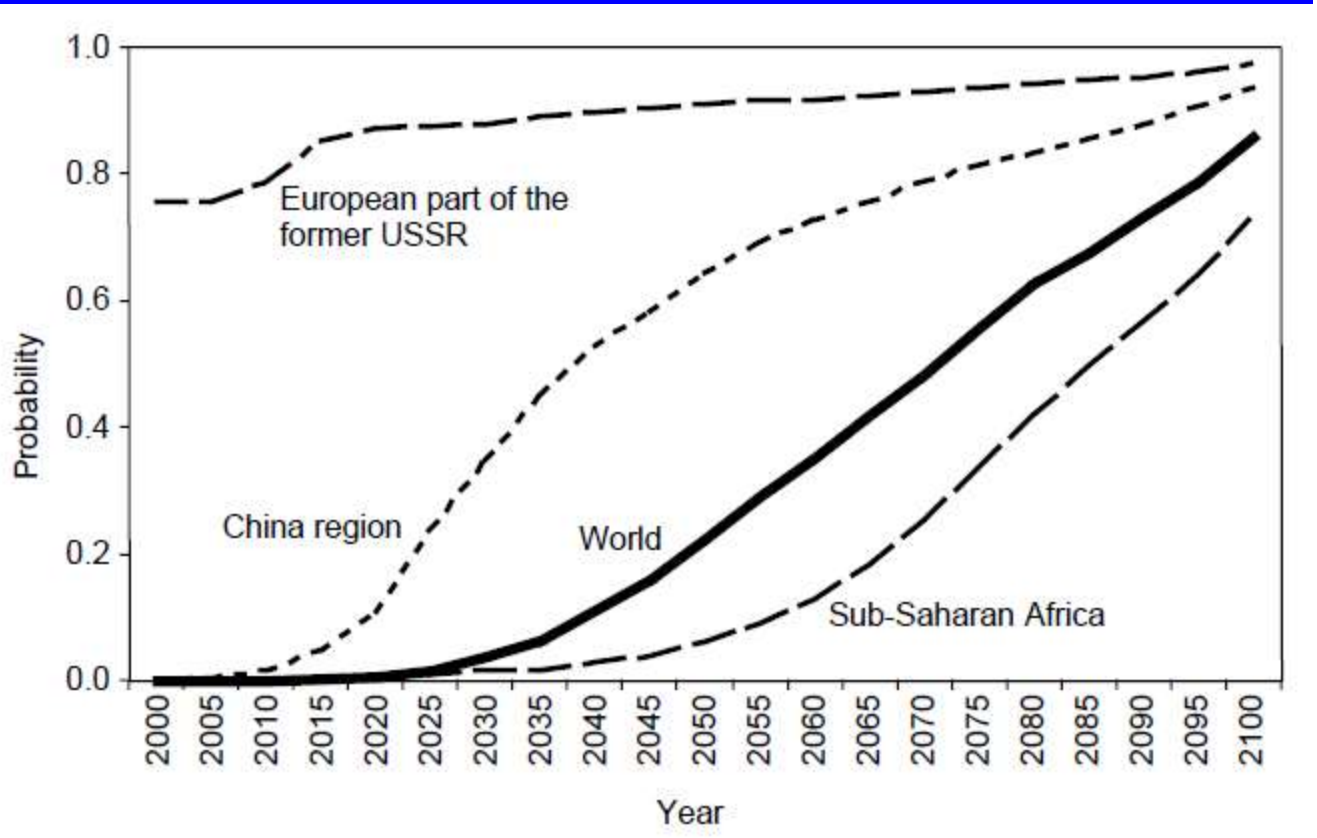
Population growth is likely to end by 2100 (expert judgment).

"… there is around an 85 per cent chance that the world's population will stop growing before the end of the [21st] century."

Lutz, Sanderson, Scherbov, The end of world population growth. *Nature* 2001

"Forecasted probability that population will start to decline at or before the indicated date."

2019-07-08



Population growth is not likely to end by 2100 (statistical models).

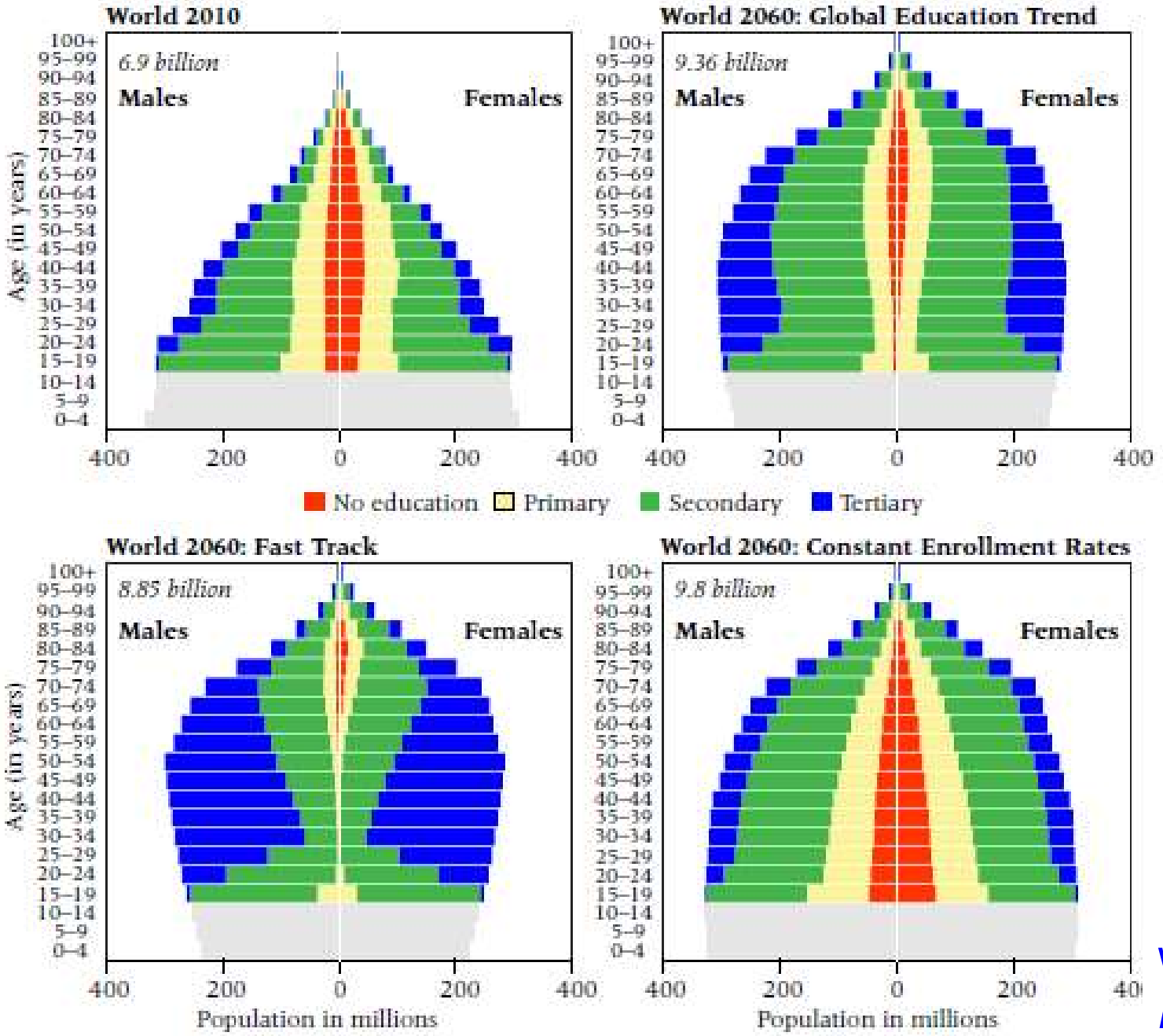
"… there is little prospect of an end to world population growth this century without unprecedented fertility declines in most parts of Sub-Saharan Africa still experiencing fast population growth."

Gerland et al. *Science* 2014

UNPD, *World Population Prospects* 2015

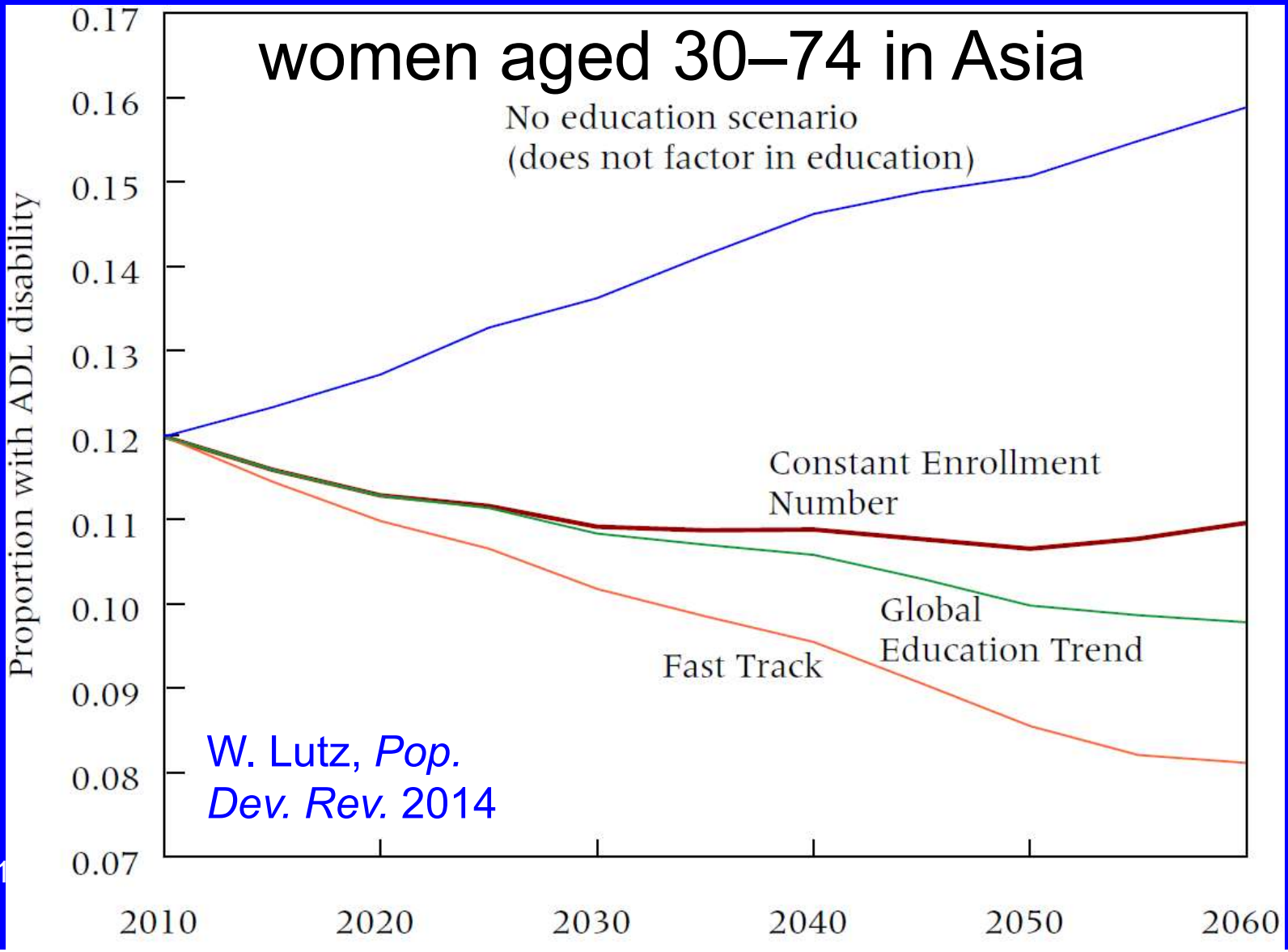
Policy perspective: Future population growth depends on what we do now.

3 scenarios for education & population growth



W. Lutz, *Pop. Dev. Rev.* 2014

Education reduces disabilities in activities of daily life (ADL).



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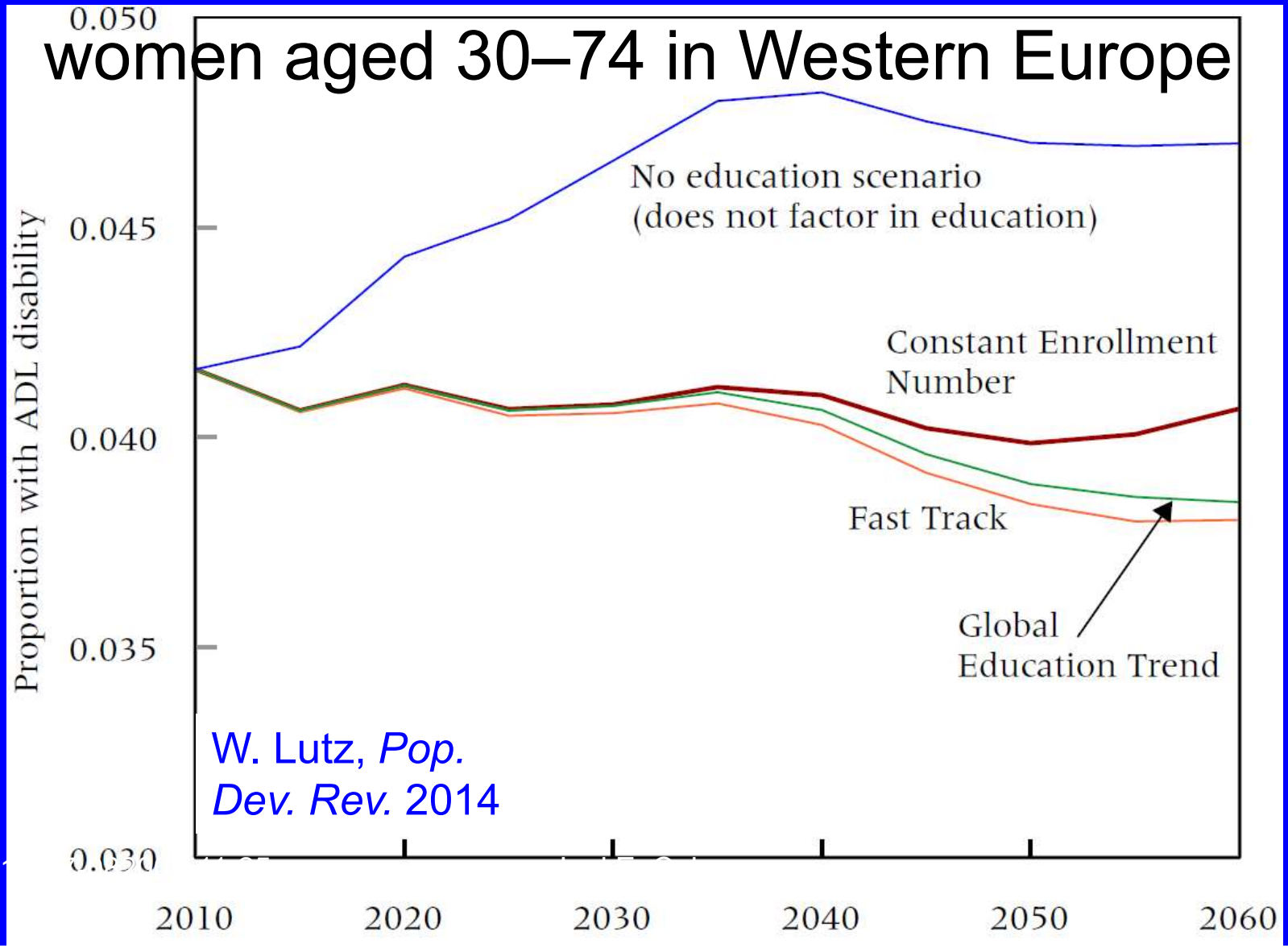
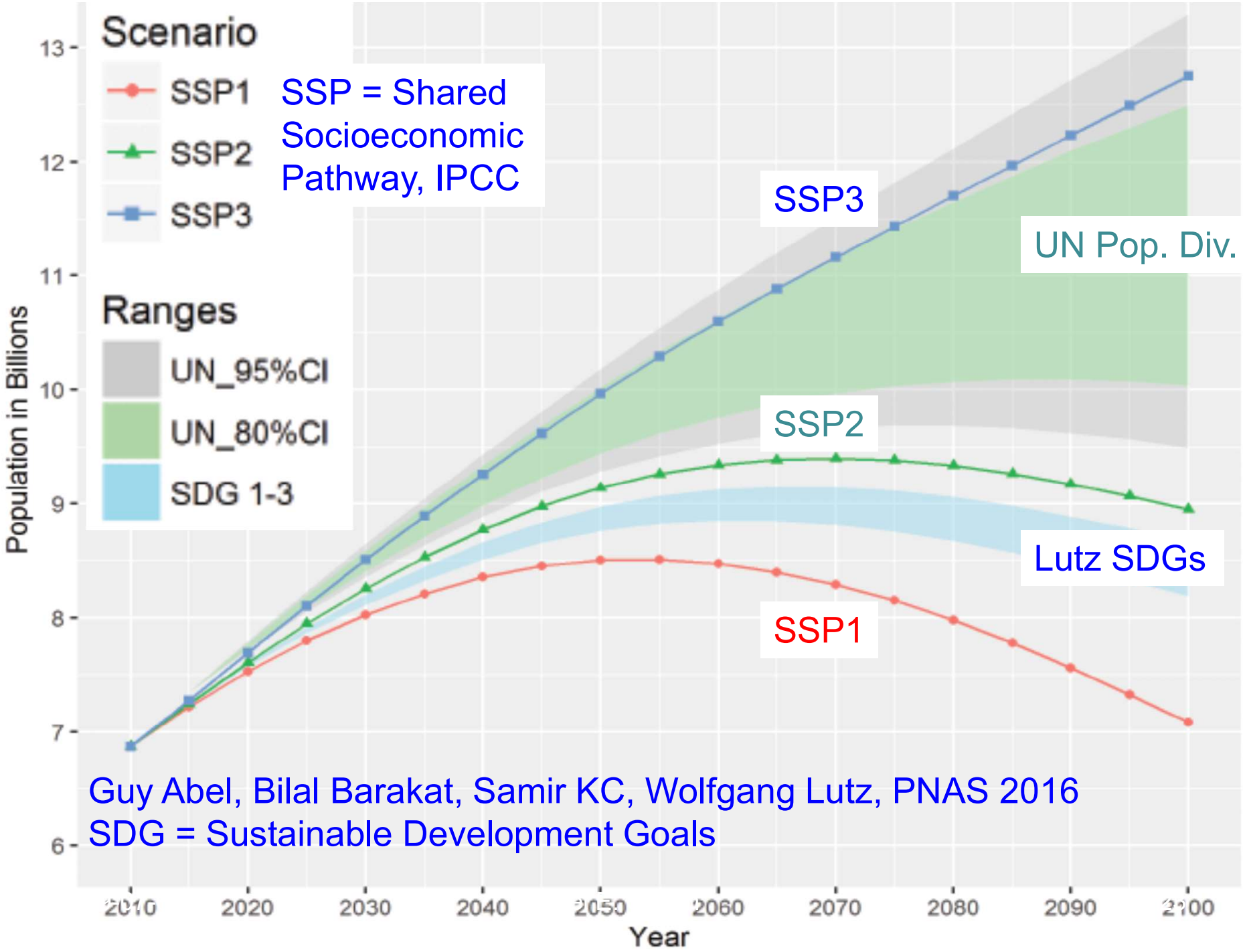



Scenario
SSP1
SSP2
SSP3
SSP = Shared Socioeconomic Pathway, IPCC
Ranges
UN_95%CI
UN_80%CI
SDG 1-3
SSP3
UN Pop. Div.
SSP2
Lutz SDGs
SSP1
Guy Abel, Bilal Barakat, Samir KC, Wolfgang Lutz, PNAS 2016
SDG = Sustainable Development Goals
Population in Billions
13
12
11
10
9
8
7
6
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year

Sources of error in predictions

1. Model
2. Initial conditions
3. Future parameters

Toy example: if we predict $P(t) = e^{rt}P(0)$,

1. growth may not be exponential;
2. our estimate of $P(0)$ may be wrong;
3. our assumed future r may be wrong.

How do we know the demographic future?

Curve fitting

Almost any reasonable model works well in short term.

No known curve-fitting model works well in long term.

Models of increase per person

Let $P(t)$ = population size at time t.

IF rate of change per person $\frac{1}{P(t)}\frac{dP(t)}{dt}$

= constant r, then exponential.

= $r(K - P(t))$, then logistic.

= $r \cdot P(t)^s$, $s > 0$, then superexponential or "doomsday" (infinite singularity in finite time).

Exponential model

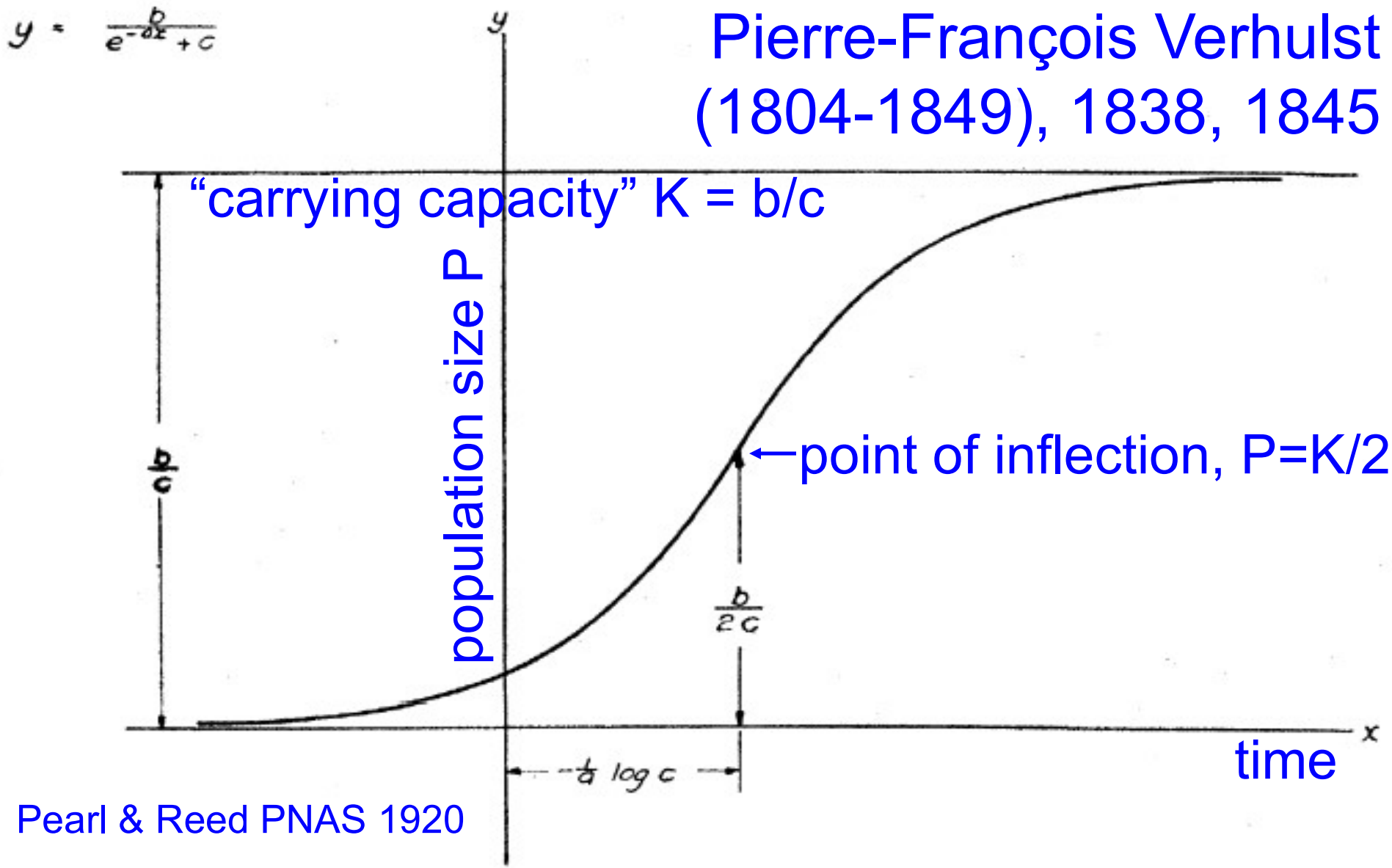
Benjamin Franklin (1706–1790), *Observations Concerning the Increase of Mankind, Peopling of Countries, etc.* (1751, published 1755)

Population of the English colonies had a doubling time of ~25 years.

Thomas Robert Malthus (1766-1834), *An Essay on the Principle of Population.* (1798 1st edition, 1803-25, 2d-6th editions.)

Population grows “geometrically”, subsistence linearly in time.

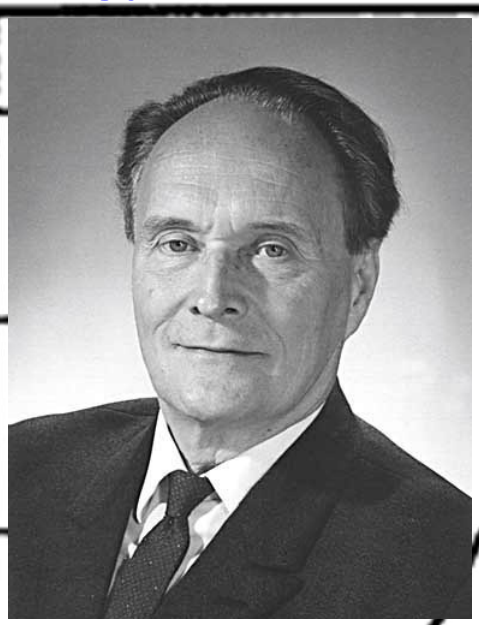
Logistic model solves dP/dt = [r(K-P)]P.



Pearl & Reed PNAS 1920

Paramecium caudatum

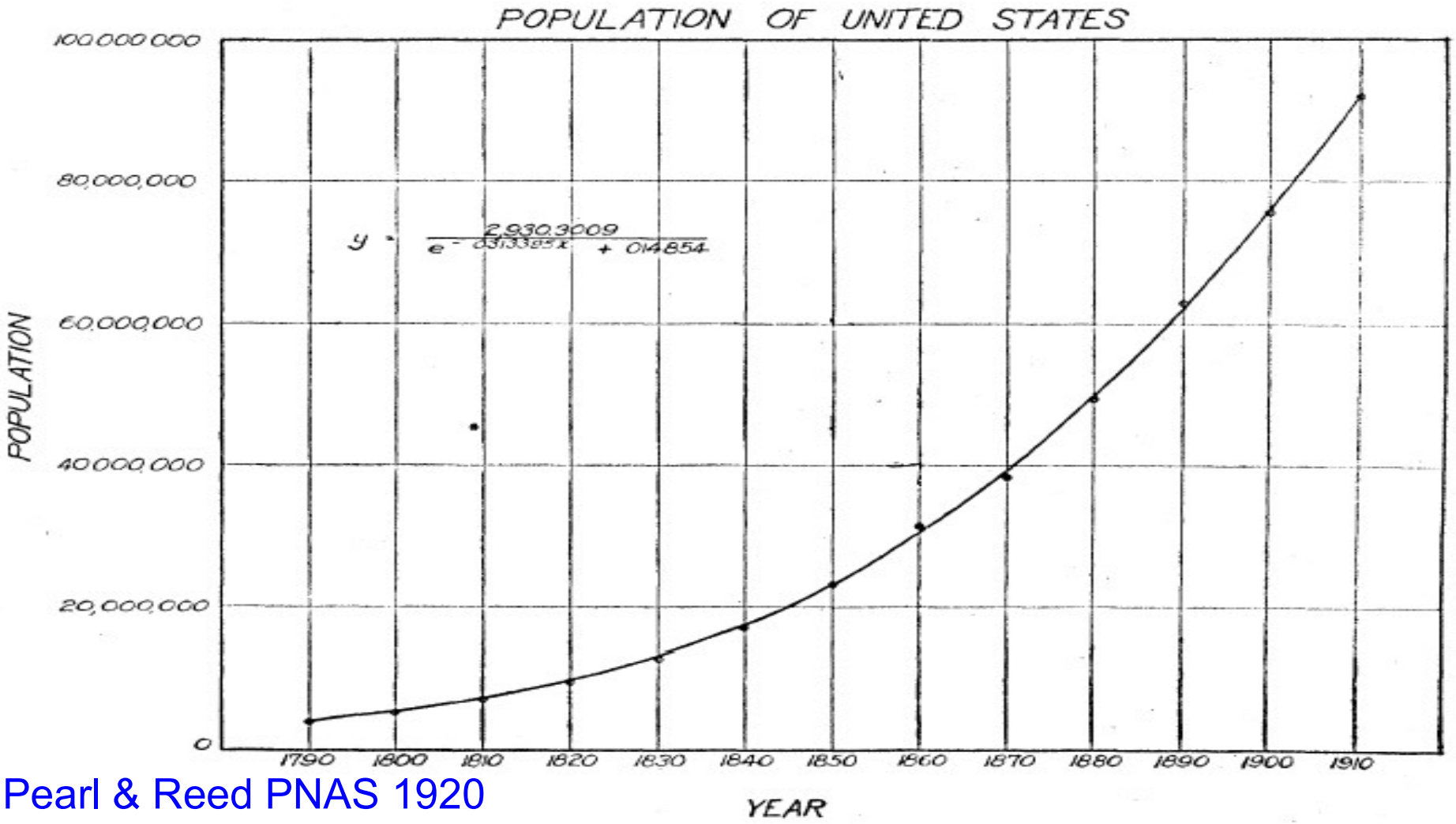
Gause Georgyi Frantsevitch 1910-1986



Gause, *The Struggle for Existence*, 1934

(he was 24 in 1934!)

Logistic curve fitted U.S. population 1790-1910 very well in 1920.



Pearl & Reed PNAS 1920

Logistic predicted U.S. censuses 1920, 1930, 1940.

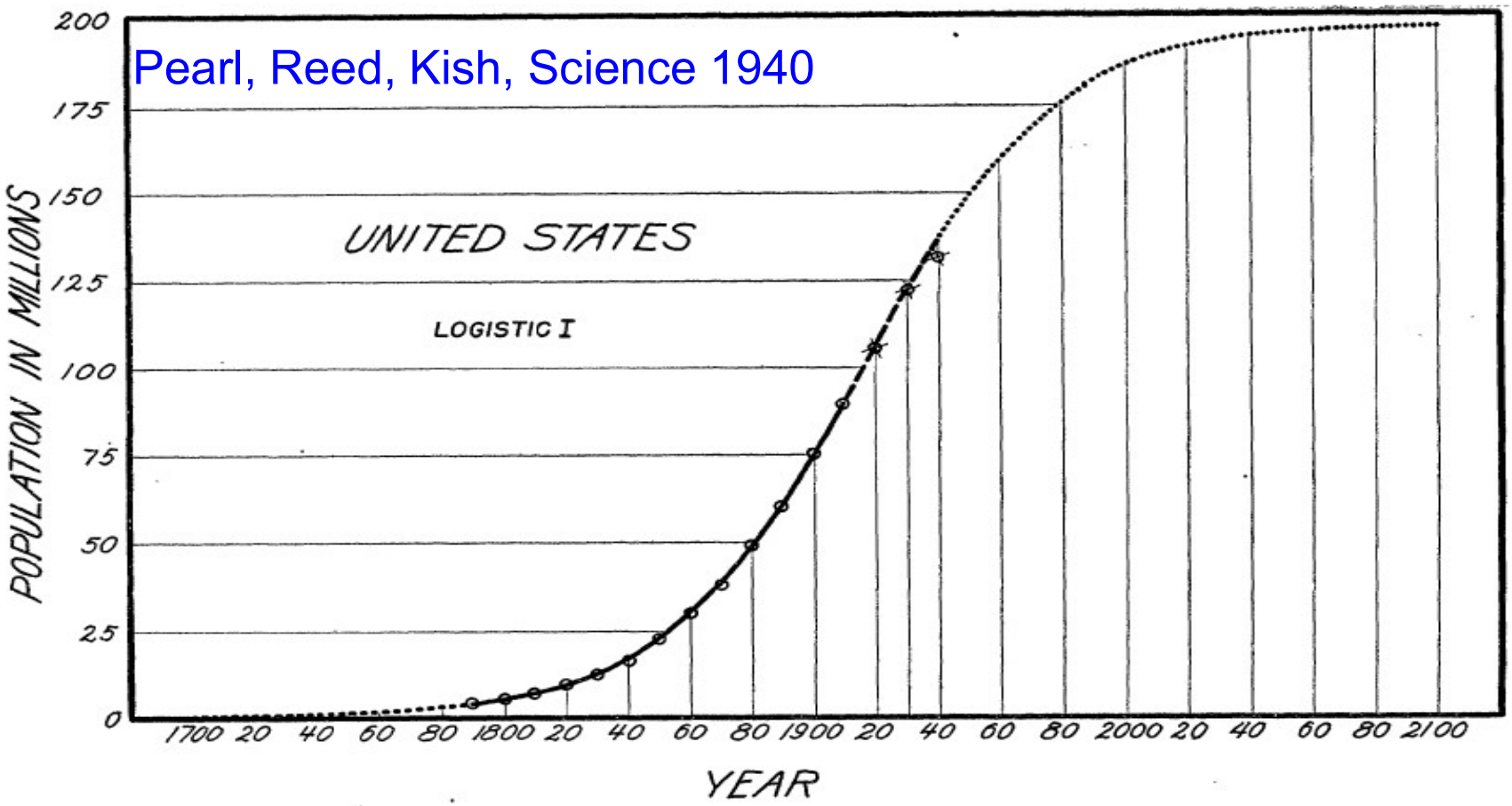
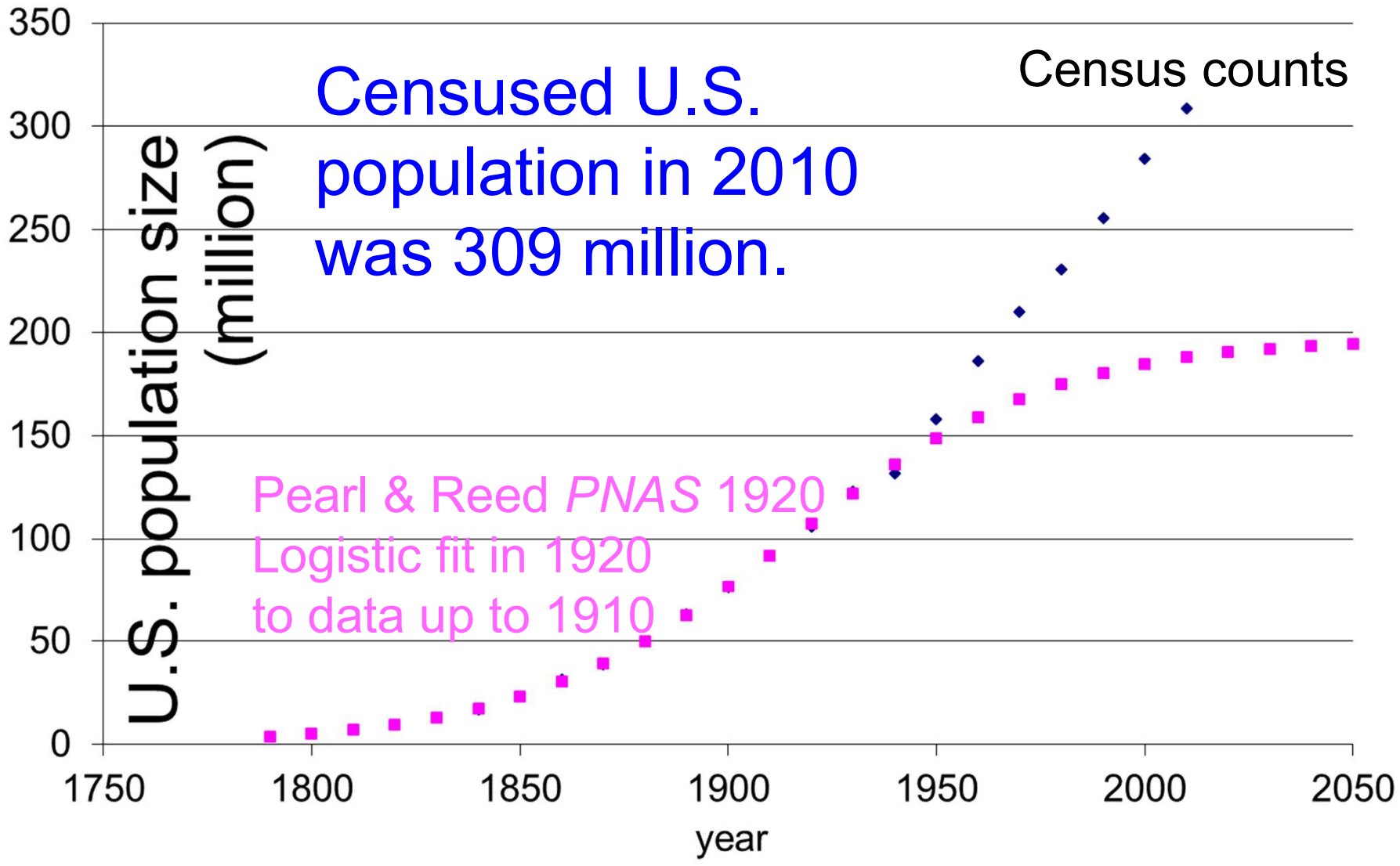


FIG. 1. The census counts of the population of the United States from 1790 to 1940, inclusive (given by circles). The smooth curve is the logistic of equation (1) fitted to the census counts from 1790 to 1910 inclusive. The broken lines show the extrapolation of the curve beyond the data to which it was fitted. The dash portion from 1910 to 1940 is the part of the extrapolation which has been tested by census counts (crossed circles) which have been made since the logistic was originally fitted. The dotted line shows the further extrapolation of the same curve.

Logistic predicted maximum U.S. population would be 197,274,000.



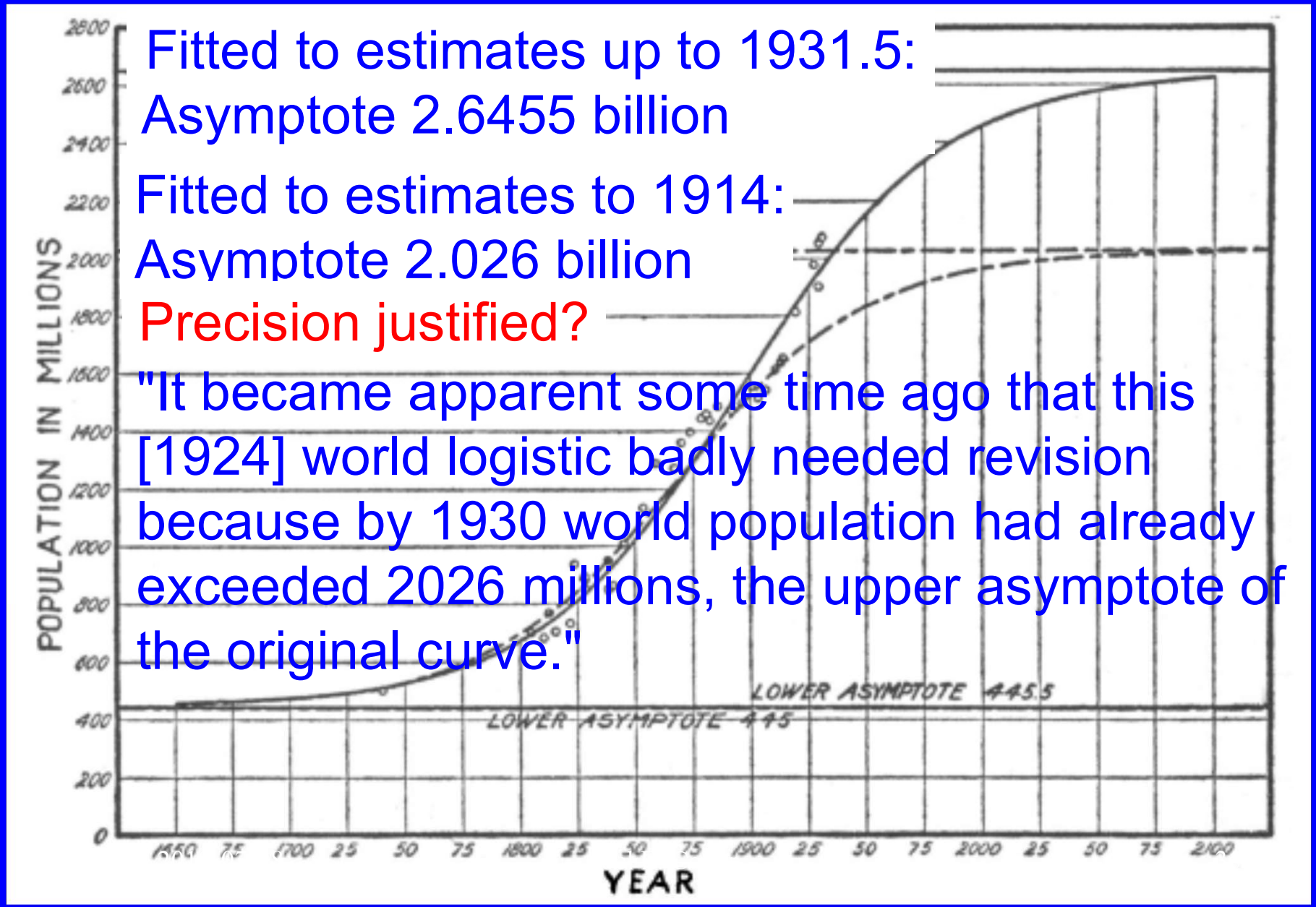
World population growth according to Pearl

Pearl, *Studies in Human Biology*, 1924 predicted world population would never exceed 2.026 billion.

World population passed 2 billion around 1927-1930.

If countries grow logistically, then global population (their sum) does not.

"World Population Growth," Pearl & Gould 1936



"World population growth"

Pearl & Gould *Human Biology* 1936

"A logistic curve fitted to the data on world population growth leads to an upper asymptotic value for the present cycle of 2,645.5 million, rather closely approached by about 2100 A. D."

"We wish to emphasize again that we have no inside information as to whether the asymptote … will reasonably accord with reality in the year 2100, and are not to be understood as advocating its absolute validity or significance."

Superexponential model

von Foerster et al. 1960

Suppose $\frac{1}{P(t)}\frac{dP(t)}{dt} = rP(t)^s, s > 0.$

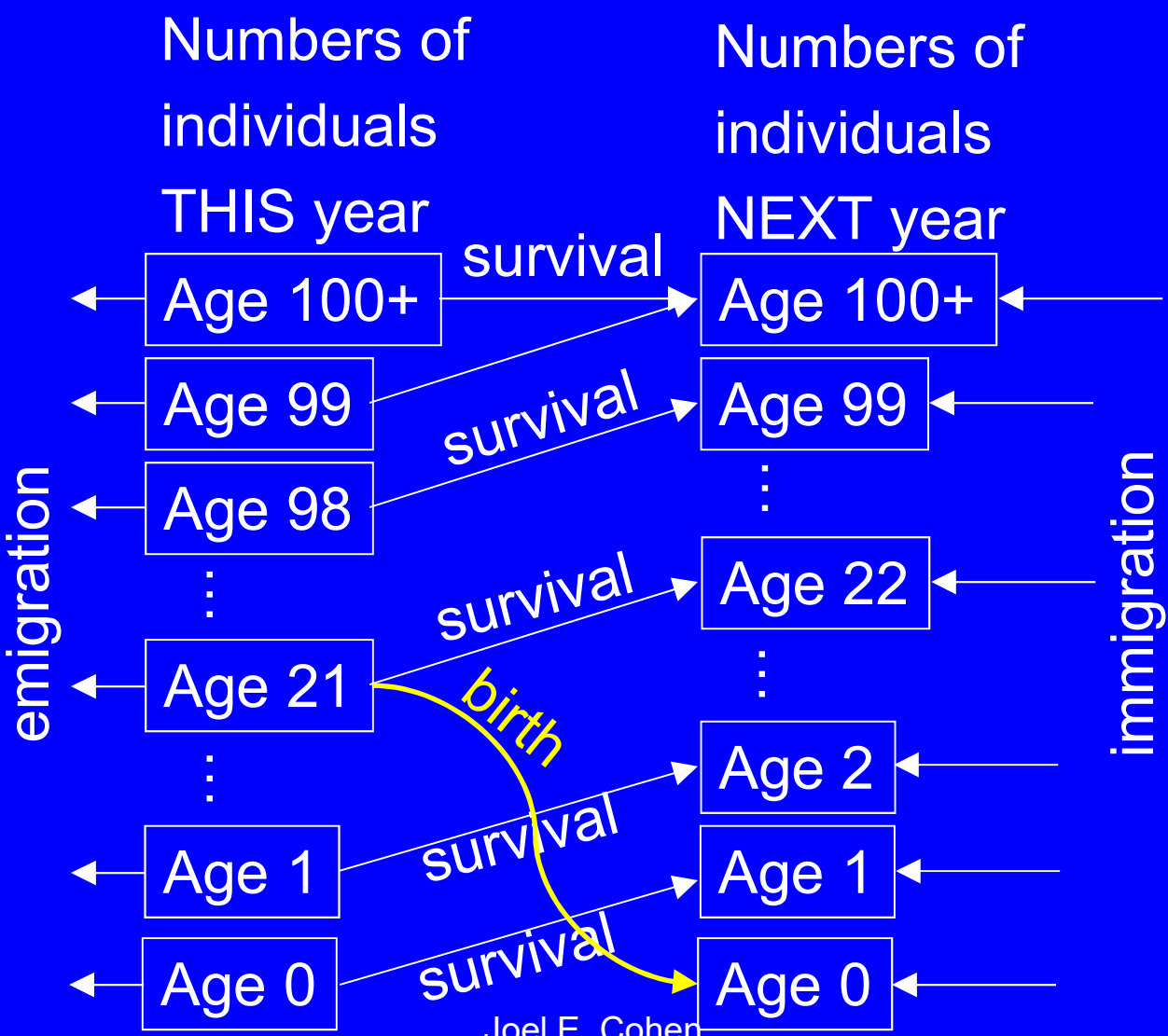
At a finite time, called "Doomsday," population size goes to infinity.

From historical data of human population size, von Foerster et al. estimated $s = 1$, Doomsday = Friday, 13 November 2026.

World population growth rate declined after 1965.

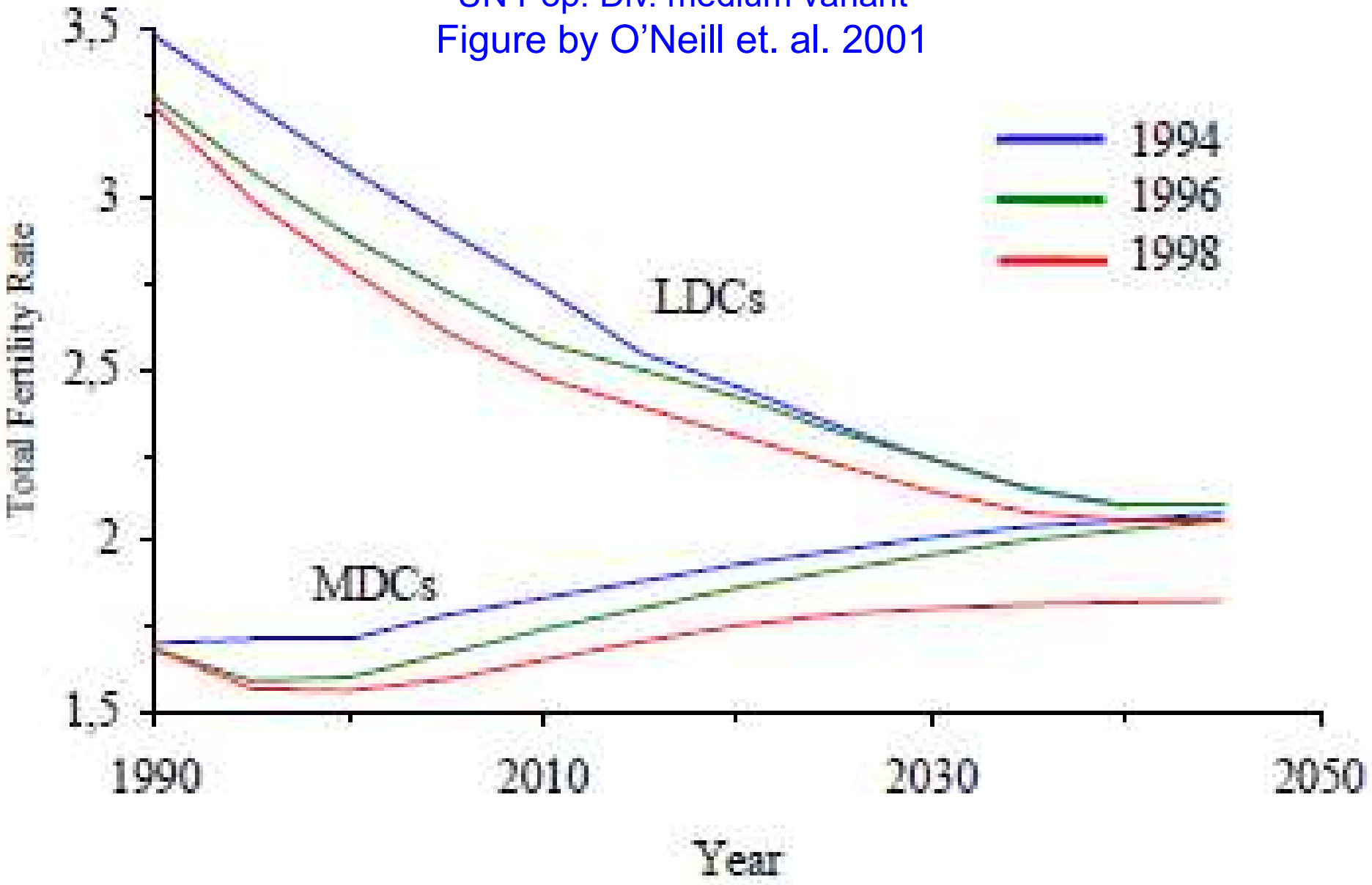
Cohort-component projection

Edward Cannan 1895



Projected total fertility rates changed.

UN Pop. Div. medium variant
Figure by O'Neill et. al. 2001



Matrix representation (no migration)

Bernadelli 1941, Leslie 1945, 1948, 1959

$$\begin{pmatrix} N_1(t+\Delta t) \\ N_2(t+\Delta t) \\ N_3(t+\Delta t) \end{pmatrix} = \begin{pmatrix} b_1 & b_2 & b_3 \\ s_1 & 0 & 0 \\ 0 & s_2 & 0 \end{pmatrix} \times \begin{pmatrix} N_1(t) \\ N_2(t) \\ N_3(t) \end{pmatrix}$$

$$N(t+\Delta t) = M \cdot N(t)$$

$$\lim_{t\to\infty} \frac{1}{t} \log ||N(t)|| = \lambda(M)$$

"Stable age structure" is the unique (positive) eigenvector ***x*** corresponding to "dominant eigenvalue" $\lambda(M)$:

$$M \cdot x = \lambda(M) \cdot x$$

Matrix representation with migration & changing vital rates

$$N(t+\Delta t) = M(t) \cdot N(t) + a(t),$$

$$a(t) = \begin{pmatrix} a_1(t) \\ a_2(t) \\ a_3(t) \end{pmatrix}.$$

$M(t)$ represents natural increase (birth, death). $a(t)$ represents net migration (immigration, emigration).

How to predict their future elements?

Bayesian hierarchical modeling of cohort-component rates

Used in UN Pop. Div. *World Population Prospects* 2012, 2015, 2017 (base year 2015).

Future rates used Bayesian hierarchical projections of TFR, life expectancy at birth & net migrants based on auto-regressive models. 10,000 simulations per country with inter-country correlations gave confidence intervals for countries & regions. Projections were adjusted by hand for plausibility.

UN Pop.Div., *WPP 2017 Rev., Methodology*

What do projections assume?

Business as usual: no more nor fewer surprises in the future than in the past; no nuclear war, lethal pandemics, climatic catastrophes, comet impacts.

Specific trajectories of

fertility (TFR): continued slow decline

how fast? where? to what limit(s), if any?

mortality ($e_0(0)$): gradually lengthening life

how fast? where? to what limit(s), if any?

migration (net): limited & decreasing.

Overall: demographic parameters of different countries become more similar.

How good were past projections?

- Some past methods of population projection have been abandoned due to conspicuous failures (e.g., exponential, logistic models).
- Cohort-component method was first used in 1895 & has been refined since then.
- For target year 2000, cohort-component projections made during 1940-2000 initially underestimated, then overestimated, then straddled estimated 2000 population size.
- Projections of details (population sizes of individual countries, age structures, urbanization) were less successful.

Projections rest on limited demographic understanding of:

- Fertility
- Migration
- Urbanization
- Households
- Families
- Spatial distribution
- Roles of policy
- Uncertainty

Inputs to projections

- fertility
- mortality
- migration
  - rural to urban
  - internal
  - international
    - neighboring
    - long-distance

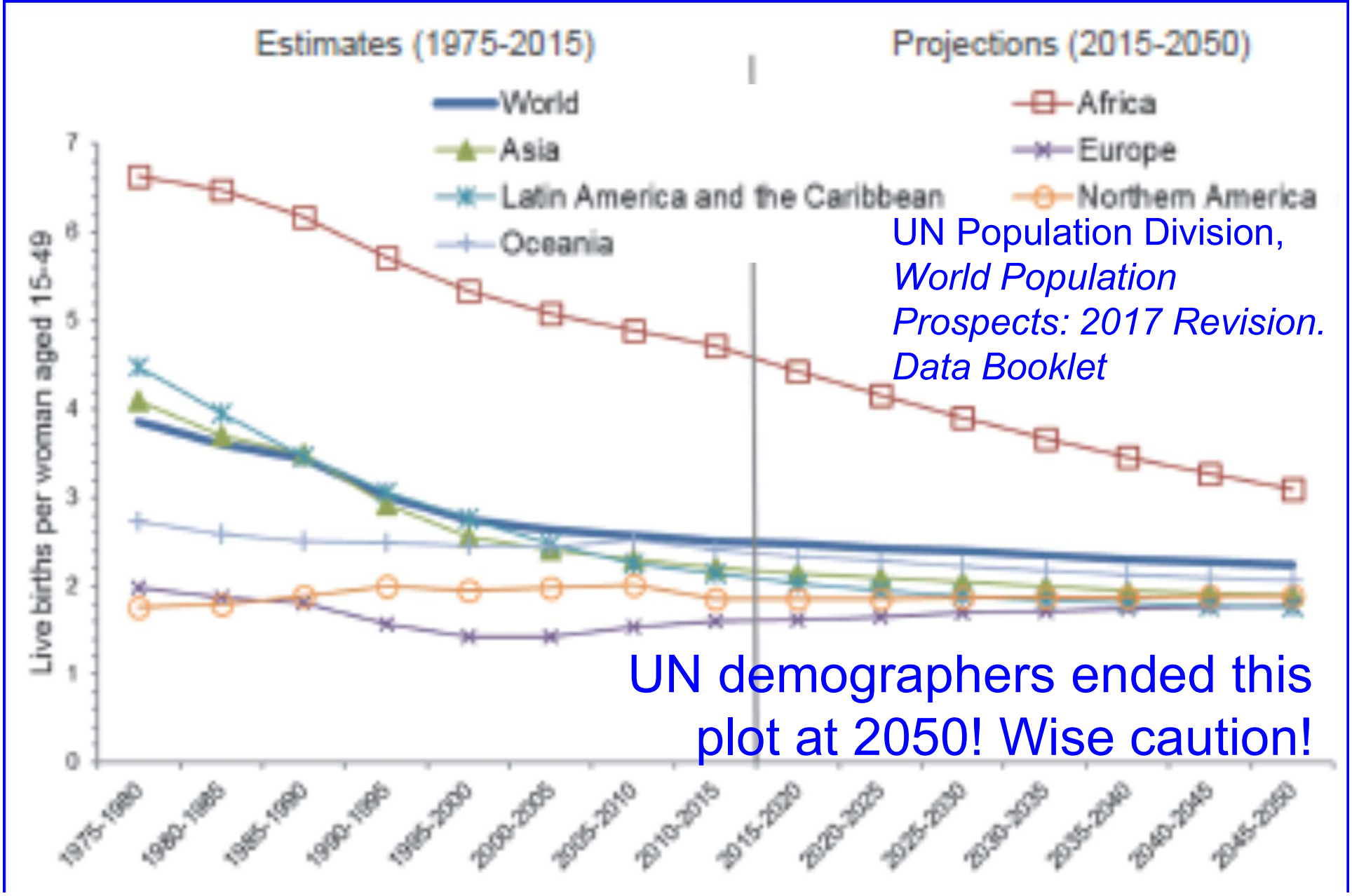
Global fertility will fall.

2020-2025: >1/2 of people will live in a country where women will have, on average, TFR <2.1 births over a lifetime.

By 2030, ~2/3 of people will live in countries where fertility lies below the replacement level (TFR < 2.1).

UN Pop. Div., World Population Prospects: The 2017 Revision

Projected total fertility rates fall.



UN Population Division, *World Population Prospects: 2017 Revision. Data Booklet*

UN demographers ended this plot at 2050! Wise caution!

High fertility will be rare (<1% with TFR>5).

UN Pop. Div., World Population Prospects: The 2017 Revision

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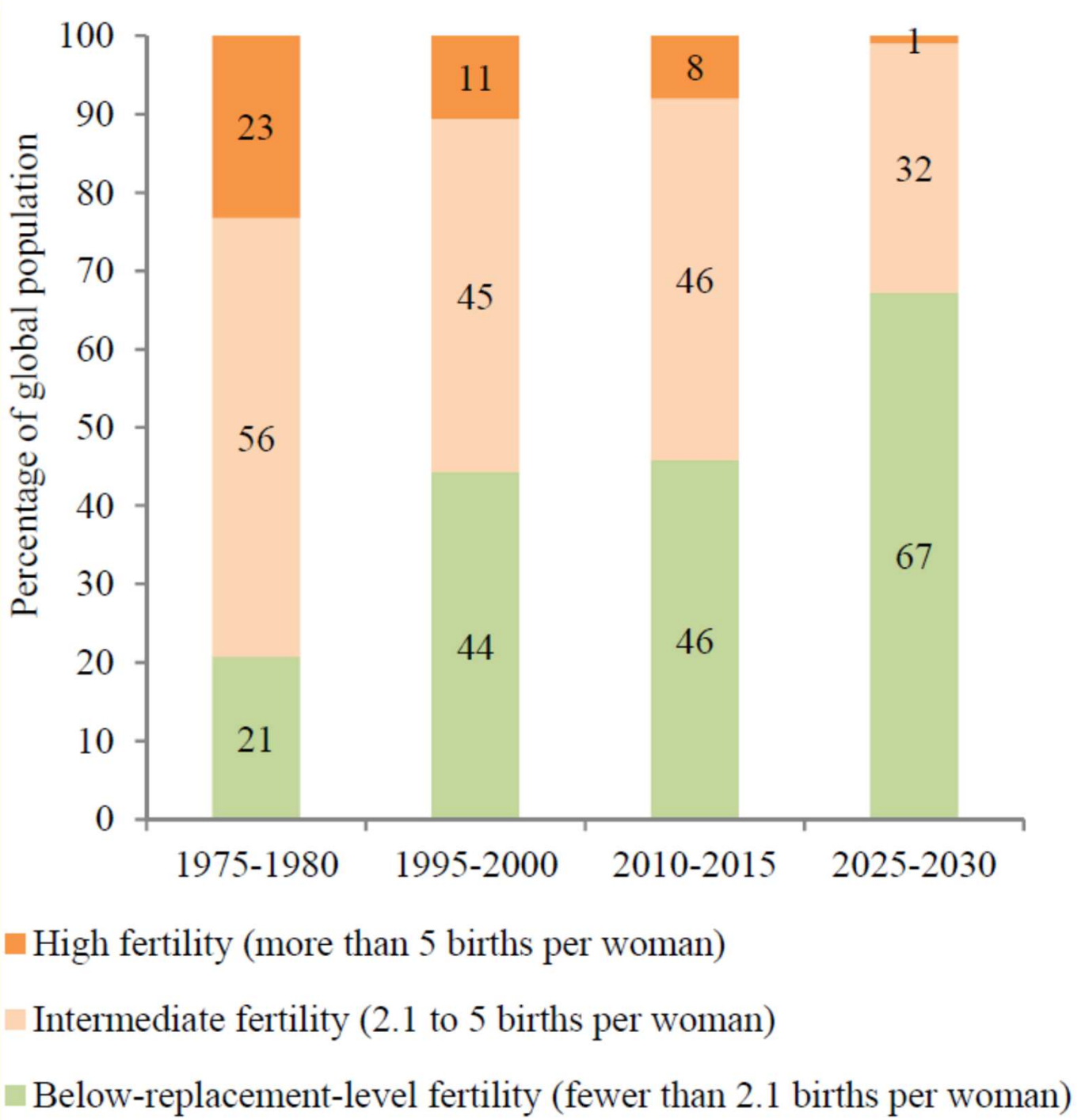
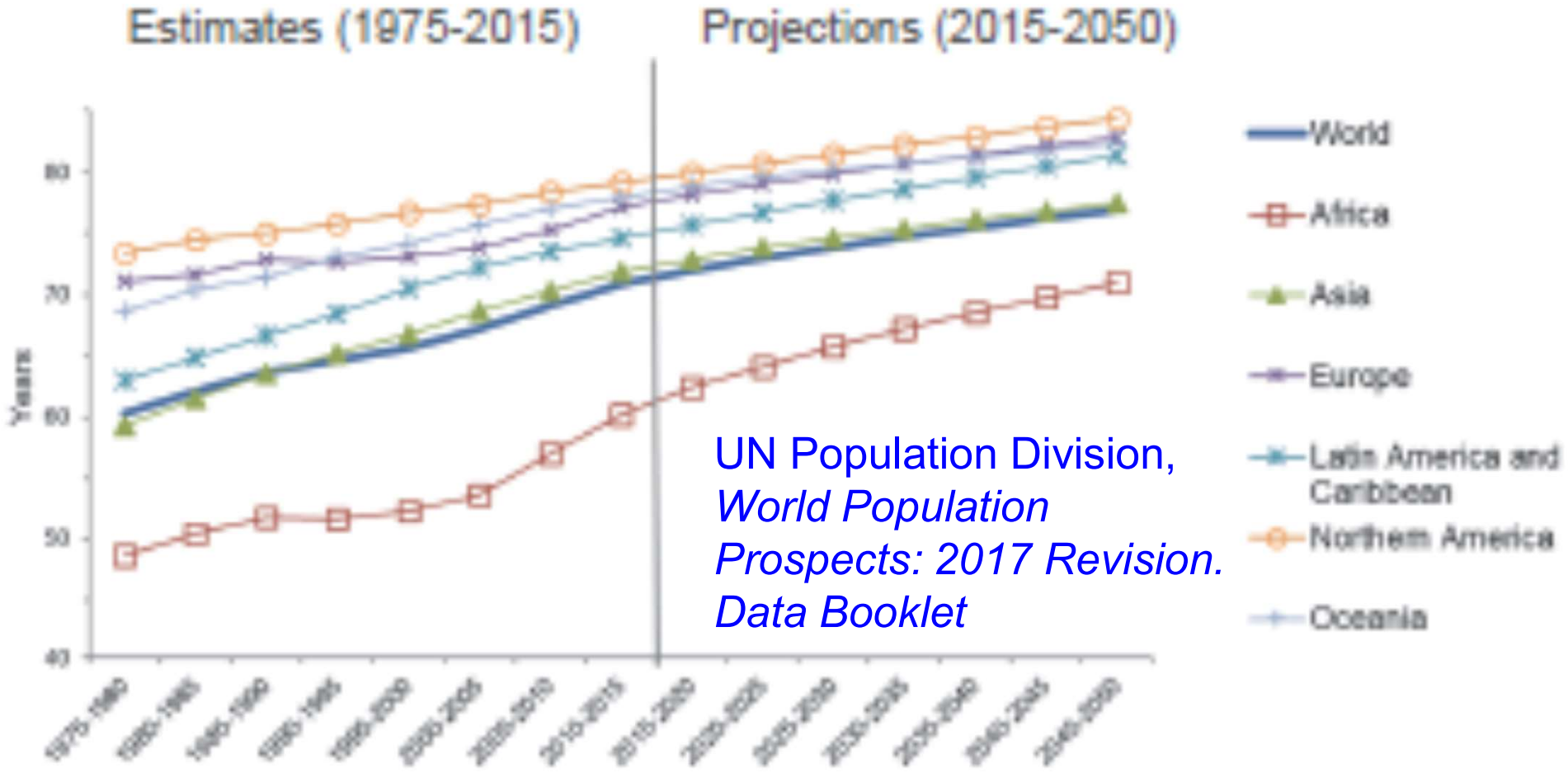
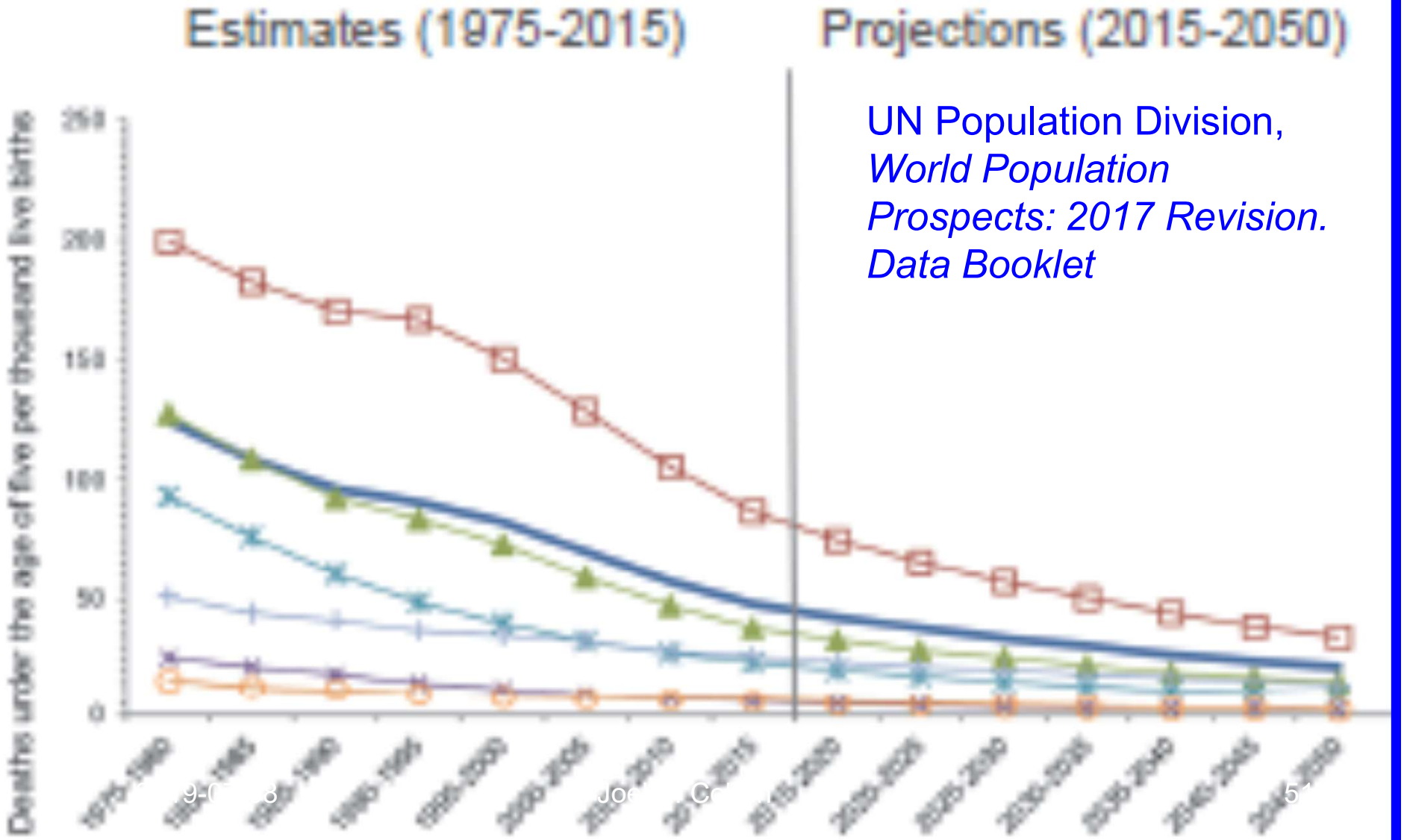


Life expectancy at birth for the world & major areas is projected to rise smoothly, 1975-2050.

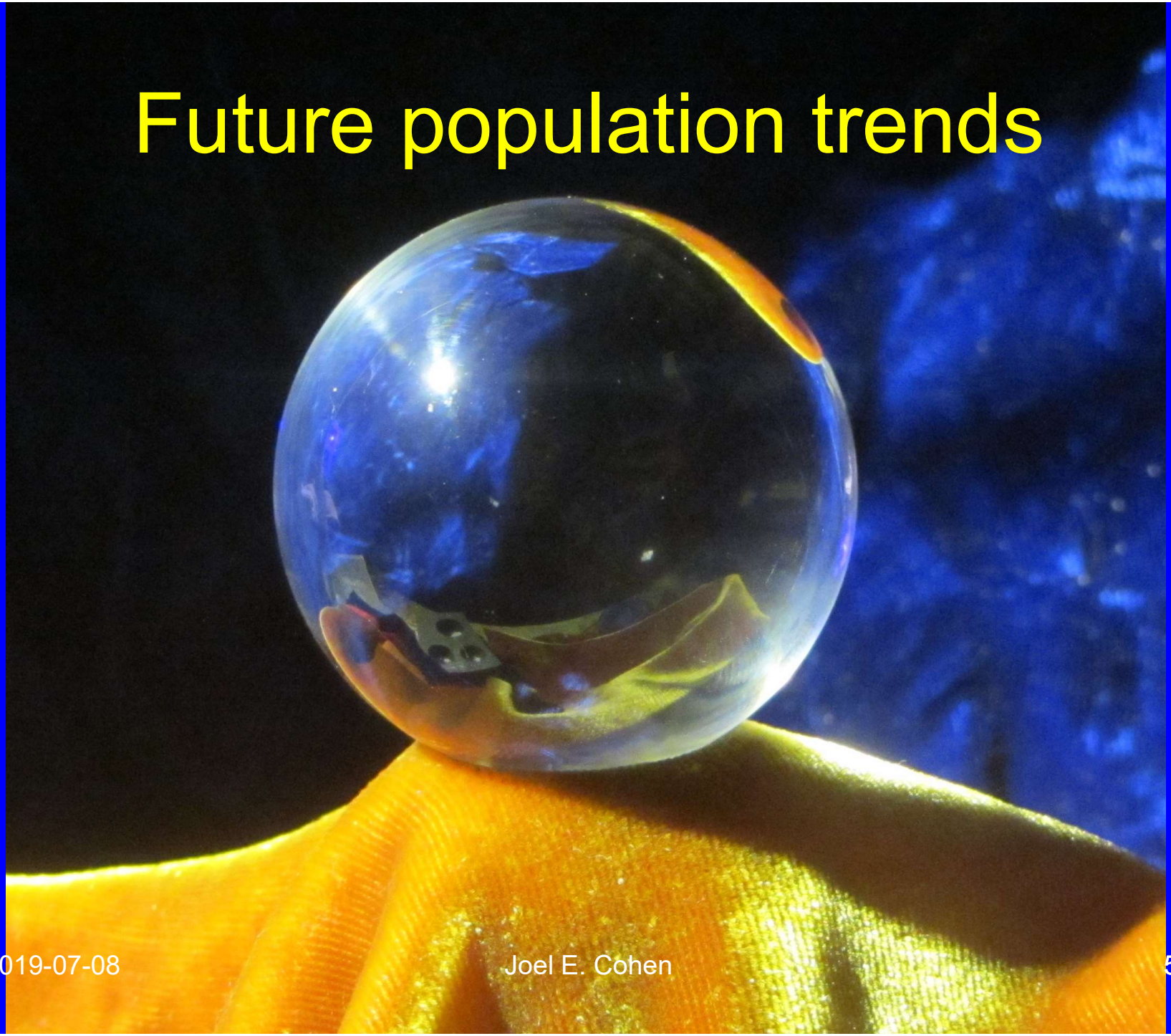


Deaths before age 5 per 1000 live births fell & will continue to fall.



UN Population Division, *World Population Prospects: 2017 Revision. Data Booklet*

Future population trends



Outputs of projections

population size

geographic distribution

cities

age structure

migration

education

Demography 2000-2050 simplified

Year 2000: 6.1 billion people

Rural 3 billion	Urban 3 billion

Year 2050: 9.4-10.2 billion people

Rural 3 billion	Urban 6-7 billion

All added people will be in cities of poor countries. Urban growth will be higher 2015-2030 where higher % of urban people now live in slums.

Population will be:

Bigger: 7.5-7.7B in 2019 → 8.6B in 2030 → 9.4-10.2B in 2050 → 11.2B in 2100

3.9B growth in cities of poorer countries.

Slower: population growth may or may not end before doubling, depending.

Older: 2B people 60+ years will match 2B children 0-14 years.

More urban: virtually all population growth will be in cities of poorer countries.

Rural population will peak around 3B.

Less predictable: migration, households, families

UN Population Div., *World Population Prospects: The 2017 Revision*

Population growth will be concentrated in a few countries.

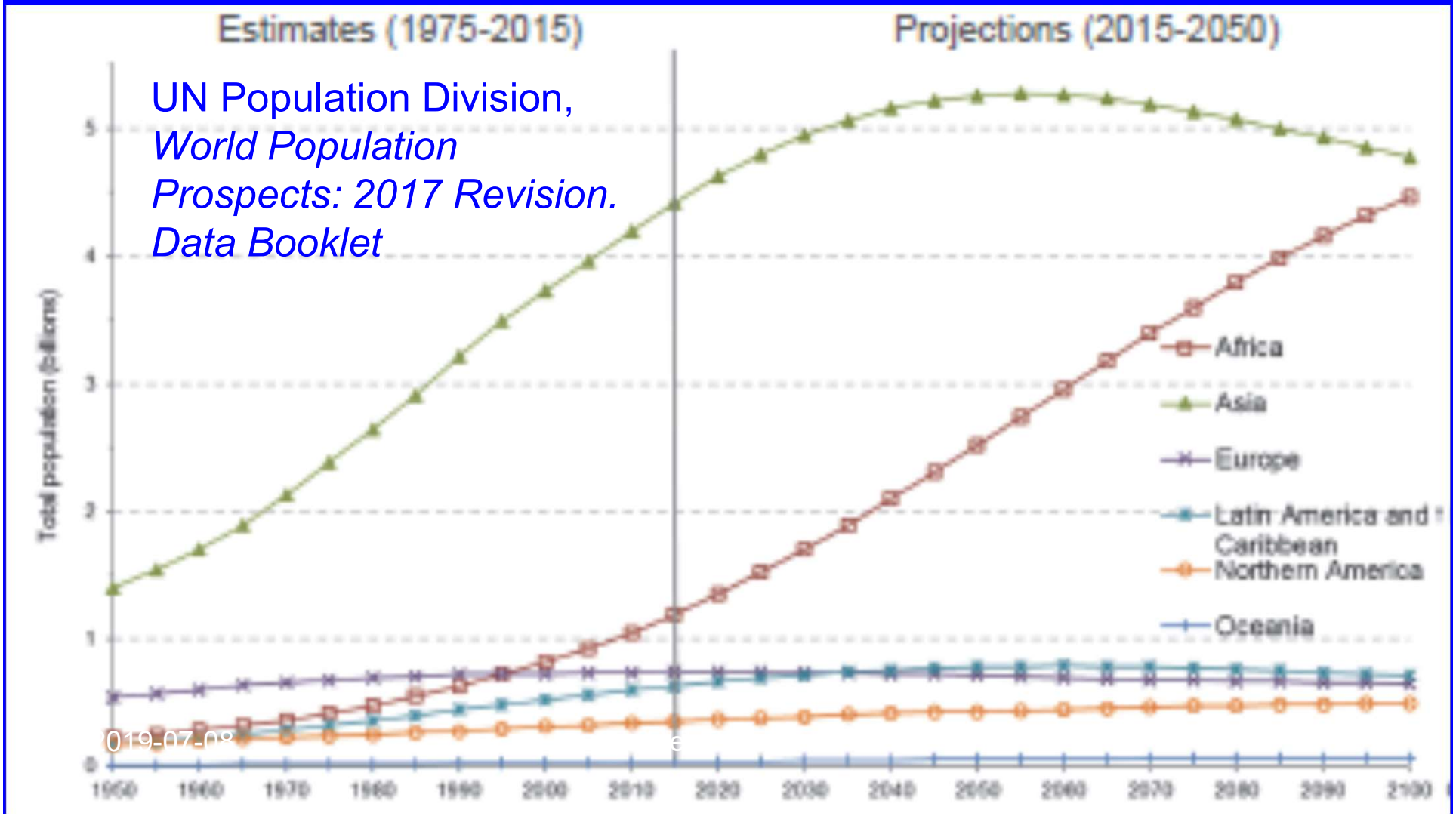
"From 2017 to 2050, … half of the world's population growth will be concentrated in just nine countries: India, Nigeria, the Democratic Republic of the Congo, Pakistan, Ethiopia, the United Republic of Tanzania, the United States of America, Uganda and Indonesia (ordered by their expected contribution to total growth)."

UN Pop. Div. World Population Prospects: The 2017 Revision

World population

UN Population Division,
World Population Prospects: 2017 Revision. Data Booklet

Africa's population will nearly match Asia's by 2100.



Ten most populous countries

UN, *World Population Prospects 2017 Data Booklet*

Rank	Country	2017 population (millions)	Country	2050 population (millions)
1	China	1 410	India	1 659
2	India	1 339	China	1 364
3	United States of America	324	Nigeria	411
4	Indonesia	264	United States of America	390
5	Brazil	209	Indonesia	322
6	Pakistan	197	Pakistan	307
7	Nigeria	191	Brazil	233
8	Bangladesh	165	Bangladesh	202
9	Russian Federation	144	Dem. Rep. of the Congo	197
10	Mexico	129	Ethiopia	191

Health implications

An increasing fraction of people will live in regions with least resources to monitor, prevent, & manage diseases.

Most births will occur to mothers in countries with largest excess maternal mortality.

Preventable childhood malnutrition & diseases will have largest long-term impacts in poor countries.


Bangalore, India JEC photo
Billions more people will live in cities of poor countries.
2003 7 27

More urban:

Virtually all population growth will be in cities of poorer countries.

World Urbanization Prospects: The 2018 Revision

World's urban population will grow by 2.5 billion 2018-2050.

Of this growth, 90% will be in Asia & Africa.

Three countries have 35% of the increase in global urban population: India (416 million), China (255 million), Nigeria (189 million).

By 2030, world will have 43 megacities (more than 10 million people), most in developing countries.

World: Urban and rural Population: 2010-2100

Urban

Rural

Add 5 billion
in 90 years
≈ 1.1 million
per week

UN Population Division, *World Population Prospects 2010*
medium variant

Source: United Nations, Department of Economic and Social Affairs, Population Division (2012): World Urbanization Prospects, the 2011 Revision. New York

United Nations Department of Economic and Social Affairs – Population Division

What is missing from this list?

K. Farrell, *Sustainability* 9, 2017, p. 17:

"…this paper asserts that rapid urban growth can only be understood when it is framed as a multidisciplinary process comprising demographic, economic and political factors, each of which dynamically interact as a result of different stages of the urban transition."

By contrast, UN, WUP 2018: "Urban growth is closely related to the three dimensions of sustainable development: economic, social and environmental."

Health implications

Clean water, sewage & solid waste removal are easier per person in cities than in dispersed rural communities.

Medical expertise is easier to collect in cities.

Failures in systems for water, sewage & solid waste removal affect more people in cities.

Each 10-fold increase in maximal city size has historically been associated with vulnerability to new infectious diseases, before modern public health knowledge & institutions.

What is "urbanization"?

LEVEL = % of population living in "urban areas," as defined by each country.

PROCESS =

1. Migration from rural to urban areas;
2. Absolute growth in urban population;
3. Urban population growth that is faster than rural population growth = increase in % of population that is urban.

UN Pop. Div. 2015 *World Urbanization Prospects: The 2014 Revision*

What drives urban growth?

Change in population of an urban area

= natural increase (+ births – deaths)

+ net migration (immigration – emigration)

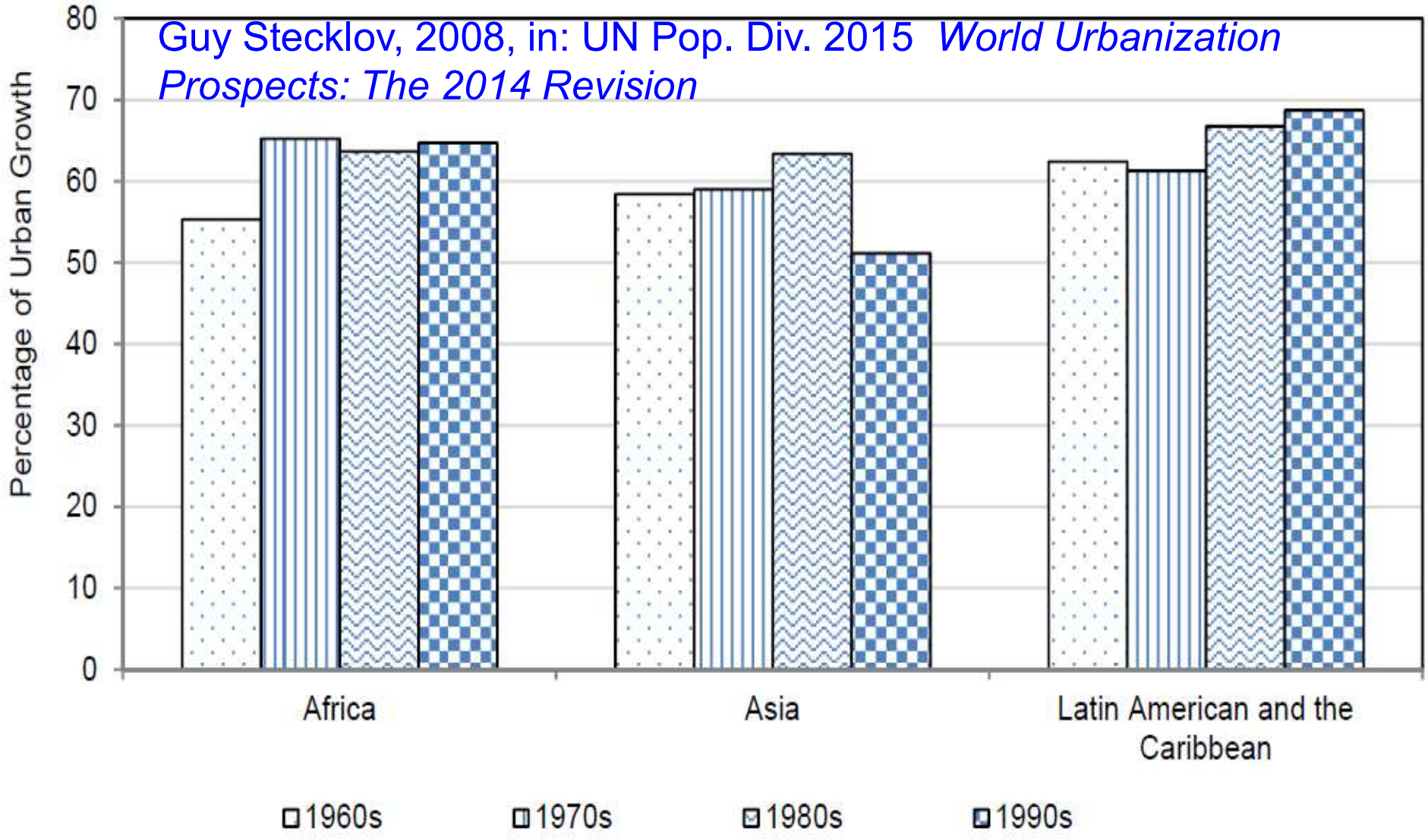
+ annexation + reclassification of rural areas.

In 18th century, urban natural increase was typically negative: cities were sinks.

Today, positive urban natural increase is ~60% urban population growth.

Fertility in cities & migration to cities are both important in growth of urban populations.

% of urban growth due to natural increase varies around 60%.



Cities will grow more by 2050.

UN Pop.Div., World Urbanization Prospects: 2018 Revision

	1950	2018	2050
Urban population (billions)	0.751	4.2	6.7
% of total	30%	55%	68%
Number of cities with ≥10 million people	1	33	43 by 2030
% urban pop. in cities with ≥10 million people	1.6	12	

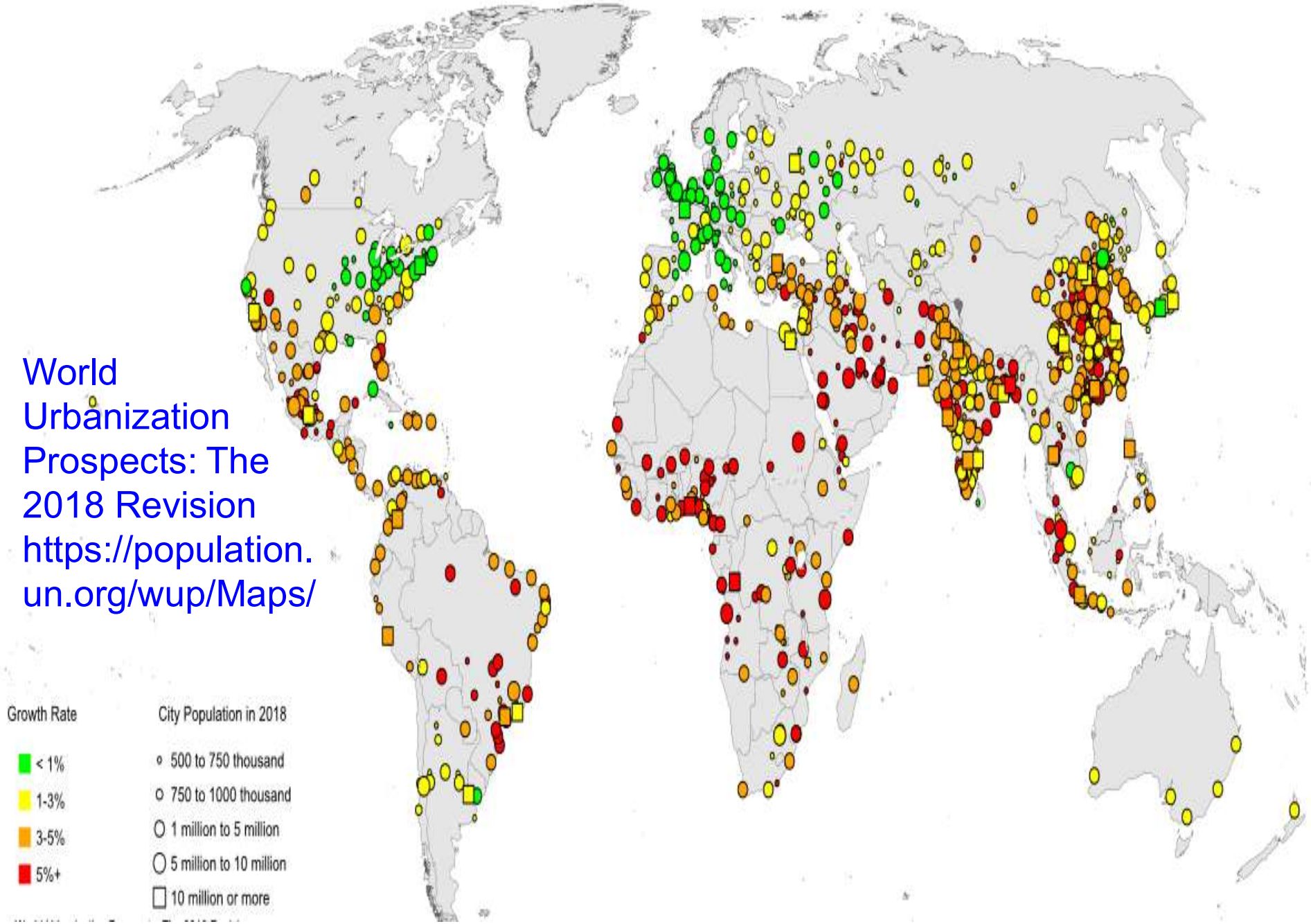
Urban growth is rapid.

2.4 billion (10^9) more urban people in next 31 years

=

1.5 million (10^6) more urban people per week, every week, for next 31 years.

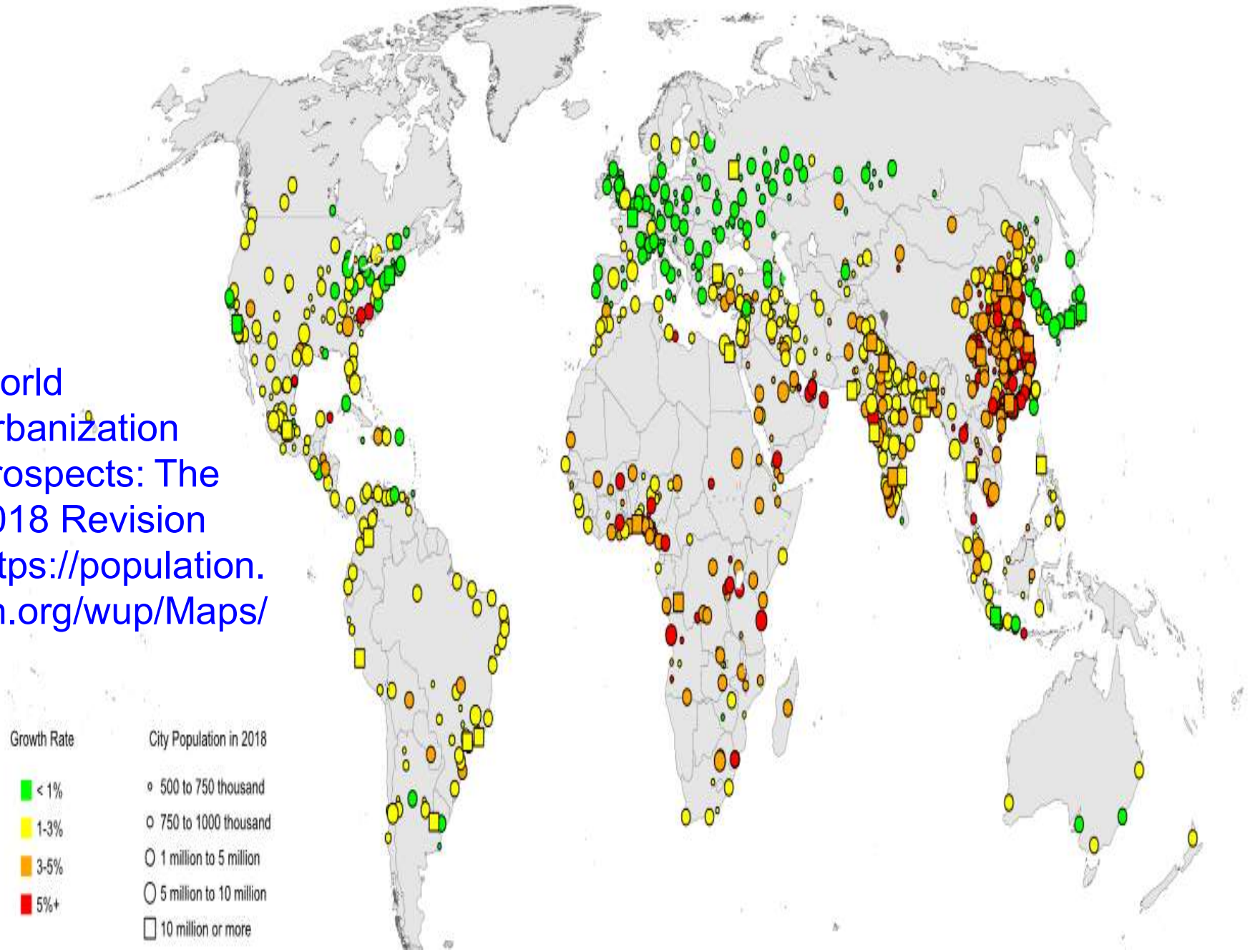
City growth rate & size 1970-1990 cities >0.5 million



World Urbanization Prospects: The 2018 Revision https://population.un.org/wup/Maps/

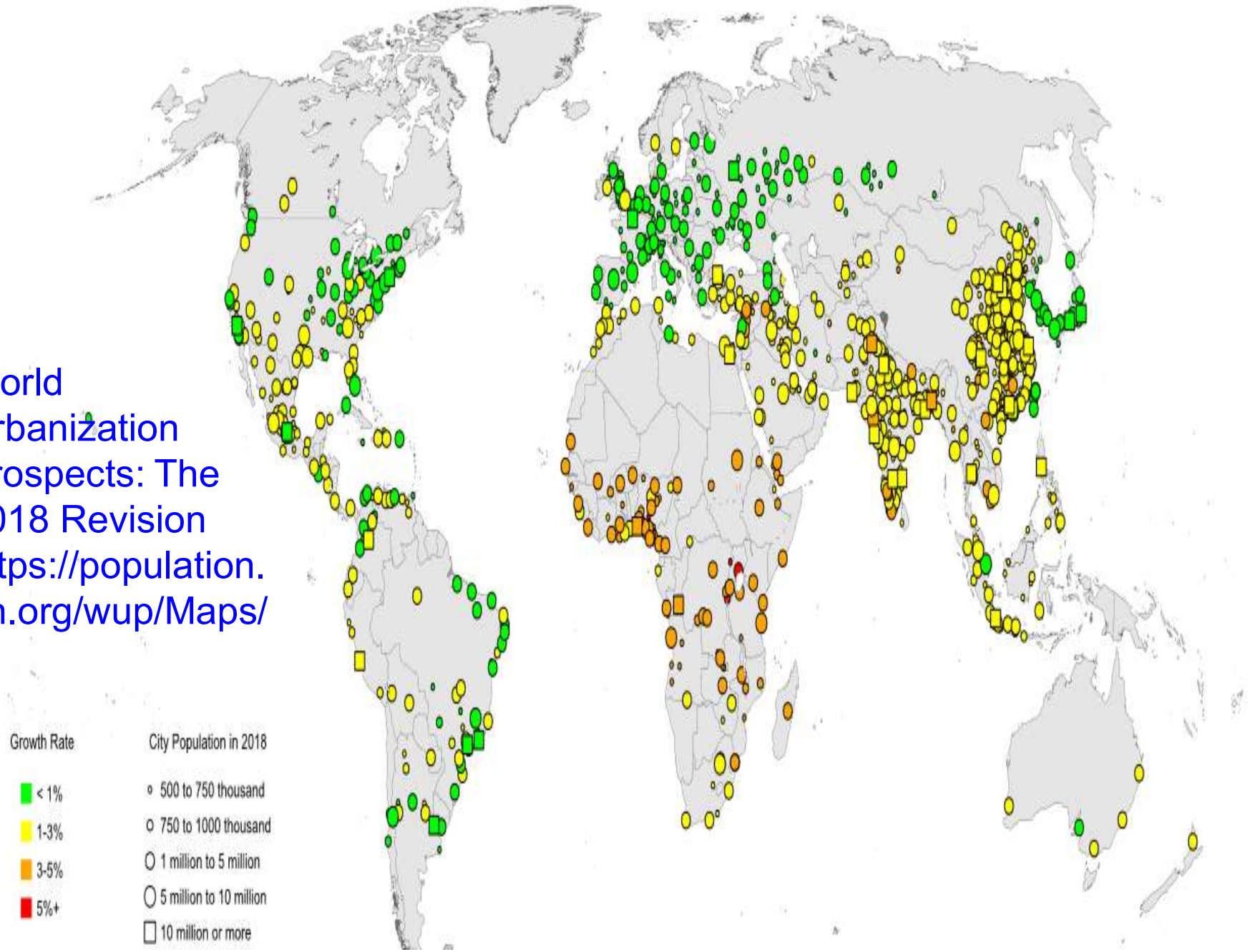
City growth rate & size 1990-2018 cities >0.5 million

World Urbanization Prospects: The 2018 Revision https://population.un.org/wup/Maps/



City growth rate & size 2018-2030 cities >0.5 million

World Urbanization Prospects: The 2018 Revision https://population.un.org/wup/Maps/



Cities have benefits.

Cities concentrate economic productivity, cultural assets, resources for education, public health, medical care.

IF appropriately designed, cities could promote energy efficiency, adaptation to elderly population, social resources for smaller households & families.

Urban growth could affect food supply.

Many cities (~3% of land) are located on prime agricultural land (~10% of land).

If doubling of urban population leads to doubling of urban area, prime agricultural land could be removed from food production.

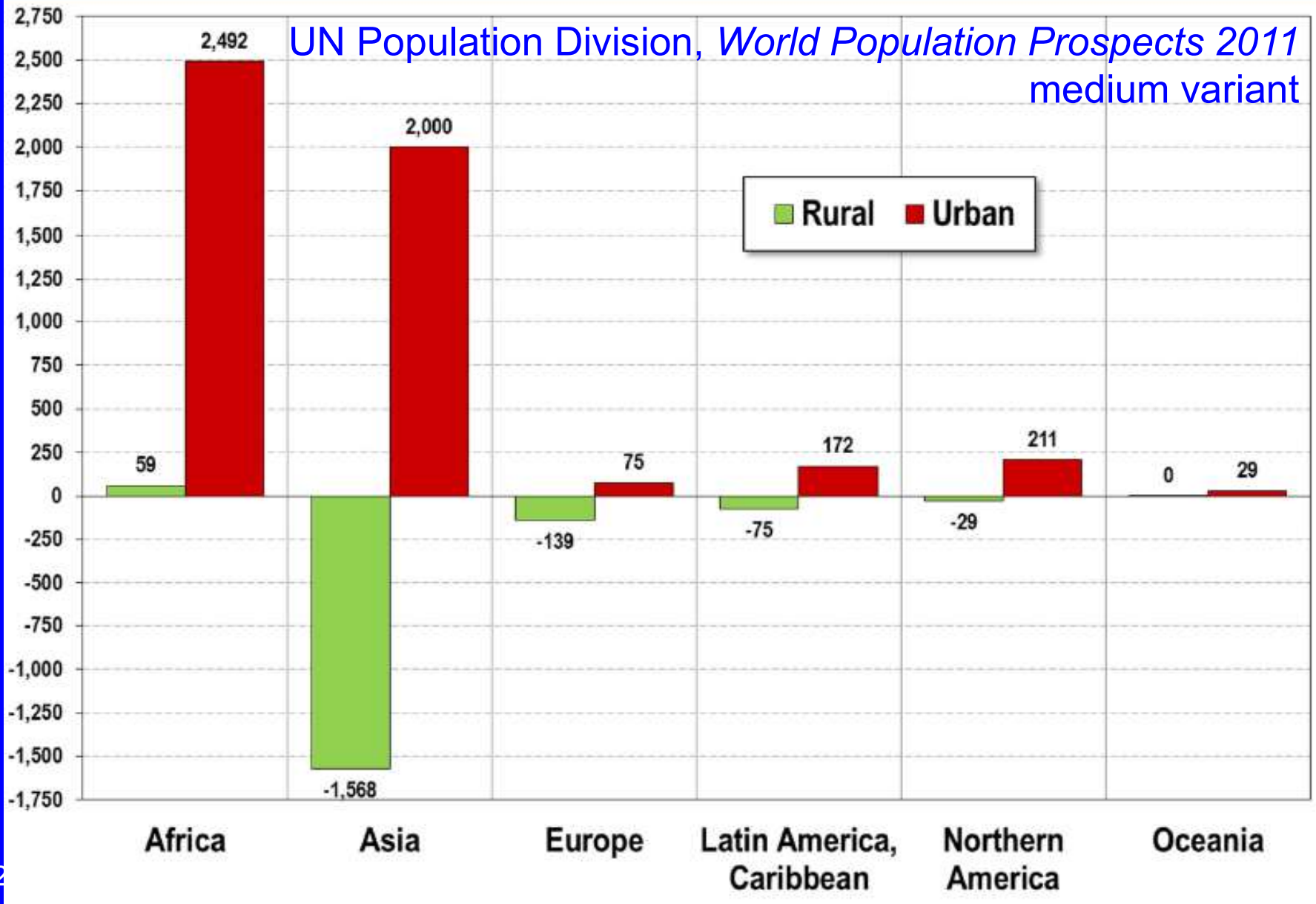
Michiko Shimoda, 2005 Rice field, Fuji City, Japan

Michiko Shimoda, 2005 Rice field, Fuji City, Japan

"China, Ruili, Yunnan Province. Dai minority threshing rice harvest in fields which are gradually being swallowed by this booming border city."

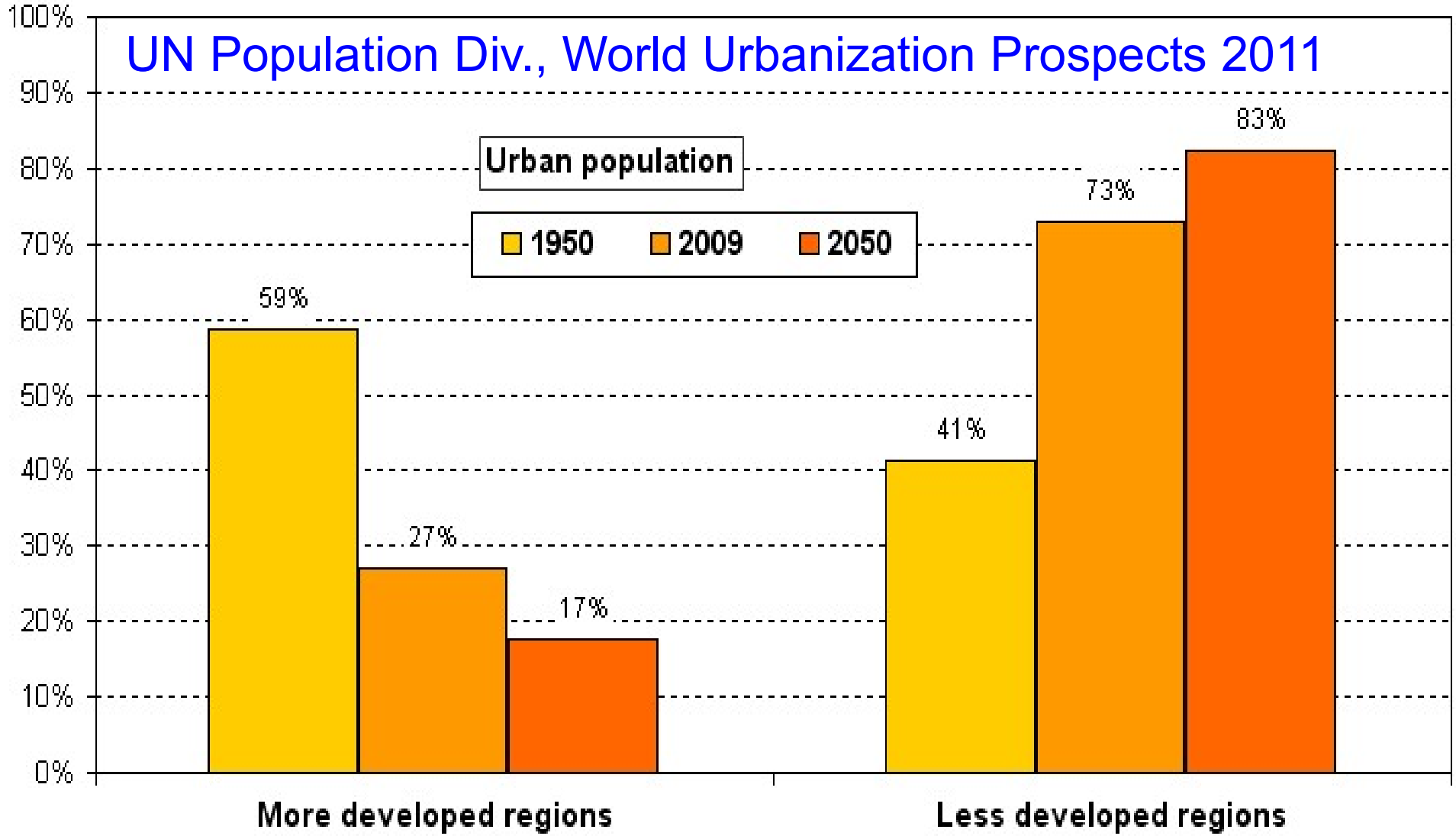
State of the World's Cities 2012/2013: Prosperity of Cities
UN Habitat, Routledge 2013

Urban and Rural Population Change: 2010-2100

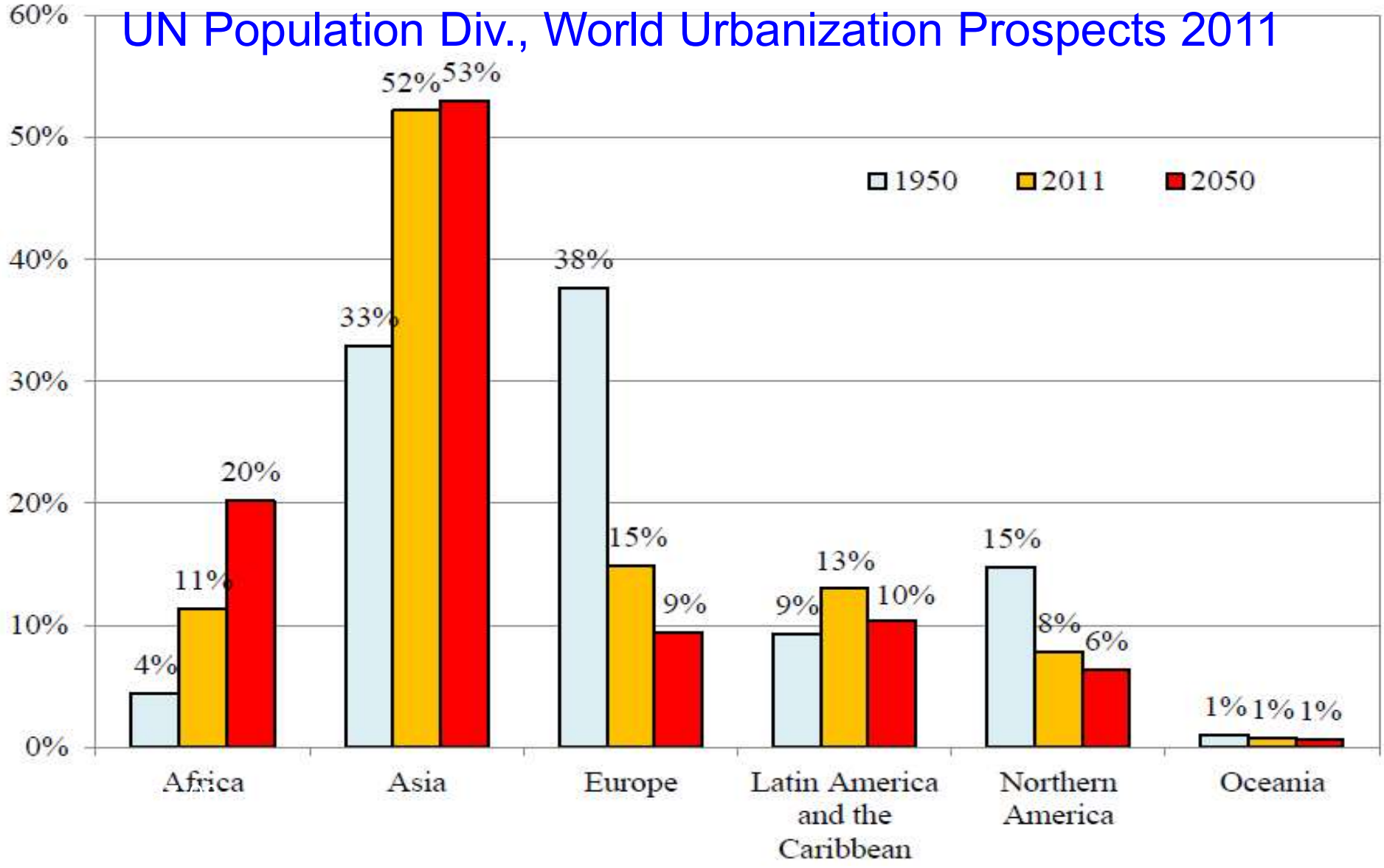


Source: United Nations, Department of Economic and Social Affairs, Population Division (2012): World Urbanization Prospects, the 2011 Revision. New York

Less developed regions will have an increasing share of urban population.



Most urban people are & will be Asian.



"Around 40 % of the world's population lives less than 100 km from the coast …

close to 100 million people around the world live less than 1 m above sea level."

UN Habitat 2007

~647 million people live contiguous to seacoasts at elevation ≤10 m.

~384 million of them live in cities.

UN Habitat 2008

In last interglacial (Eemian, 130-115 ka), global sea level was ~6 m higher. Migration potential?

Port Arthur, Texas 2017-08-31

https://upload.wikimedia.org/wikipedia/commons/5/51/Support_during_Hurricane_Harvey_%28TX%29_%2850%29.jpg

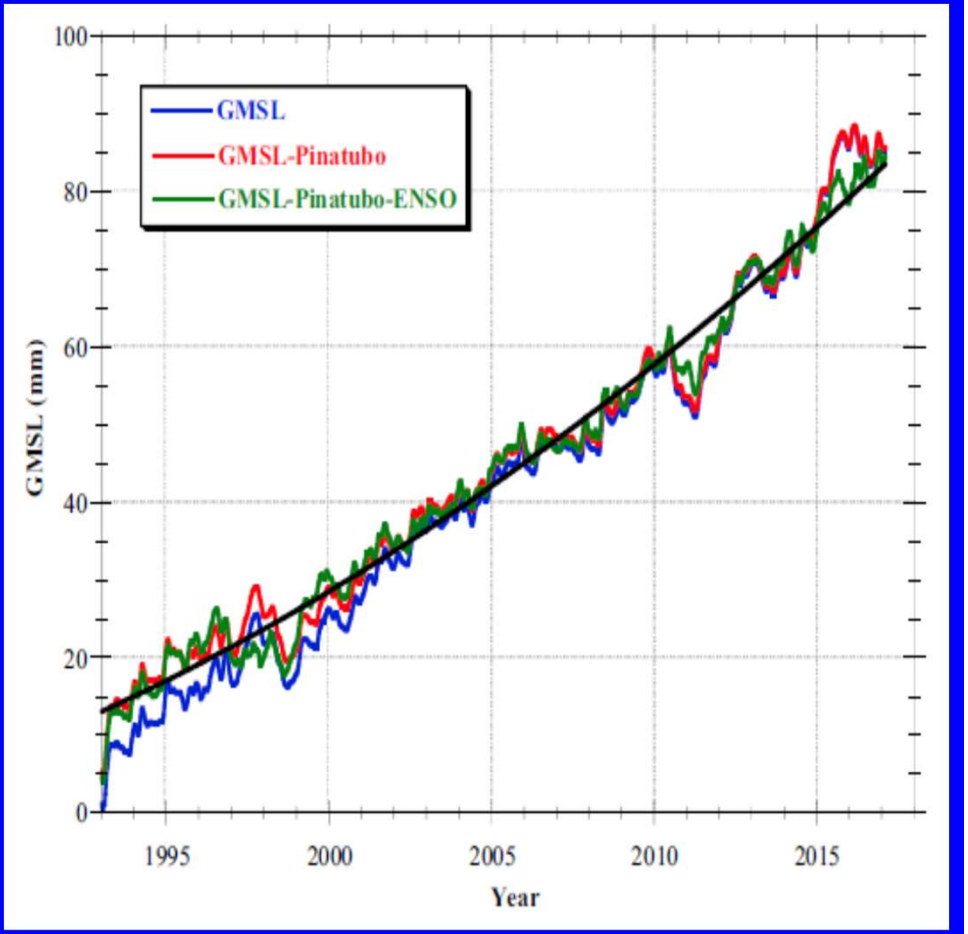
Aguadilla, Puerto Rico 2017-09-22

Global mean sea level is rising at accelerating rate.

Nerem et al. *PNAS* 2018-02-27

"… the observed acceleration will more than double the amount of sea-level rise by 2100 compared with the current rate of sea-level rise continuing unchanged. … this simple extrapolation will likely represent a conservative lower bound on future sea-level change."

2005-2100: +65±12cm



More water increased sea level twice as fast as changed heat content & salinity.

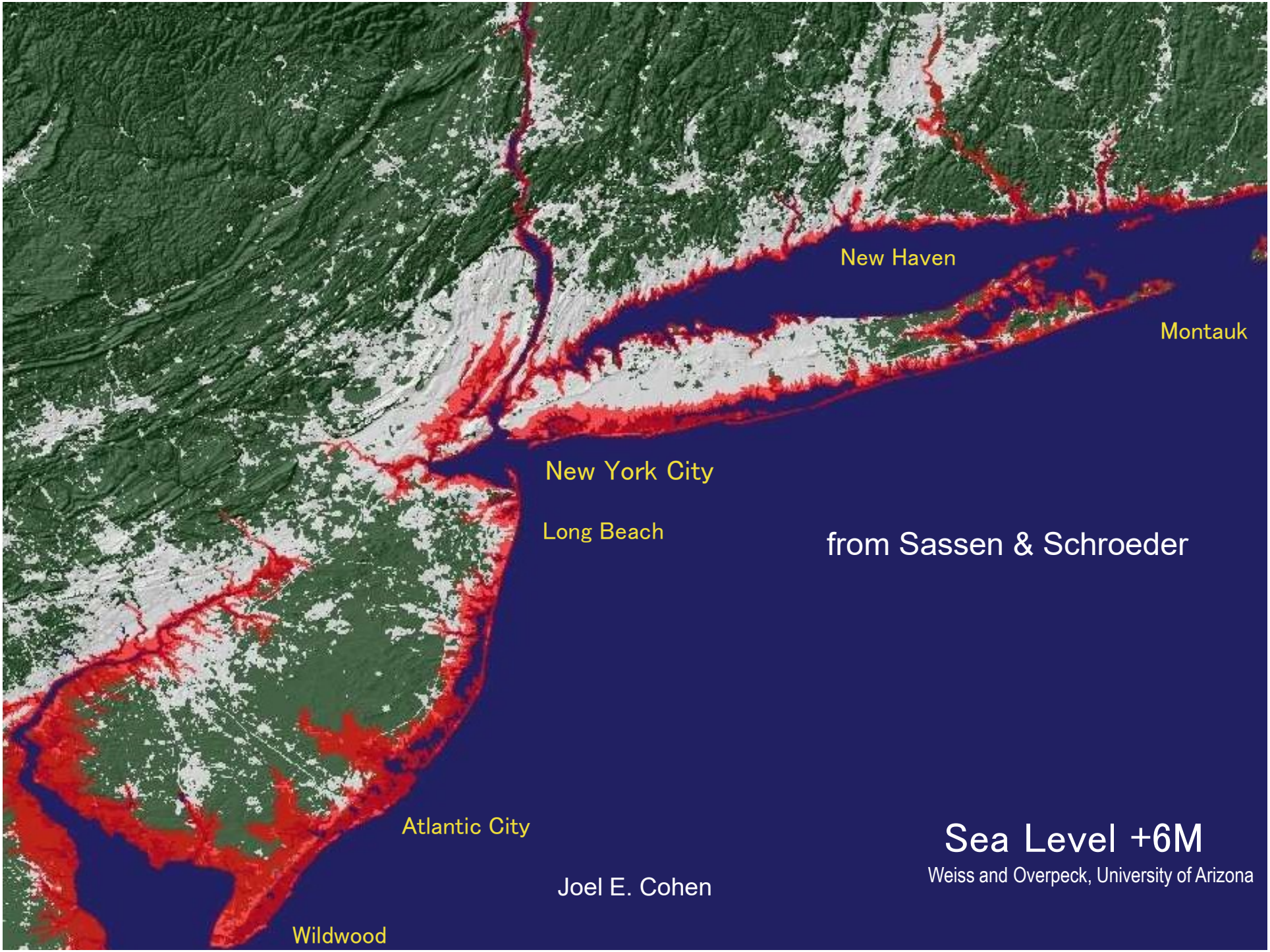
Leuliette, Eric. (2014). The budget of recent global sea level rise: 1995-2013. NOAA

Sea level rise budget for January 2005 to December 2013

$SL_{total} = SL_{steric} + SL_{mass}$	**Trend (mm/year)**
Ocean mass Glaciers, ice caps, ice sheets	2.0 ± 0.2
Steric (0–2000m) Heat content, salinity	0.8 to 1.1 ± 0.5
Steric + mass	2.8 to 3.1 ± 0.5
Total sea level (Jason-1 and Jason-2)	3.0 ± 0.4


New Haven
Montauk
New York City
Long Beach
from Sassen & Schroeder
Atlantic City
Joel E. Cohen
Weiss and Overpeck, University of Arizona
Wildwood


New Haven
Montauk
New York City
Long Beach
from Sassen & Schroeder
Atlantic City
Sea Level +1M
Weiss and Overpeck, University of Arizona
Joel E. Cohen
Wildwood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New York City
Long Beach
from Sassen & Schroeder
Atlantic City
Sea Level +6M
Weiss and Overpeck, University of Arizona
Joel E. Cohen
Wildwood


Weiss & Overpeck
University of Arizona
from Sassen & Schroeder
Legend
1-meter rise
6-meter rise
high population
low population
Susceptibility to Sea Level Rise
Weiss & Overpeck
The University of Arizona
0 140 280 420 560
Kilometers
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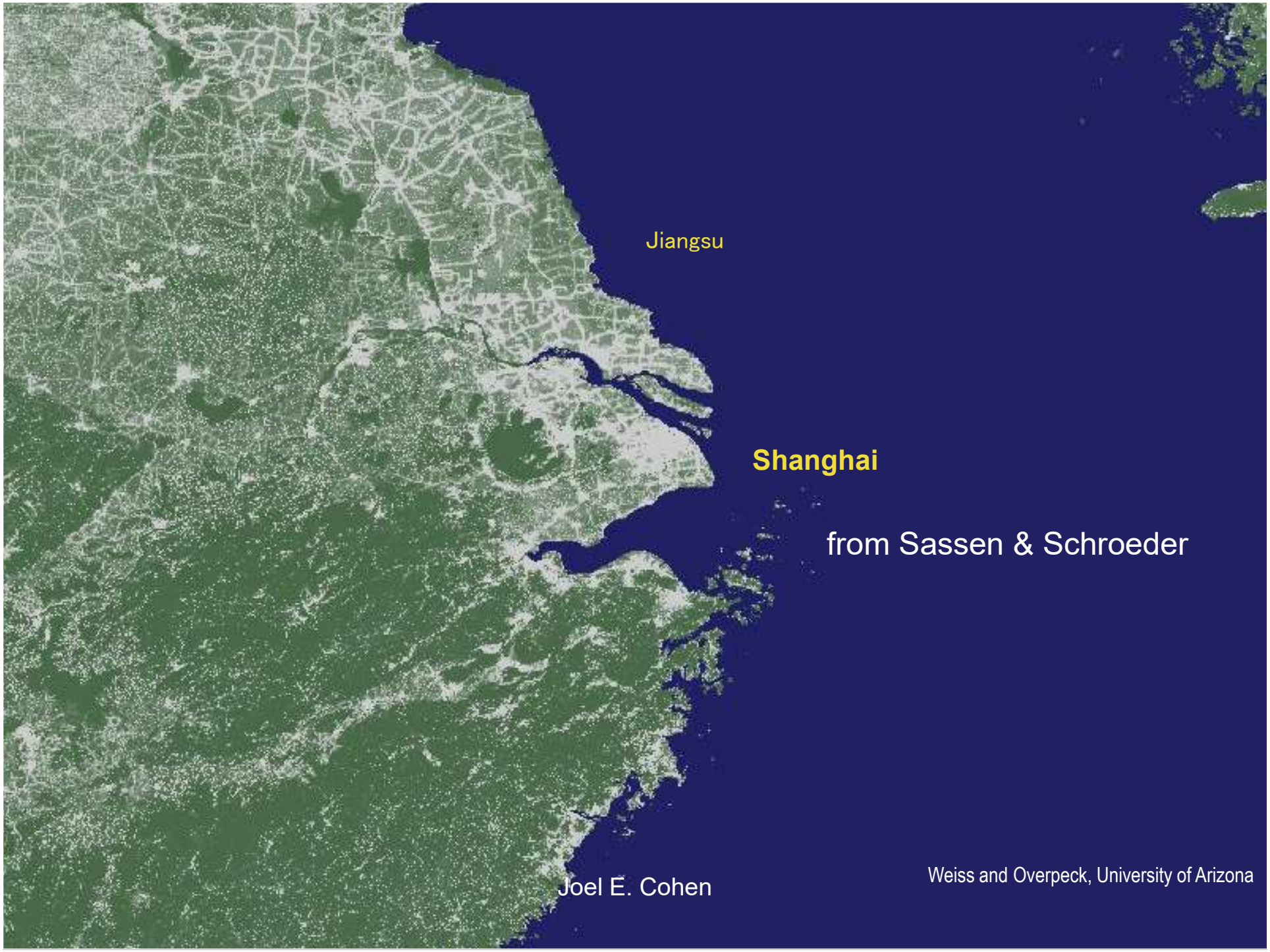
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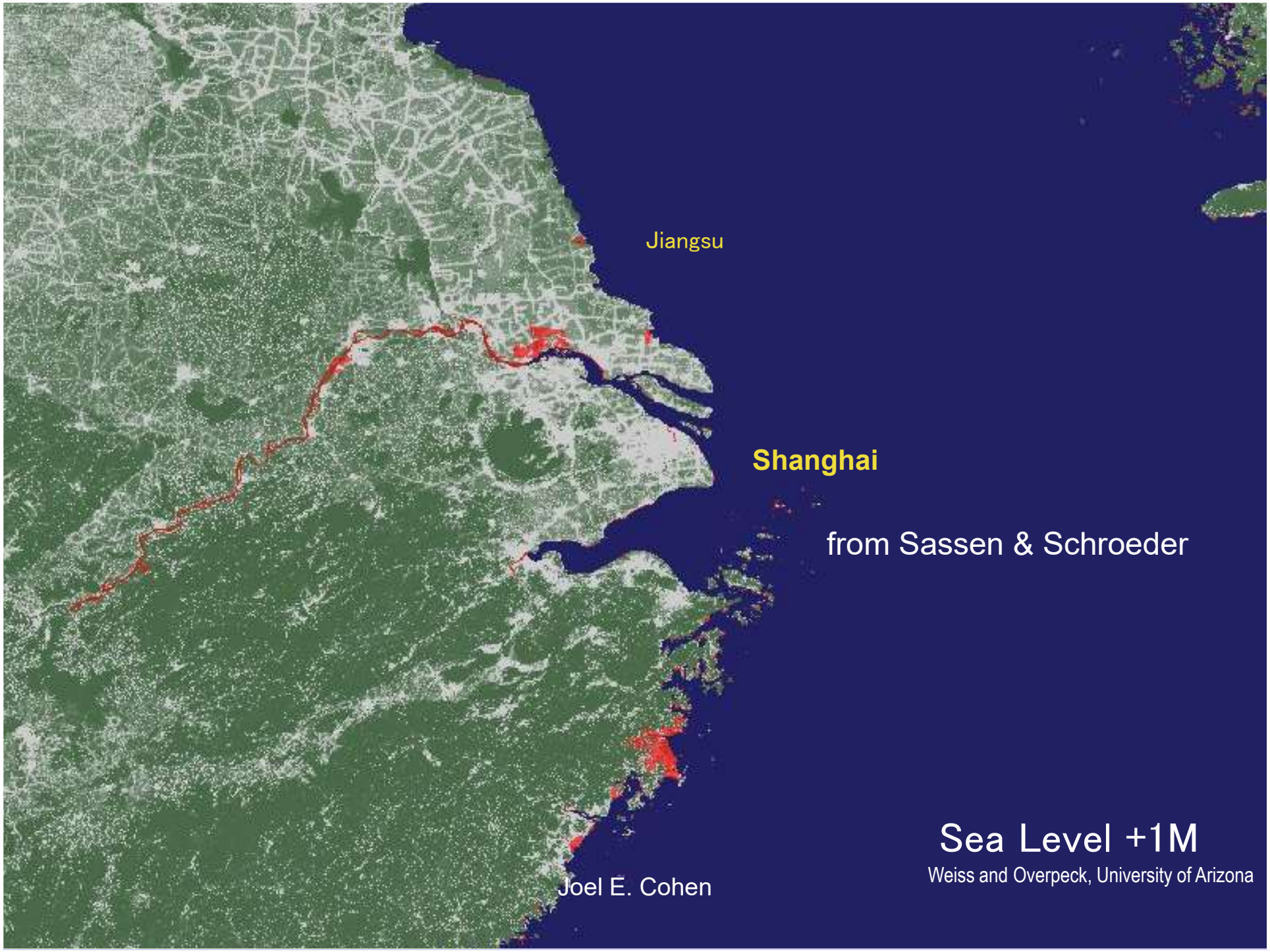
Shanghai
from Sassen & Schroeder
Joel E. Cohen
Weiss and Overpeck, University of Arizona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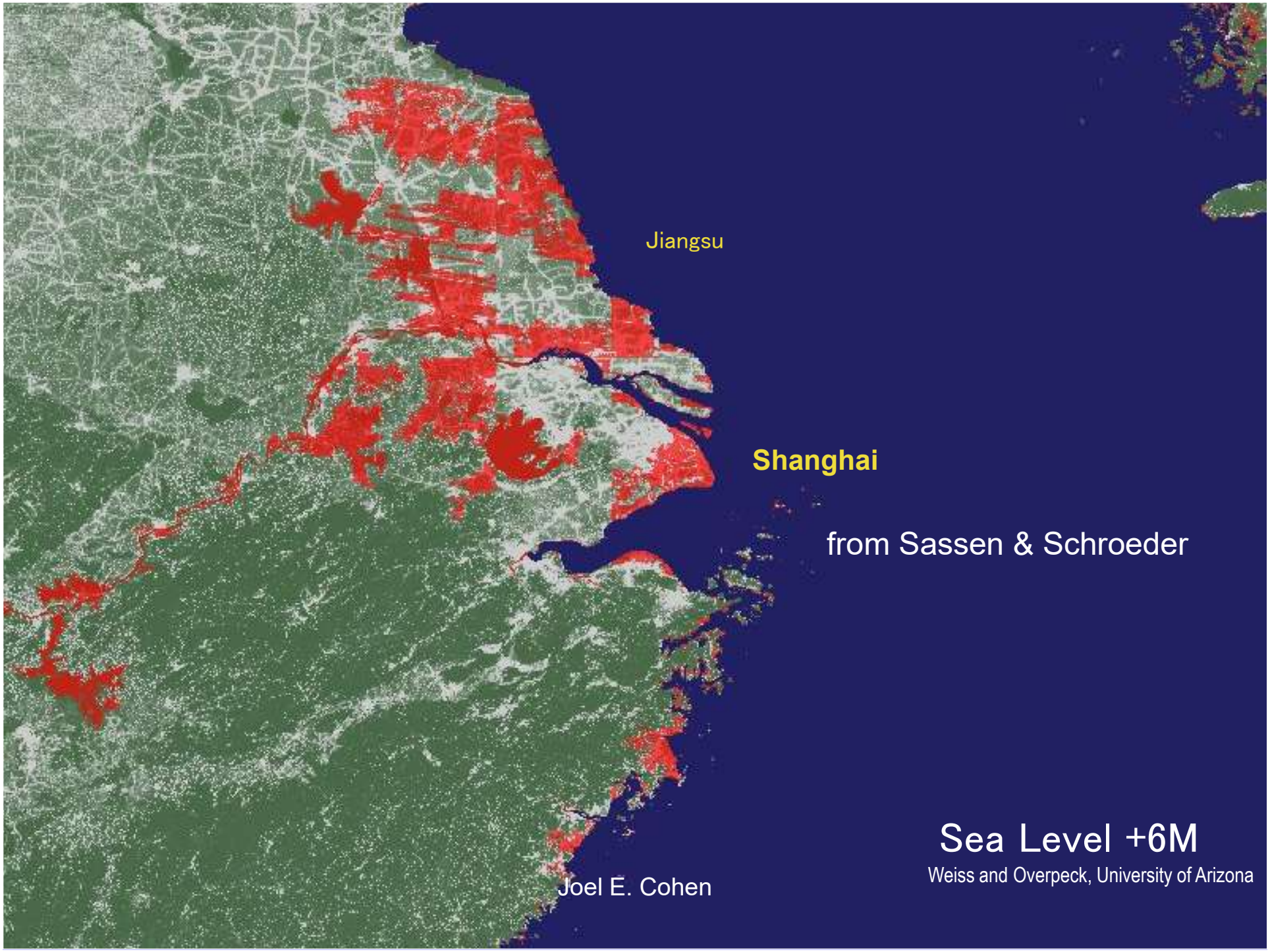
Joel E. Cohen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Joel E. Cohen


Weiss and Overpeck, University of Arizona
Haarlem
The Hague
Amsterdam
from Sassen & Schroeder
Uitrecht
Rotterdam
Joel E. Cohen


Weiss and Overpeck, University of Arizona
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Weiss and Overpeck, University of Arizona
Sea Level +6M
Haarlem
The Hague
Amsterdam
Uitrecht
Rotterdam
from Sassen & Schroeder
Joel E. Cohen

S&P: "Climate Resilience Can Protect Ratings from Sea-Level Rise & Threats to U.S. Coastal Infrastructure"

2015-10-22

- Cities & infrastructure on coasts are exposed increasingly to rising sea levels.
- Barriers to flooding could avert losses of billions of dollars.
- Credit impacts of threat & preventive actions are unknown now.
- Cities that act now to protect future credit rating need not damage current ratings.

Flood losses in major coastal cities could total >$1 T/y by 2050.

- Flood exposure in coastal cities is growing because of growing population & assets, climatic change, & subsidence of land.
- Average annual losses (AAL) := how much of city's economic output should be saved annually to pay for future flood losses.
- Of 136 coastal port cities, 13 now have AAL >$100 million (5 of them in USA).
- Miami, NYC, New Orleans are 31% of global AAL. Hallegatte et al. *Nature Climate Change* 2013

Problems of coastal, low cities

- Population
  - Internal migration to coastal cities
  - Increasing population density
  - Aging of urban populations
  - Decreasing household size

Problems of coastal, low cities

Economics

- Vulnerability of seaports, airports, roads, railroads, bridges
- Vulnerability of power plants, refineries
- Threats to coastal real estate values
- Threats to tax base, credit ratings of local governments
- Rapidly increasing flood insurance costs

Problems of coastal, low cities

- Environment
  - Probably related to climate change
    - Sea-level rise
    - Increasingly intense ocean storms
    - More vectors of infectious disease
    - Heat waves
    - Salt-water invasion of coastal fresh-water aquifers
    - Bursty precipitation overwhelms stormwater management & combined sewage-runoff waste treatment capacities
    - Mud slides
    - Fires from surrounding vegetation
    - Urban drought from reduced freshwater supplies

Problems of coastal, low cities

- Environment
  - Not necessarily related to climate change
    - Earthquakes at edges of tectonic plates
    - Tsunamis
    - Depletion of surrounding agriculture
    - Reductions of biodiversity in and around cities
    - Heat island effects
    - Increased flood risk from impervious surfaces
    - Particulate matter air pollution
    - Vulnerability of water supplies
    - Land subsidence

Problems of coastal, low cities

- Culture
  - Denial of reality of climate changes
  - Empowering local governments, especially cities, to lead response to climate change
  - Zoning & building codes & standards
  - Outdated flood maps
  - Misguided flood insurance incentives
  - Learning from successes of other cities
  - Changing school populations
  - Slums or “informal settlements” (housing, education, employment, health, security)
  - Flooding of coastal military facilities

Options for responding

Ignore problems, take no action

Fortify with hard engineering

Use natural partial protections adaptively (e.g., maintain coastal wetlands)

Abandon, retreat

The numbers & proportions of older people will increase,

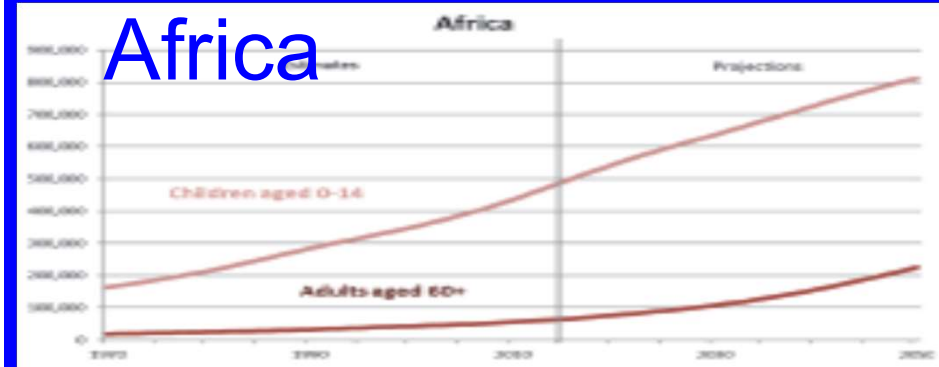
first in rich countries, then in poor.

World ages 0-14 & 60+, 2015-2050

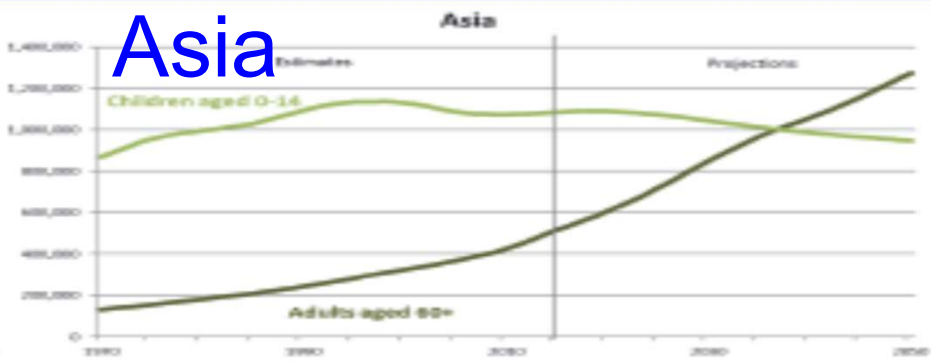
UN, *World Population Prospects 2017 Data Booklet*

World ages 0-14 & 60+, by region

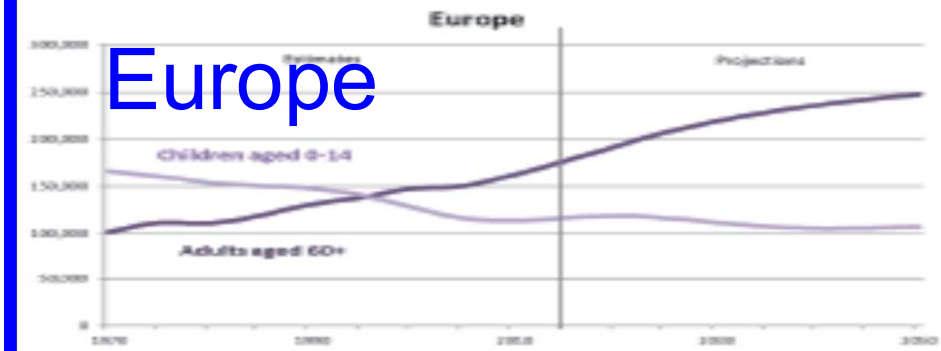
UN, *World Population Prospects 2017 Data Booklet*



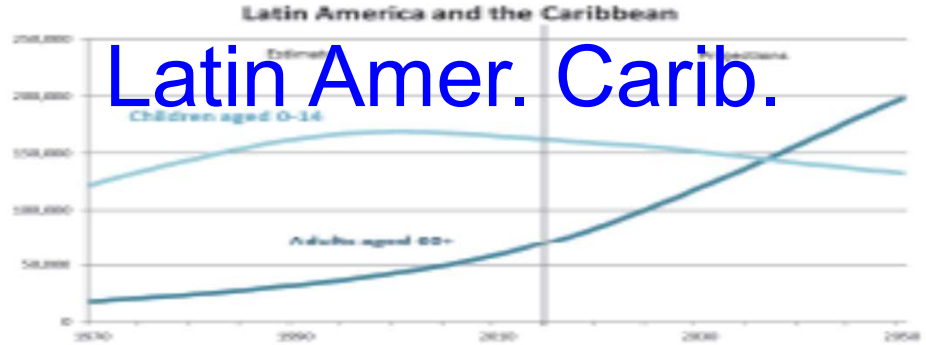
Africa



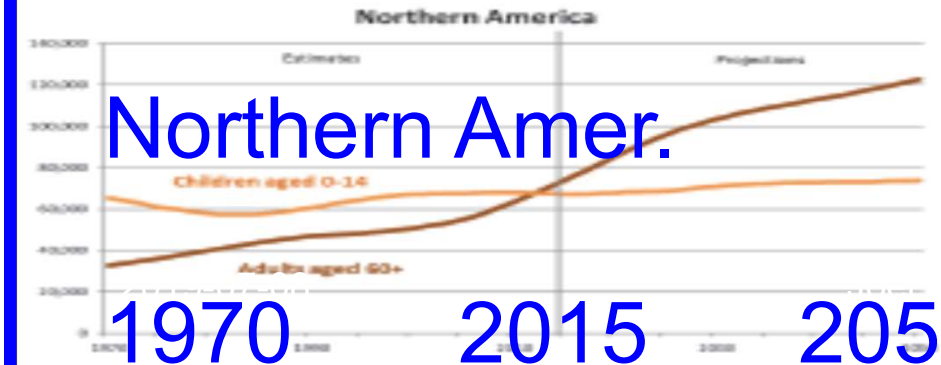
Asia



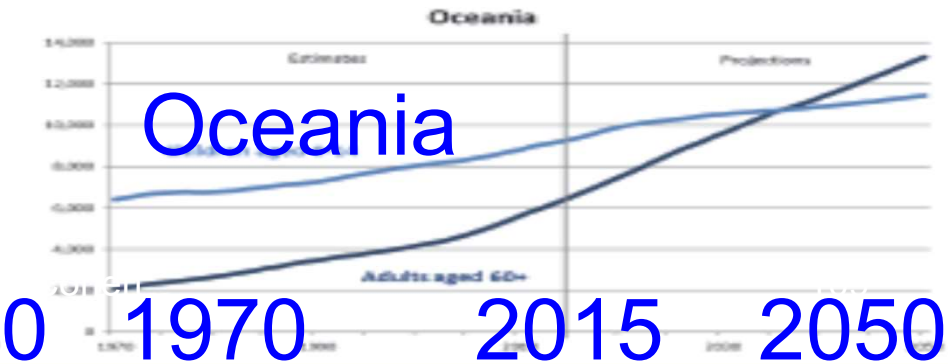
Europe



Latin Amer. Carib.



Northern Amer.



Oceania

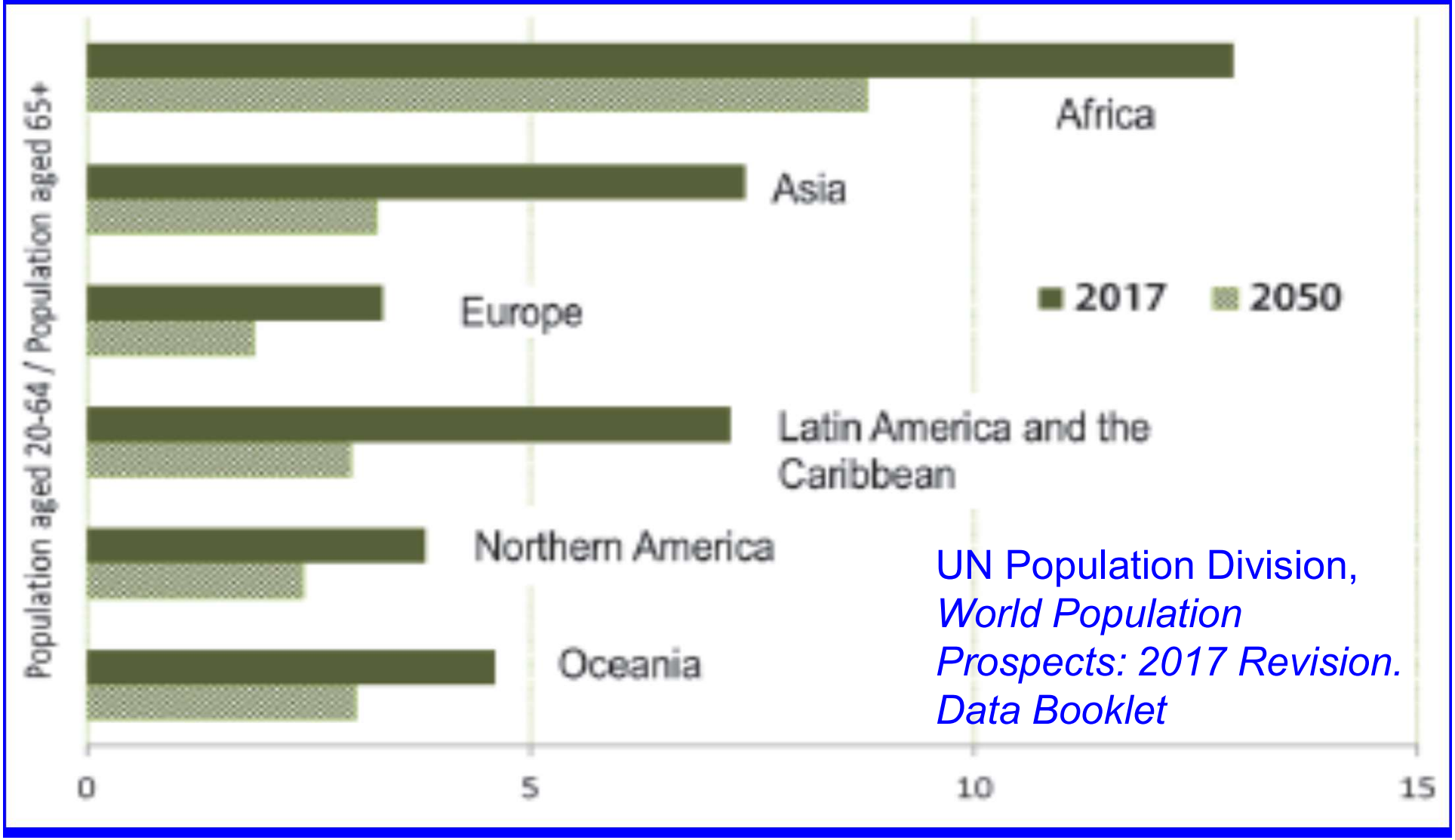
1970 2015 2050 1970 2015 2050

Potential Support Ratio (PSR)

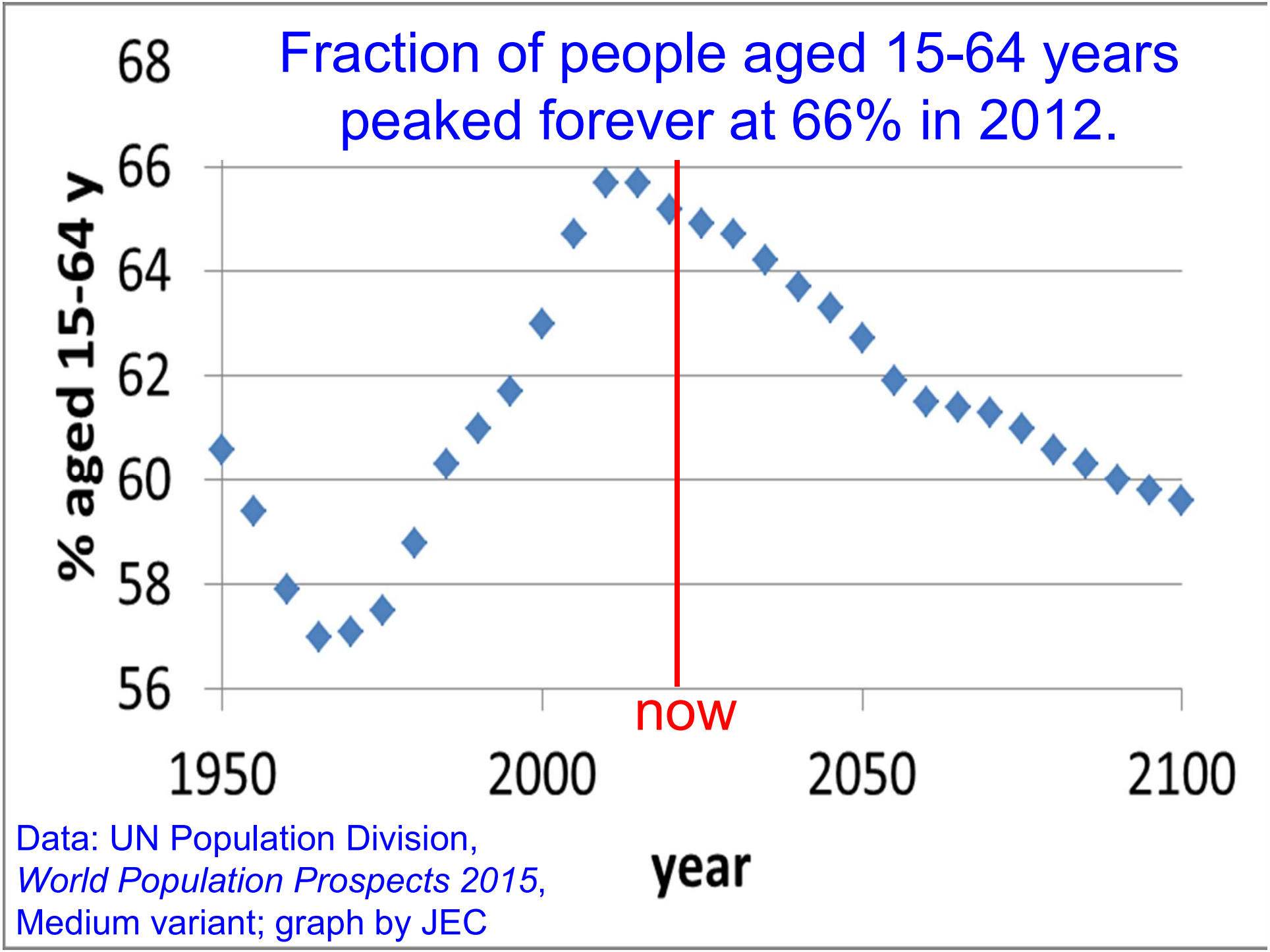
$$\text{PSR} = \frac{\text{number of people aged 20-64 years}}{\text{number of people 65+ years}}$$

Japan's PSR = 2.6, lowest in the world.

Potential support ratio (20-64/65+) by region, 2017 & 2050

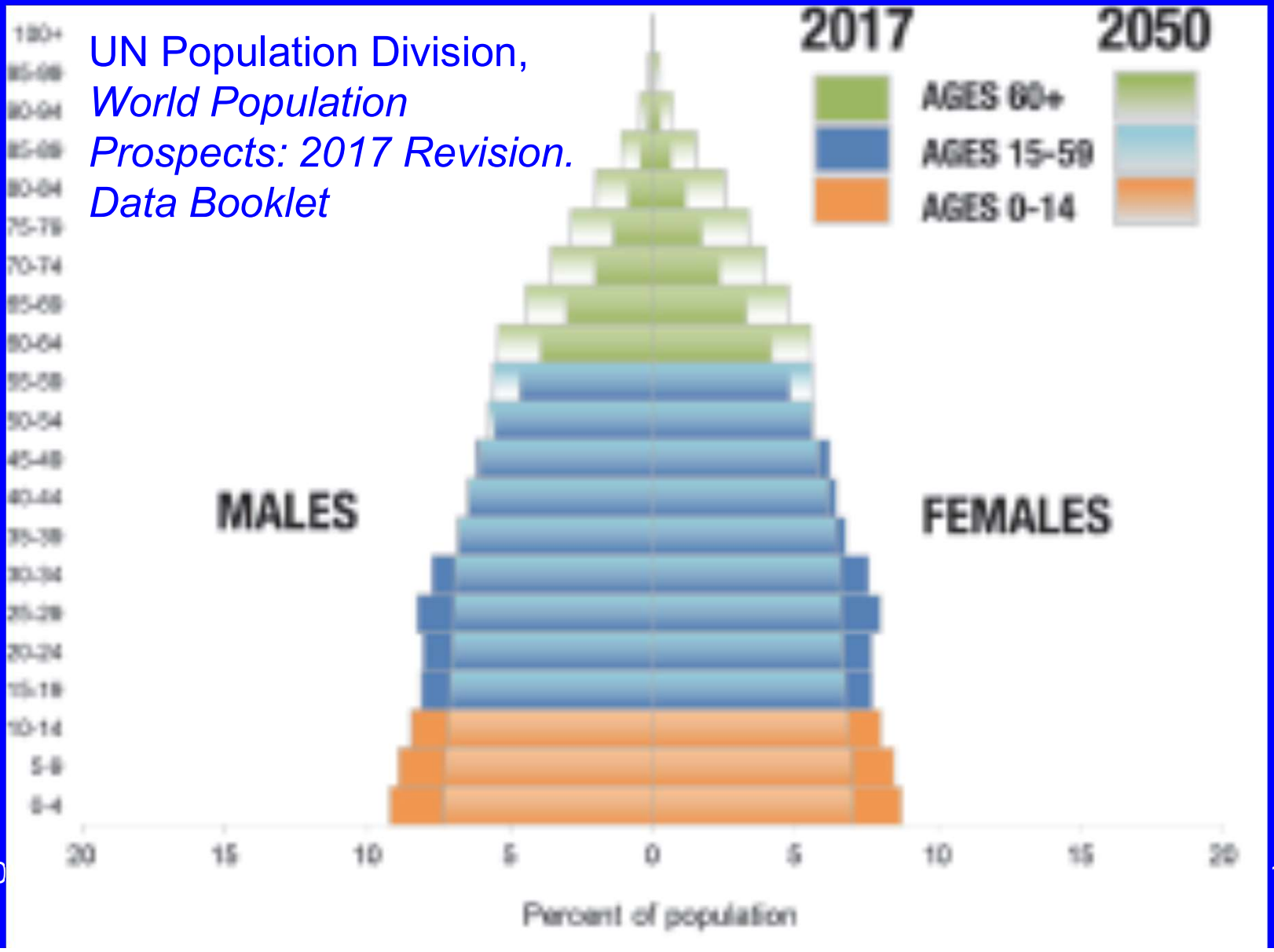


UN Population Division, *World Population Prospects: 2017 Revision. Data Booklet*

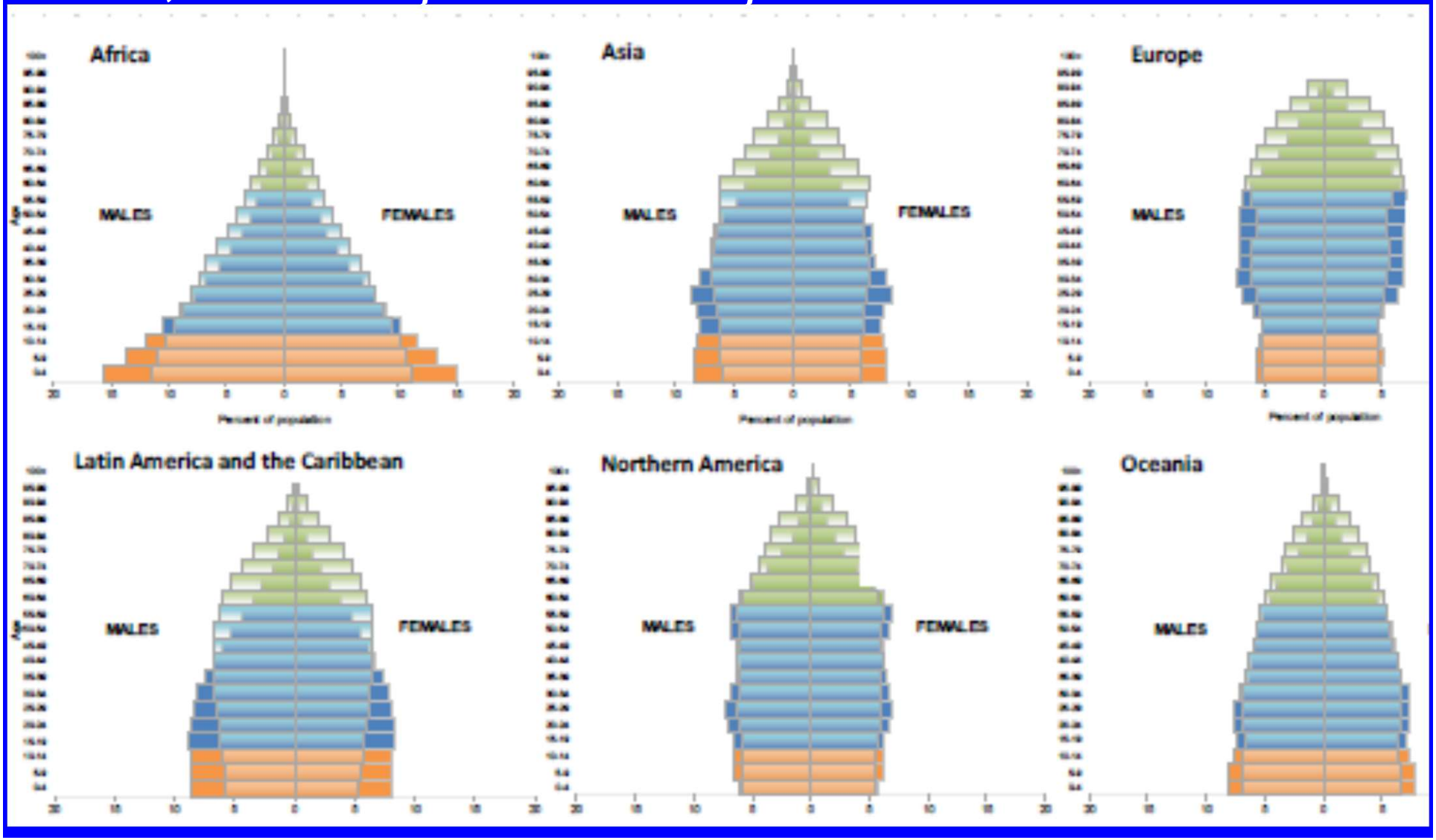

Fraction of people aged 15-64 years peaked forever at 66% in 2012.
% aged 15-64 y
68
66
64
62
60
58
56
now
1950
2000
2050
2100
year
Data: UN Population Division,
World Population Prospects 2015,
Medium variant; graph by JEC

World population pyramid

UN Population Division,
World Population Prospects: 2017 Revision. Data Booklet



World population pyramids
2017, 2050
UN, *World Population Prospects 2017 Data Booklet*



Population aging depends more on birth rates than death rates.

Birth rates control the size of youngest age groups at the bottom of the age pyramid.

Family support policies do not raise fertility enough to avert population aging.

Immigration cannot keep a population young because immigrants age, too.

Disability at older ages is declining, especially for people who were healthy & educated in their youth.

70 is the new 60.

In USA, people (of both sexes) aged 70-74 in 2005-2009 had remaining life expectancy of people aged 60-64 years in 1935-39.

Year	Age	Remaining life expectancy
1935-1939	70-74	9.95
1935-1939	60-64	15.72
2005-2009	70-74	15.24

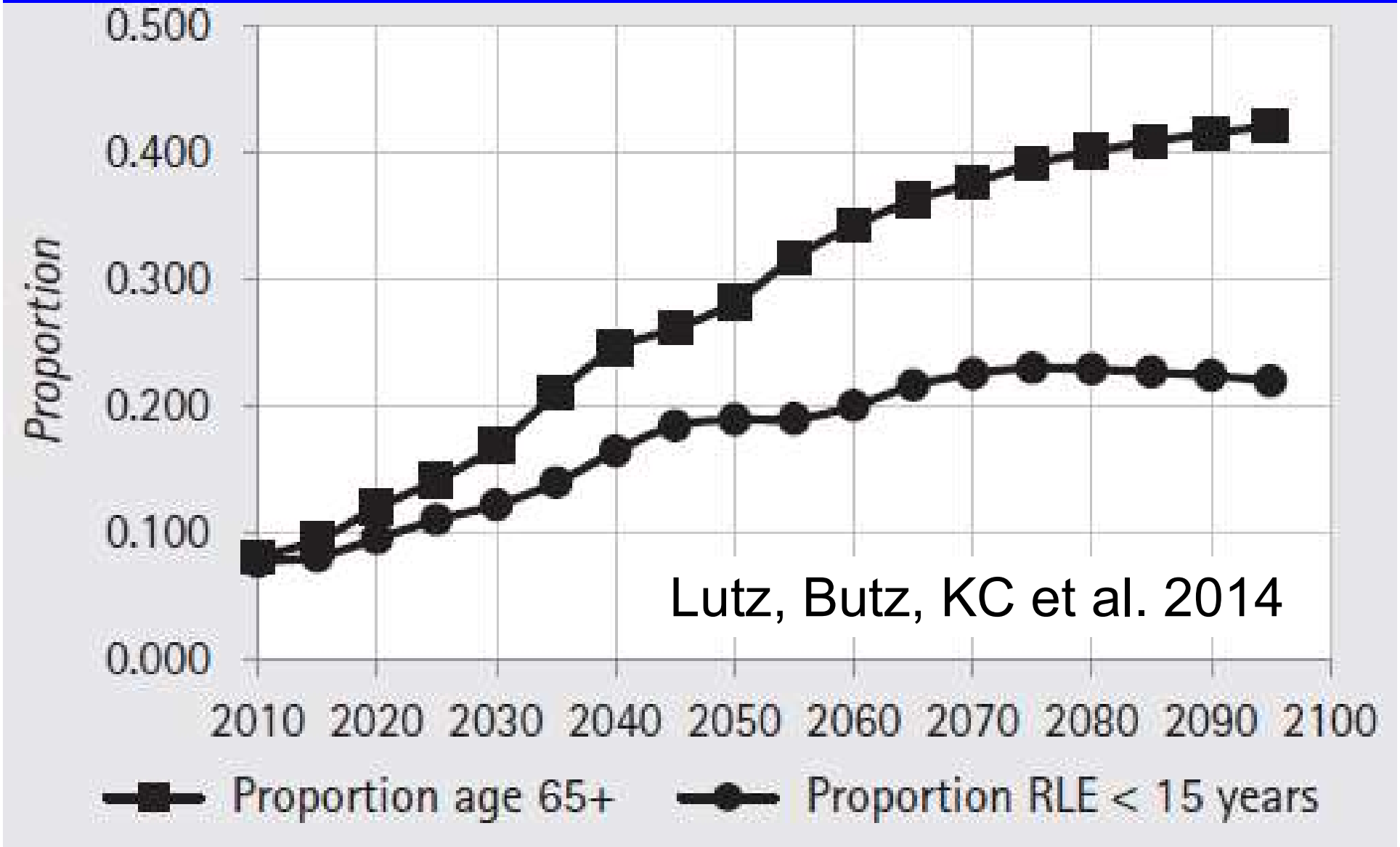
Data: Human Mortality Database www.mortality.org

What does “old” mean? Age 65+ years? Or Remaining life expectancy 15 years? Norman Ryder 1975

In 2010, old = 71 years in North America, 63 in Africa, 67 for the world.

Prediction for the world: old = 73 in 2050, 78 in 2090. Lutz et al. 2014

China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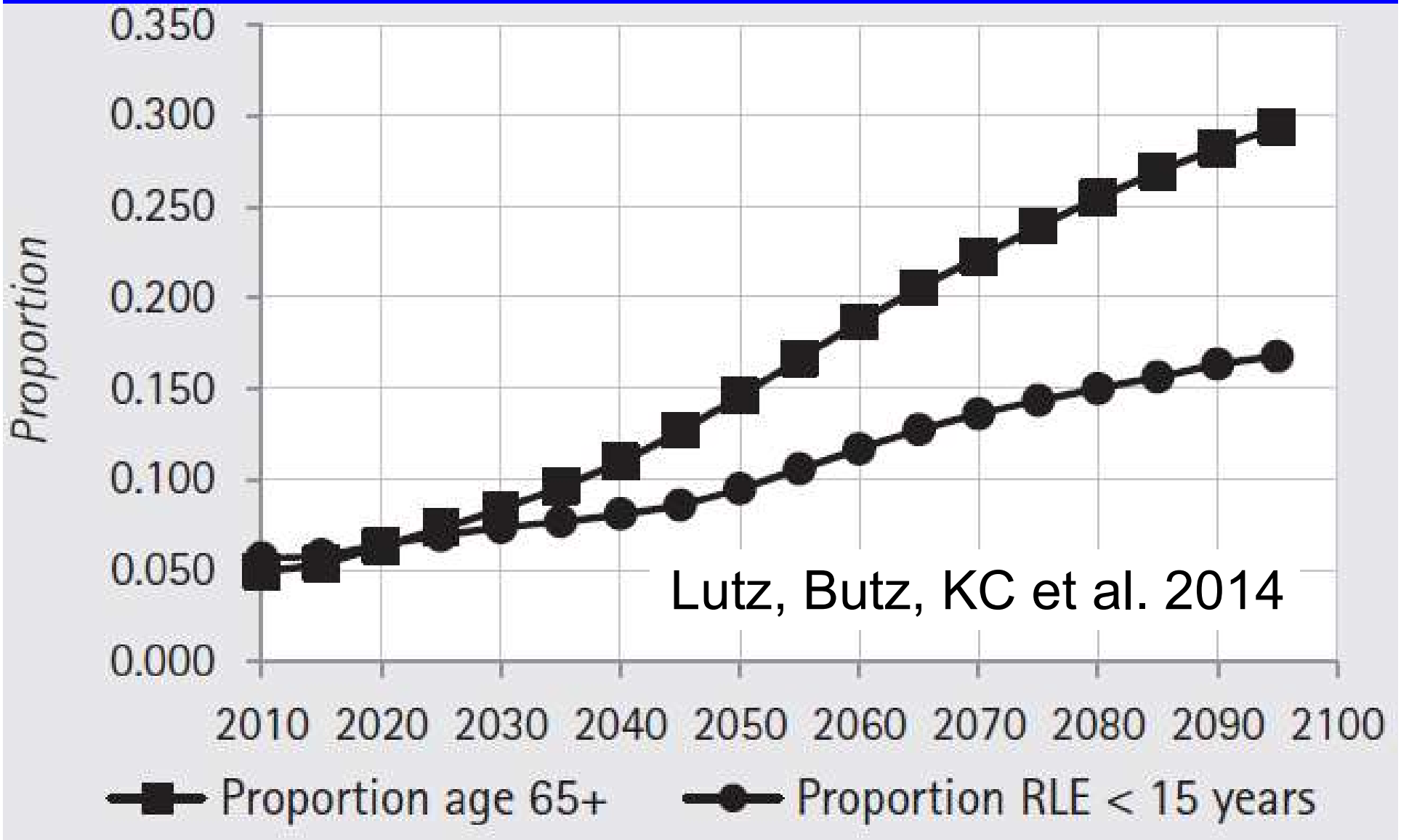
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

India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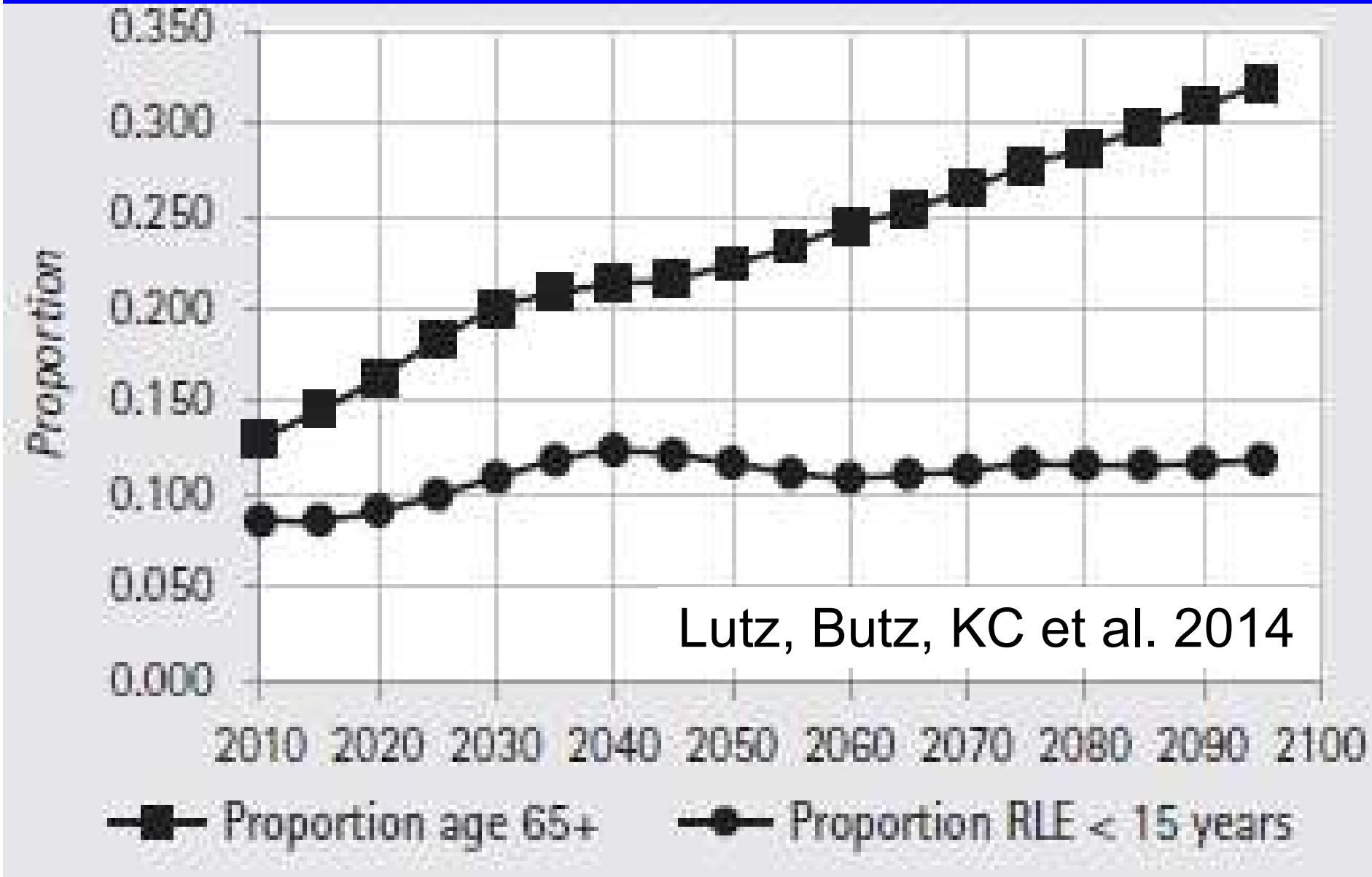
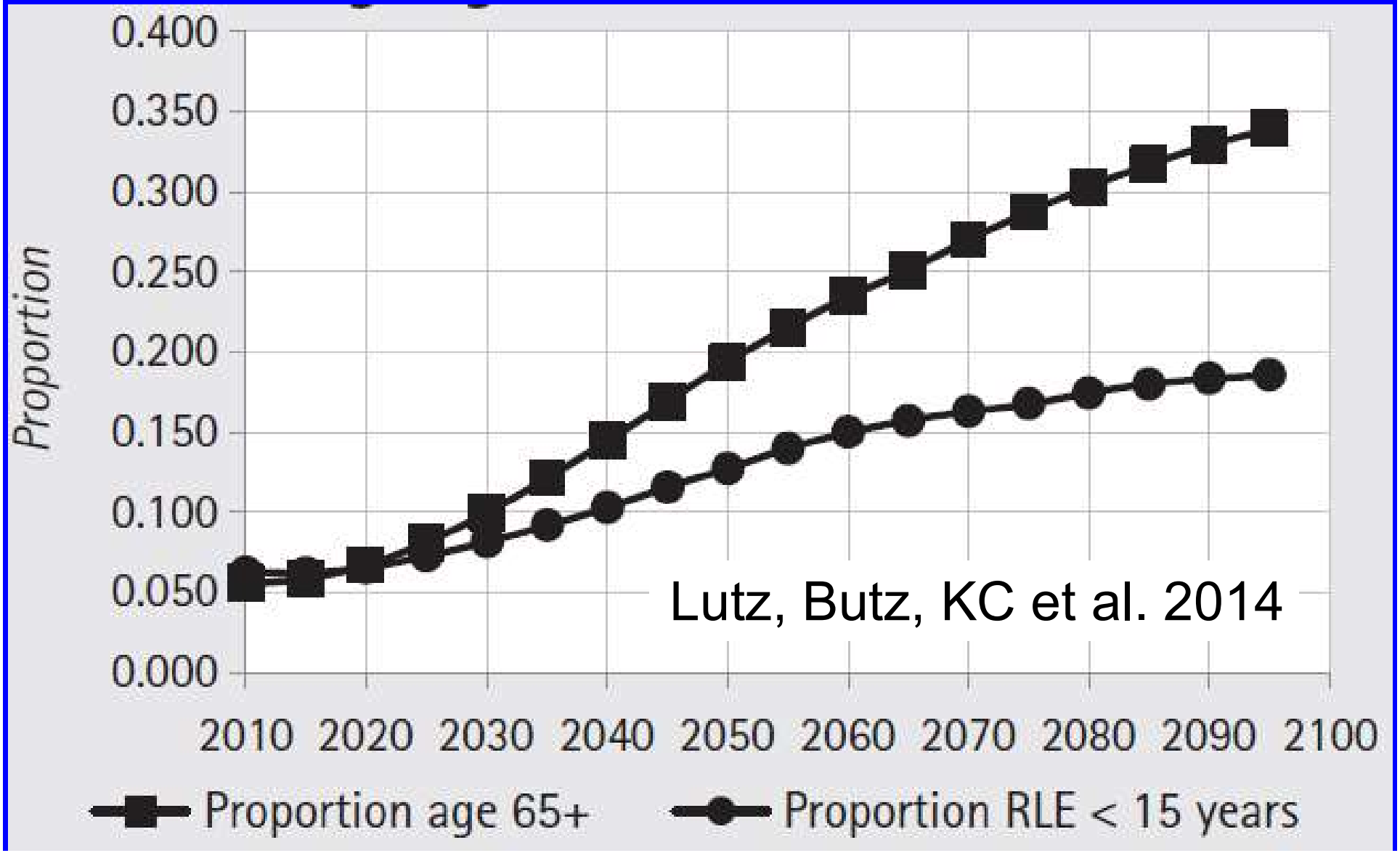
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

United States of America



Indonesia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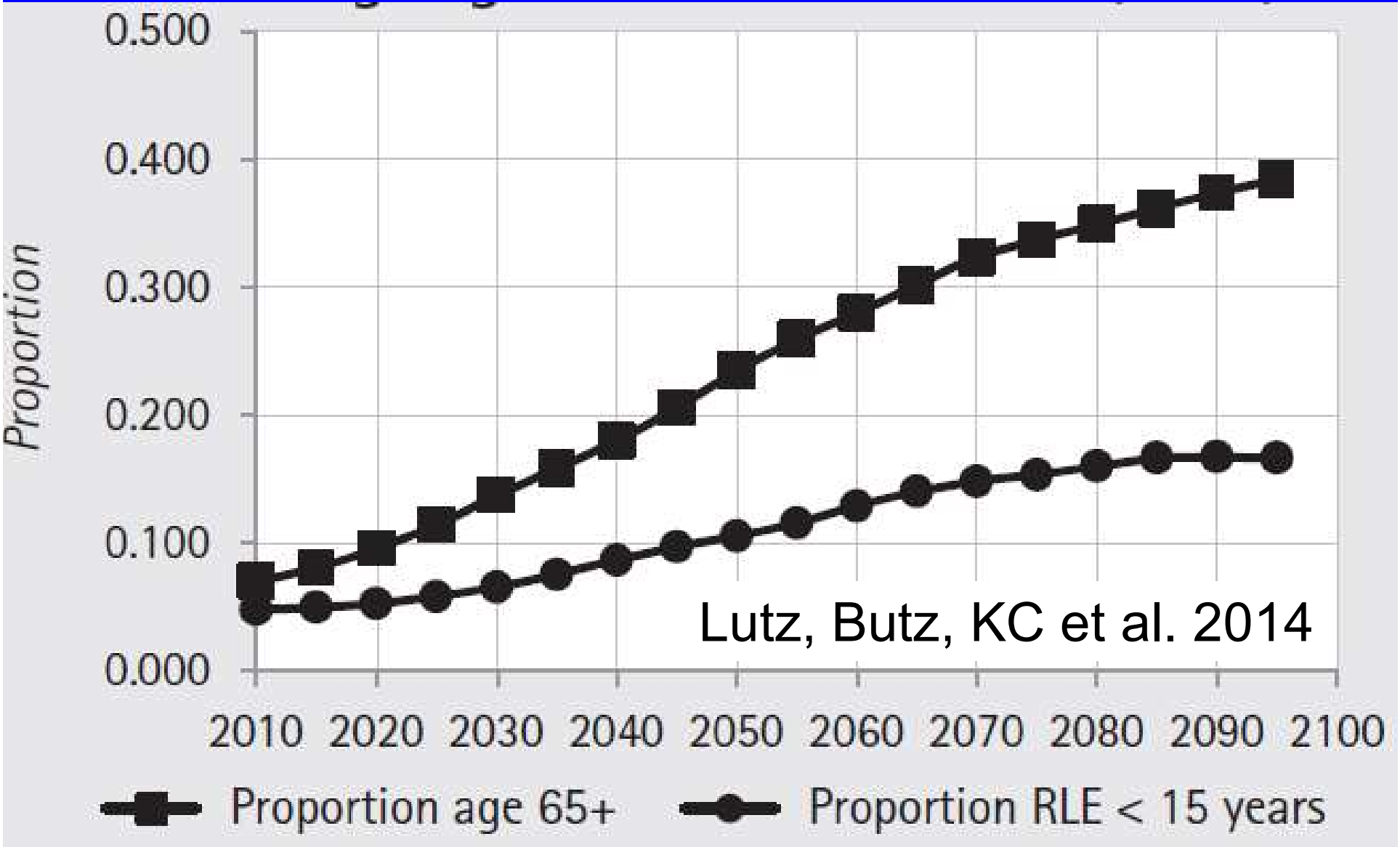
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

Brazil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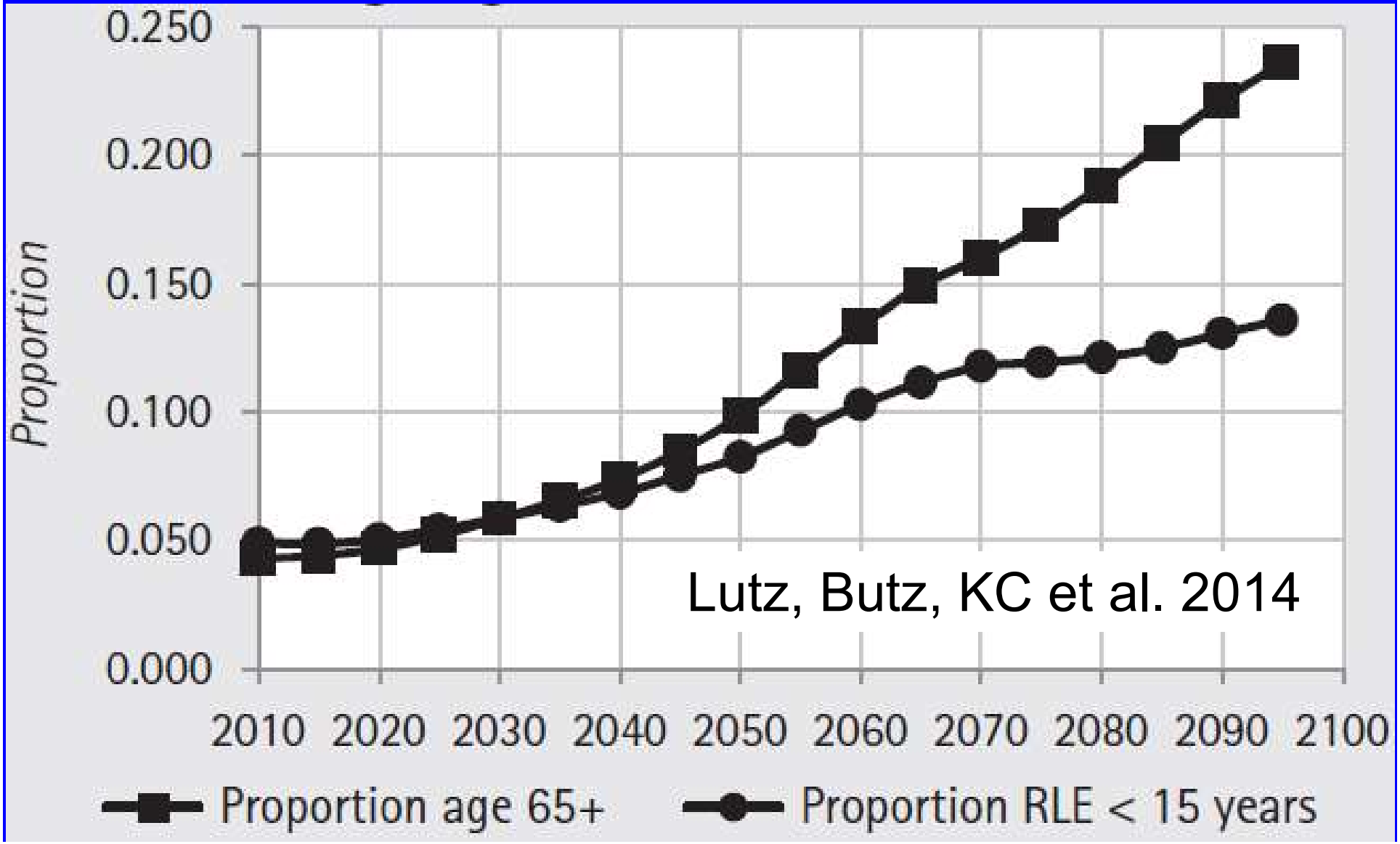
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

Pakistan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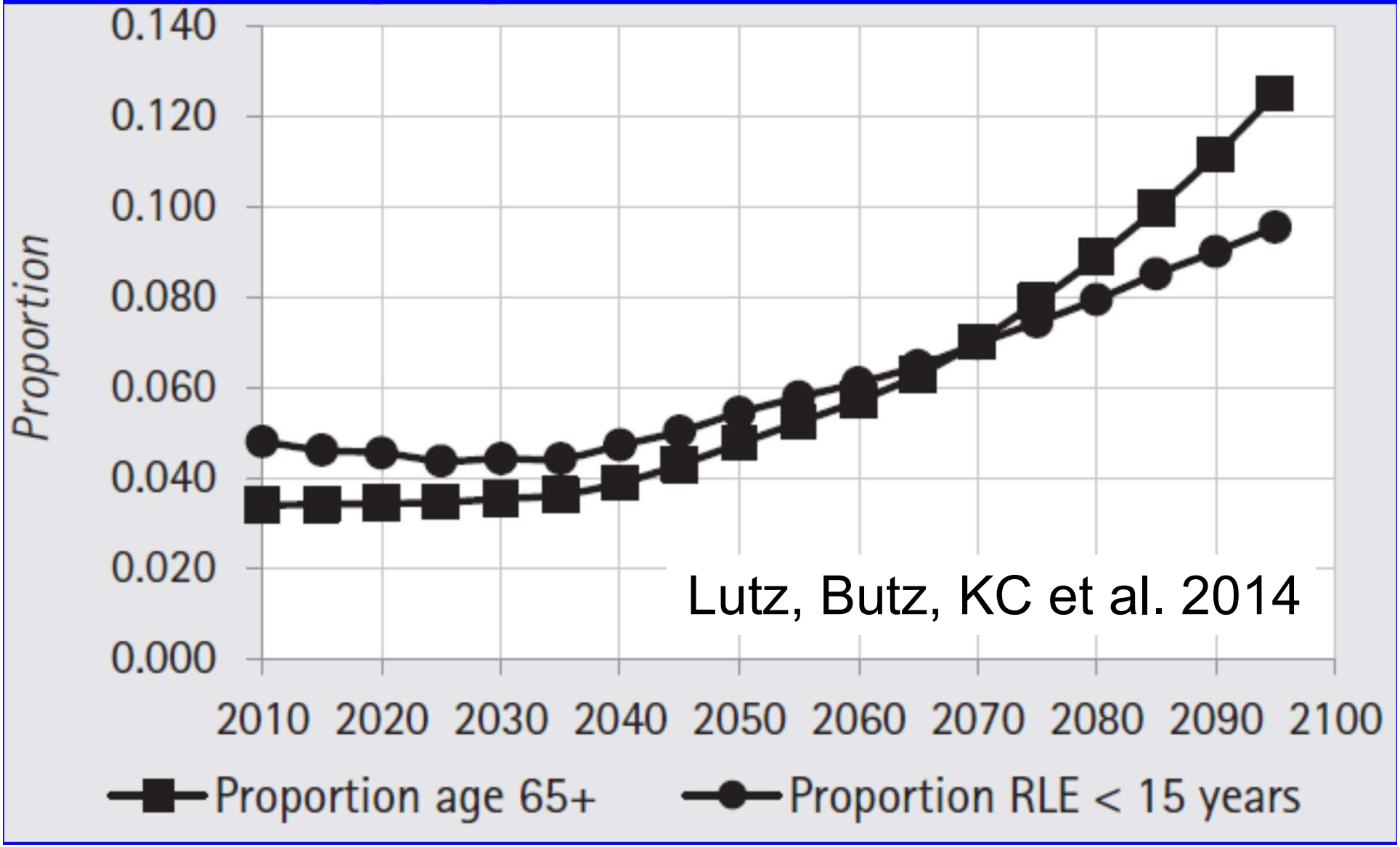
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

Nigeria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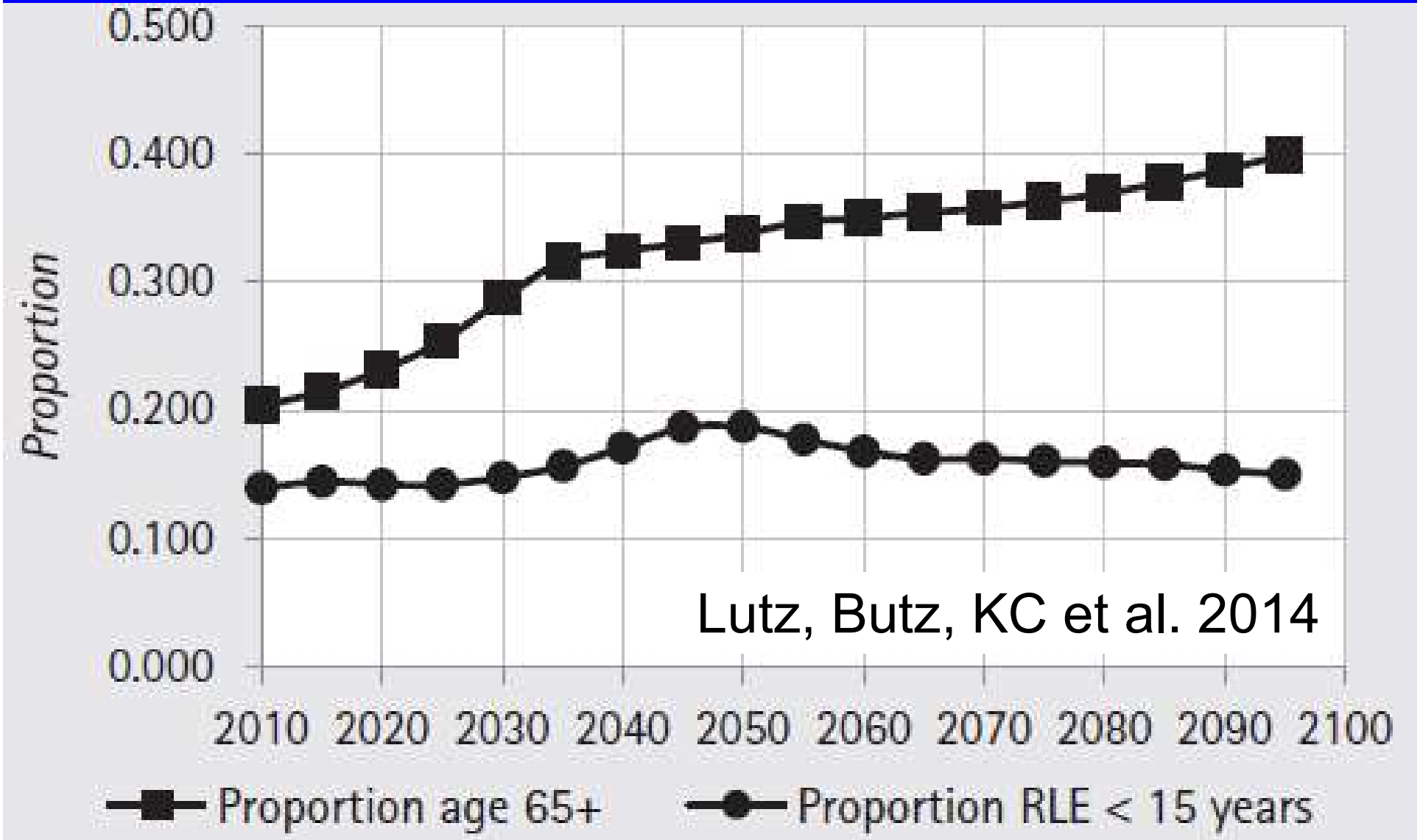
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

Germany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Proportion
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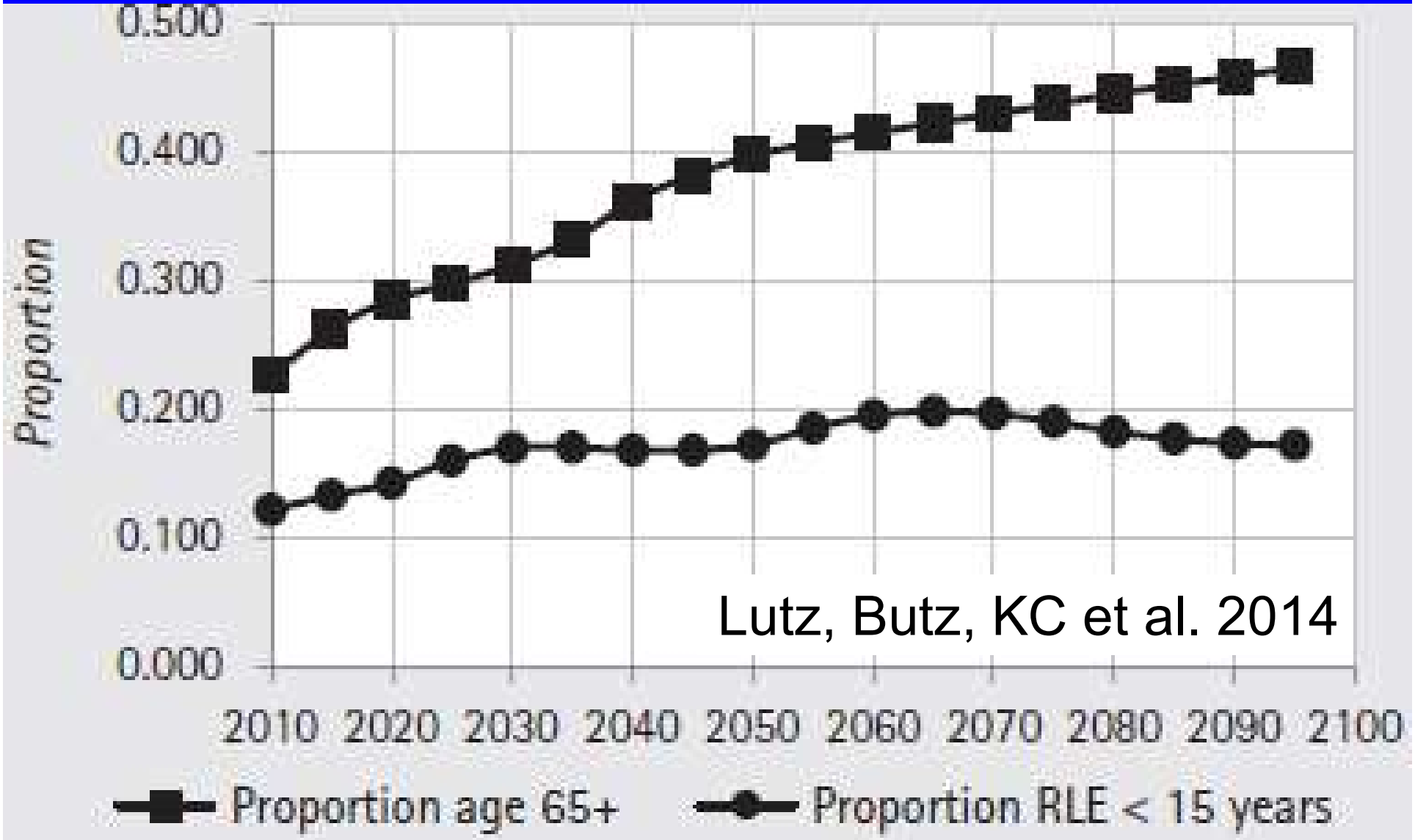
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

Japan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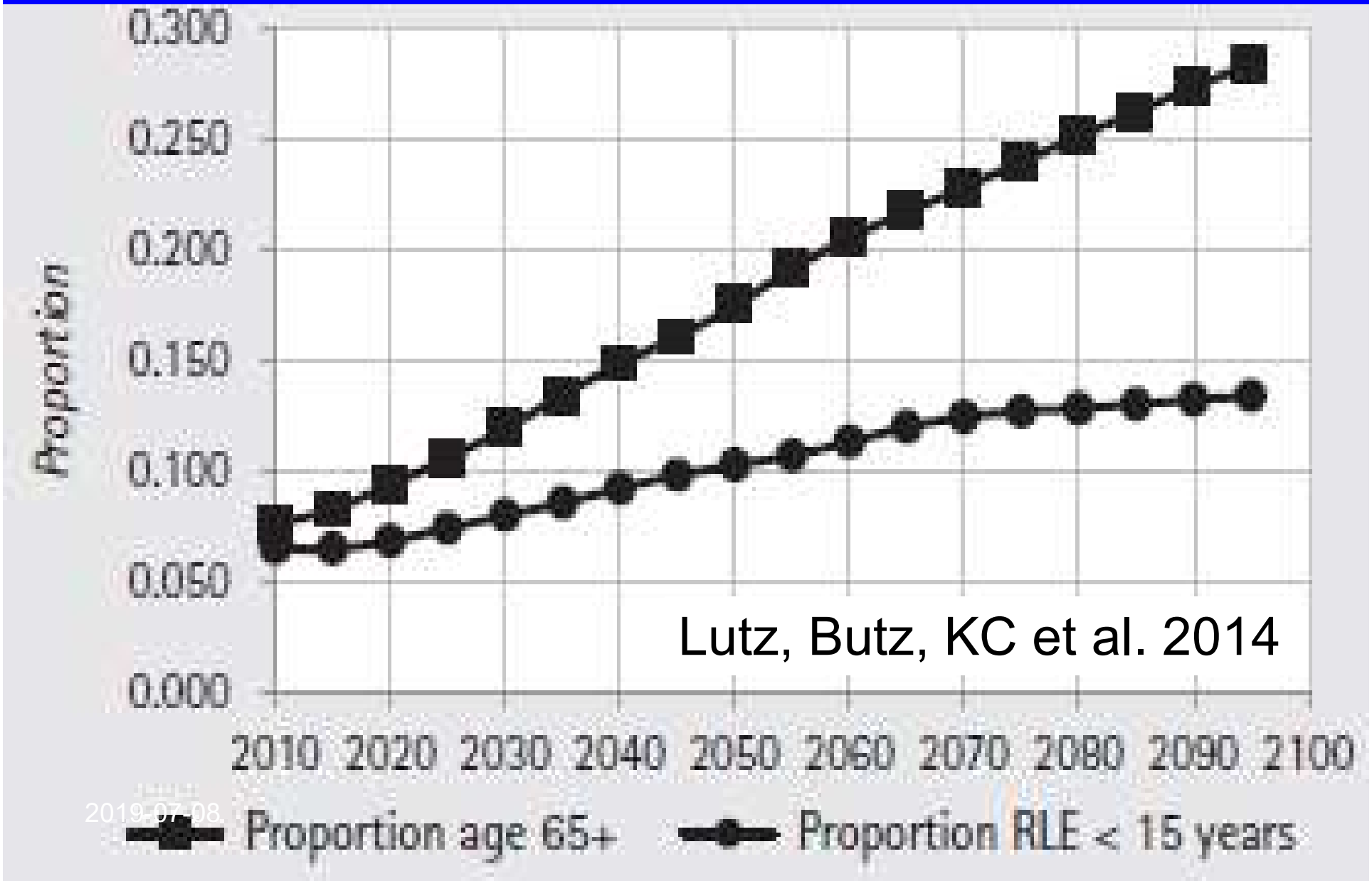
Proportion
2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Lutz, Butz, KC et al. 2014
Proportion age 65+
Proportion RLE < 15 years

World



Lutz, Butz, KC et al. 2014

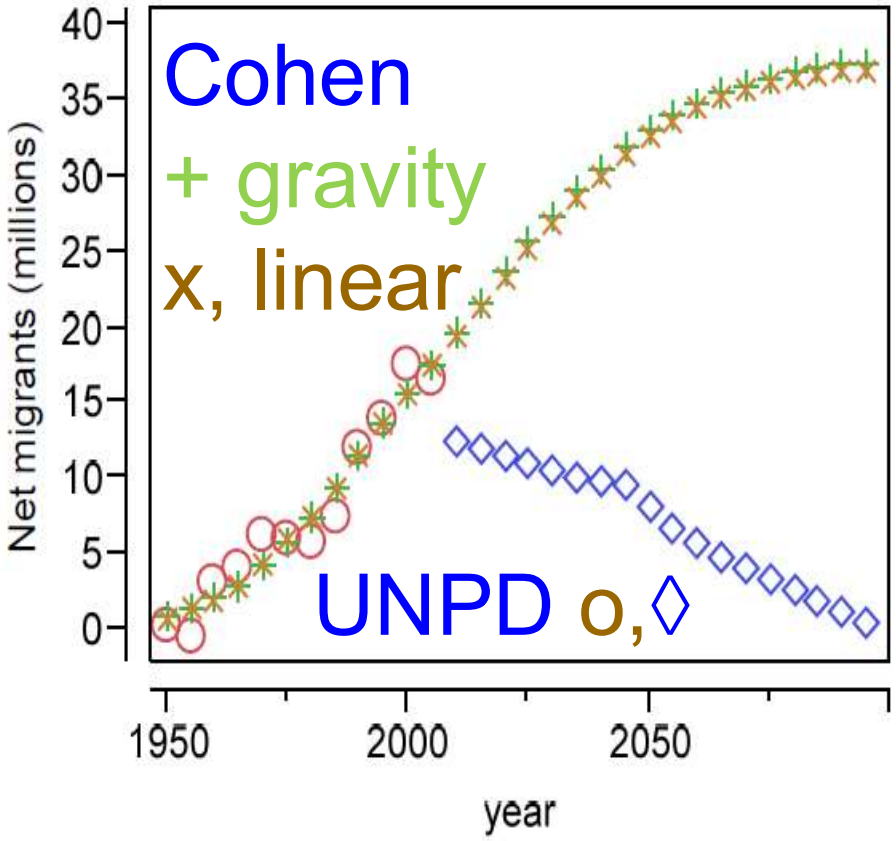
“What can grow younger as it grows older?”

“Functionally, human populations can become younger even as they grow older chronologically. This is the key to understanding what ageing will really be like in the twenty-first century.”

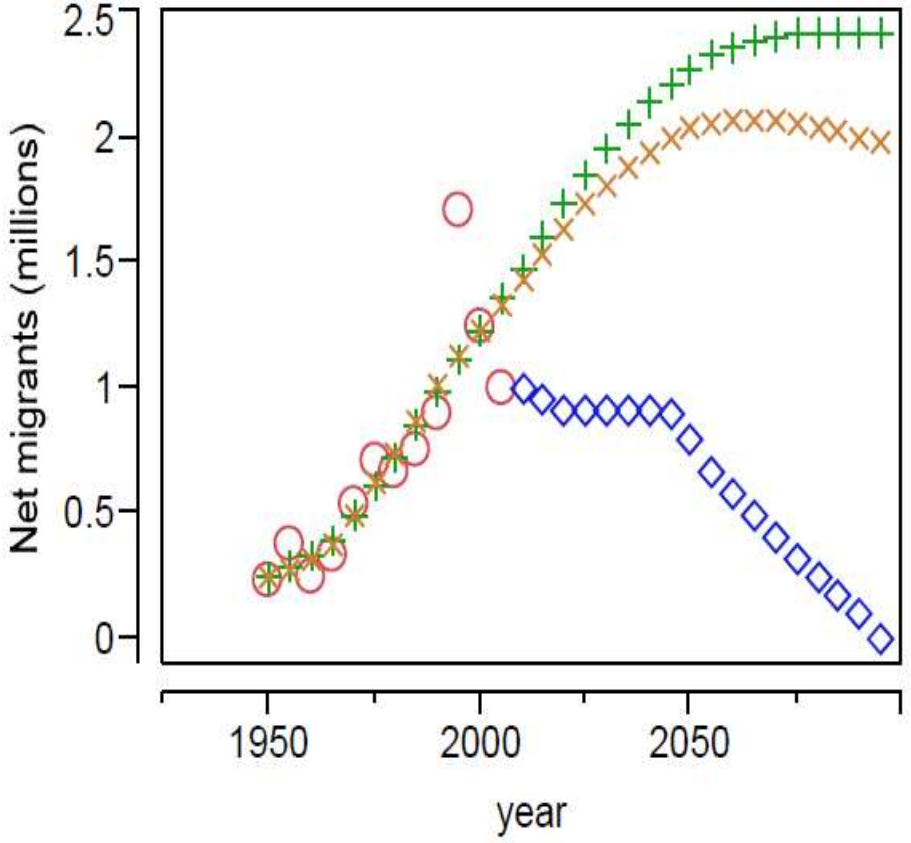
Lutz, Butz, KC et al. 2014

Net migration per year, estimated & projected by UN Population Div., & by gravity, linear models

more developed regions



USA



750 million people (15% of adults) “say they would like to leave their country permanently.”

Gallup polls of 453,122 adults in 152 countries 2015-17

158 million “say they would like to move to the US” (21% of potential migrants). 16% of Americans "in 2017 … would like to move to another country … the highest measure to date." 33% of sub-Saharan African adults want to move. "In 13 countries, at least half of the adult population would like to move to another country if they had the chance." https://news.gallup.com/ December 10, 2018

Other expert projections of global migrant flows

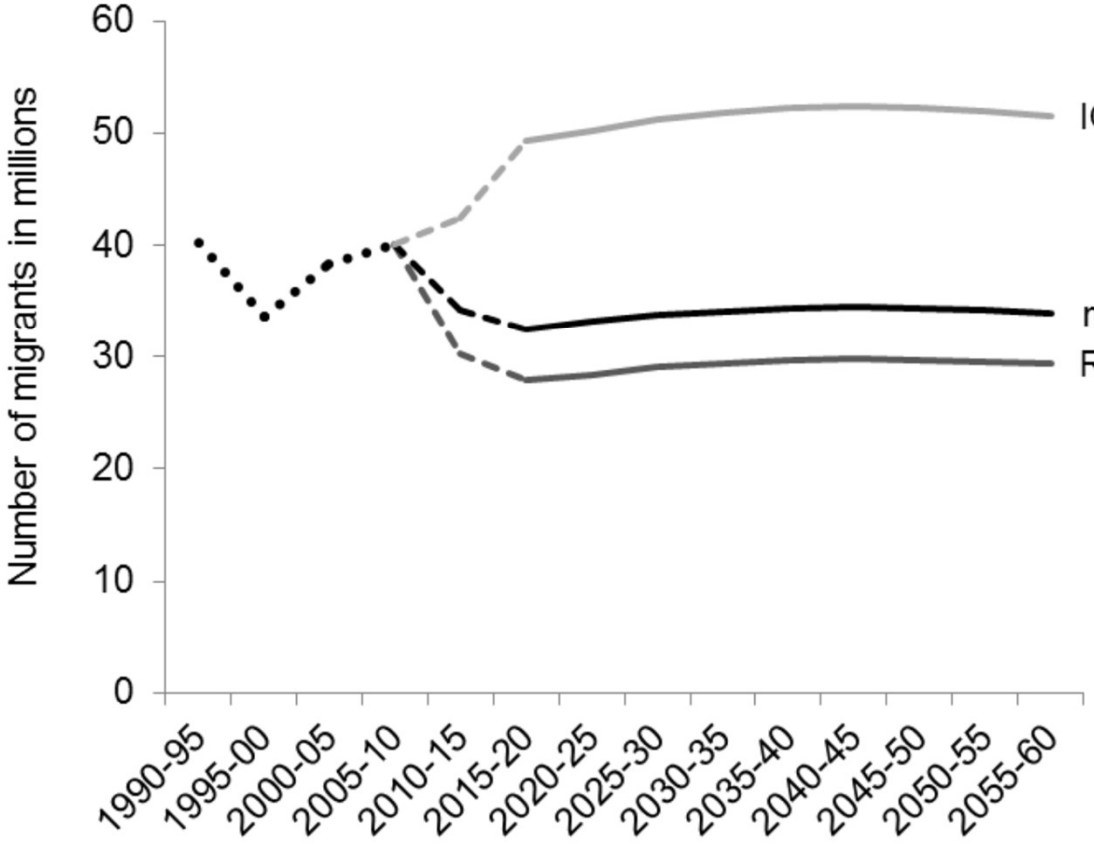
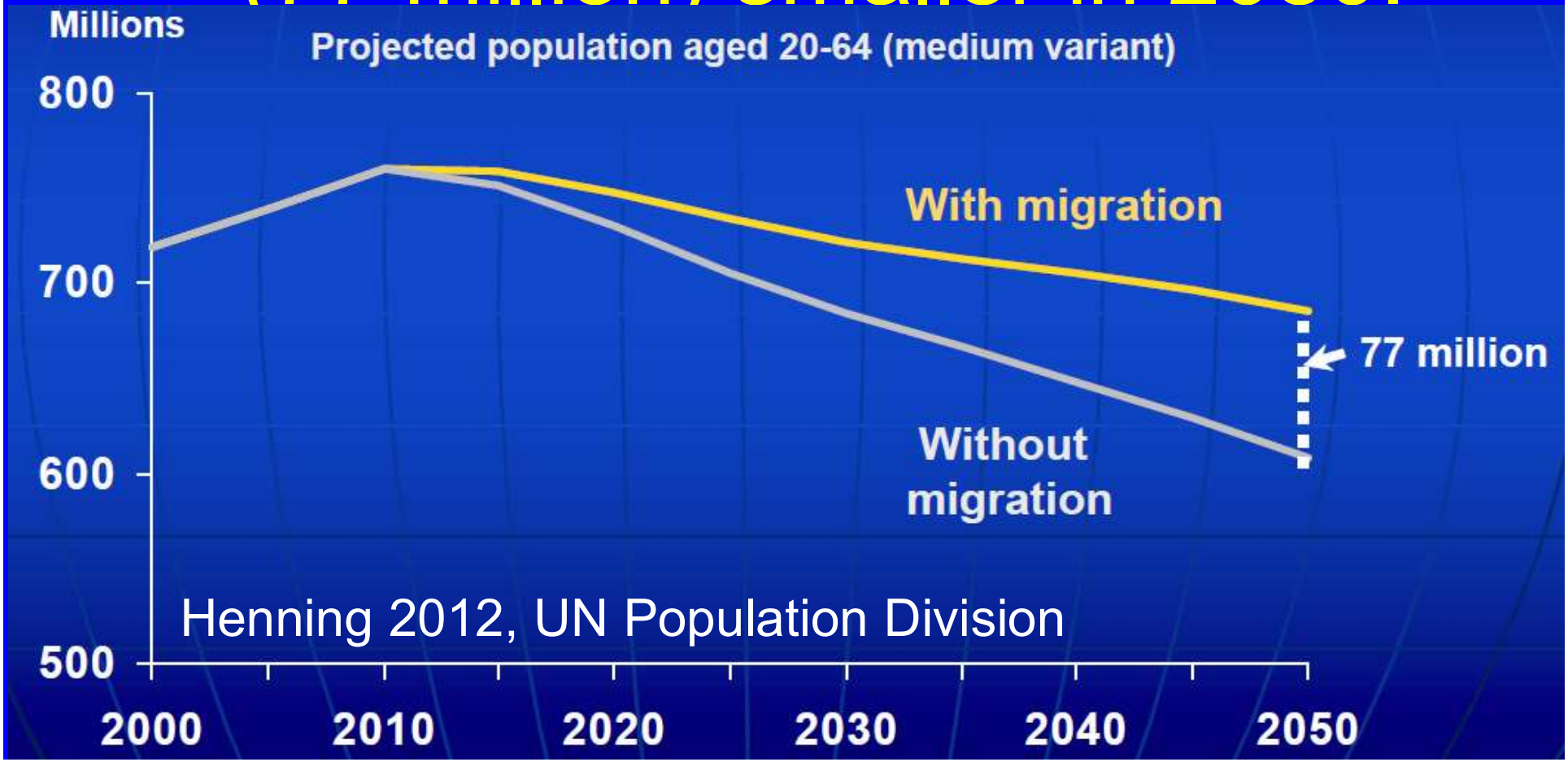


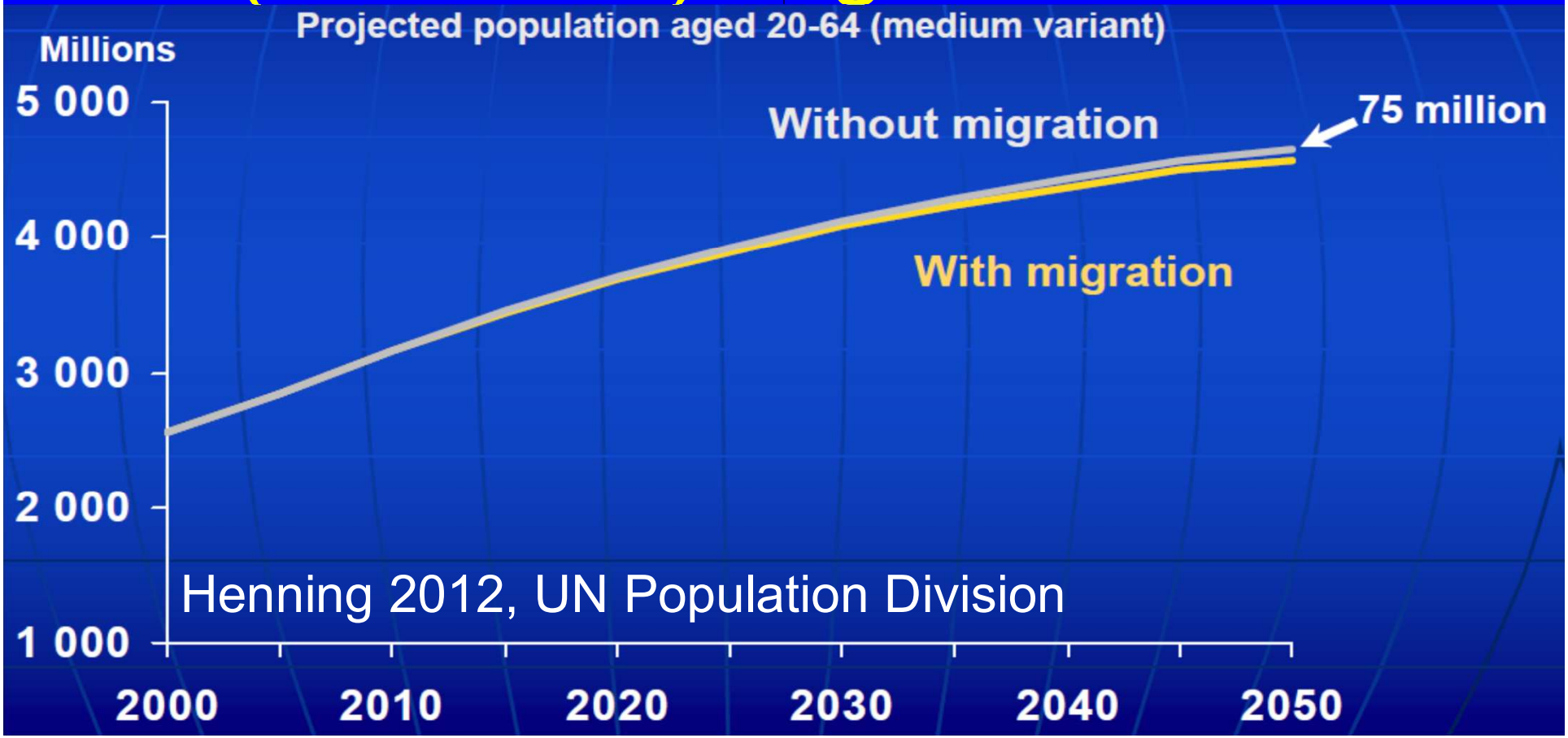
Figure 12: Estimated (1990-95 to 2005-10) and projected (2010-15 to 2055-60) number of global migrants moving over five-year periods under alternative scenarios.

Frans Willekens, Reflections on international migration forecasting. Vienna Institute of Demography December 2016.

Without international migration, developed regions' population aged 20-64 would be 11% (77 million) smaller in 2050.



Without international migration, developing regions' population aged 20-64 would be negligibly (75 million) larger in 2050.



Human right vs national sovereignty

Article 13 of the Universal Declaration of Human Rights (December 10, 1948):

"1. Everyone has the right to freedom of movement and residence within the borders of each State.

2. Everyone has the right to leave any country, including his own, and to return to his country."

But there is no right to enter another country without that state's permission.

Multiple choice test

1. If global population size continues to grow 1.0%/y, it will more than double by 2100. T, F
2. Global population growth is likely to end by 2100. T, F, do not know
3. Globally, most growth in urban populations comes from rural migrants to cities. T, F
4. By 2050, it is reasonable to expect as many adults 60+ as children 0-14. T, F
5. The fraction of people aged 15-64 years peaked forever around 2012. T, F

Thank you! Questions?