Migration measurement

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Migration (SOCI 647)

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Outline

- Exponential growth
  - Wachter 2014, Chapter 1, pp. 5–29
- Periods and cohorts
  - Wachter 2014, Chapter 2, pp. 30–47
  - Fleurence, Hollenbeak 2007
  - Weeks 2015, Chapter 7, pp. 251–297
- Migration data across countries
  - Bell and colleagues 2002, 2009, 2013, 2015
- Age profile of internal migration
  - Bernard, Bell, Charles-Edwards 2014
  - Amaral 2008
- Proximate determinants of migration age profiles
  - Bernard, Bell, Charles-Edwards 2014
- Consistent measures of migration are needed
  - Raymer 2017

Exponential growth

(Wachter 2014, Chapter 1, pp. 5–29)

- Balancing equation
- Growth rate R
- Exponential curve
- Doubling times

Balancing equation

- Balancing equation for the world, 2010–2011

$$K(2011) = K(2010) + B(2010) - D(2010)$$

  - $K(2010)$: world population at start of 2010
  - $B(2010)$: births during 2010
  - $D(2010)$: deaths during 2010
  - $K(2011)$: population at start of 2011

World population 2010 to 2011

Population 1 January 2010	**6,851 million**
+ Births 2010	+140 million
+ Deaths 2010	–57 million
= Population 1 January 2011	6,934 million

Source: 2010 Population Data Sheet of the Population Reference Bureau (PRB). Wachter 2014, p. 6.

General form of balancing equation

- For closed population

$$K(t + n) = K(t) + B(t) - D(t)$$

  - n: length of a period, e.g. 1 year or 10 years
  - $B(t)$, $D(t)$: births, deaths during period from t to $t+n$

- Equation for national or regional populations more complicated due to migration
  - Closed population examples to understand concepts

Pattern when combining equations

- Decompose next year's "stock" into this year's "stock" plus "flow"

$$K(1) = K(0) + [B(0) - D(0)]$$

- t=0 for present year, n=1 year long

Separate elements

- Multiply and divide by starting population *K*(0)

$$K(1) = K(0)\left(1 + \frac{B(0)}{K(0)} - \frac{D(0)}{K(0)}\right)$$

- Following year

$$K(2) = K(1)\left(1 + \frac{B(1)}{K(1)} - \frac{D(1)}{K(1)}\right)$$

- Substituting for *K*(1)

$$K(2) = \left(1 + \frac{B(1)}{K(1)} - \frac{D(1)}{K(1)}\right)\left(1 + \frac{B(0)}{K(0)} - \frac{D(0)}{K(0)}\right)K(0)$$

From starting to later population

- Geometric growth through time intervals
  - Population growth as multiplicative process
  - *B*/*K* and *D*/*K* are less dependent on *K* than *B* and *D*

- Exponential growth
  - When fractions of intervals are involved, we use exponential function

Simple case

- When *B*/*K* and *D*/*K* are not changing much

$$A = 1 + \frac{B}{K} - \frac{D}{K}$$

$$K(1) = A\ K(0)$$
$$K(2) = A^2\ K(0)$$
$$\ldots$$
$$K(T) = A^T\ K(0)$$

Example

- In 2000, 6.048 billion people with births exceeding deaths by 75 million

$$A = 1 + \frac{B}{K} - \frac{D}{K} = 1 + \frac{B - D}{K} = 1 + \frac{75}{6{,}048} = 1.0124$$

$K(0) = 1.0124^{0} * 6.048 = 6.048$

$K(1) = 1.0124^{1} * 6.048 = 6.123$

$K(10) = 1.0124^{10} * 6.048 = 6.841$

$K(12) = 1.0124^{12} * 6.048 = 7.012$

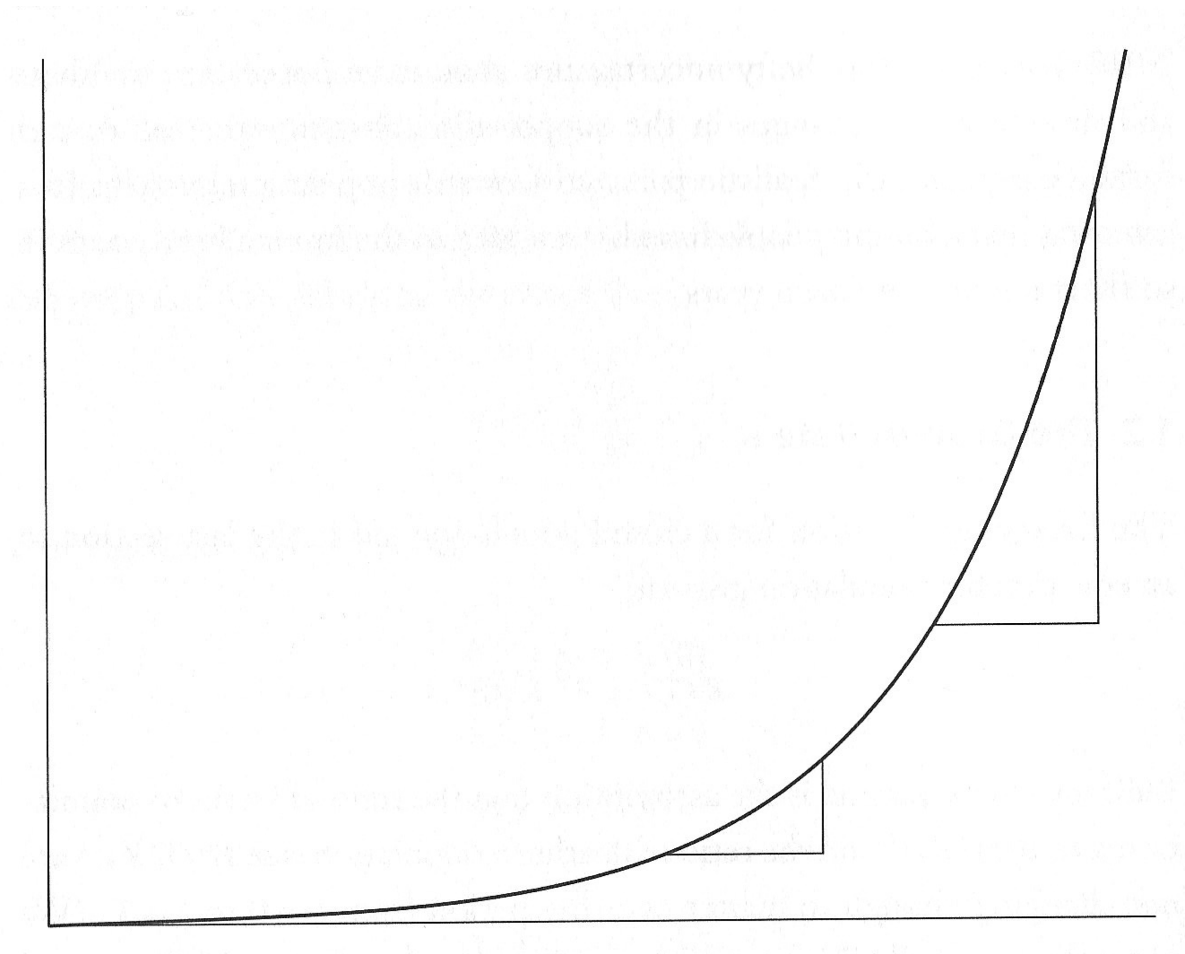
Growth rate R

- Balancing equation for closed population led to equation for population growth

$$K(T) = A^T K(0)$$

- $B(t)/K(t)$ and $D(t)/K(t)$ not changing much
- When births exceed deaths, A is bigger than 1 and population increases
- Keeping same value of A through time, we get...

K(t) with ever-changing slope



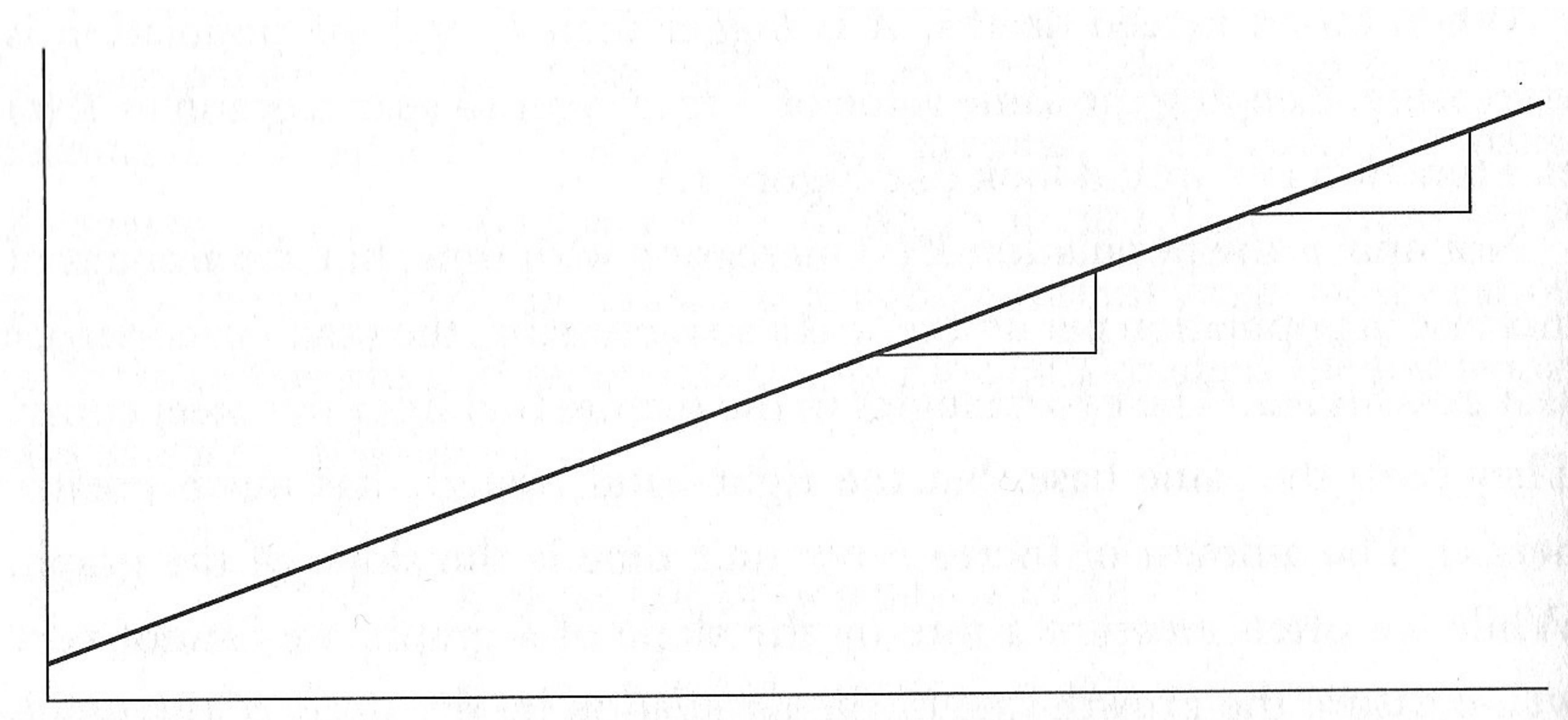
Source: Wachter 2014, p. 10.

Constant slope

- Previous graph, we cannot measure growth rate by graph slope, because it varies
  - Slope changes even when B/K and D/K are fixed

- We need a measure of growth that stays fixed when B/K and D/K are fixed
  - Take logarithms of K(t)
  - Usual way of converting multiplication into addition
  - log K(t) versus t has constant slope...

Log *K(t)* with constant slope



Source: Wachter 2014, p. 10.

Linear equation

- Taking logarithms converts the equation

$$K(t) = A^t K(0)$$

- Into the equation

$$\log(K(t)) = \log(K(0)) + \log(A)t$$

- General form

$$Y = a + bX$$

- Slope b is log(A), which is called slope R
  - Measure of population growth

Example of slope R

Population 1 January 2010	**6,851 million**
+ Births 2010	+140 million
+ Deaths 2010	–57 million
= Population 1 January 2011	6,934 million

- R = log(1+(B–D)/K) = log(1+(140–57)/6,851)=0.012042
- World population has been growing at a rate of about 12 per thousand per year since 2000

Natural logarithms

- We use natural logarithms, which have base *e*=2.71828
  - "e" is the choice for A that makes the slope of the graph of K(t) equal 1 when t=0 and K(0)=1
- Population growth rate R
  - Slope of the graph of the logarithm of population size over time
  - Proportional rate of change in population size

Population growth rate (R)

- Ratio of change in vertical axis (rise) to horizontal axis (run)

$$R = \frac{\log\left(K(T)\right) - \log\left(K(0)\right)}{T - 0}$$

- It can also be written as

$$R = \frac{1}{T} log\left(\frac{K(T)}{K(0)}\right)$$

Average growth rate

- As slope of logarithm of population size

$$R = \frac{1}{T} log\left(1 + \frac{K(T) - K(0)}{K(0)}\right)$$

- As proportional rate of change in population size

$$R \approx \frac{K(T) - K(0)}{T} \frac{1}{K(0)}$$

  - When T (interval in years) is close to zero
  - First factor is ratio of vertical to horizontal axis
  - Divide it by K(0) to get slope as proportion of size

Exponential function

- Population over time when ratios of births and deaths to population remain constant

$$K(t) = A^t K(0) = e^{Rt} K(0) = \exp(Rt)K(0)$$

- Exponential function is the inverse function for natural logarithms

$$e^{\log(x)} = \exp(\log(x)) = x$$

$$\log(e^y) = \log(\exp(y)) = y$$

Exponential curve

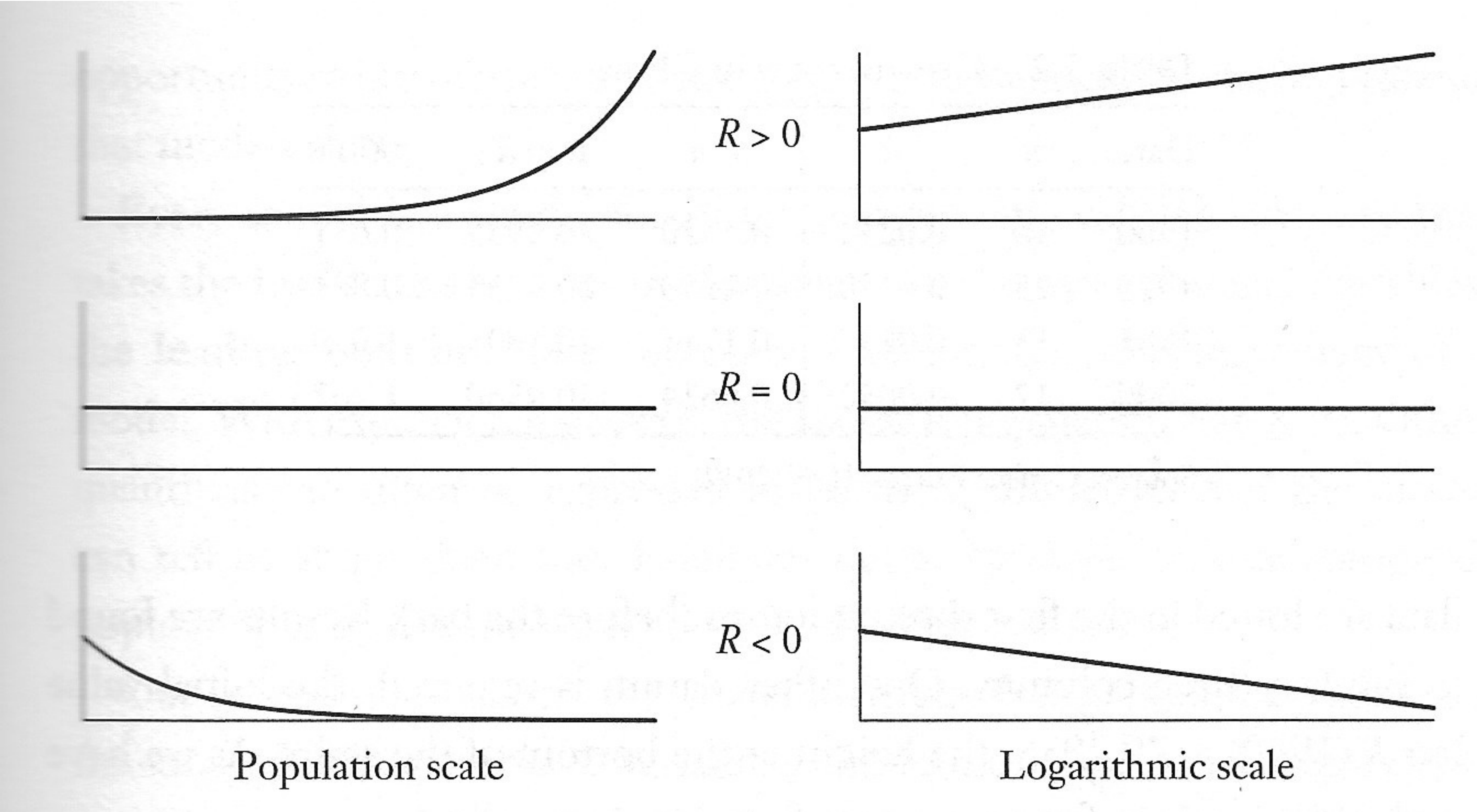
- We know that log(A) is R

$$A = e^{\log(A)} = e^{R}$$

$$A^{t} = (e^{R})^{t} = e^{Rt} = \exp(Rt)$$

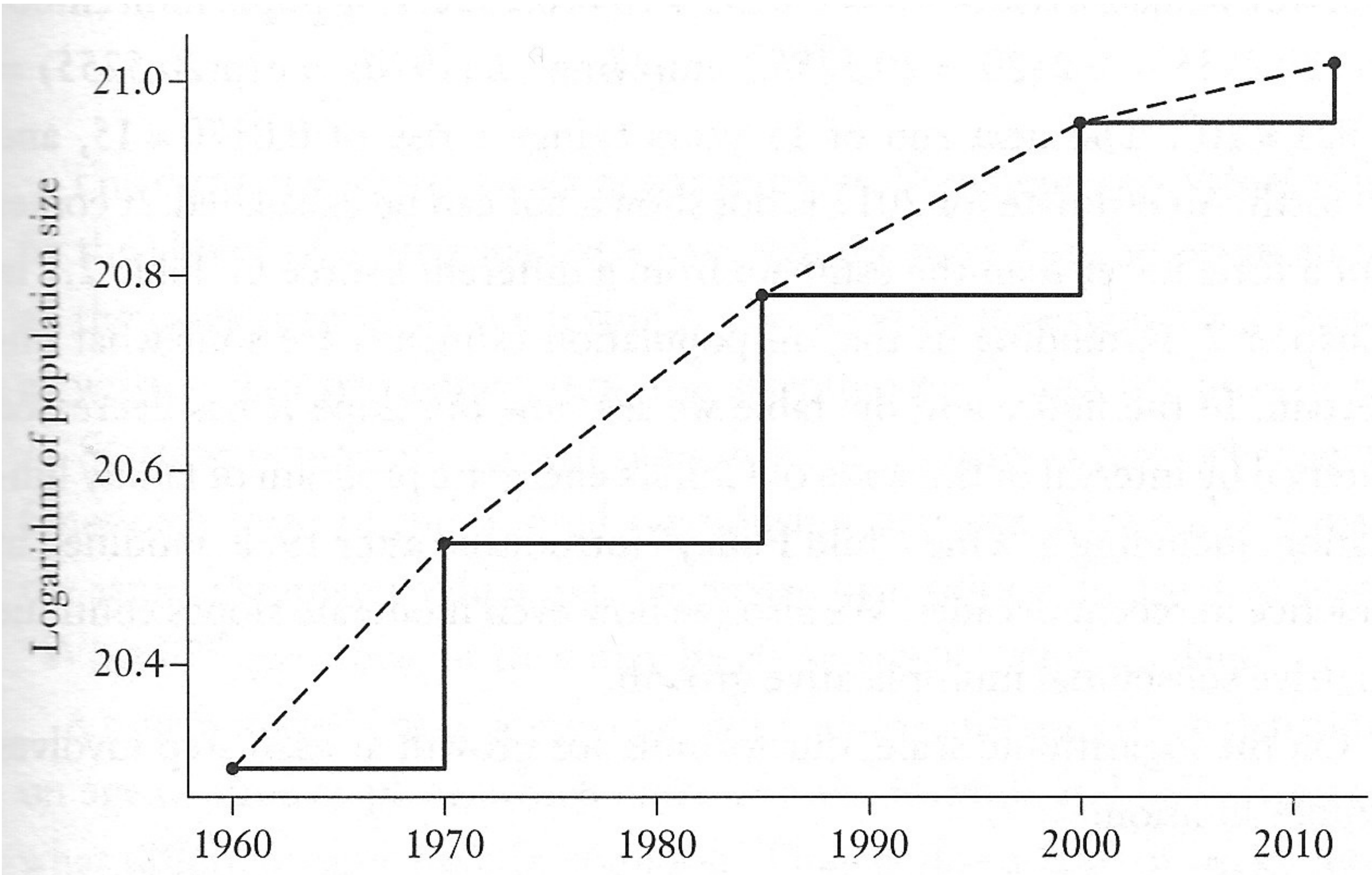
- Exponential curve
  - Graph of exp(Rt) as a function of *t*
  - Continuous-time version of the curve for geometric growth

Trajectories of exponential growth



Source: Wachter 2014, p. 15.

Rise and run: China's log-population



Source: Wachter 2014, p. 15.

Growth rates in China

$$\log K(t+n) = \log K(t) + Rn$$

$$K(t+n) = K(t)e^{Rn}$$

Date	*n* "run"	R	R *n* "rise"	log(*K*)	*K*(*t*)
1960	10	0.0232	0.2320	20.2935	0.651
1970	15	0.0170	0.2550	20.5255	0.821
1985	15	0.0117	0.1755	20.7805	1.059
2000	12	0.0052	0.0624	20.9560	1.262

Source: Census Bureau IDB (2012). Wachter 2014, p. 16.

Doubling times

- Doubling times

$$K(t) = \exp(Rt)\, K(0)$$

$$K(T_{double}) = 2K(0) = \exp(RT_{double})\, K(0)$$

$$2 = \exp(RT_{double})$$

$$\log(2) = RT_{double}$$

$$T_{double} = \log(2)/R \approx 0.6931/R$$

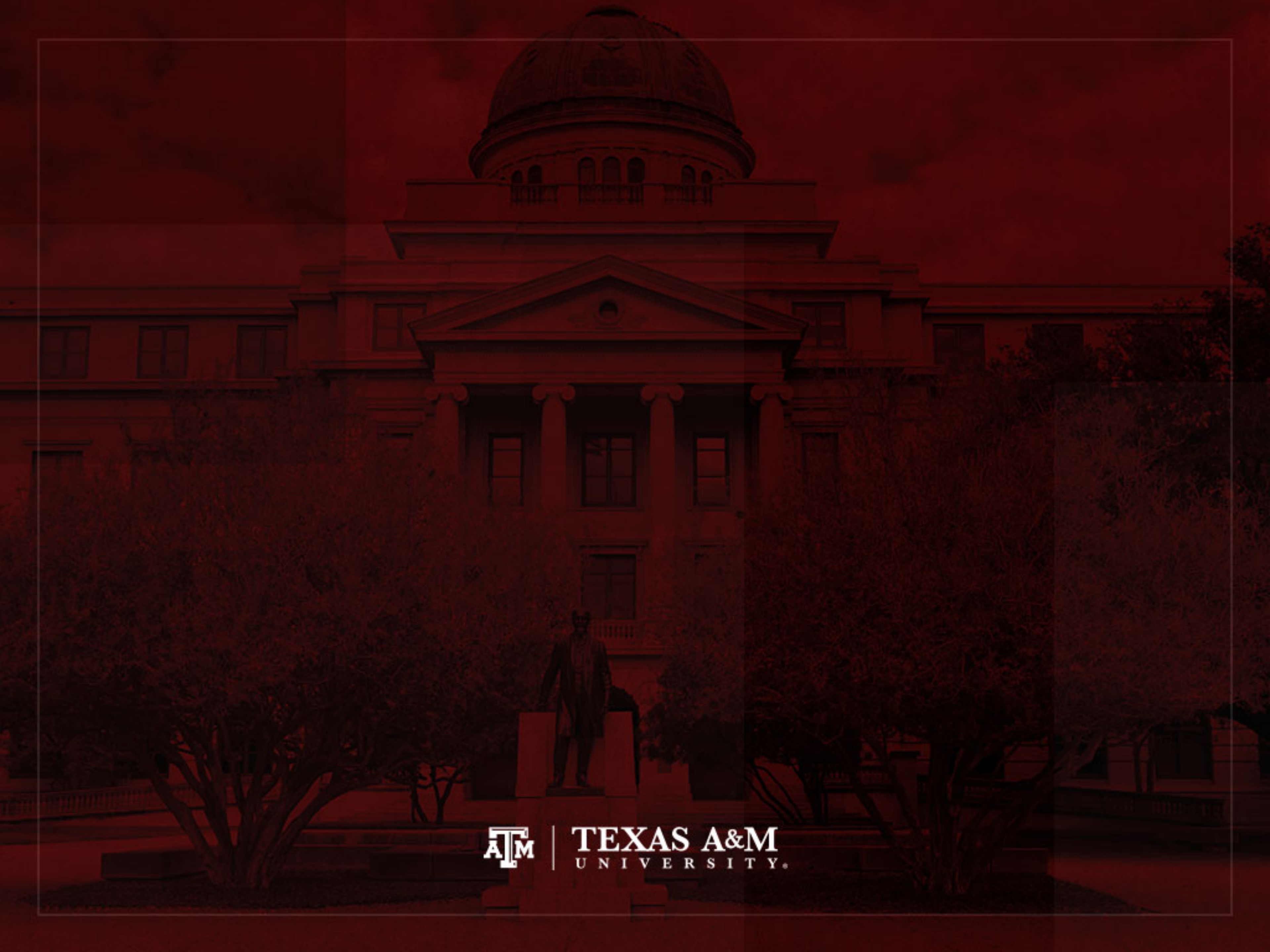
- Growth rate

$$R = \frac{1}{T} log\left(\frac{K(T)}{K(0)}\right)$$

World population and doubling times

Date	Population	Growth rate	Doubling time
8000 B.C.	5 million	0.000489	1417 years
1 A.D.	250 million	–0.000373	–1858 years
600	200 million	0.000558	1272 years
1000	250 million	0.001465	473 years
1750	750 million	0.004426	157 years
1815	1,000 million	0.006957	100 years
1950	2,558 million	0.018753	37 years
1975	4,088 million	0.015937	43 years
2000	6,089 million		

Source: Estimates drawn from Cohen (1995) and IDB (2012). Wachter 2014, p. 25.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Periods and cohorts

(Wachter 2014, Chapter 2, pp. 30–47)
(Fleurence, Hollenbeak 2007)

- Lexis diagrams
- Period person-years lived
- Crude rate model
- Infant mortality rate
- Person-years and areas
- Cohort person-years lived
- Stationary population identity

Exponential population growth model

- The exponential model treats all people as if they were alike
  - No mention to *age*
  - However, people are aging in the population
- Time enters demography in two ways
  - Chronological time: calendar dates, same for everyone
  - Personal time: age for each set of people who share same birthdate

Lexis diagram

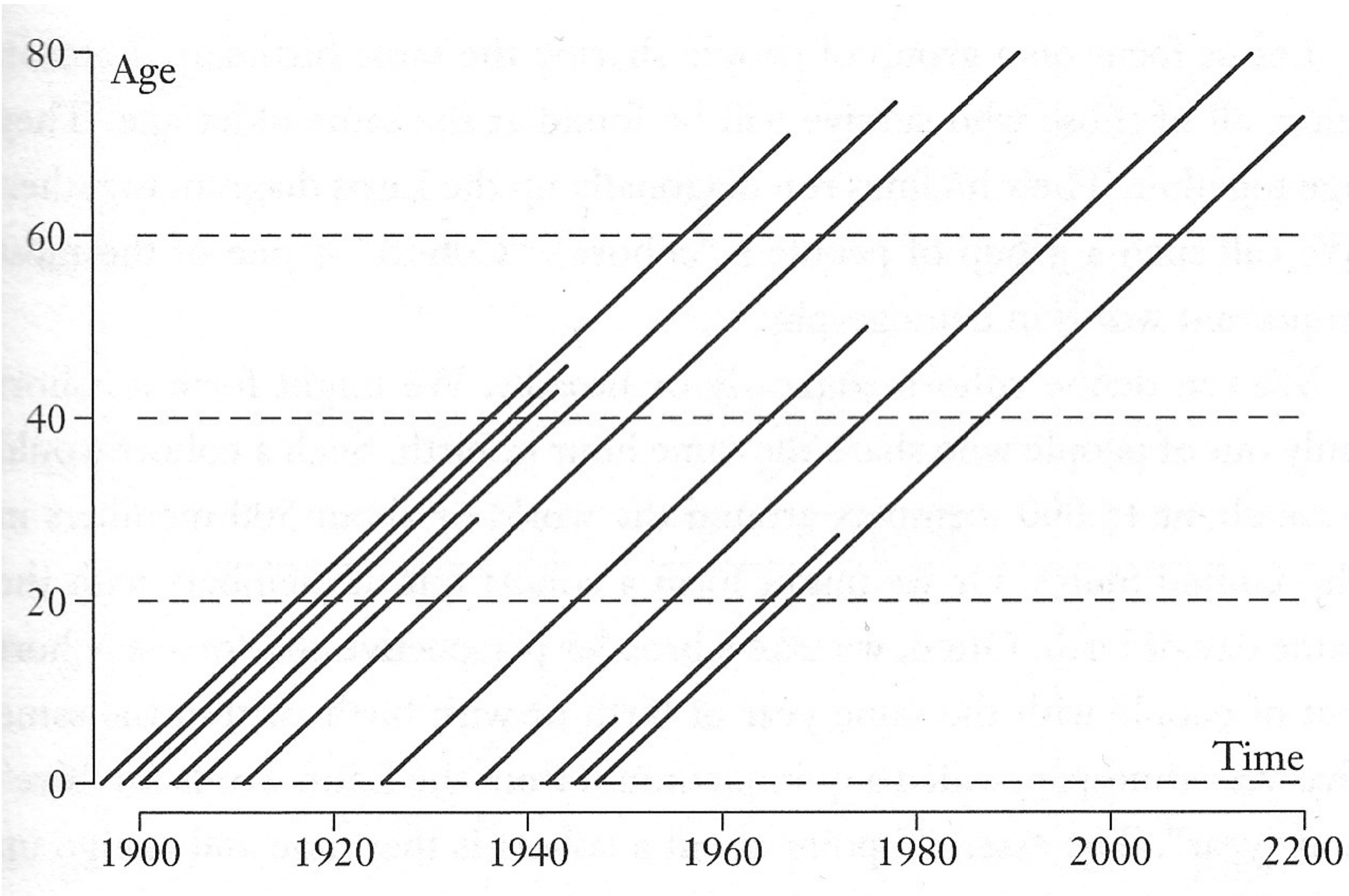
- Lexis diagram provides relationships between chronological time *t* (horizontal) and age *x* (vertical)

- Each person has a lifeline on a Lexis diagram
  - Starting at (t_b, 0), where t_b is the person's birthdate and 0 is the person's age at birth

- Line goes up to the right with a slope equal to 1
  - People age one year in one calendar year

- Lifeline goes up until time and age of the person's death

Lexis diagram



Source: Wachter 2014, p. 31.

Exploring Lexis diagram

- To find population size
  - Draw vertical line upward from the time point
  - Count how many lifelines cross vertical line

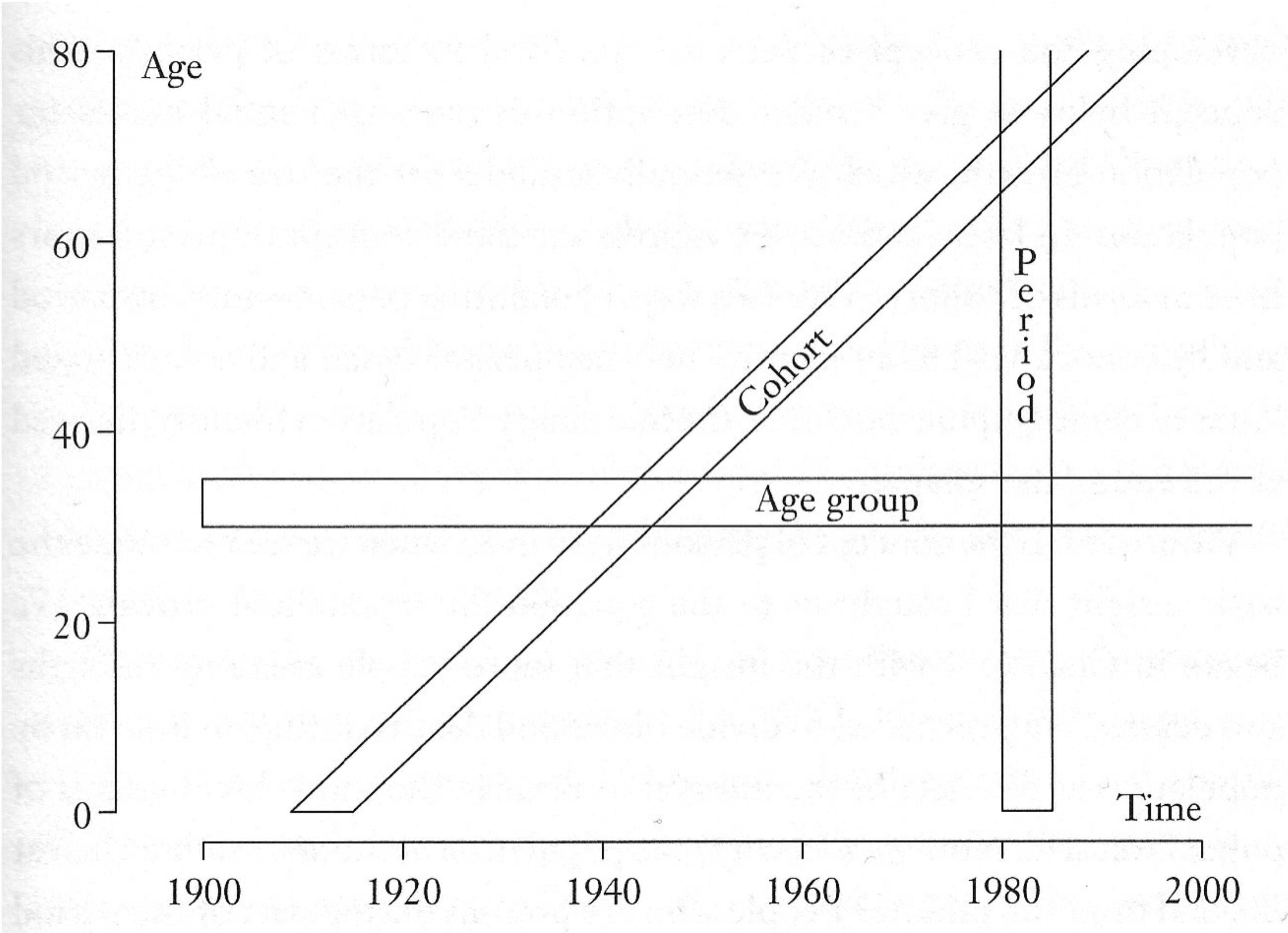
- To find how many people survive to some age
  - Draw horizontal line across at the height corresponding to that age
  - Count how many lifelines cross that horizontal line

- Immigrants start at age and time of immigration

Cohort

- Group of people sharing the same birthdate
- Group of individuals followed simultaneously through time and age
- Their lifelines run diagonally up the Lexis diagram together
- In a cohort, time and age go up together
- A cohort shares experiences

Age, period, cohort



Source: Wachter 2014, p. 33.

Exponential growth

- For the equation for exponential growth
  - We divided births and deaths during an interval by population at the start of the interval

$$K(1) = K(0)\left(1 + \frac{B(0)}{K(0)} - \frac{D(0)}{K(0)}\right)$$

- Why not population at the end or in the middle?
  - People who are present during part of the period can also have babies or become corpses
  - More people present for more time in the denominator generate higher exposure ("risk") to births and deaths

Rates

(Fleurence, Hollenbeak 2007)

- Rates are an instantaneous measure that range from zero to infinity
  - Rates describe the number of occurrences of an event for a given number of individuals per unit of time
  - Time is included directly in the denominator
  - Rates take into account the time spent at risk

- Incidence rate describes the number of new cases of an event during a given time period over the total **person-years** of observation
  - **Numerator**: number of events (e.g. births, deaths, migrations)
  - **Denominator**: number of "**person-years** of exposure to risk" experienced by a population during a certain time period

Person-years

- **Person-years** is the sum of each individual's time at risk of experiencing an event (e.g. birth, death, migration)
  - For those who do not experience event, person-years is the sum of time until end of period
  - For those who experience event, it is the time until the event

- **Period person-years lived** take into account that people are present during part of the period (fraction of years)
  - Each full year that a person is present in a period, he/she contributes one "person-year" to the total of PPYL
  - Each month a person is present in the population, he/she contributes 1 person-month or 1/12 person-year, to PPYL

Calculating person-years

- Whenever we know the population sizes on each month over the period of a year
  - We can add up the person-years month by month
  - Take the number of people present on each month and divide by 12
  - Add up all monthly contributions

- When our subintervals are small enough
  - Our sum is virtually equal to the area under the curve of population as a function of time during the period

Approximation for PPYL

- When sequence of population sizes throughout a period are unknown

- Take the population in the middle of the period and multiply by the length of the period

- Or take the average of the starting and ending populations and multiply by the length of the period

Example of person-years

Hypothetical population increasing at the rate of 0.001 per month

Month	Population	Person-years (population / 12)	Approximation for person-years: Mid-period	Approximation for person-years: Average of start and end
January	200.00	16.67		200.00
February	200.20	16.68		
March	200.40	16.70		
April	200.60	16.72		
May	200.80	16.73		
June	201.00	16.75		
July	201.20	16.77	201.20	
August	201.40	16.78		
September	201.61	16.80		
October	201.81	16.82		
November	202.01	16.83		
December	202.21	16.85		202.21
Period person-years lived (PPYL)		**201.10**	**201.20**	**201.11**

Examples of rates

- Express the number of actual occurrences of an event (e.g. births, deaths, homicides) vs. number of possible occurrences per some unit of time
- Examples

$$Crude\ birth\ rate = \frac{Number\ of\ births}{Total\ population} \times 1000$$

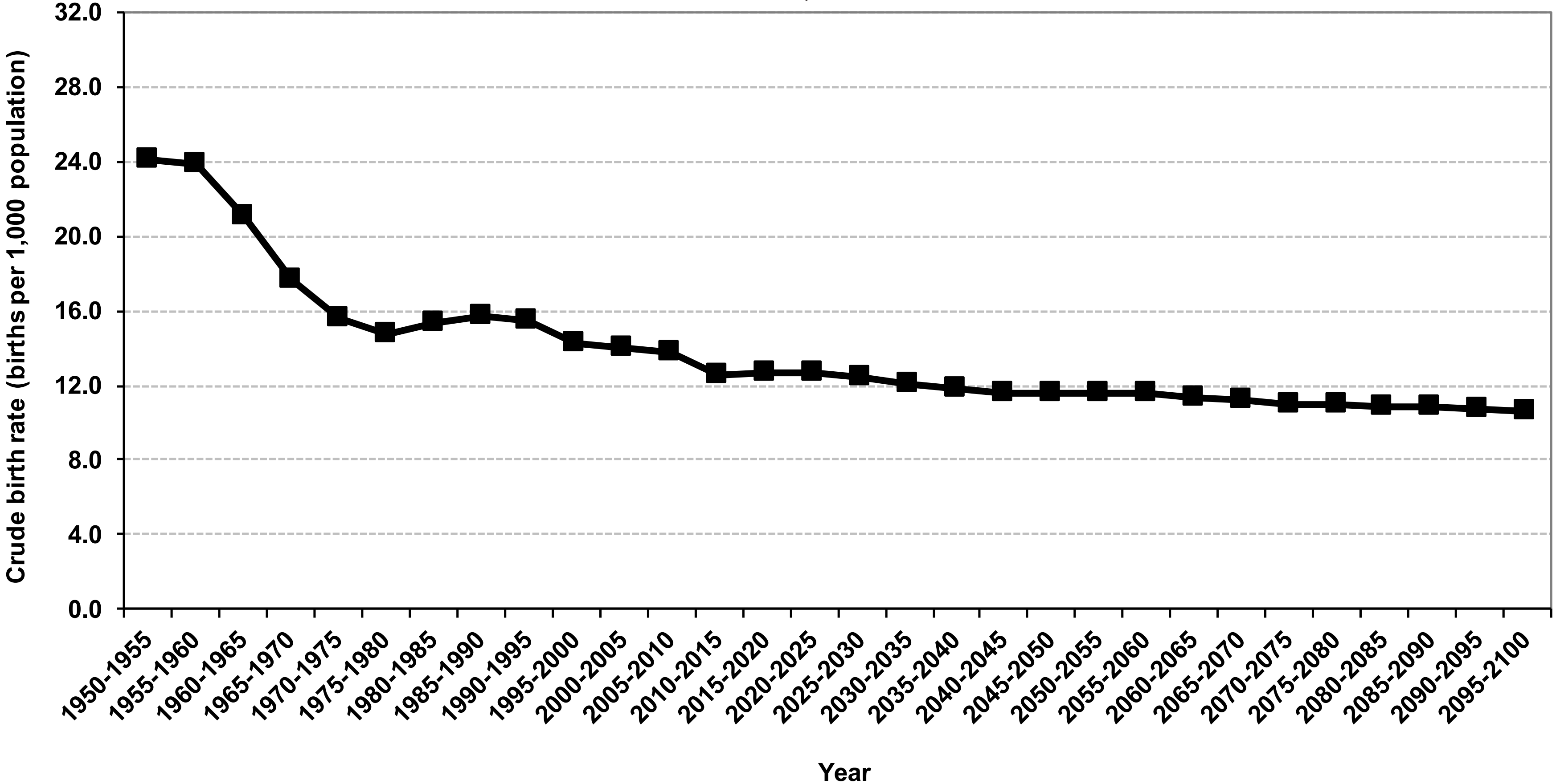
$$Crude\ death\ rate = \frac{Number\ of\ deaths}{Total\ population} \times 1000$$

CBR and CDR

- Crude Birth Rate (CBR or *b*)
  - Number of births to members of the population in the period divided by the total period person-years lived

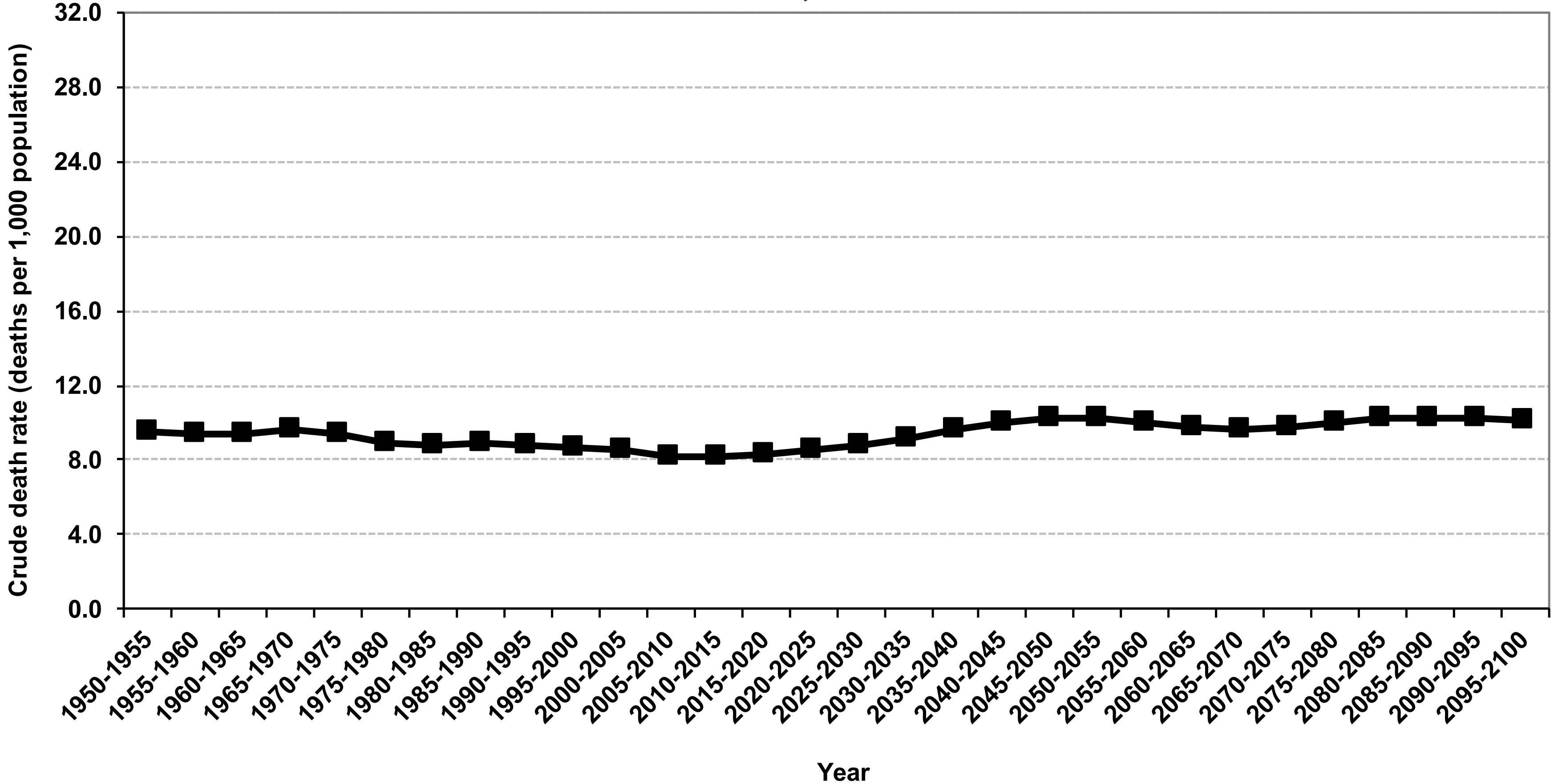
- Crude Death Rate (CDR or *d*)
  - Number of deaths to members of the population in the period divided by the total period person-years lived

Crude birth rates, United States, 1950–2100



Source: United Nations, World Population Prospects 2017
https://esa.un.org/unpd/wpp/Download/Standard/Population/
(medium variant).

Crude death rates, United States, 1950–2100



Source: United Nations, World Population Prospects 2017
https://esa.un.org/unpd/wpp/Download/Standard/Population/
(medium variant).

Migration indices

- Crude or gross rate of out-migration

$$OMigR = OM / p * 1{,}000$$

- Crude or gross rate of in-migration

$$IMigR = IM / p * 1{,}000$$

- Crude net migration rate

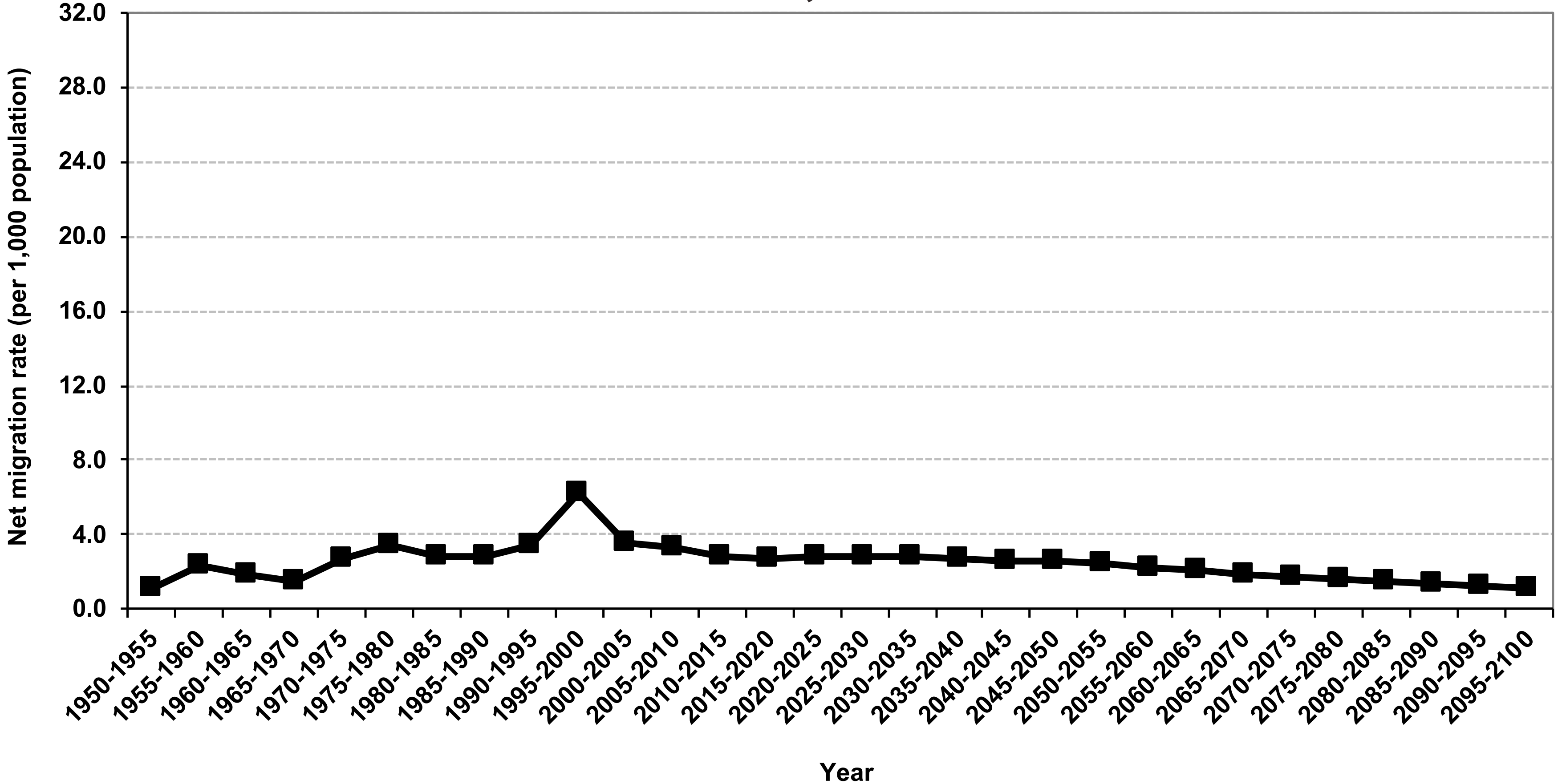
$$CNMigR = IMigR – OMigR$$

- Net migration rate

$$NMigR = IM – OM / \text{person-years lived} * 1{,}000$$

Source: Weeks 2015, Chapter 7, pp. 251–297.

Net migration rates, United States, 1950–2100



Source: United Nations, World Population Prospects 2017
https://esa.un.org/unpd/wpp/Download/Standard/Population/
(medium variant).

Other migration indices

- Total or gross migration rate

$$TMigR = IMigR + OMigR$$

- Migration effectiveness

$$E = CNMigR / TMigR * 100$$

- Migration ratio

$$MigRatio = (IM – OM) / (b – d)$$

- Percent of total growth due to migration

$$MigPct = \frac{IM - OM}{(IM - OM) + (b - d)} * 100$$

Source: Weeks 2015, Chapter 7, pp. 251–297.

Probabilities

(Fleurence, Hollenbeak 2007)

- Probabilities describe the likelihood that an event will occur for a single individual in a given time period and range from 0 to 1
- Does not include time in the denominator
- Divides the number of events by the total number of people at risk in the relevant time frame
- Conversion between rates and probabilities

$$\text{probability: } p = 1 - e^{-rt}$$

$$\text{rate: } r = -1/t * \ln(1-p)$$

Ratios

- Describe a relationship between two numbers
  - Compare the size of one number to the size of another number
  - Compare the relative sizes of categories
  - Indicate how many times the first number contains the second
  - Denominator is not at "risk" of moving to numerator
  - Optional: multiply by 100 to get percentage

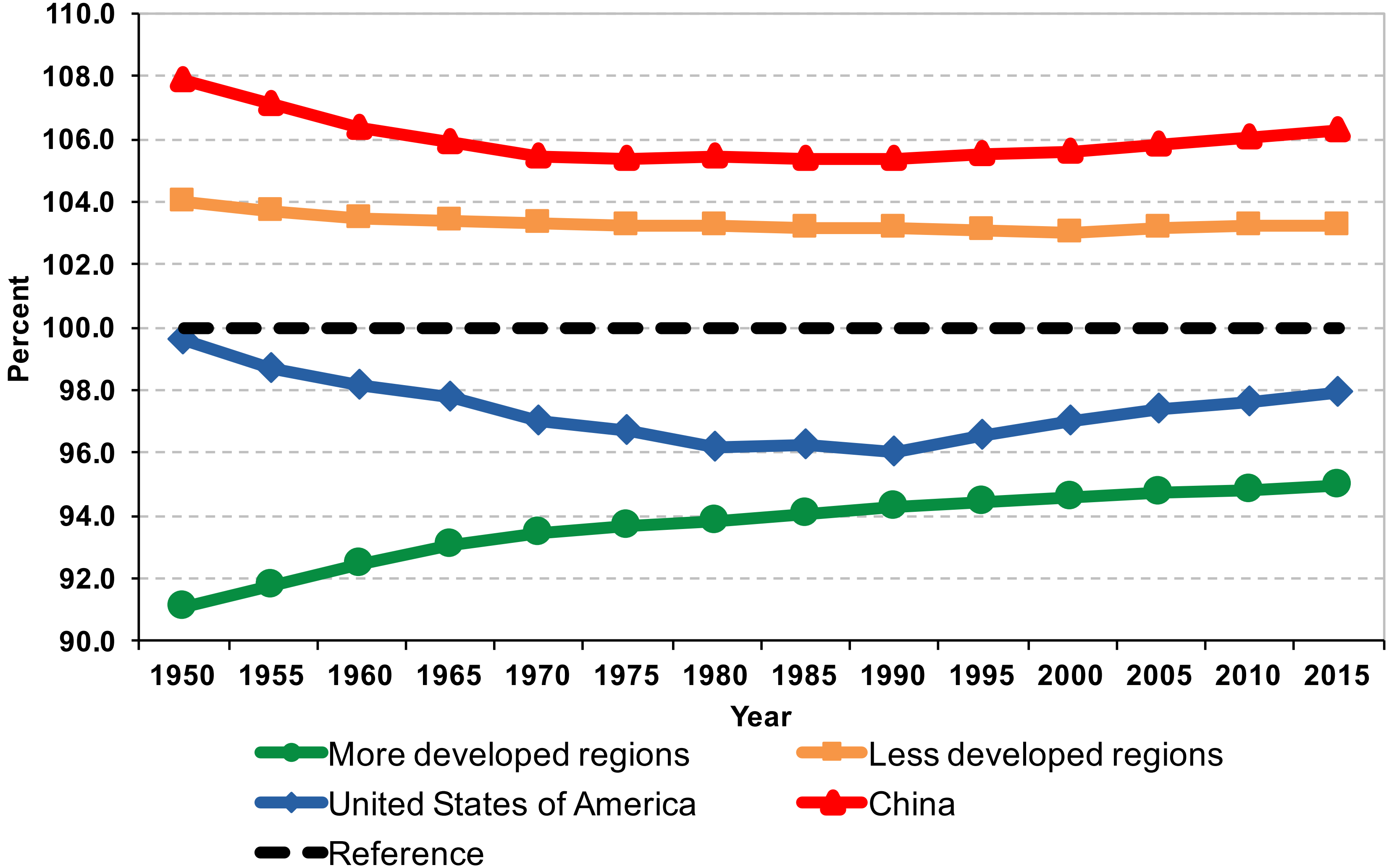
$$Sex\ ratio = \frac{Population\ of\ males}{Population\ of\ females}$$

$$Total\ dependency\ ratio = \frac{Pop.\ children\ (0\ to\ 14)\ +\ Elderly\ pop.(65+)}{Working\ age\ population\ (15\ to\ 64)}$$

Sex ratio

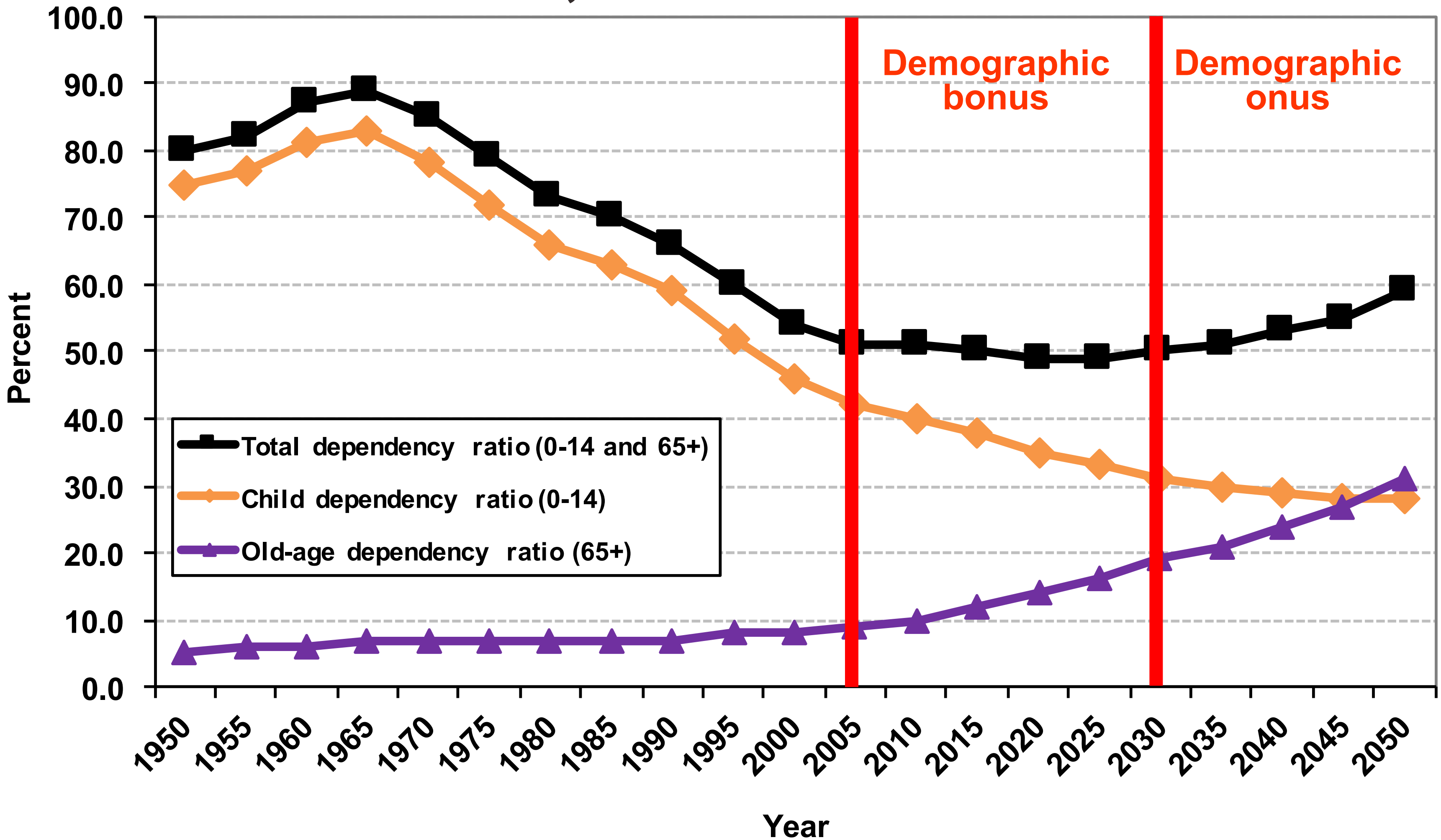
- In a class of 25 females and 10 males
  - Sex ratio (ratio of males to females)
    - 10/25 = 0.4
    - For every female, there are 0.4 males
  - Feminity ratio (ratio of females to males)
    - 25/10 = 2.5
    - For every male, there are 2.5 females
- In another class of 32 females and 3 males
  - Sex ratio: 3/32 = 0.09 males for every female
  - Feminity ratio: 32/3 = 10.7 females for every male

Sex ratios, 1950–2015



Source: United Nations, World Population Prospects 2017
https://esa.un.org/unpd/wpp/Download/Standard/Population/

Dependency ratios, Brazil, 1950–2050



Source: United Nations - http://esa.un.org/unpp (medium variant).

Crude rate model

- Imagine a population
  - In which each person, each instant, is subject to constant independent risks of dying and having a baby
  - *b*: expected numbers of births per person per year
  - *d*: expected number of deaths per person per year

- Assumptions
  - Closed population
  - Homogeneous risks among people
  - No measurement of change over time inside the period

Growth rate

- Expected size of population has exponential growth
  - Growth rate = R = $b - d$
- Most actual populations are not closed and risks are not homogeneous over time
  - Need a measure of Crude Net Migration Rate (MIG)
  - Crude Growth Rate (CGR) = CBR – CDR + MIG

Most populous countries, 2012

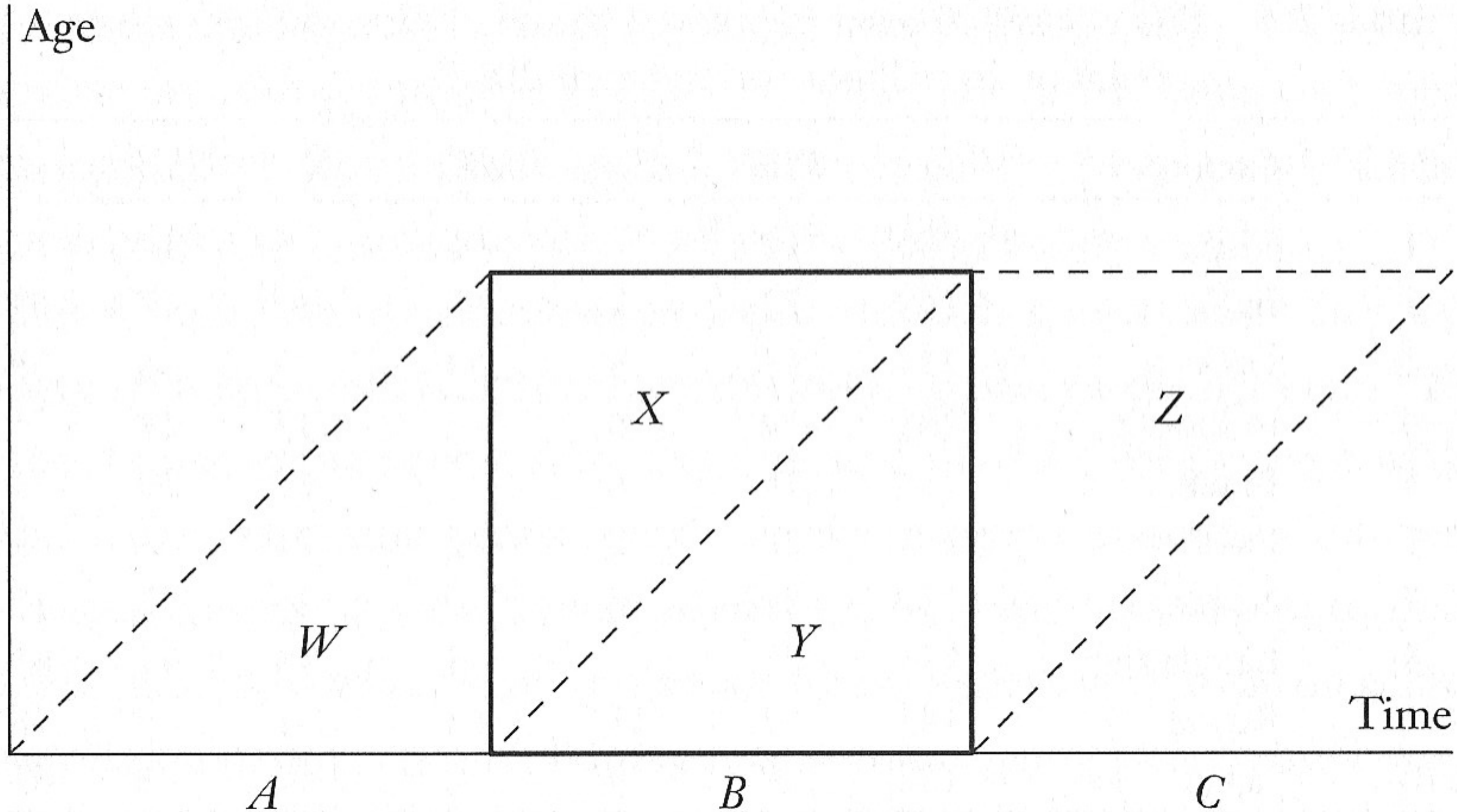
Rank	Country	Pop. (million)	CBR (‰)	CDR (‰)	MIG (‰)	R (‰)	IMR (‰)	e_0
1	China	1,350	12	7	–0	5	17	73
2	India	1,260	22	7	–0	16	47	65
3	USA	314	13	8	+3	9	6	78
4	Indonesia	245	19	6	–1	12	29	71
5	Brazil	194	16	6	–0	11	20	73
6	Pakistan	188	28	8	–2	21	64	63
7	Nigeria	170	40	14	0	24	77	47
8	Bangladesh	153	23	6	–3	14	43	65
9	Russia	143	12	15	+2	–1	8	68
10	Japan	128	9	9	0	0	3	83
	World	**7,017**	**20**	**8**	**0**	**12**	**46**	**69**

Infant mortality rate (IMR)

$$IMR = \frac{the\ number\ of\ deaths\ under\ age\ 1\ in\ the\ period}{the\ number\ of\ live\ births\ in\ the\ period}$$

- IMR is a period measure
- It uses current information from vital registration
- It can be computed for countries without reliable census or other source for a count of the population at risk by age
- Infants borne by teenagers and by older mothers are at higher risk

IMR contributions on a Lexis diagram



Source: Wachter 2014, p. 38.

Understanding previous figure

- Any lifeline which ends within the square
  - Contributes a death to the numerator of the IMR

- Any lifeline that starts on the base of the square
  - Contributes a birth to the denominator of the IMR

Still on previous figure

- Babies born outside the period in the preceding year (A) may die as infants during the period (X)
  - Counted in the numerator, but not in denominator
- Babies born during the period (B) may die after the end of the period (Z)
  - Counted in the denominator, but not in numerator
- Usually mismatched terms balance each other
  - IMR is close to the probability of dying before age 1

Period ≠ Cohort

- Period deaths and period person-years lived
  - Come from deaths and lifelines in the square (*X*, *Y*)
  - Dividing these deaths by person-years gives a period age-specific mortality rate (*M*)

- Cohort deaths and cohort person-years lived
  - Come from deaths and lifelines in parallelogram (*Y*, *Z*)
  - Dividing these deaths by person-years gives a cohort age-specific mortality rate (*m*)

Person-years and areas

- PPYL in the period between time 0 and time T is the area under the curve K(t) between 0 and T

$$PPYL = \int_0^T K(t)\,dt$$

- When growth is constant (exactly exponential)

$$PPYL = K(0)(e^{RT} - 1) / R = (K(T) - K(0)) / R$$

$$Growth\ Rate = R = CBR - CDR$$

Cohort person-years lived (CPYL)

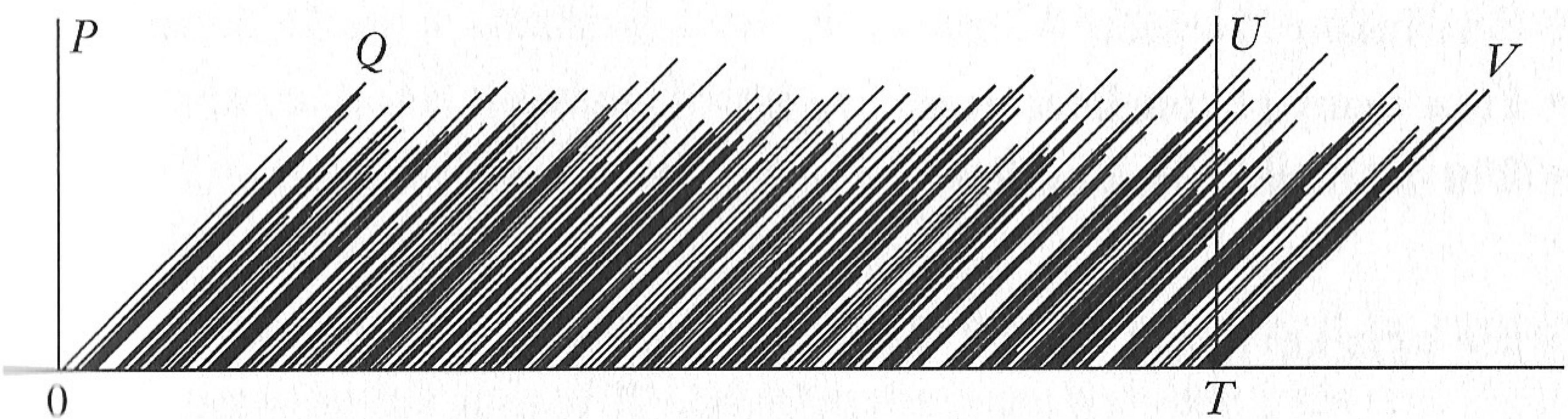
- We get CPYL when we add up all person-years lived by all members of the cohort
  - Instead of counting people from a rectangle of the Lexis diagram, we consider a parallelogram

- If we divide by the total number of members of the cohort (counted at birth)
  - We get expectation of life at birth (e_0)
  - Average number of person-years lived in their whole lifetimes by members of the cohort

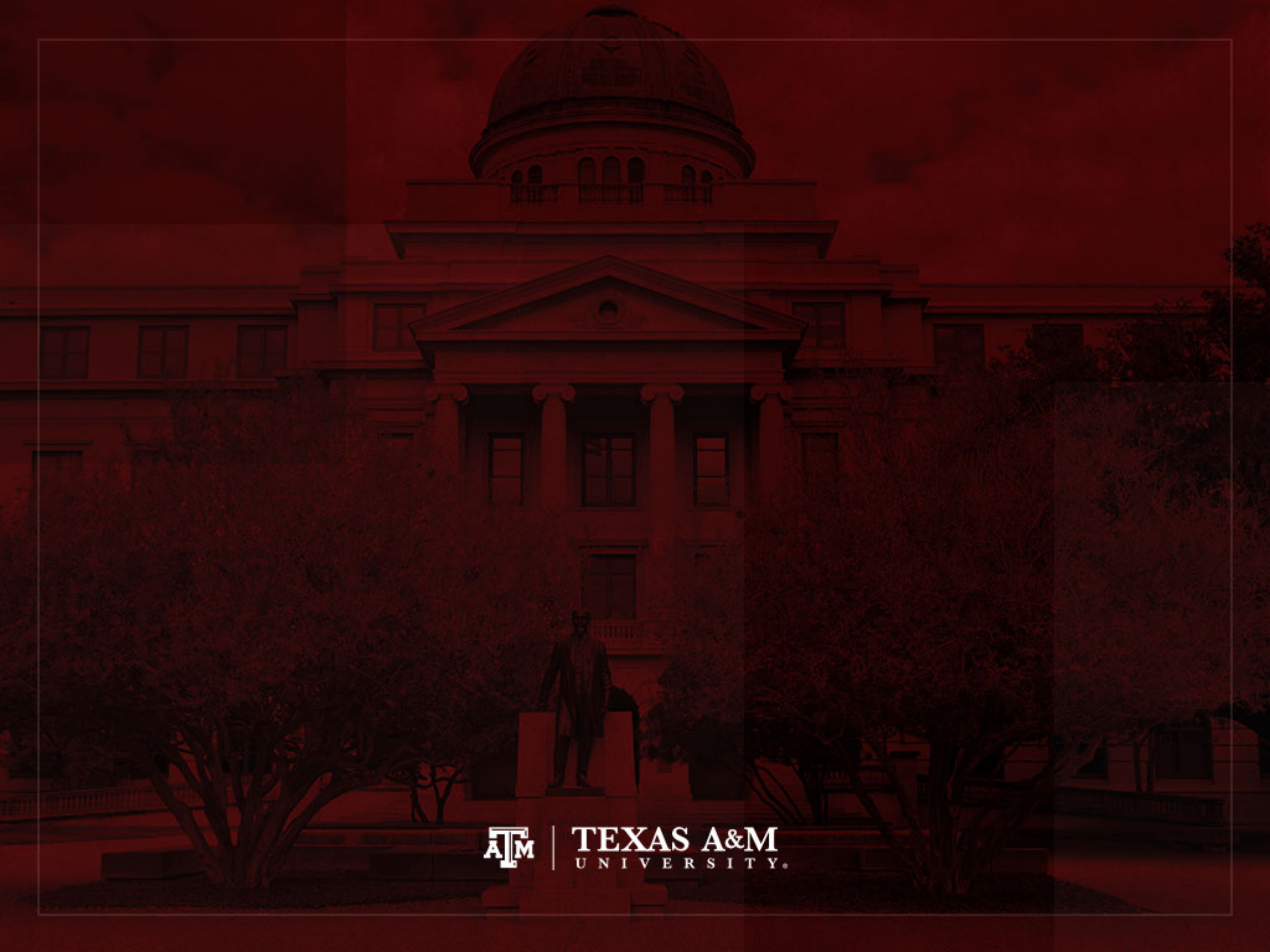
Stationary population identity

- Stable population
  - Demographic rates are unchanging
  - Size might be growing, constant or declining
- Stationary population
  - Numbers are unchanging
  - Total population is the same from year to year (*B*=*D*)
  - # births is constant = *B* = Population * CBR = *Kb*
  - # deaths is constant = *D* = Population * CDR = *Kd*
- PPYL ≈ CPYL, so we have: $K\,T = K\,b\,e_0\,T$
- Stationary population identity: $1 = b\,e_0$ *when R=0*

Lexis diagram for a stationary population



Source: Wachter 2014, p. 45.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Migration data across countries

TABLE 1. COUNTRIES COLLECTING DATA ON INTERNAL MIGRATION BY CONTINENT, 2000 AND 2010 ROUND OF CENSUSES AND OTHER SOURCES

Region	2000 Round of Censuses	2010 Round of Censuses	Register	Survey[1]	Multiple data sources	Total countries collecting internal migration data	Total No. of countries
Africa	32	27	0	38	31	50	54
Asia	34	24	15	23	26	40	46
Europe	32	23	32	34	36	42	44
Latin America and the Caribbean	28	19	0	12	12	31	32
North America	3	2	2	2	2	3	3
Oceania	13	11	1	2	3	13	14
Total	142	106	50	111	110	179	193

Source: Bell, Charles-Edwards 2013, p.2.

TABLE 2. INTERNAL MIGRATION DATA COLLECTED IN THE 2000 ROUND OF CENSUSES (1995-2004)

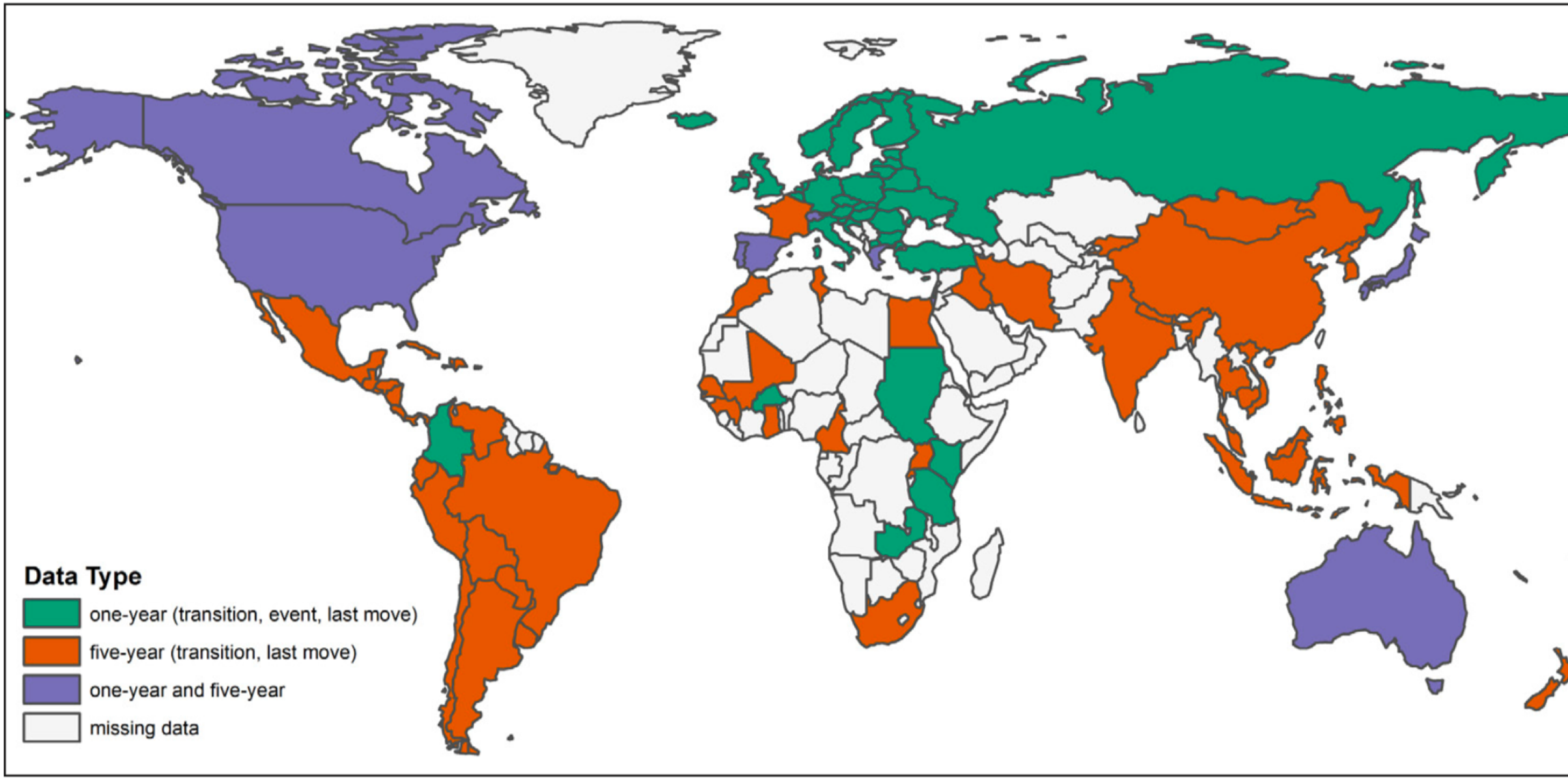
Region	Type of Data						Total No. of countries collecting data
	Observation Period					Duration of residence	
	One year	Five years	Other fixed interval	Lifetime	Latest move		
Africa	9	8	8	29	13	17	32
Asia	1	13	8	26	18	24	34
Europe	14	4	12	26	10	13	32
Latin America and the Caribbean	2	16	2	28	12	13	28
North America	1	3	0	3	0	0	3
Oceania	2	8	2	10	2	5	13
TOTAL	29	52	32	122	55	71	142

TABLE 3. INTERNAL MIGRATION DATA COLLECTED IN THE 2010 ROUND OF CENSUSES (2005-2014)

Region	Type of Data						Total No. of countries collecting data
	Observation Period					Duration of residence	
	One year	Five year	Other fixed interval	Lifetime	Latest move		
Africa	8	7	5	26	10	9	27
Asia	5	12	3	16	12	9	24
Europe	12	3	2	16	10	14	23
Latin America and the Caribbean	1	13	3	19	8	10	19
North America	1	2	0	2	0	2	2
Oceania	4	10	1	9	0	9	11
TOTAL	31	47	14	88	40	53	106

Source: Bell, Charles-Edwards 2013, p.4.

FIGURE 2 League table coverage by type of data



Source: Bell et al. 2015, p.43.

Measures of internal migration

- **Aggregate Crude Migration Intensity**
  - It expresses the total number of internal migrants (*M*) in a given time period as a percentage of the population at risk (*P*)

$$ACMI = 100\ M / P$$

- **Age at peak migration intensity**
  - It is determined from the profile of age-specific migration intensities

- **Crude Migration Intensity,** based on Courgeau's Index *k*
  - It compares migration among countries with different territorial divisions

$$CMI = k\ ln(n)$$

  - *n*: number of regions in the zonal system
  - *k*: slope of a regression line for various *n* and *ACMI*, which reflects the overall intensity of migration at various spatial scales

Source: Bell et al. 2002; Bell, Muhidin 2009; Bell, Charles-Edwards 2013; Bell et al. 2015.

Migration Effectiveness Index (MEI)

- MEI measures the degree of (a)symmetry or (dis)equilibrium in the network of interregional migration flows
- It informs the overall efficiency of migration as a mechanism for population redistribution
- It can assume values between 0 and 100
- **High values:** migration is an efficient mechanism of population redistribution, generating a large net effect for the given volume of movement
- **Low values:** migration flows are more closely balanced, leading to comparatively little redistribution

$$\mathrm{MEI} = 100 \sum_i |D_i - O_i| \Big/ \sum_i (D_i + O_i)$$

  - D_i: total inflows to zone i
  - O_i: total outflows from zone i

Source: Bell et al. 2002; Bell, Muhidin 2009; Bell, Charles-Edwards 2013; Bell et al. 2015.

Aggregate Net Migration Rate (ANMR)

- ANMR indicates more directly the overall impact of net migration in changing the population distribution of the country
- It summarizes the extent of population redistribution arising from the net migration balances
- It represents a logical extension of net migration rate commonly used for specific regions

$$\mathrm{ANMR} = 100 \times \frac{1}{2} \sum_i |D_i - O_i| \bigg/ \sum_i P_i$$

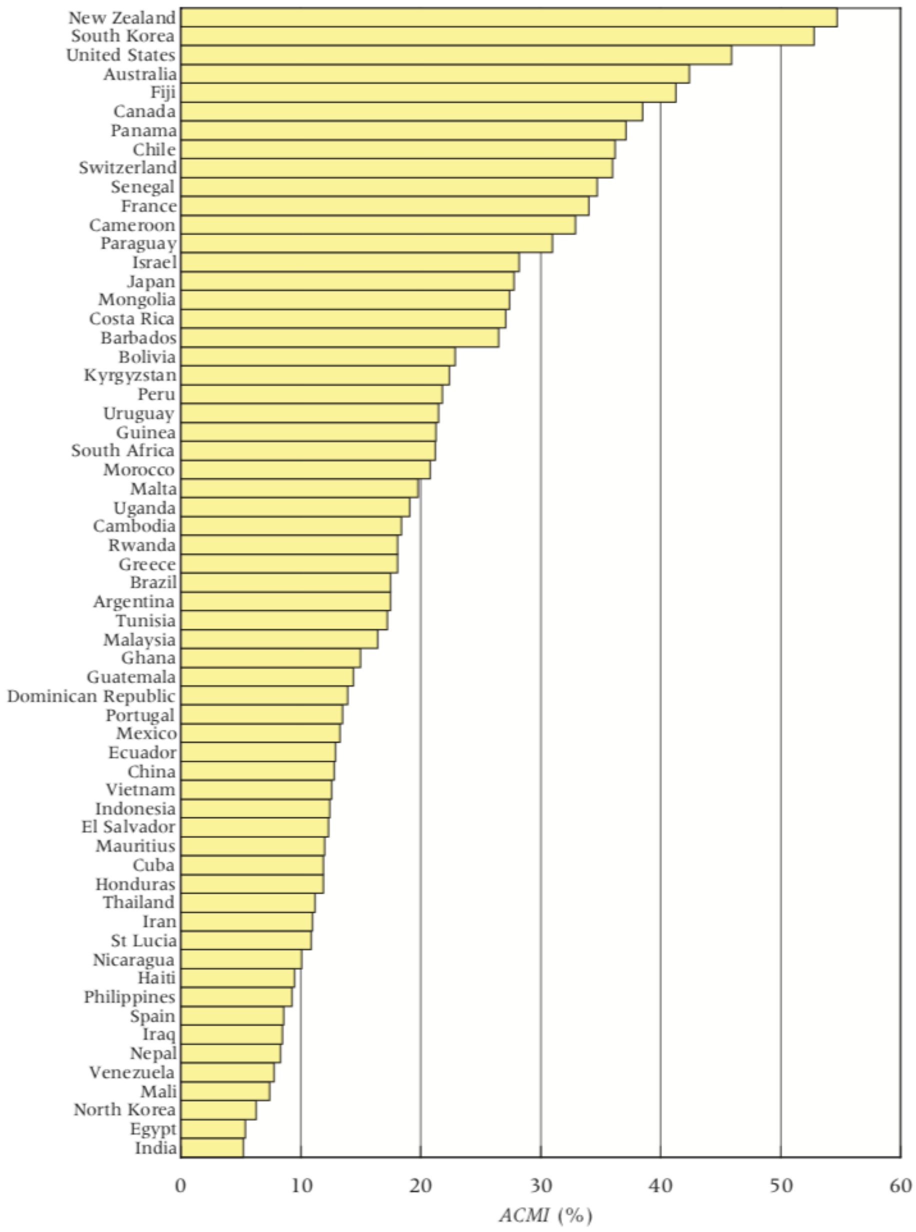
  – P_i: Population at risk (PAR) in region i

Source: Bell et al. 2002; Bell, Muhidin 2009; Bell, Charles-Edwards 2013; Bell et al. 2015.

No.	Indicator Name	Shorthand	Description
Measures of migration intensity			
1	Crude Migration Intensity	CMI	Total moves over population at risk
2	Standardized Migration Intensity	SMI	Age-standardised intensity
3	Gross Migraproduction Rate	GMR	Sum of age-specific migration intensities
4	Migration Expectancy	ME	Total moves over a hypothetical lifetime
5	Peak Migration Intensity	PMI	Peak intensity on the age schedule
6	Age at Peak Intensity	API	Age at which the peak occurs
Measures of migration distance			
7	Median Distance	MD	Distance moved at the 50^{th} percentile
8	Distance Decay Parameter	B	Exponent from a spatial interaction model
9	Courgeau's Index	K	Regression slope of CMIs at various scales
Measures of migration connectivity			
10	Index of Migration Connectivity	I_{MC}	Proportion of non-zero flows in a matrix
11	Index of Migration Inequality	I_{MI}	Departure from a hypothetical flow matrix
12	Migration Weighted Gini	MWG	System-wide index of spatial concentration
13	Coefficient of Variation	ACV	SD divided by the mean of a flow matrix
Measures of migration impact			
14	Migration Effectiveness Index	MEI	Asymmetry of inter-zonal migration flows
15	Aggregate Net Migration Rate	ANMR	Extent of redistribution through migration

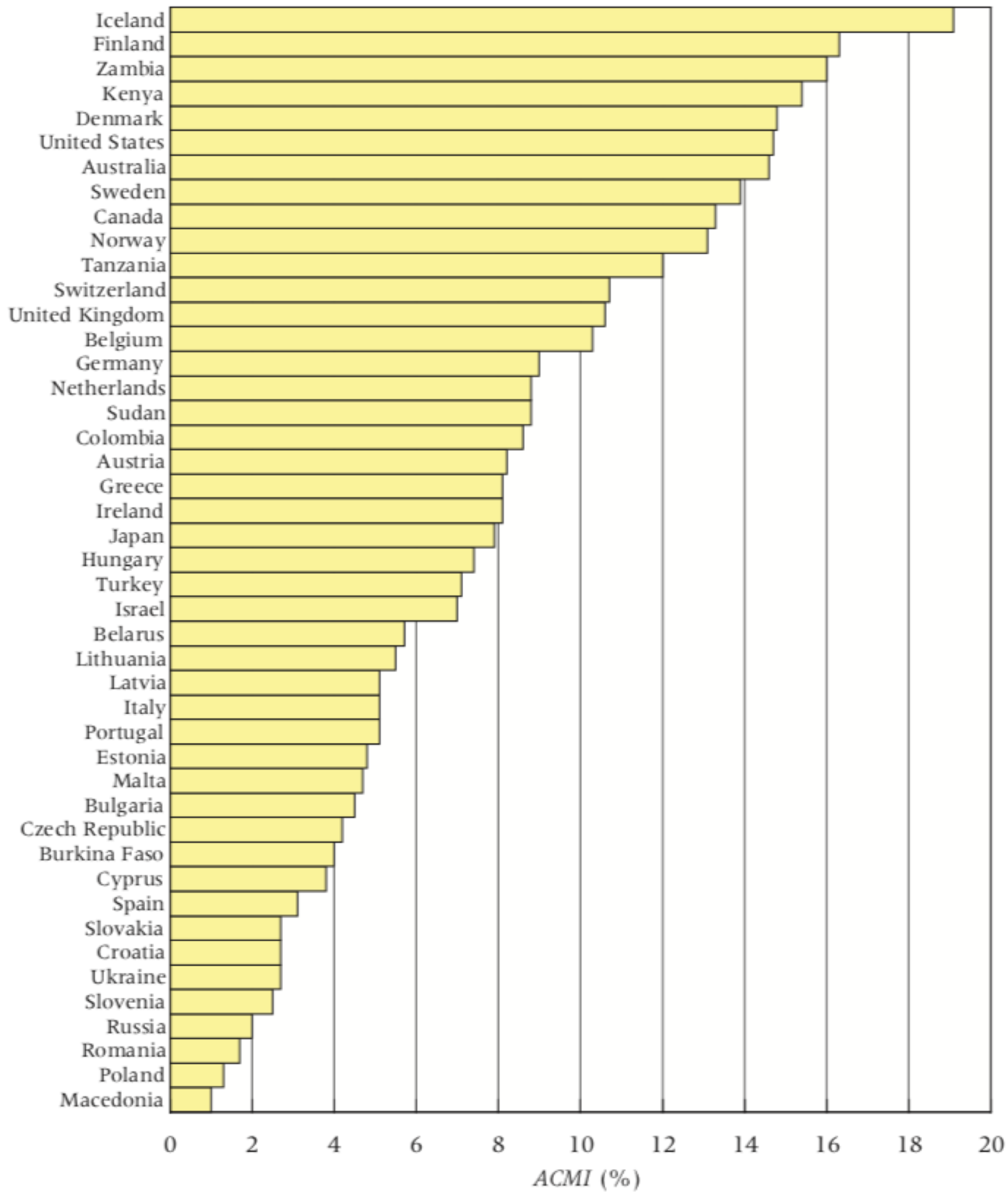
Source: Bell, Muhidin 2009, p.15 (for details see Bell et al. 2002).

FIGURE 3 Five-year *ACMIs* by country, ranked



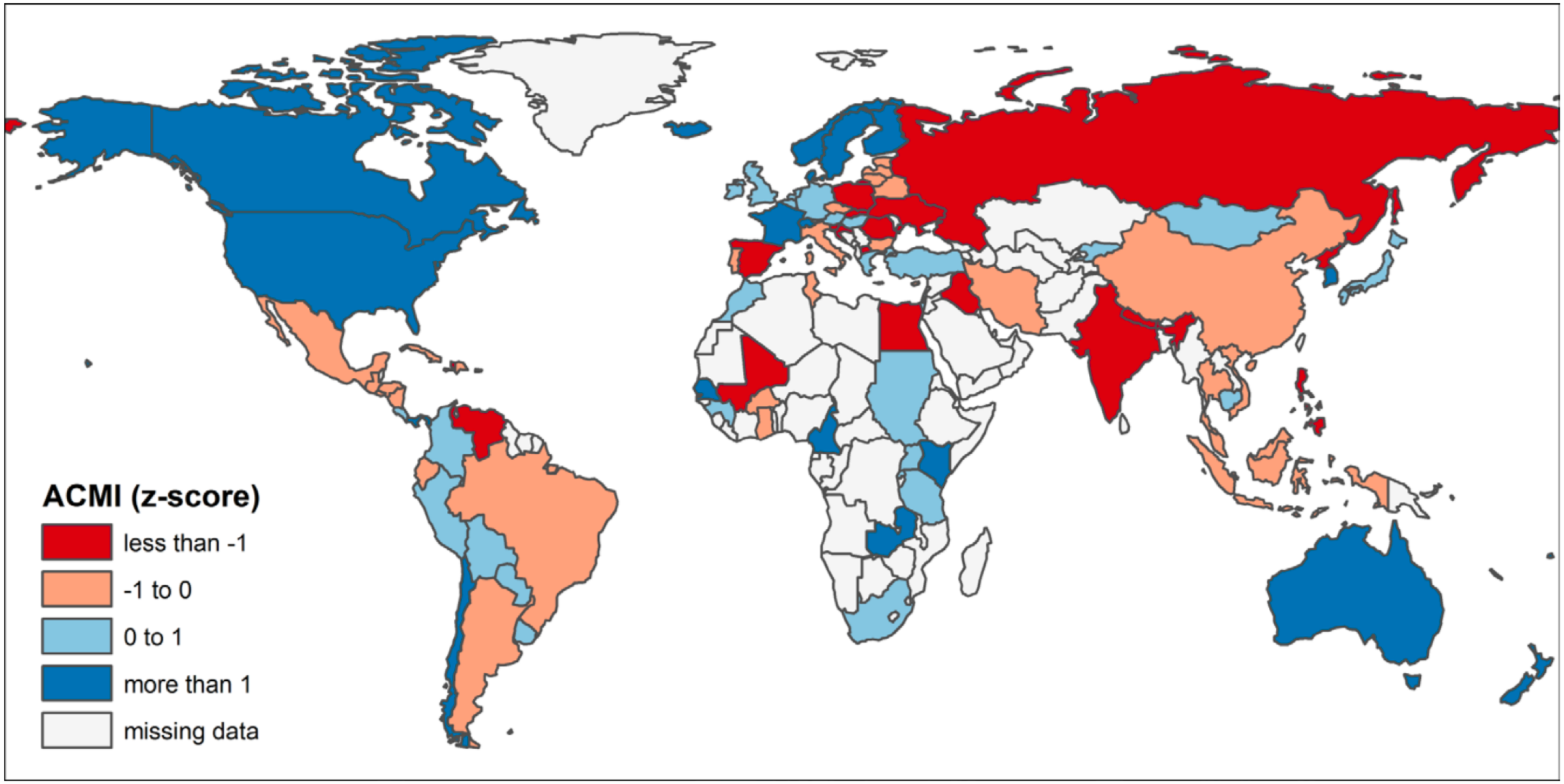
Source: Bell et al. 2015, p.44.

FIGURE 4 One-year *ACMI*s by country, ranked



Source: Bell et al. 2015, p.45.

FIGURE 5 Standardized *ACMIs*, one year and five years (z-scores)



NOTE: Where estimates are available for both one-year and five-year intervals, five-year data are shown.

Source: Bell et al. 2015, p.47.

TABLE 1 Crude and standardized migration intensities, selected countries

			Standard population (2000)					
			Malaysia		Japan		Unweighted average	
Country and interval	Median age	*ACMI*	*SMI*	Percent difference	*SMI*	Percent difference	*SMI*	Percent difference
Five-year interval								
Malaysia	23.8	17.1	18.9	10.5	15.6	–8.8	16.4	–4.1
Japan	41.3	27.6	34.3	24.3	27.7	0.4	29.4	6.5
France	37.6	34.0	41.8	22.9	34.0	0.0	35.9	5.6
Switzerland	38.6	36.1	41.1	13.9	35.5	–1.7	37.0	2.5
Canada	36.8	38.5	45.1	17.1	38.5	0.0	40.1	4.2
Australia	35.4	42.4	47.5	12.0	40.8	–3.8	42.4	0.0
United States	35.3	44.3	49.5	11.7	42.1	–5.0	43.9	–0.9
New Zealand	34.3	54.7	60.6	10.8	53.7	–1.8	55.0	0.5
Range		37.6	41.7	—	38.1	—	38.6	—
One-year interval								
Italy	40.2	5.1	5.8	13.7	5.0	–2.0	5.2	2.0
Austria	38.2	8.1	10.1	24.7	7.9	–2.5	8.4	3.7
Canada	36.8	13.3	15.5	16.5	12.9	–3.0	13.4	0.8
United States (CPS 2000)	35.3	15.5	18.2	17.6	14.8	–4.6	15.5	–0.2
Denmark	38.4	16.0	20.6	29.1	16.6	4.0	17.3	8.4
Iceland	32.8	19.1	21.9	14.7	17.7	–7.3	18.6	–2.6
Australia	35.4	17.6	19.9	13.1	16.7	–5.1	17.4	–1.1
Range		14.0	16.1	—	12.7	—	13.4	—

NOTE: Direct standardization, see text.

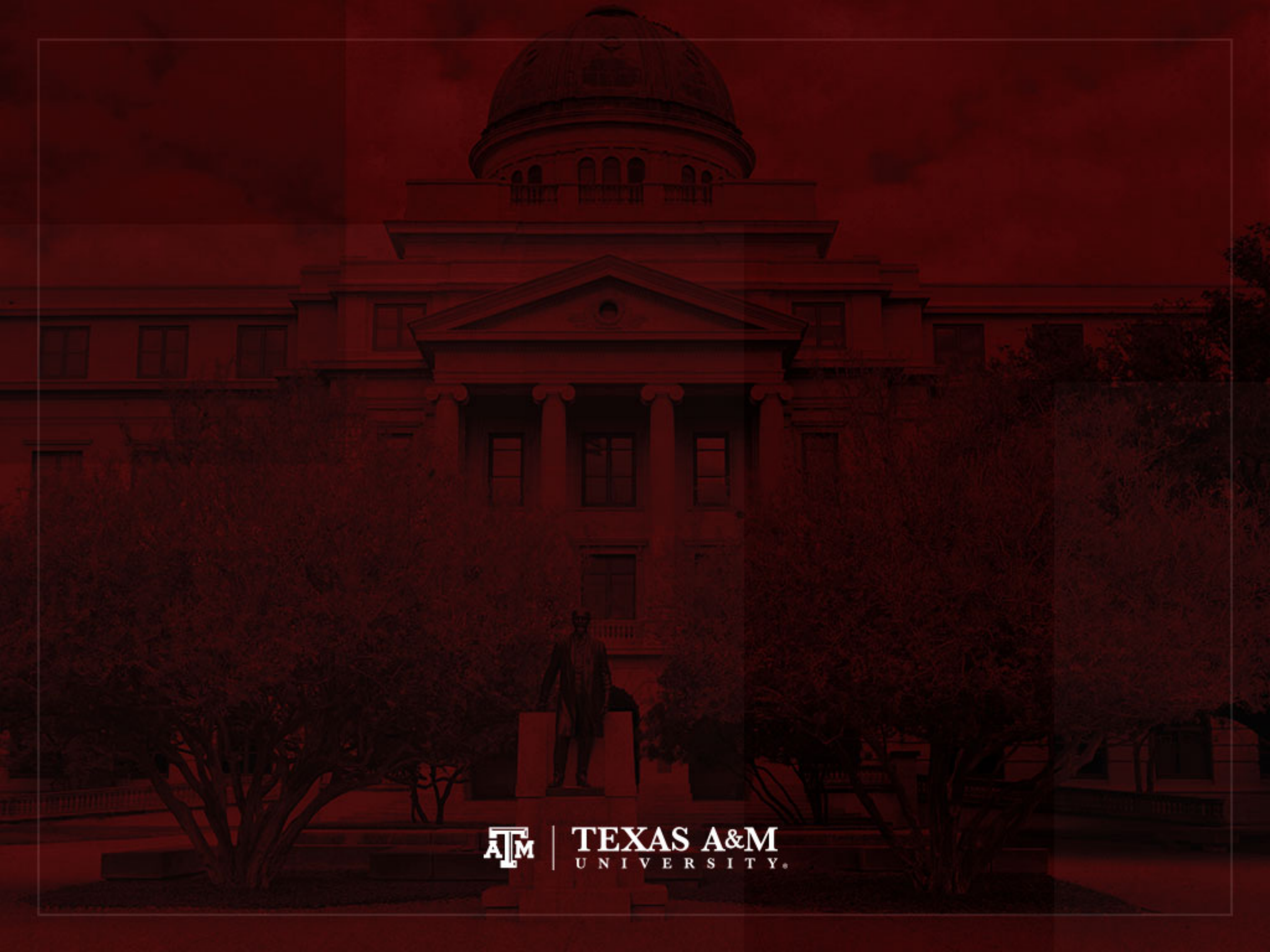
Source: Bell et al. 2015, p.49.

TABLE 2 Correlation coefficients, one-year and five-year *ACMI*s with selected indicators

Variable	One-year interval n	One-year interval r	Five-year interval n	Five-year interval r
Geographic				
Geographic area (sq. root)	44	0.46**	61	0.14
Population density	44	–0.10	60	–0.10
Urbanization	40	0.65**	61	0.39**
Economic				
Gross domestic product (GDP) per capita (2005 PPP$)	40	0.69**	57	0.61**
Gini coefficient (income inequality 2000, 2005)	28	0.07	34	0.01
Foreign direct investment/GDP (2000)	43	0.03	56	0.02
Female labor force participation (2000)	43	0.53**	61	0.20
Labor force participation (2000)	42	0.40*	61	0.24
Social				
Human Development Index (2000)	40	0.62**	59	0.48**
Mobile phone subscribers (2000)	40	0.66**	61	0.54**
Literacy (2000)	25	–0.76**	49	0.06
Percent males 20–24 living at home	11	–0.81**	4	–0.97*
Demographic				
Growth rate (2000–2005)	45	0.40**	60	–0.25
Life expectancy at birth (2000–2005)	45	–0.01	61	0.25
Total fertility rate (TFR) (2000–2005)	40	0.45**	59	–0.14
Median age	40	0.05	61	0.38**
Net international migration rate (2000–2005)	40	0.35*	56	0.48**
Remittances as percent of GDP (2000)	41	–0.27	54	–0.34*

*Significant at $p < 0.05$; **$p < 0.01$.

Source: Bell et al. 2015, p.51.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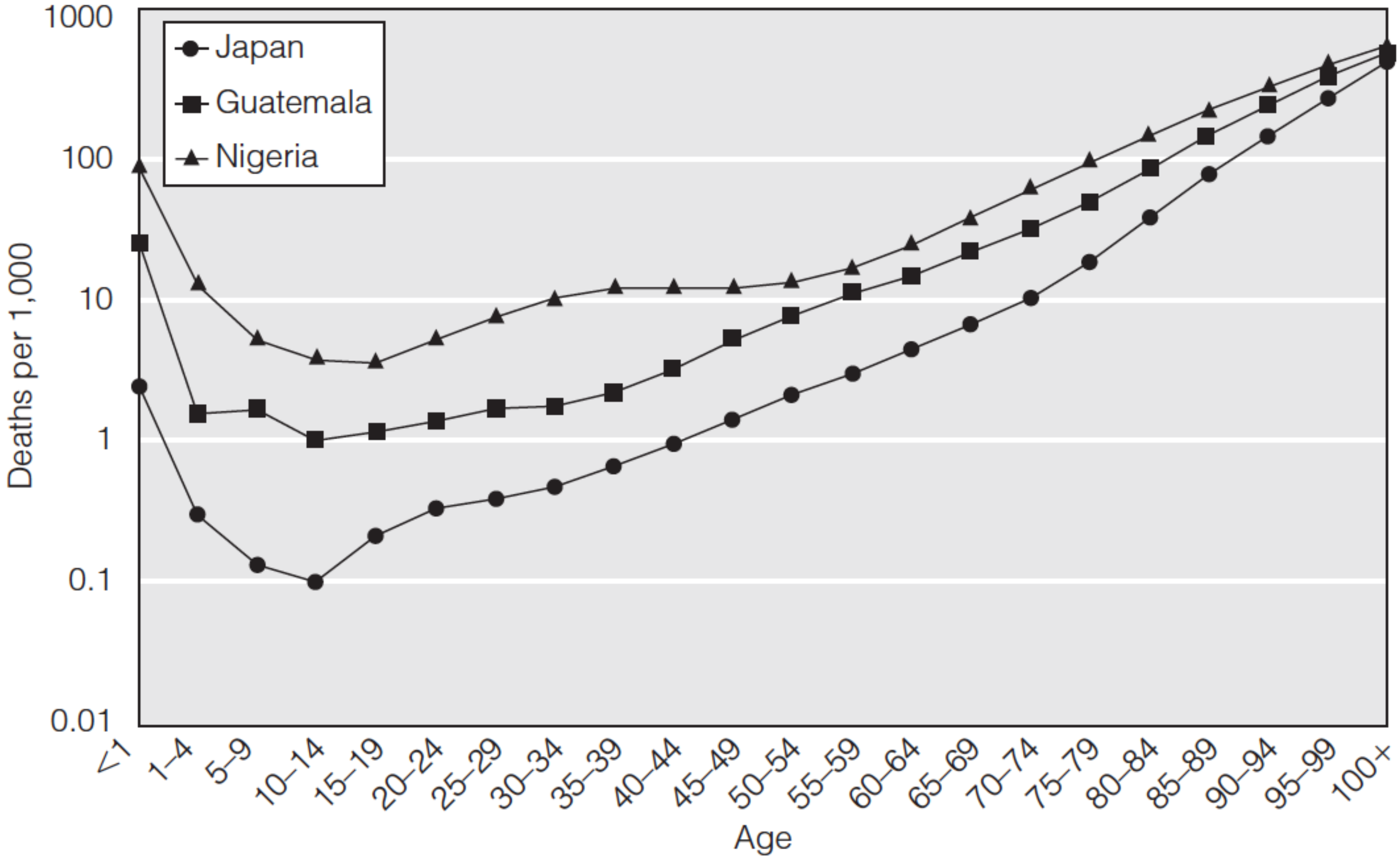
Age profile of internal migration

- Migration is an age-selective process, with young adults being the most mobile group
  - The propensity to migrate typically peaks at young adult ages
  - Steadily declines with increasing age
  - Rising again among young children and sometimes around the age of retirement
- Recent cross-national studies have revealed systematic variations in the age profile of migration, particularly at young adult ages
  - We are usually more familiar with age profile of mortality and fertility...

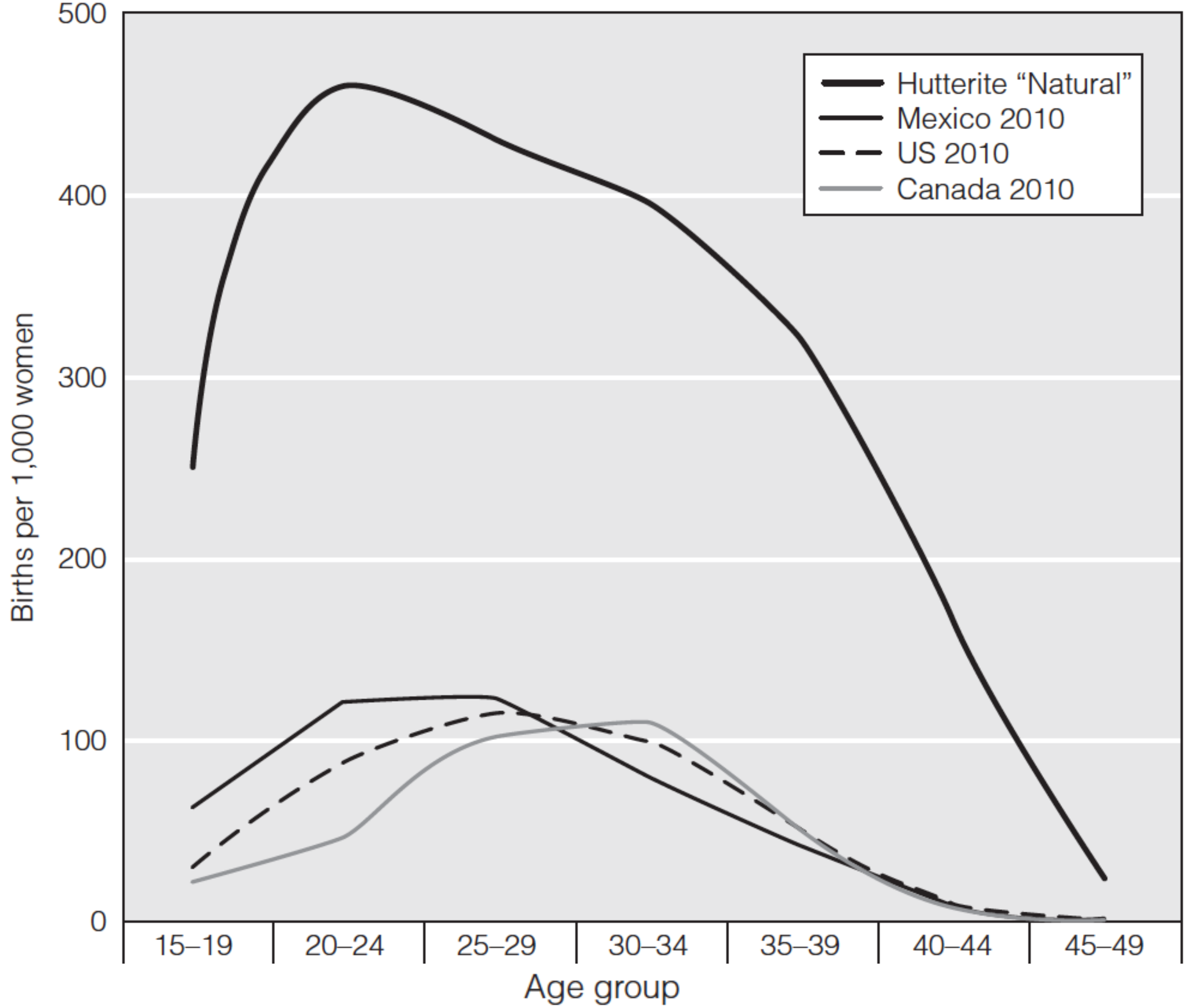
Source: Bernard, Bell, Charles-Edwards 2014.

Age-specific mortality rates, 2011



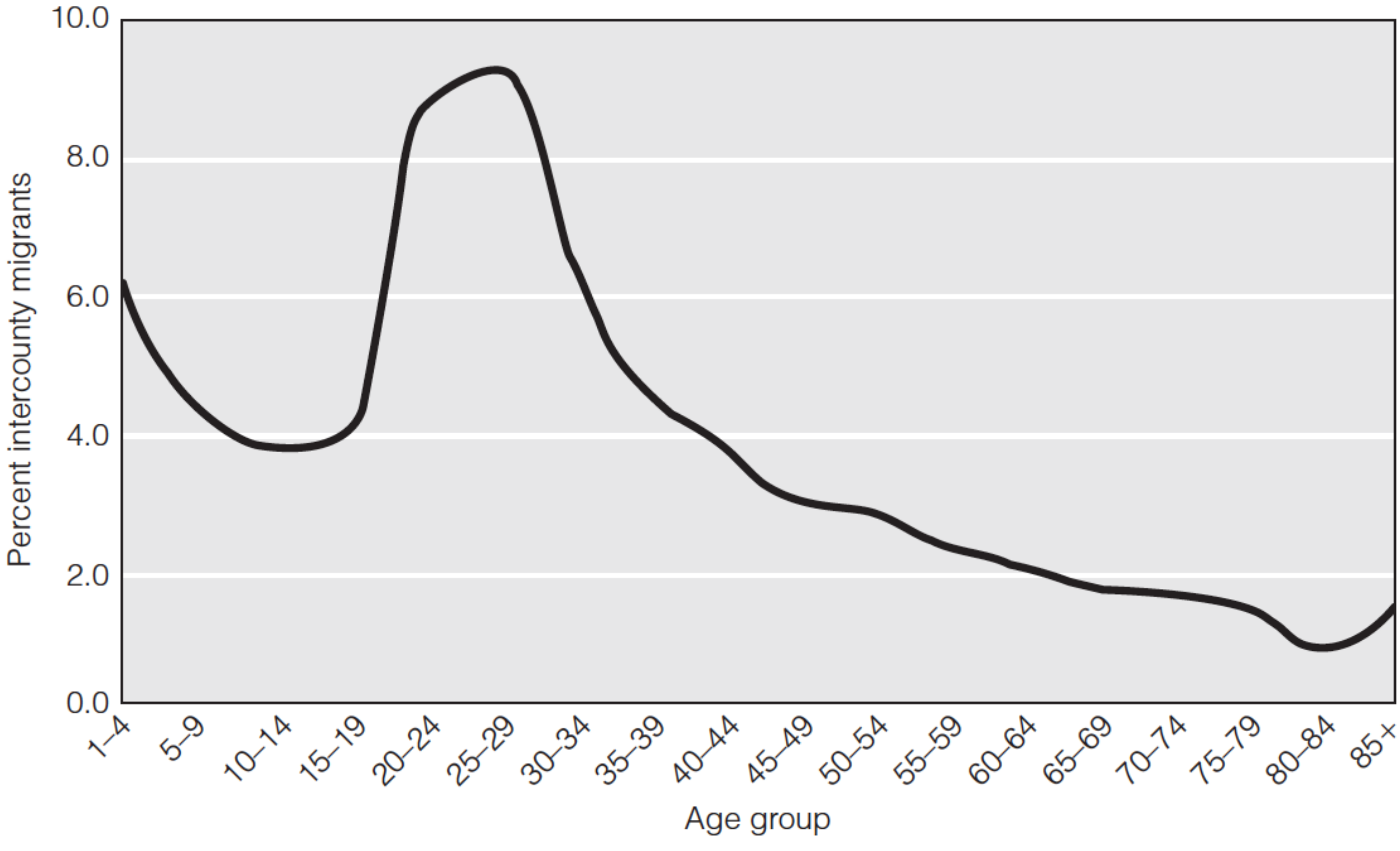
Source: Weeks 2015, p.154.

Age-specific fertility rates



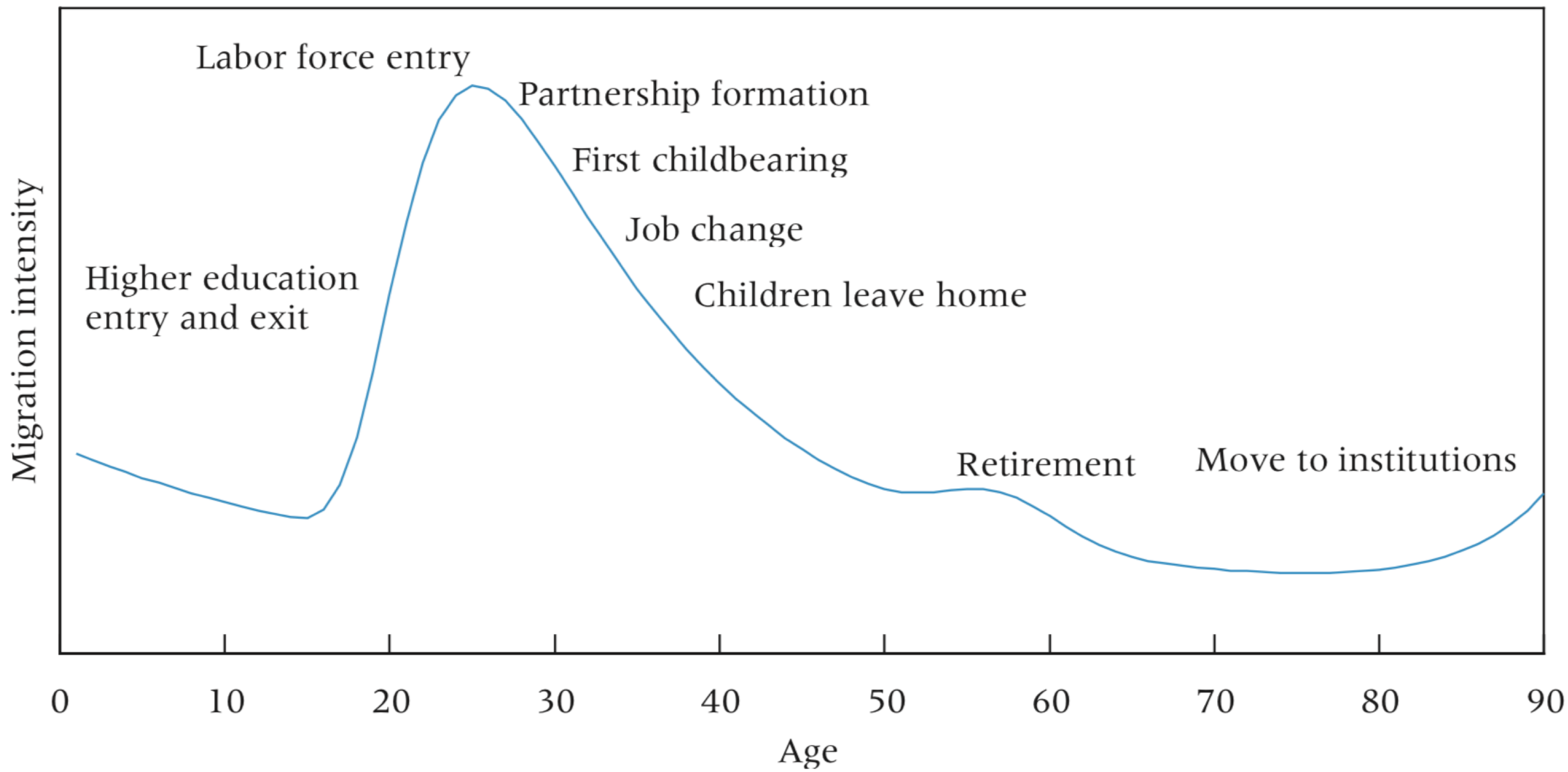
Source: Weeks 2015, p.195.

Age-specific migration rates, United States, 2011–2012



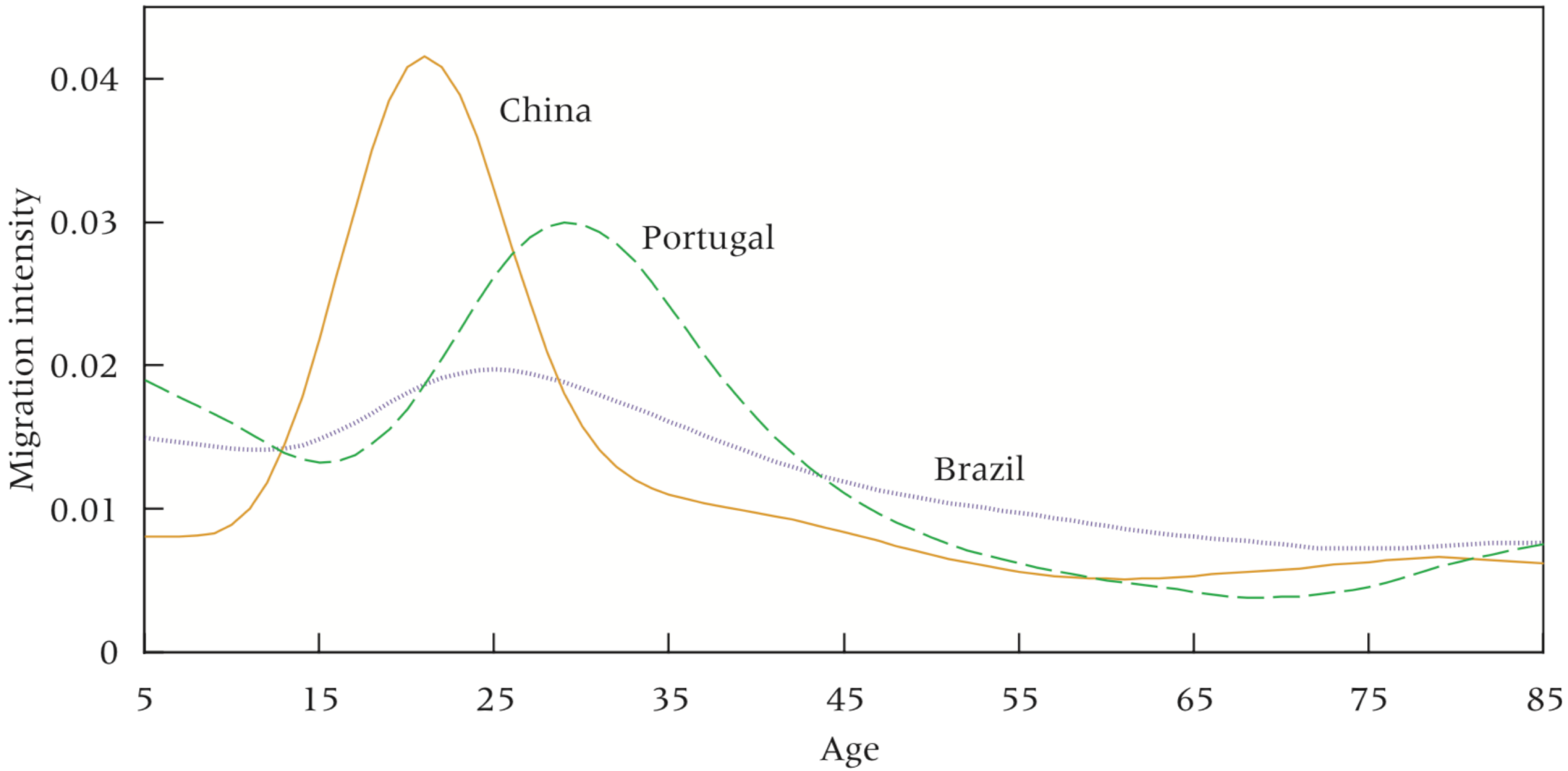
Source: Weeks 2015, p.266.

FIGURE 1 Typical age profile of migration and key life-course transitions



Source: Bernard, Bell, Charles-Edwards 2014, p.215.

FIGURE 2 Cross-national variations in migration age profiles



SOURCE: Authors' calculations based on five-year-interval migration data reported by single-year age groups. Migration data were normalized to sum to unity and smoothed using kernel regression (Bernard and Bell 2012).

Source: Bernard, Bell, Charles-Edwards 2014, p.216.

Last-move, duration vs. Fixed prior date

- **Last-move data (previous residence) & duration of residence**
  - Best approach to measure migration (Xu-Doeve 2006)
  - The exact date of the move is reported by the duration of residence, which provides the full reconstruction of migration processes as they took place in real time
- **Place of residence at a fixed date in the past**
  - Interval transition measure: usually one or five years in the past
  - Highlighted as the one suited to estimate internal migration (UNECE 2005)

Source: Amaral 2008.

Last-move & duration of residence

1. Estimation of consistent instantaneous migration rates, along cohort lines, as a function of continuous time and age

2. Estimation of probabilities to make several moves within specified times intervals (multiple moves, trajectories)

3. Estimation of migrant stocks (absolute numbers)

4. Calculation of period rates

5. Adjustment of migration data for incompleteness of enumeration

6. Computation of transitions in any arbitrarily specified discrete interval of time and age

Source: Amaral 2008.

Residence at some fixed prior date

1. Impossibility to estimate cohort instantaneous migration rates as a function of continuous time/age (analysis in discrete time)

2. No proper data to estimate multiple moves, trajectories

3. Estimation of migrant stocks and flows is not properly identified

4. Migration rates obtained are not consistent with the standard definition of occurrence/exposure rates (denominator is not the number of person-years exposed to the risk of migration)

5. No correction for undercount migrant enumeration can be done

6. Only estimation of migration transitions in discrete time and age between fixed date in the past and date of enumeration

Source: Amaral 2008.

Age-specific out-migration rate

(last-move & duration of residence)

- $ASOMR_{x,ij}$ from region *i* to region *j* for age group *x*

$$ASOMR_{ij}^{x} = \frac{\sum_{t=0}^{4} K_{t,ij}^{x}}{0.5K_{0,.i}^{x} + 1.5K_{1,.i}^{x} + 2.5K_{2,.i}^{x} + 3.5K_{3,.i}^{x} + 4.5K_{4,.i}^{x} + 4.5K_{0,i.}^{x} + 3.5K_{1,i.}^{x} + 2.5K_{2,i.}^{x} + 1.5K_{3,i.}^{x} + 0.5K_{4,i.}^{x} + 5K_{nm,i}^{x}}$$

- *t*: duration of residence in current place of residence (years)
- $K_{xt,ij}$: migrants from *i* to *j* for age group *x*
- $K_{xt,.i}$: migrants from all regions different than *i* to region *i* for age group *x*
- $K_{xt,i.}$: migrants from region *i* to all regions different than *i* for age group *x*
- $K_{xt,nm}$: non-migrants for age group *x*
- Sum of weights of immigrants ($K_{xt,.i}$ for specific destination) and emigrants ($K_{xt,i.}$ for specific origin) equals 5 years (length of period)

Source: Amaral 2008.

Age-specific out-migration rate

(place of residence at some fixed prior date)

- $ASOMR_{x,ij}$ from region *i* to region *j* for age group *x*

$$ASOMR_{ij}^{x} = \frac{\sum K_{ij}^{x}}{t * \sum\left[\frac{\left(K_{i.}^{x} + K_{ii}^{x}\right) + \left(K_{i}^{x}\right)}{2}\right]}$$

- *t*: years between date of reference and fixed prior date
- $K_{x,ij}$: migrants who lived in region *i* at the beginning of period and moved to region *j* at the end of period for age group *x*
- $K_{x,i.}$: migrants who lived in region *i* at the beginning of the period and live in another region at the end of period for age group *x*
- $K_{x,ii}$: population who lived in region *i* at the beginning, as well as at the end of period for age group *x*
- $K_{x,i}$: population who lived in region *i* at the end of period for age group *x*

Source: Amaral 2008.

Some considerations

(place of residence at some fixed prior date)

- Denominator is an approximation for period person-years lived, based on estimation of population at the middle of the period
  - Population at the beginning of period for age group *x*

    $K_{x,i.} + K_{x,ii}$
  - Population at the end of period for age group *x*

    $K_{x,i}$
  - Population at the middle of period for age group *x*

    $[(K_{x,i.} + K_{x,ii}) + (K_{x,i})] / 2$
  - Length of the period

    t
- Assumption
  - Rate of migration is the same between those who died and those who survived during the period

Source: Amaral 2008.

Total out-migration rate

- Total non-out-migration rate (*$TNOMR_{ij}$*) for each time and combination of areas of origin and destination

$$TNOMR_{ij} = exp(-\Sigma ASOMR_{x,ij})$$

  - It is analogous to the relationship between the survivor function and the force of mortality

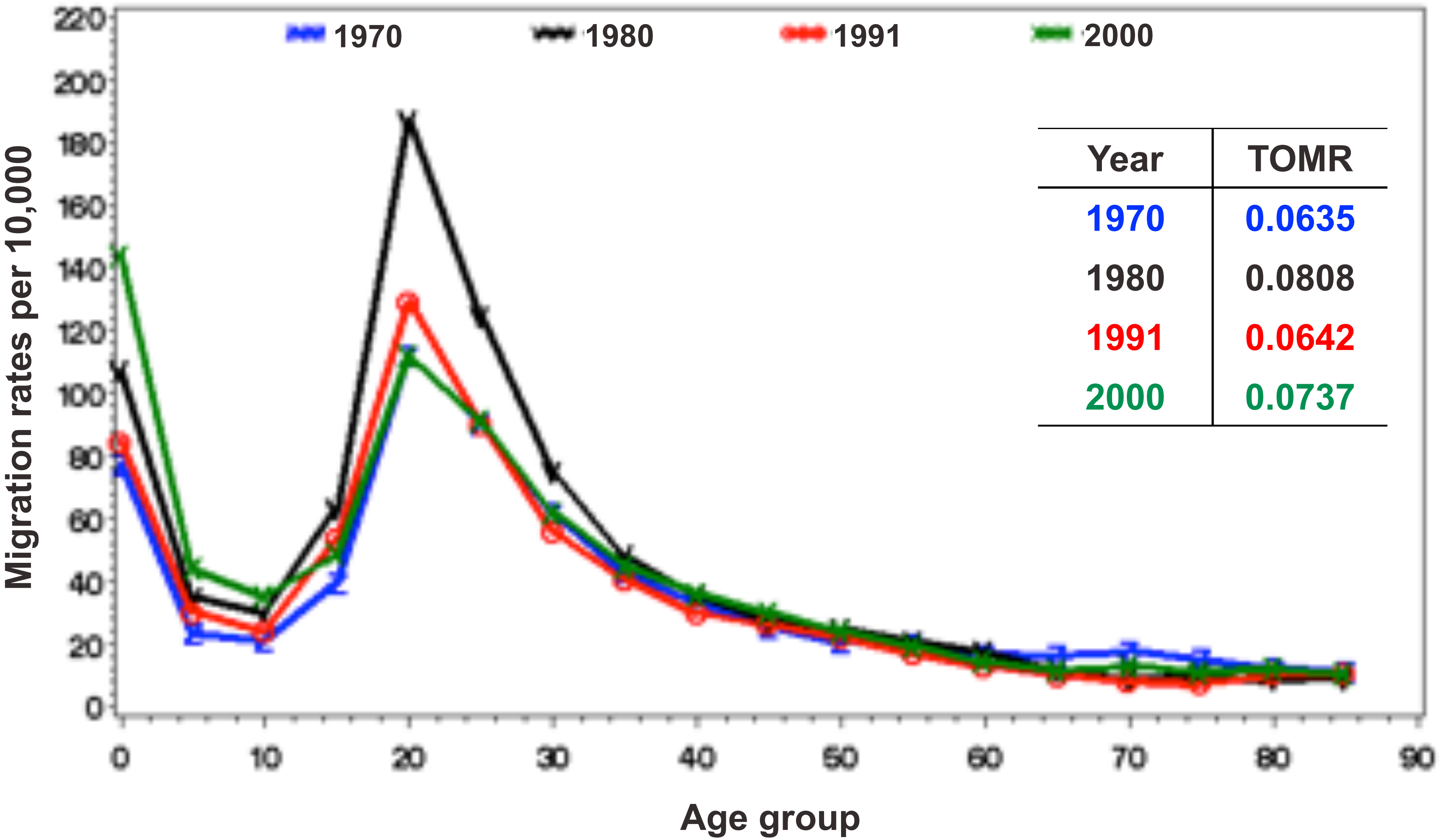
- Total out-migration rate (*$TOMR_{ij}$*)

$$TOMR_{ij} = 1 - TNOMR_{ij}$$

Source: Amaral 2008.

ASOMR, Northeast to Southeast, Males, Brazil

(last-move & duration of residence)

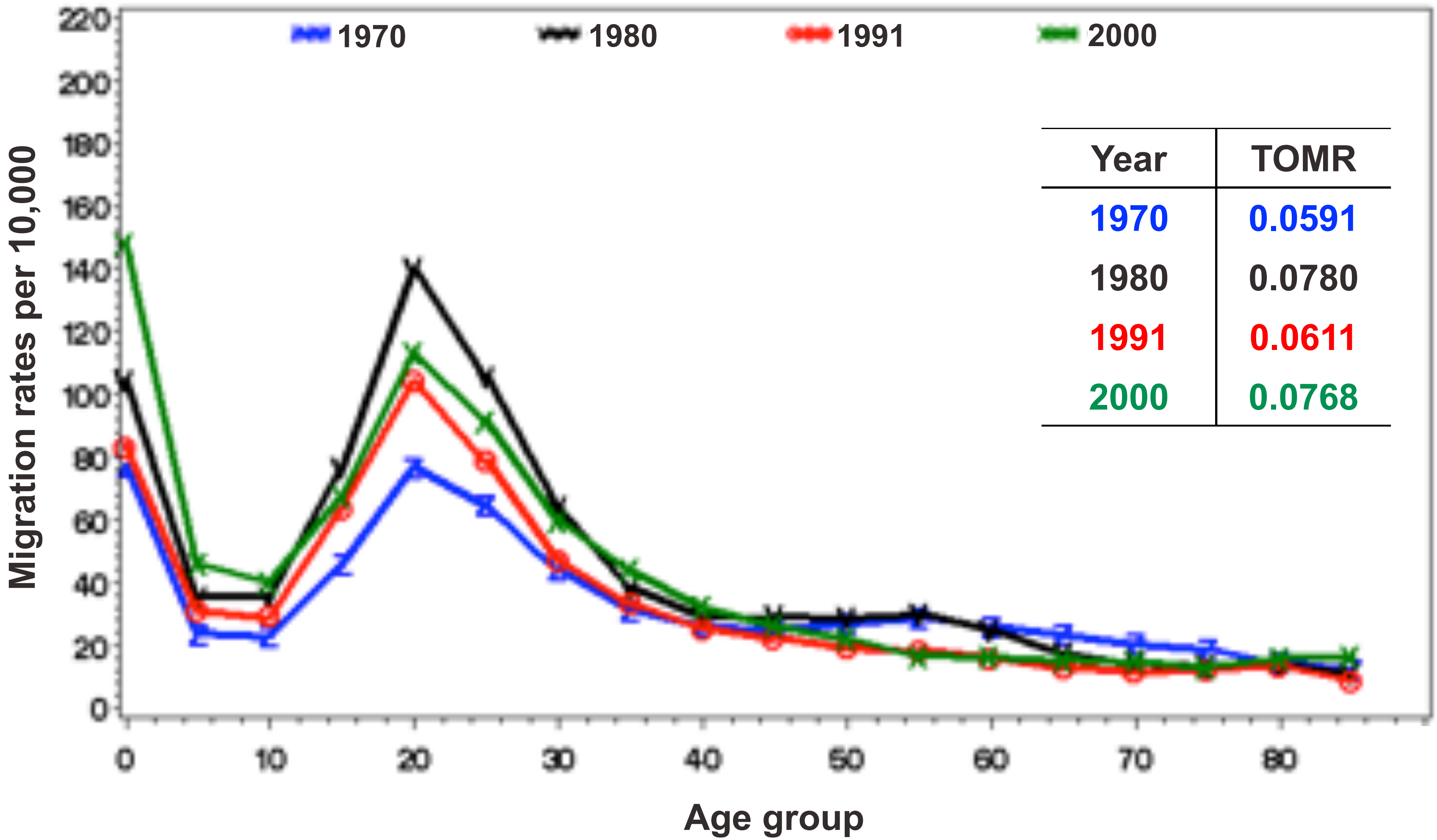


Year	TOMR
1970	0.0635
1980	0.0808
1991	0.0642
2000	0.0737

Source: Amaral 2008, pp.13, 22.

ASOMR, Northeast to Southeast, Females, Brazil

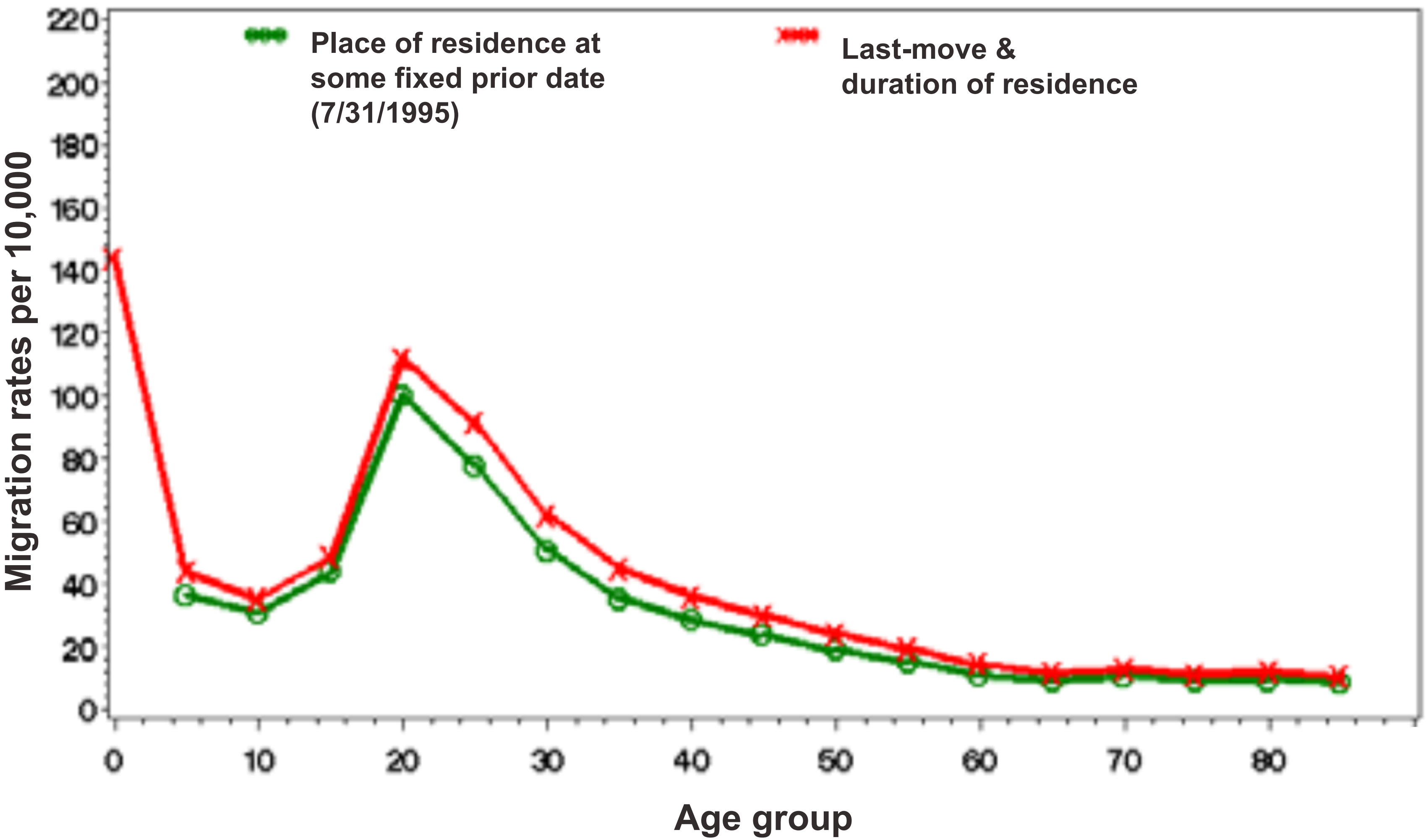
(last-move & duration of residence)



Year	TOMR
1970	0.0591
1980	0.0780
1991	0.0611
2000	0.0768

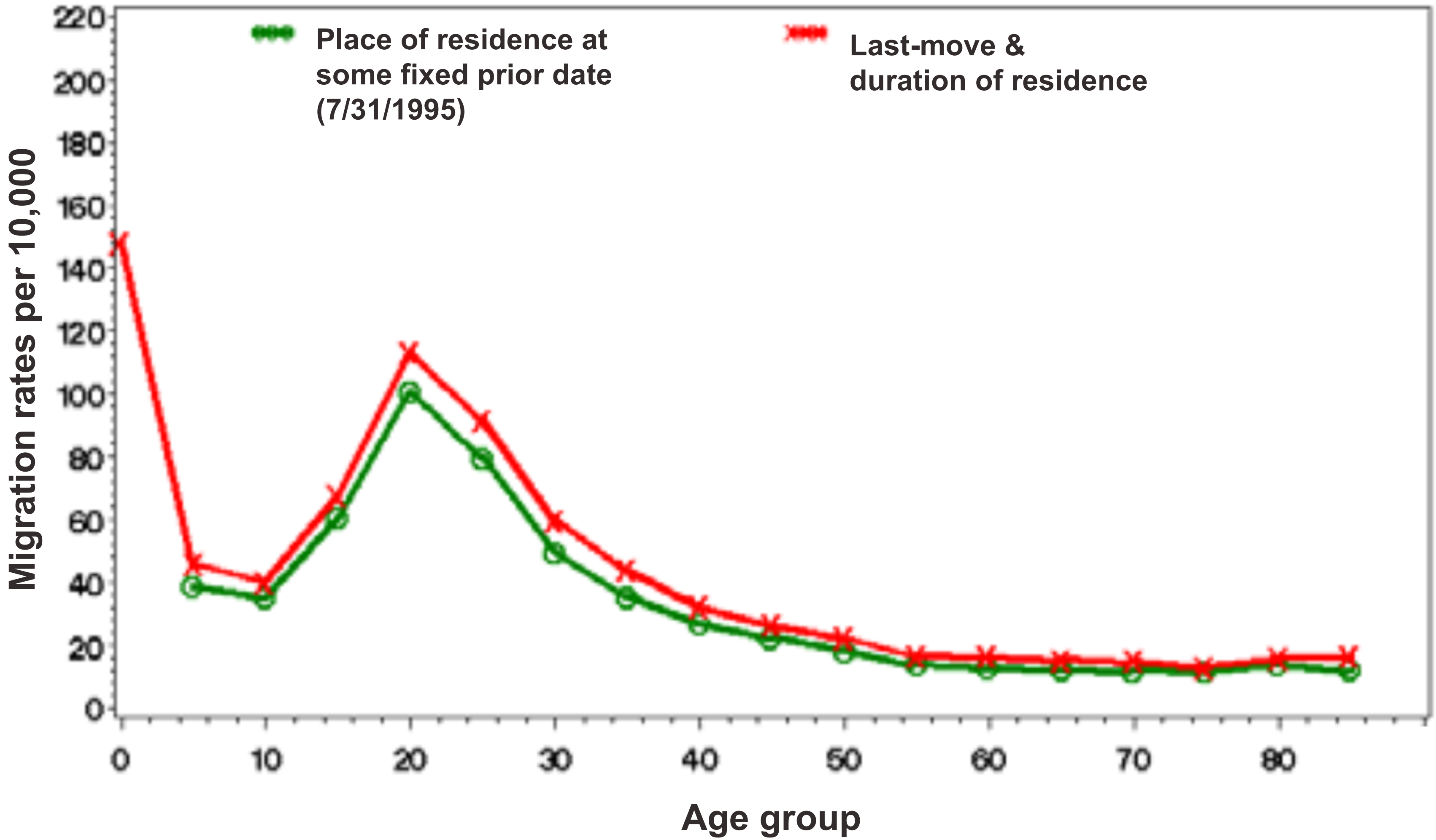
Source: Amaral 2008, pp.13, 22.

ASOMR, Northeast to Southeast, Males, Brazil, 2000



Source: Amaral 2008, pp.18.

ASOMR, Northeast to Southeast, Females, Brazil, 2000



Source: Amaral 2008, pp.18.

Age-specific in-migration rate

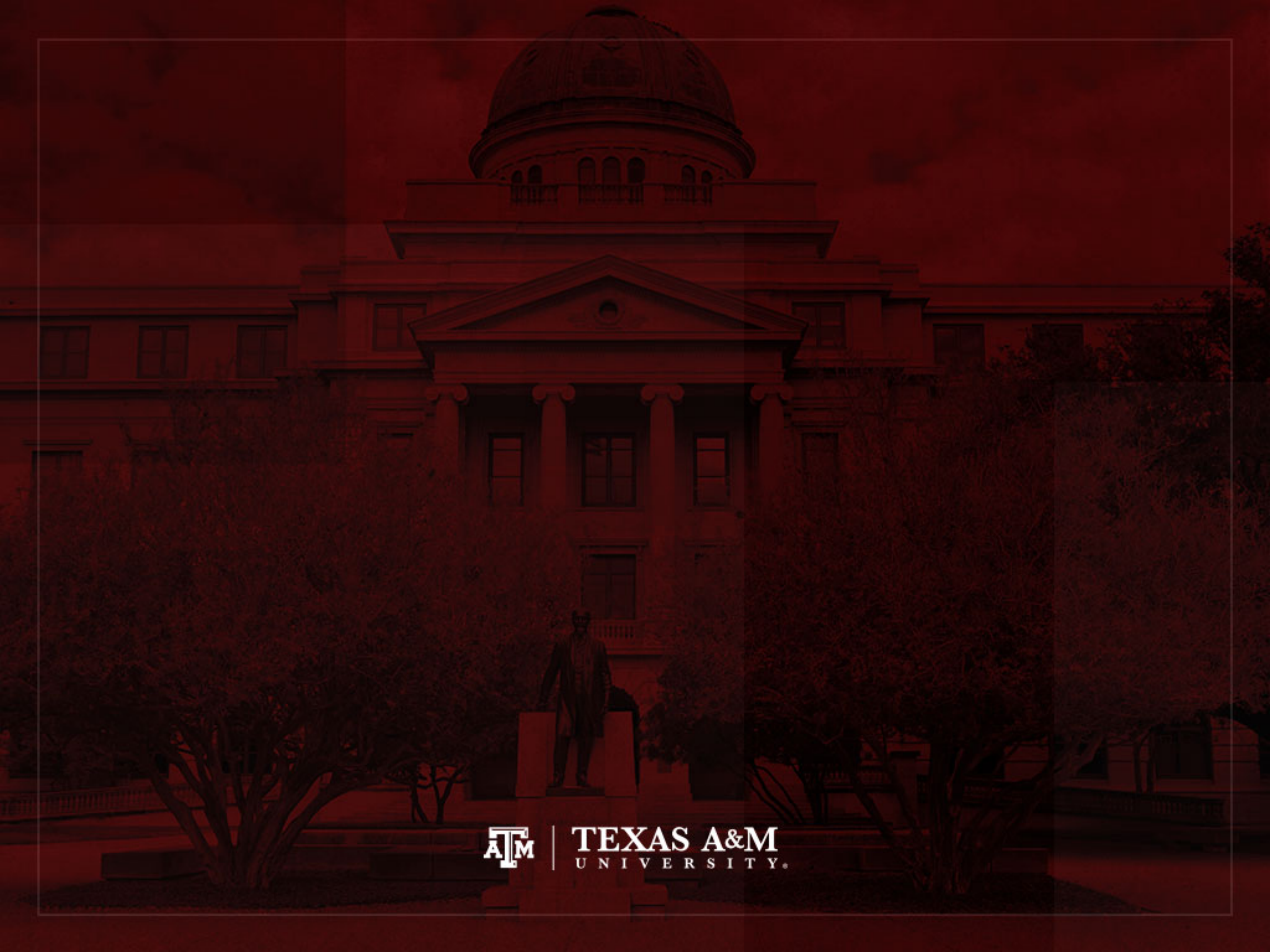
(place of residence at some fixed prior date)

- *$ASIMR_{x,ij}$* from region *i* to region *j* for age group *x*
  - Denominator is adjusted to estimate the population at the middle of the period for the region of destination

$$ASIMR_{ij}^{x} = \frac{\sum K_{ij}^{x}}{t * \sum \left[\frac{\left(K_{j.}^{x} + K_{jj}^{x}\right) + \left(K_{j}^{x}\right)}{2} \right]}$$

- This rate is misleading
  - The denominator refers to people living in area of destination, which is not the group of people at risk of moving in
  - These people are precisely the ones who are not at risk of moving in, because they are already there

Source: Amaral 2008.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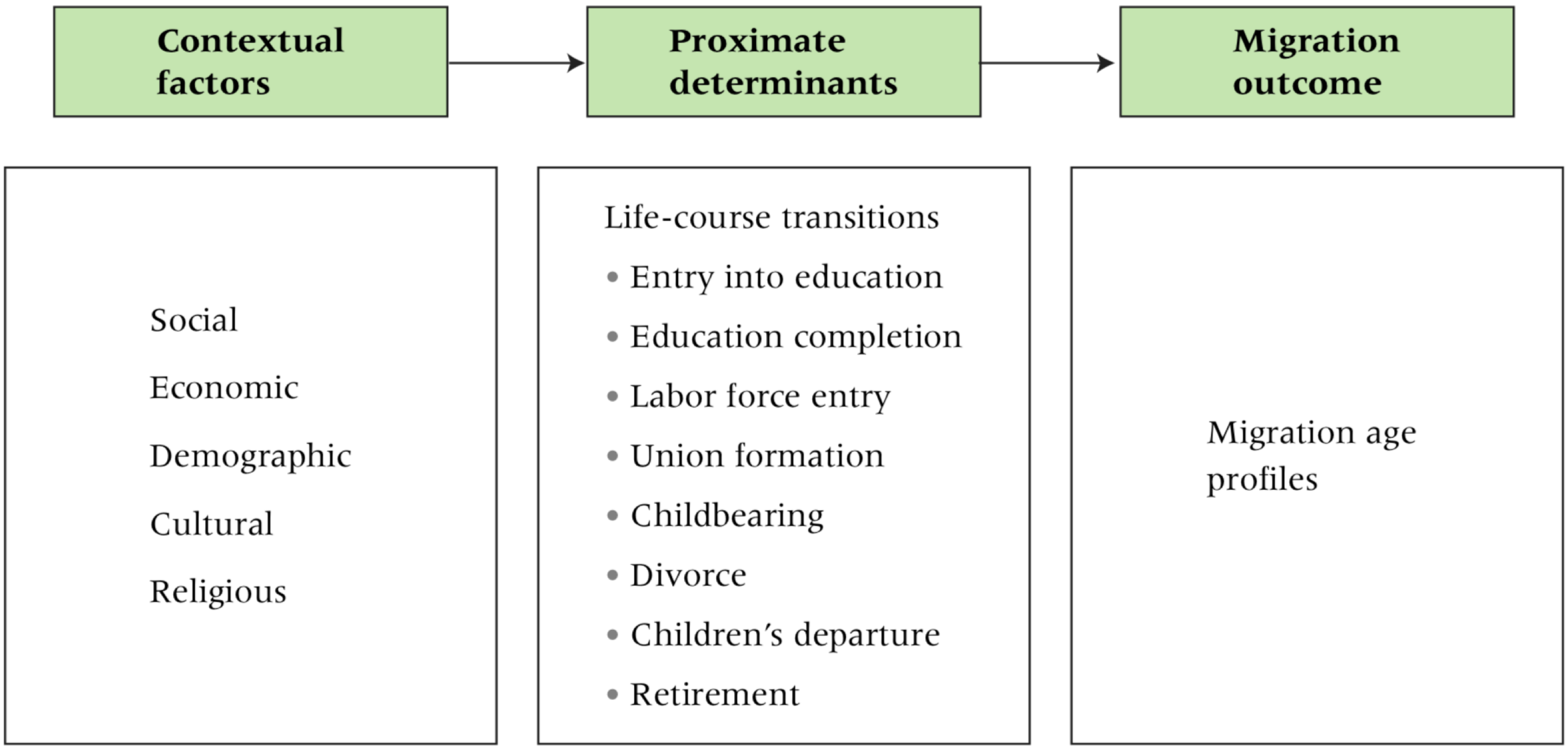
Proximate determinants

FIGURE 3 Proximate determinants of migration age profiles



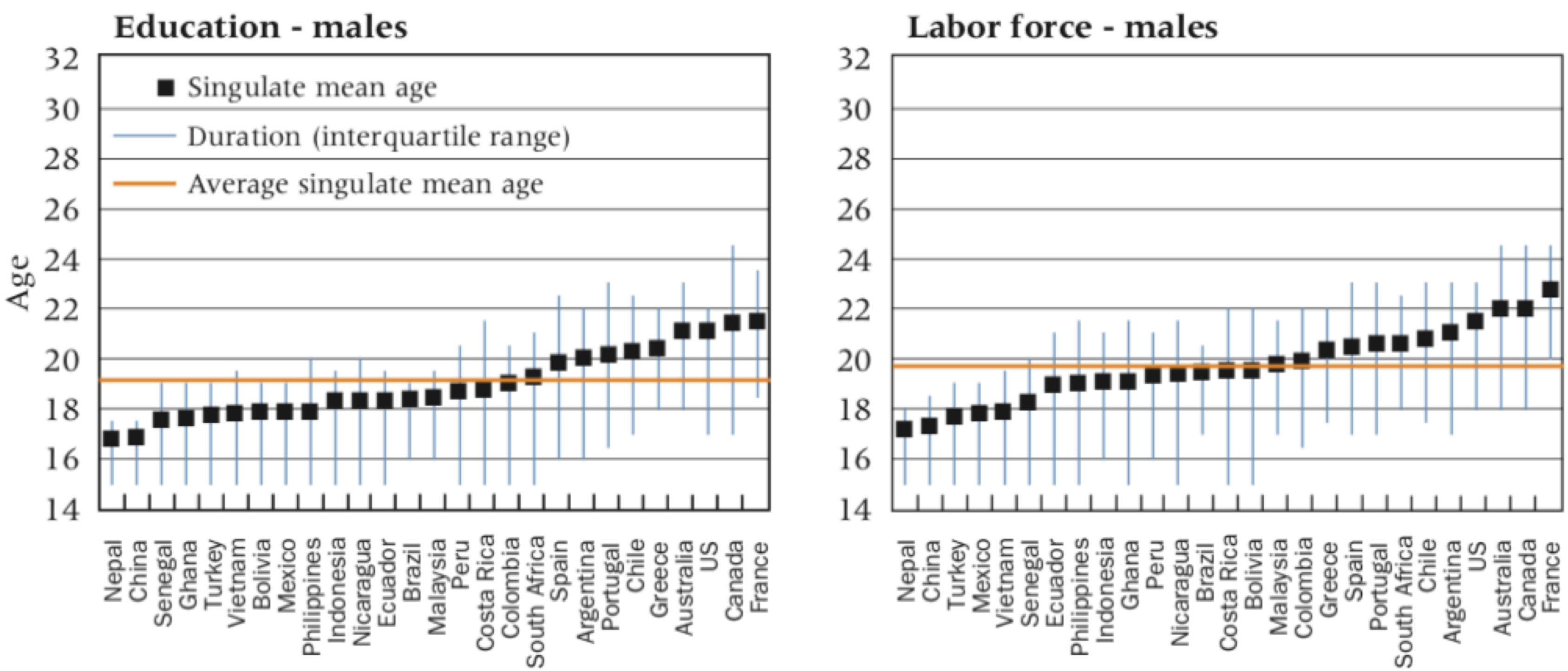
Source: Bernard, Bell, Charles-Edwards 2014, p.217.

TABLE 1 Life-course transition and migration age profile metrics

Metric	Definition	Measure	Interpretation	References
Life-course transitions				
Prevalence	Proportion of a population that experiences a transition	Proportion of a population that has experienced a transition by age 35	Transition may be almost universal or less common	Modell, Furstenberg, and Hershberg (1976)
Timing	Typical ages at which a transition occurs	Singulate mean age computed between ages 15 and 35	Transition may occur early or late in life	Hajnal (1953)
Spread	Period of time required for a fixed proportion of a population to undergo a transition	Duration (interquartile range)	Transition may be brief or protracted	Carter and Glick (1970); Modell, Furstenberg, and Hershberg (1976)
Migration				
Age at peak migration	Age at which most moves occur	Age at which migration intensity peaks	Migration can occur early or late in life	Bernard, Bell, and Charles-Edwards (2014)
Intensity at peak migration	Degree of concentration of migration over a narrow age range	Intensity at which migration peaks	Migration can be concentrated or dispersed	Bernard, Bell, and Charles-Edwards (2014)

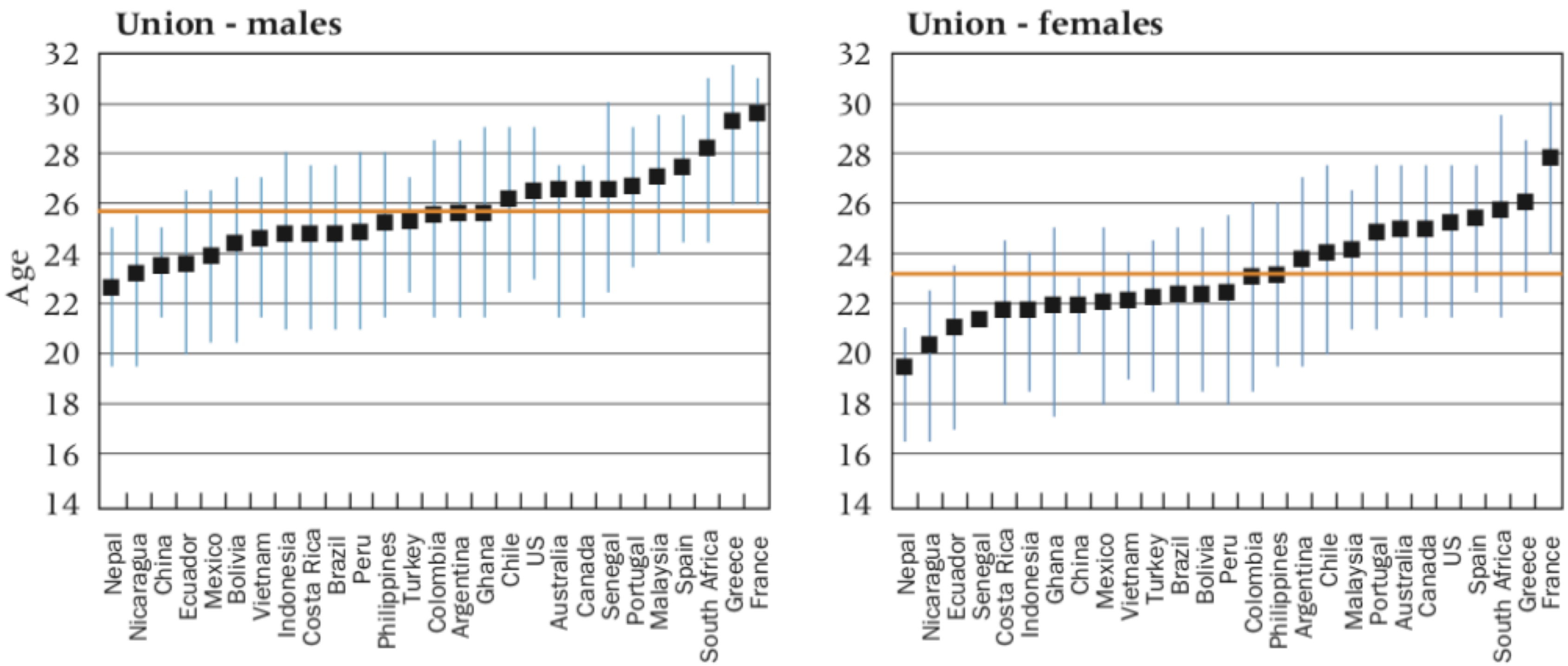
Source: Bernard, Bell, Charles-Edwards 2014, p.222.

Timing and spread of life-course transitions



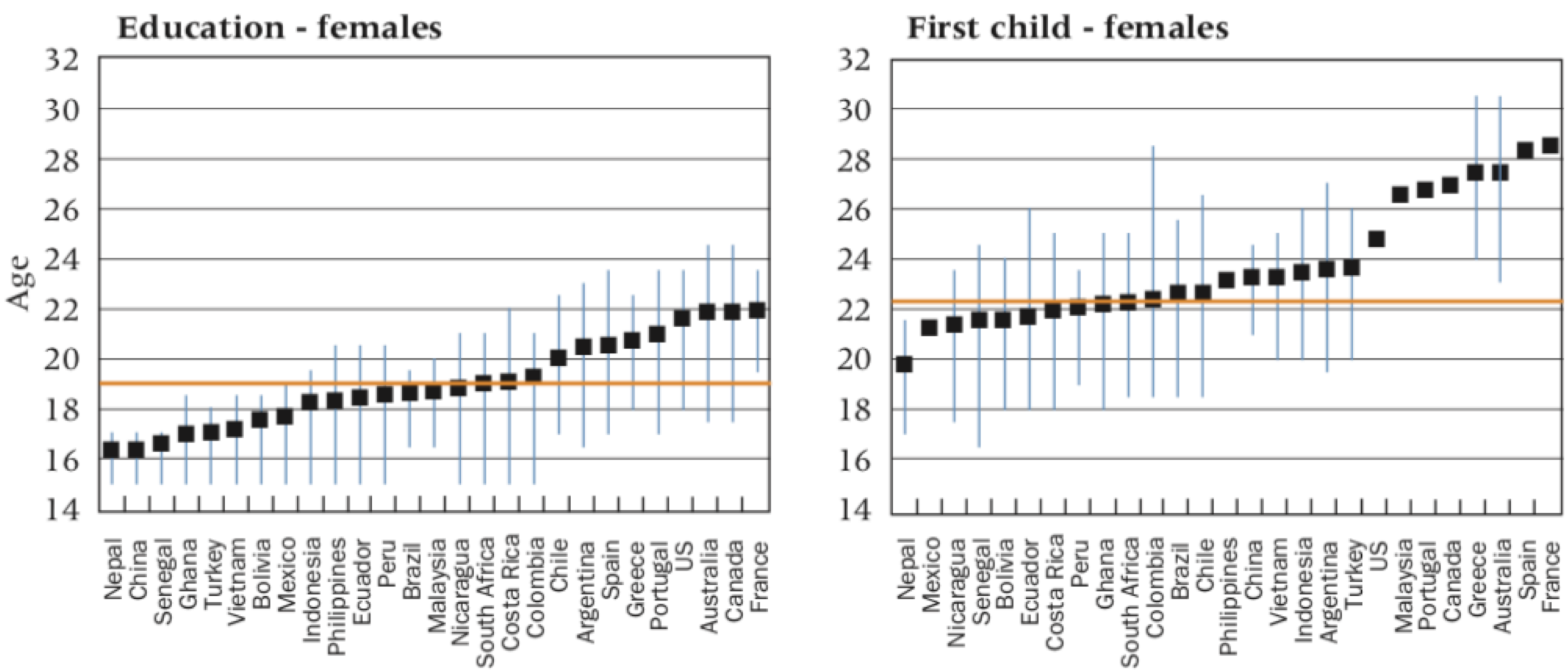
Source: Bernard, Bell, Charles-Edwards 2014, p.223.

Timing and spread of life-course transitions



Source: Bernard, Bell, Charles-Edwards 2014, p.223.

Timing and spread of life-course transitions



Source: Bernard, Bell, Charles-Edwards 2014, p.223.

TABLE 2A Pearson correlation coefficients between life-course timing and age at migration peak by transition and sex

Transition	Male	Female
Education completion	0.52*	0.67*
Labor force entry	0.47**	—
Union formation	0.45**	0.66*
Parenthood	—	0.61*

*Significant at $p \leq 0.01$; ** $p \leq 0.05$.

TABLE 2B Pearson correlation coefficients between life-course spread and intensity at migration peak by transition and sex

Transition	Male	Female
Education completion	0.01	0.34
Labor force entry	0.31	—
Union formation	0.72*	0.76*
Parenthood	—	0.75*

*Significant at $p \leq 0.01$; ** $p \leq 0.05$.

Source: Bernard, Bell, Charles-Edwards 2014, p.227.

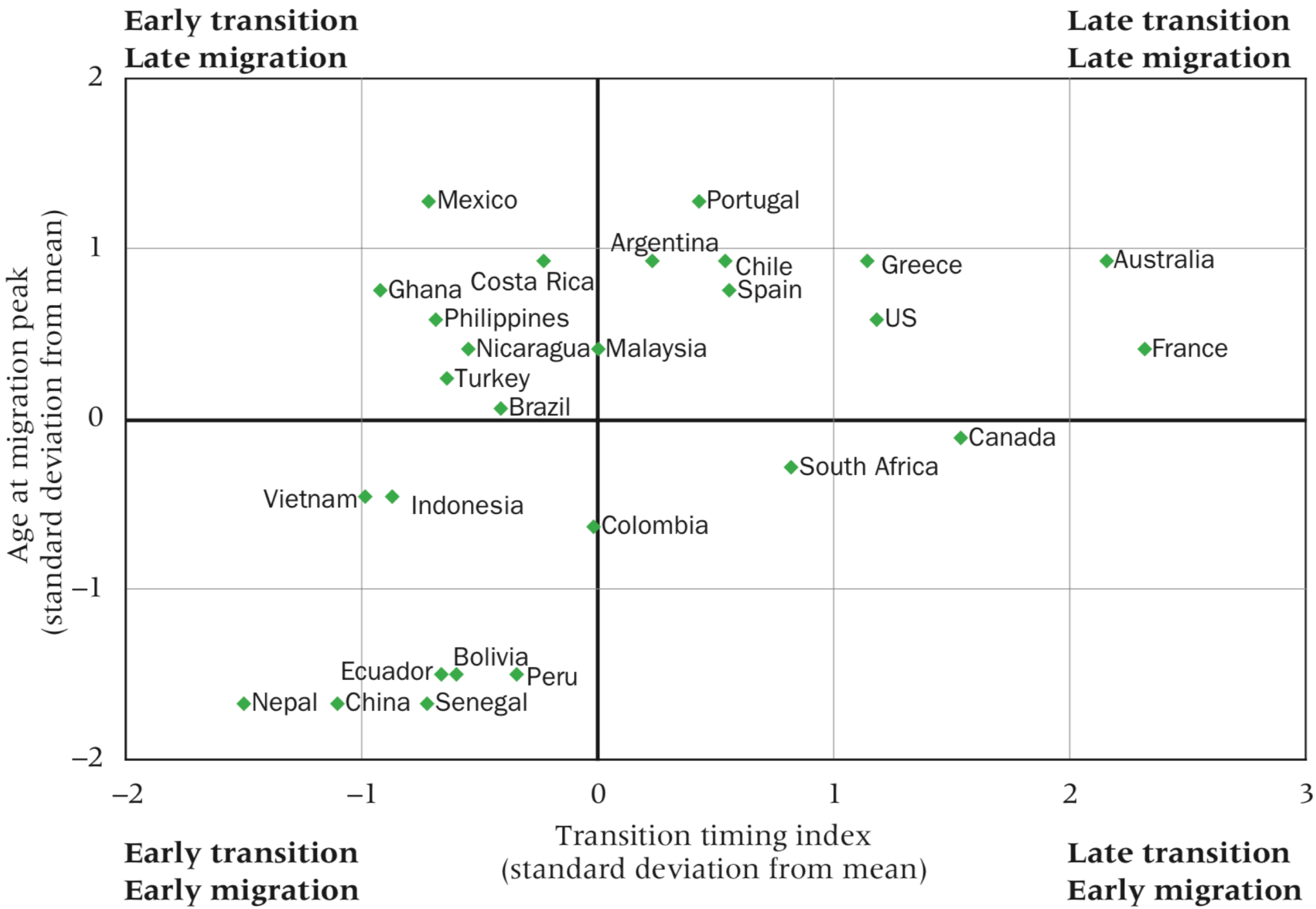
TABLE 3 Factor loading against timing and spread of life-course transitions

	Males		Females	
	Factor 1: Transition timing index	Factor 2: Transition spread index	Factor 1: Transition timing index	Factor 2: Transition spread index
Prevalence				
Higher education	**0.82**	0.14	**0.86**	0.09
Labor force	**–0.54**	**–0.54**	—	—
Union formation	**–0.88**	–0.15	**–0.70**	–0.46
Timing				
Education completion	**0.94**	0.12	**0.94**	0.15
Labor force entry	**0.90**	0.28	—	—
Union formation	**0.85**	–0.16	**0.92**	–0.01
Parenthood	—	—	**0.85**	–0.36
Spread				
Education completion	**0.63**	**0.56**	**0.58**	**0.55**
Labor force entry	0.18	**0.86**	—	—
Union formation	–0.12	**0.76**	–0.10	**0.91**
Share of total variance	0.51	0.23	0.58	0.22

NOTES: Factor loadings of 0.50 and greater and factor loadings of –0.50 and lower are indicated in boldface. An orthogonal rotation was used to ensure that the resulting factors are not correlated (Basilevsky 2008). Two factors were retained based on the Kaiser criterion (eigenvalues greater than one). Prevalence and spread of the transition to parenthood were excluded for females since they are available for only 19 of the 27 countries.

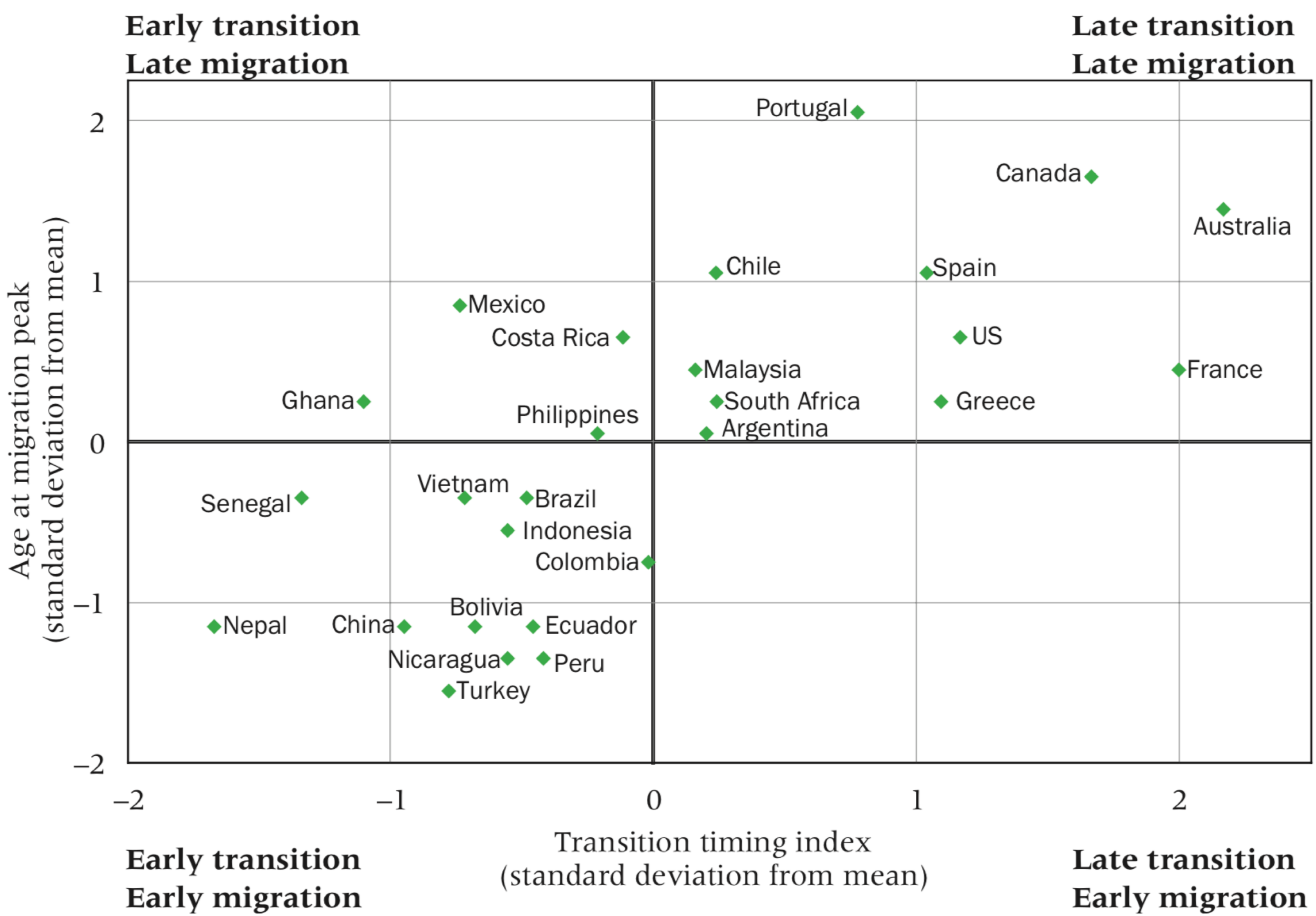
Source: Bernard, Bell, Charles-Edwards 2014, p.228.

FIGURE 5A   Age at migration peak versus transition timing index, males



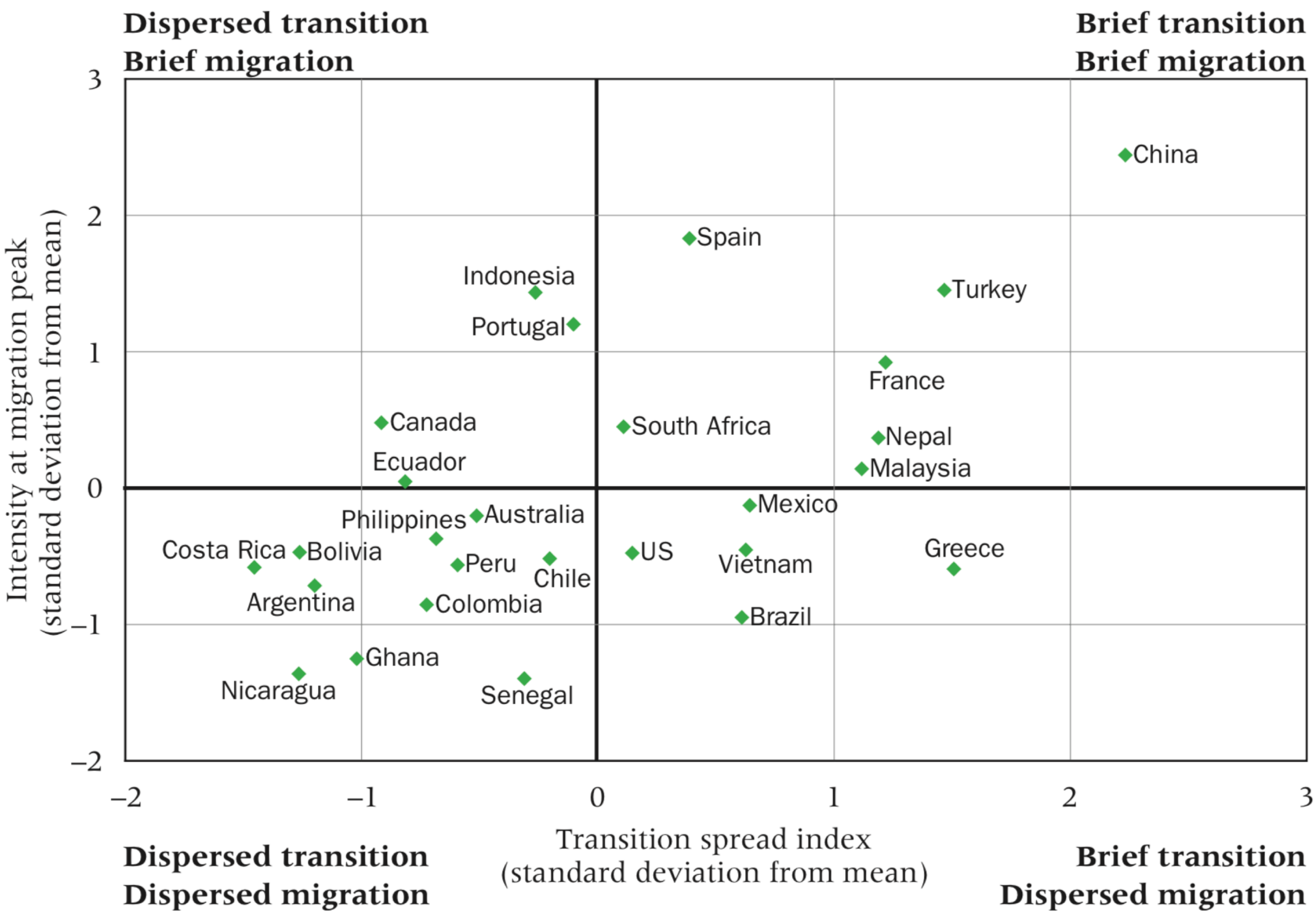
Source: Bernard, Bell, Charles-Edwards 2014, p.230.

FIGURE 5B Age at migration peak versus transition timing index, females



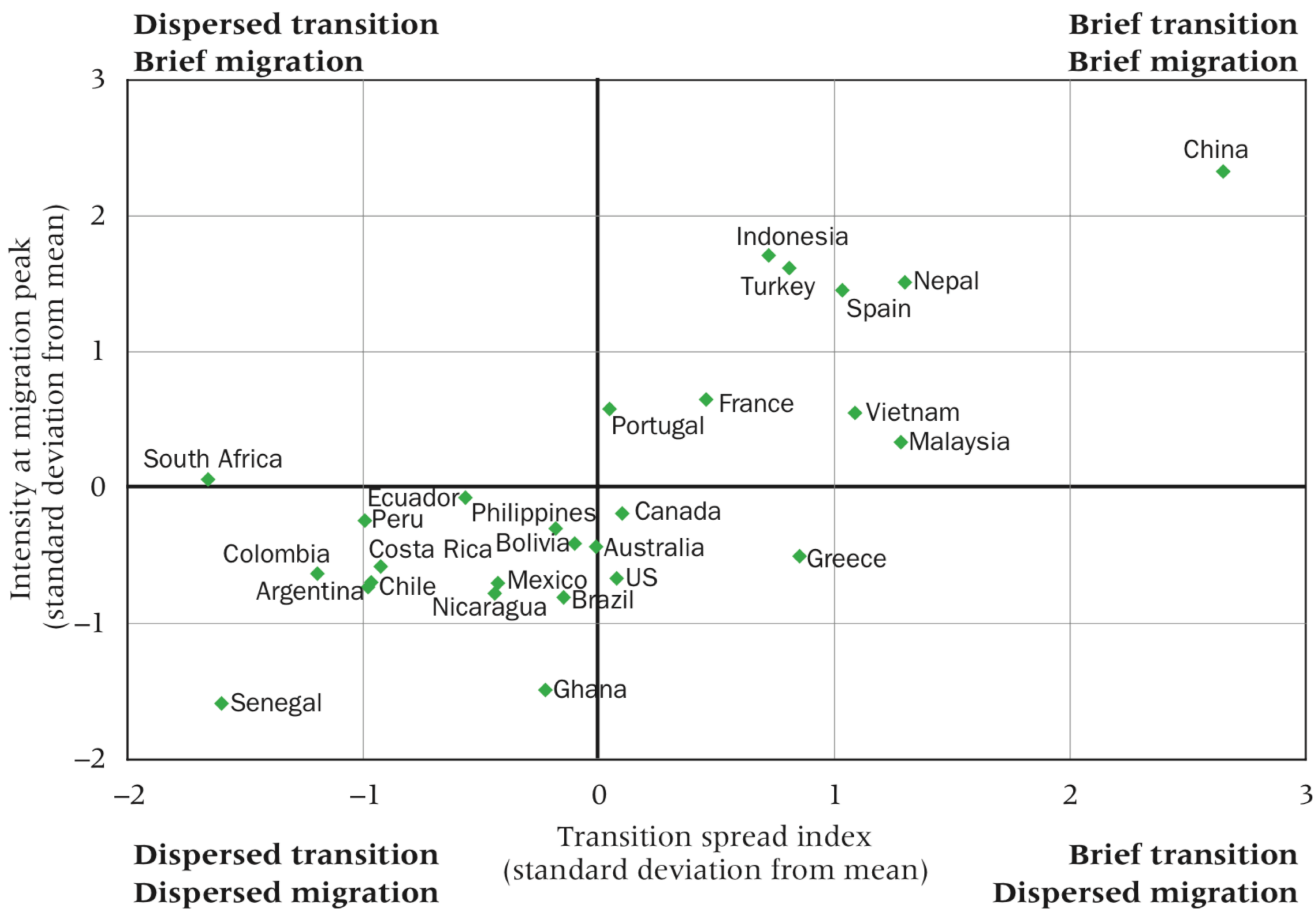
Source: Bernard, Bell, Charles-Edwards 2014, p.230.

FIGURE 6A Migration intensity at peak versus transition spread index, males

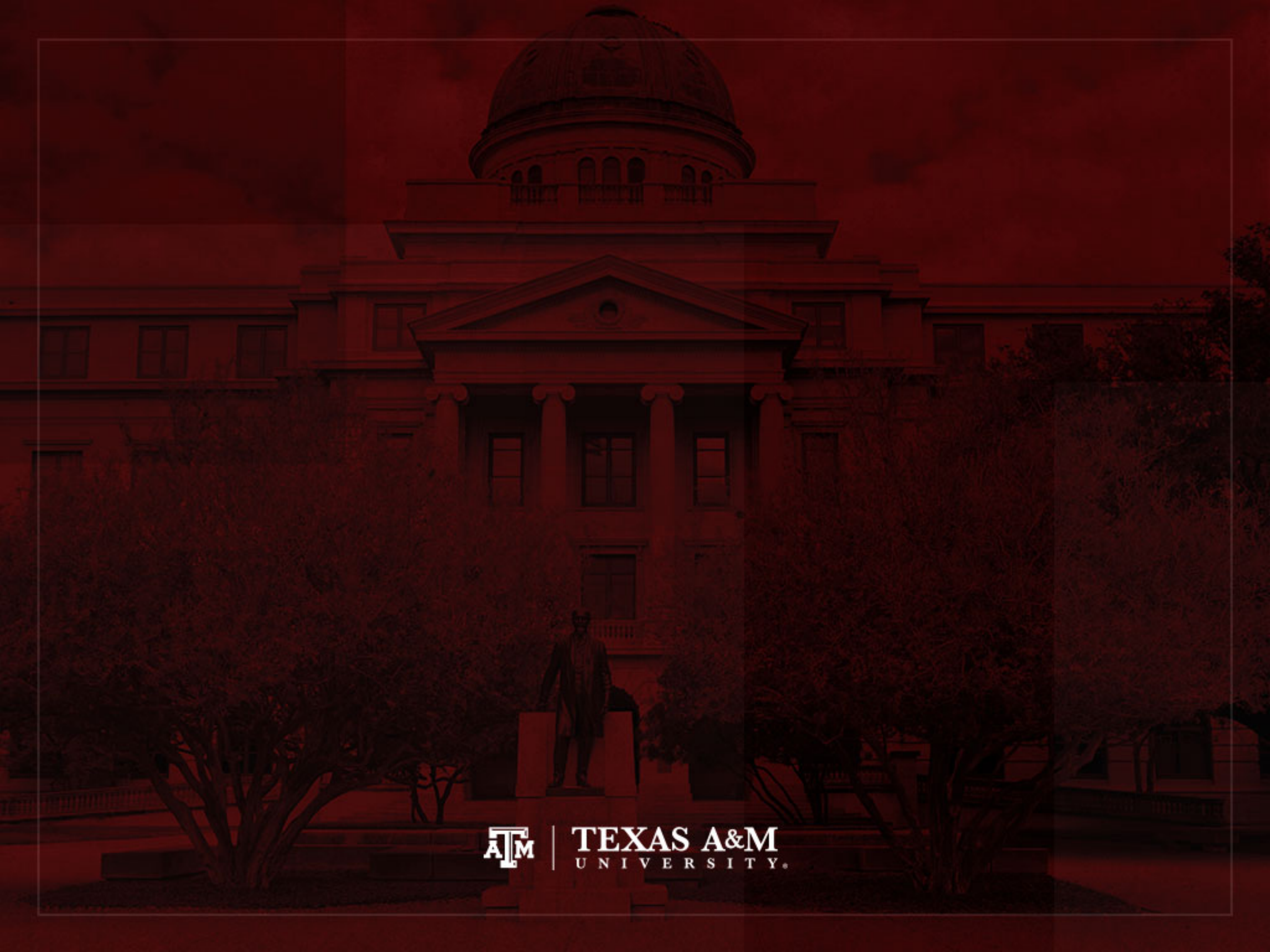


Source: Bernard, Bell, Charles-Edwards 2014, p.231.

FIGURE 6B Migration intensity at peak versus transition spread index, females



Source: Bernard, Bell, Charles-Edwards 2014, p.231.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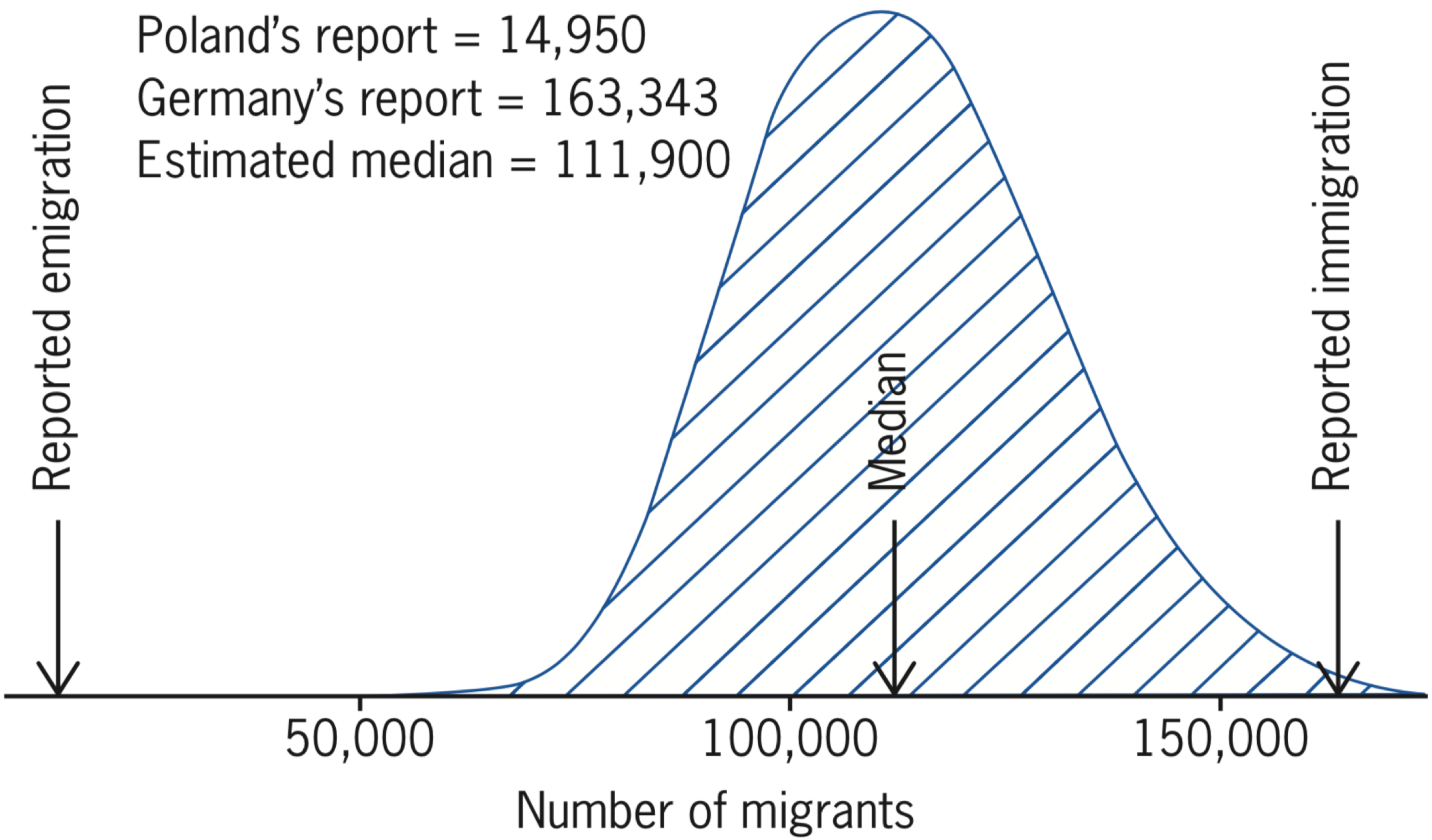
Consistent measures of migration

- Despite long-term efforts by the UN to provide clear guidelines on how to measure migration
  - Very little is known about the actual number of annual migrants throughout the world
  - Countries typically rely on their own definitions of what constitutes a migration
  - The scarce information available is contradictory

Source: Raymer 2017.

Vast difference between reported immigration and emigration data on Polish migrants to Germany, 2006



Source: [1].

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World of Labor

Source: Raymer 2017, p.1.

Key findings: Pros

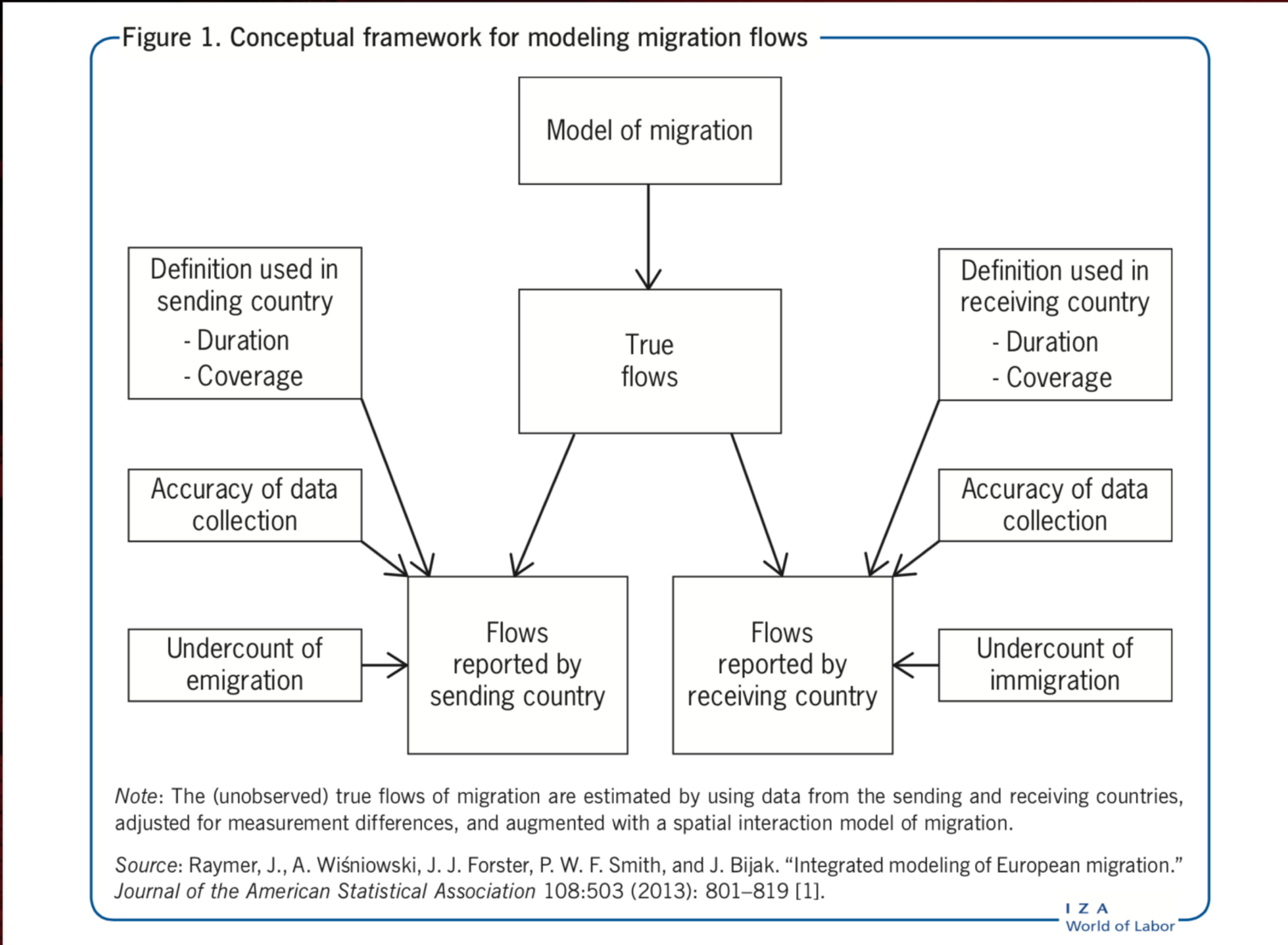
- Migration is important for understanding population and societal changes
- Data on international migration flows are becoming increasingly available, especially in Europe
- Countries can improve their migration flow reports by sharing data with each other
- Statistical modeling can be used to harmonize and estimate missing and conflicting international migration flows
- Measures of uncertainty improve researchers' understanding of the quality of migration data and estimates

Source: Raymer 2017.

Key Findings: Cons

- International migration data are highly inconsistent and incomplete due to different measurements and collection methods
- The effects of incorrect measurement on the levels of migration are poorly understood
- Even the best available data sources likely undercount flows of immigration and emigration
- Most national statistical offices do not share information on cross-border movements
- It is unrealistic to expect countries to change their data collection practices in the next ten years

Source: Raymer 2017.

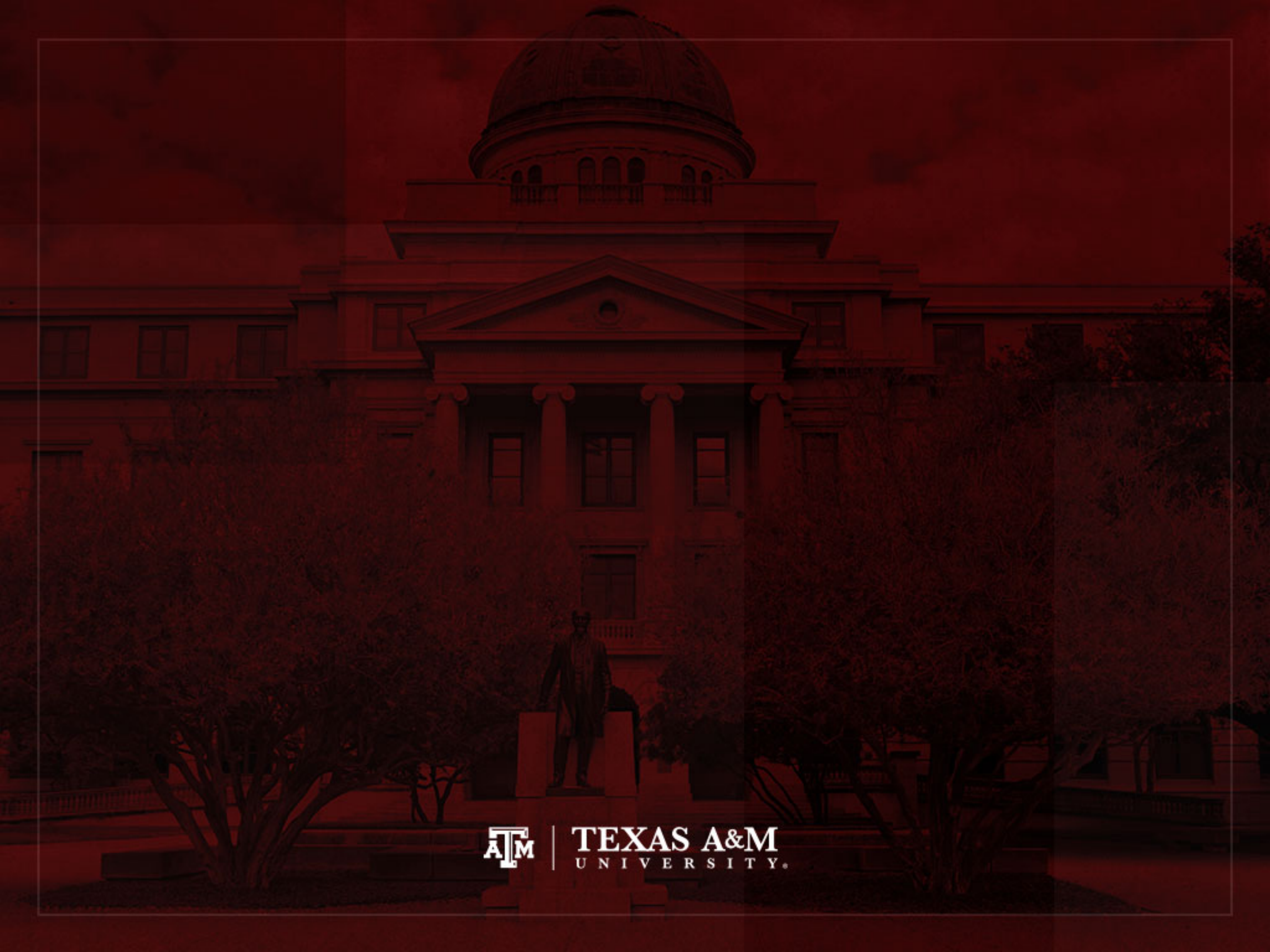


Source: Raymer 2017, p.7.

Benefits of consistent measures

- Improving the available information on global migration patterns would result in numerous and wide-ranging benefits
  - Improved population estimations/projections
  - Clearer picture of why certain migrants choose certain destinations
  - **Emigration:** Governments would know where their populations are moving
  - **Immigration:** Recruit the appropriate types of workers needed in increasingly specialized markets
  - Develop policies for providing effective services for immigrants and emigrants

Source: Raymer 2017.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Data sources

- Sources from the U.S. Census Bureau
  - Migration/geographic mobility (https://www.census.gov/topics/population/migration.html)
  - County-to-county migration flows (https://www.census.gov/topics/population/migration/guidance/county-to-county-migration-flows.html)
  - Census Flows Mapper (https://flowsmapper.geo.census.gov/)
  - TIGER/Line Shapefiles (https://www.census.gov/geo/maps-data/data/tiger-line.html)
  - Demographic Analysis & Population Projection System (DAPPS) Software (https://www.census.gov/data/software/dapps.html)
- Integrated Public Use Microdata Series (IPUMS) (https://www.ipums.org/)
- World Migration Map (http://metrocosm.com/global-migration-map.html)
- Internal Migration Around the GlobE (IMAGE) (https://www.archive.gpem.uq.edu.au/qcpr-image)
- Mexican Migration Project (MMP) (http://mmp.opr.princeton.edu/)
- Mexican Family Life Survey (MxFLS) (http://www.ennvih-mxfls.org/english/index.html)
- UN Population Division (https://esa.un.org/unpd/wpp/)

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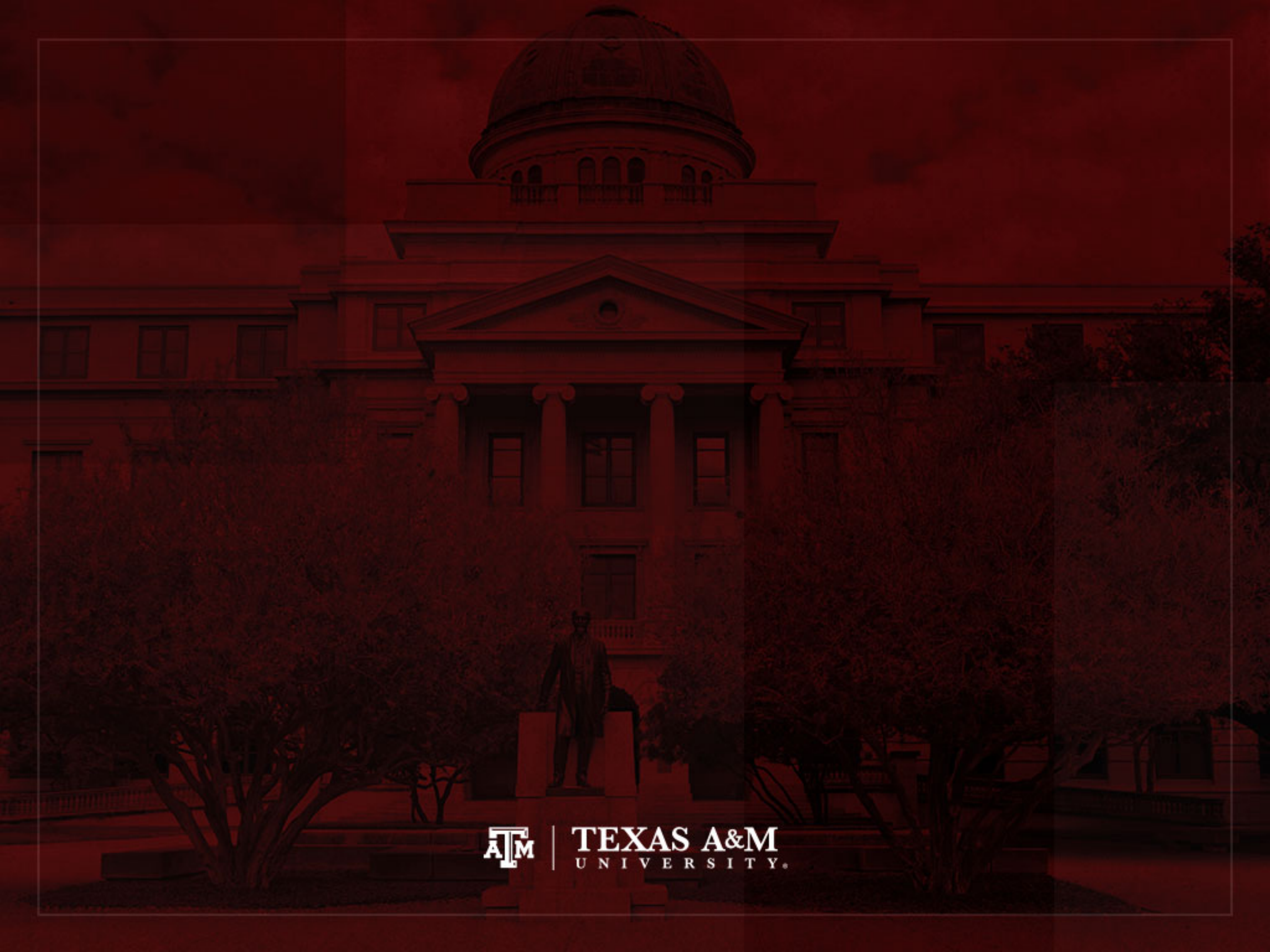
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