Lecture 4:
Cohort fertility

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Cohort fertility

- Generational renewal
- Age-specific fertility
- *ASFRs* and the *NRR*
- Cohort parity
- Natural fertility
- Proximate determinants

Generational renewal

- We have covered mainly the beginning and ending of lifelines on a Lexis diagram
  - The start of life when one is born into a cohort
  - The end of life when one takes one's exit by dying

- On the Lexis diagrams, we have been marking nothing at all along the lifeline, as if nothing happened in between birth and death
  - In between, among other things, comes childbearing

Example of cohort fertility

- Example of a cohort of women, focusing on their daughters

- Sample of 10 women drawn from the 5,994,000 women born into the 5-year birth cohort born between 1930 and 1935 in the United States
  - One of these women died 4 months after birth
  - Another woman died at the age of 30

Fertility in the Lexis diagram

- The remaining eight women survived through to the end of the ages of childbearing
  - Two of them had two daughters each
  - Four of them had a single daughter
  - Two of them had no daughters

- Each of these births is a droplet along the mother's lifeline

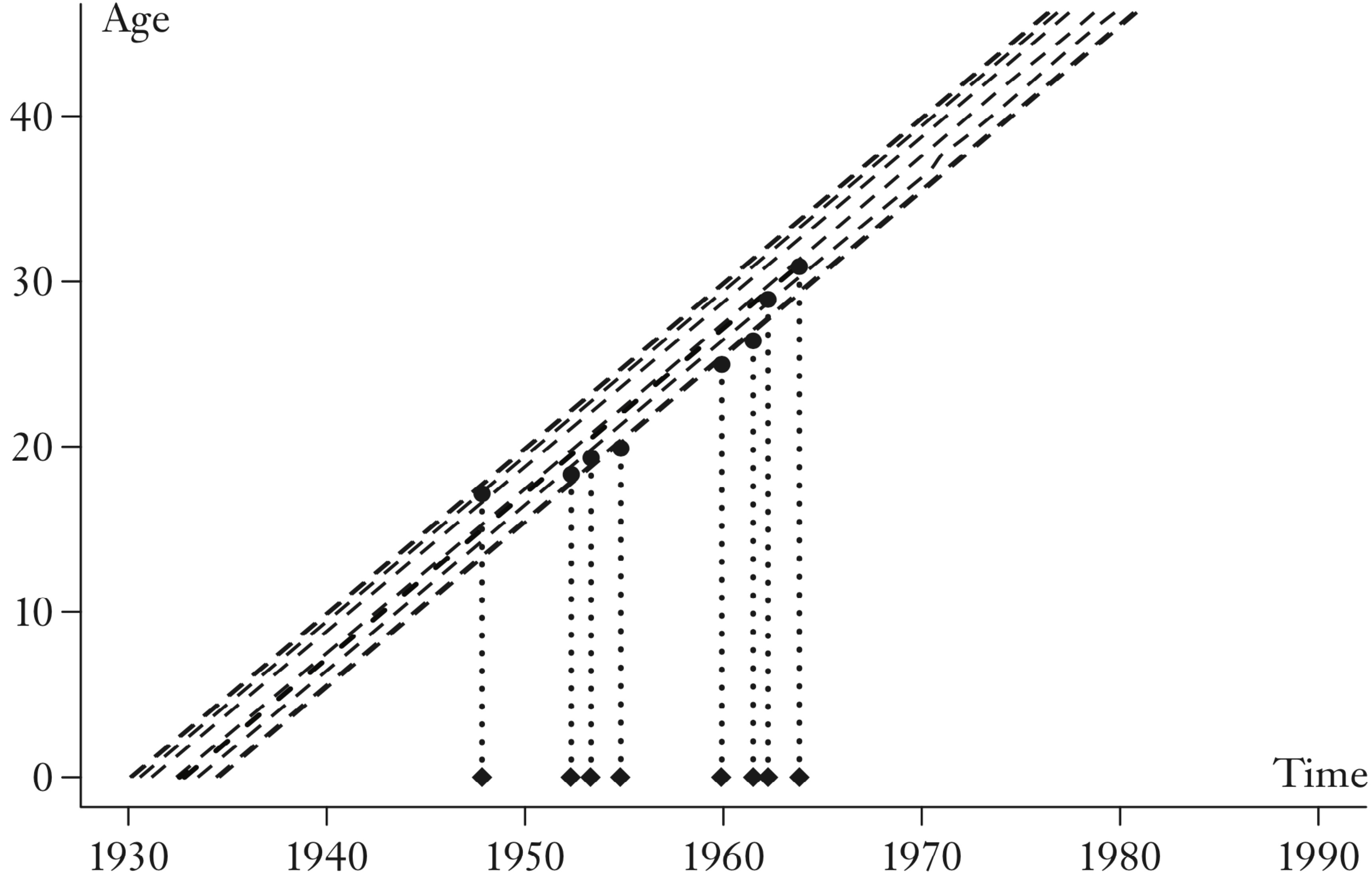


Figure 4.1 Cohort fertility on a Lexis diagram

Process of generational renewal

- The Lexis diagram shows a process of generational renewal
  - First generation: cohort of women
  - Second generation: their daughters
  - Third generation: daughters' daughters
- The ratio of the total number of daughters born by cohort members to the initial number of women in the cohort is a generational replacement ratio
  - This is the ratio of the size of the second generation to the first
  - Net Reproduction Ratio
  - Less precisely but more commonly, Net Reproduction Rate (*NRR*)

Be precise with name

- The name “Net Reproduction Rate” is more common than “Net Reproduction Ratio”
  - But to call the *NRR* a “rate” is a misnomer
  - A rate in demography is a value per unit of time, per year, per month, per decade
- The *NRR* is a pure ratio
  - Daughters divided by mothers
  - Mothers (denominator) do not have a chance to experience the event (move to numerator)
  - *NRR* is not expressed in units of time
- Other names used are “Generational Replacement Ratio” and “Net Reproductive Ratio”

NRR formula

- Historical data usually has numbers of babies rather than numbers of daughters
- We need to convert from babies of both sexes to daughters when we calculate an *NRR*
- The conversion factor is the fraction female at birth (f_{fab})
- Cohort of U.S. women born in 1934
  - They generated the peak of the Baby Boom
  - 1,054,933 women
  - 3,231,638 babies
  - 1,576,094 daughters

$$NRR = \frac{(3{,}231{,}638) * (0.4877)}{1{,}054{,}933} = 1.494$$

$NRR = 1{,}576{,}094 / 1{,}054{,}933 = 1.494$

NRR and population growth

- In a closed population, if cohort after cohort each has a Net Reproduction Ratio greater than 1
  - Then we expect each generation to be larger than the next
  - So, we expect a growing population
- If cohorts have *NRR* values equal to 1 over the course of many generations
  - Then we expect a stationary population
- If cohorts all have *NRR* values less than 1
  - Then we expect a contracting population

NRR calculation

- When totals for cohorts and their babies are available, the calculation of the *NRR* is elementary
  1. Number of babies born by the cohort
  2. Fraction female at birth (f_{fab})
  3. Number of women in the cohort
- We multiply (1) and (2) and divide by (3) to obtain the *NRR*

$$NRR = \frac{(\text{births to women in cohort})(f_{\text{fab}})}{\text{women in cohort}}$$

- In the next example, we see
  - *NRR* rising up to the 1934 cohort of Baby Boom mothers
  - *NRR* falling back below 1 as the Baby Boom gave way to a “Baby Lull”

Table 4.1 Generation sizes and the *NRR*

Cohort	Babies	f_{fab}	Cohort Size	*NRR*
1910	2,665,122	0.4871	1,353,682	0.959
1922	3,579,318	0.4866	1,408,021	1.237
1934	3,231,638	0.4877	1,054,933	1.494
1947	3,788,342	0.4871	1,884,884	0.979

Default value for female birth

- Frequently, the fraction female at birth is not published
  - We need a default value
  - This fraction is generally a little less than one-half

- Current studies suggest that nearly equal numbers of boys and girls are conceived
  - Slightly more male fetuses normally survive to birth
  - The default value adopted is $f_{fab} = 0.4886$
  - But when the true value is known, we always use it

Default fraction and sex ratio

- The advantage of using a special number like 0.4886 for our default rather than a common number (0.5000) is ease of recognition
  - The number 0.4886 occurs nowhere in formulas except as f_{fab}, whereas 0.5000 may occur in formulas for many other reasons
  - 0.4886 was the fraction in America at the time of textbook publication
- Demographers often quote sex ratios on a percentage basis in place of fractions female
  - The sex ratio at birth implied by the default fraction is
  - $100 * (0.5114) / (0.4886) = 104.67$

NRR is an input-output ratio

- **Input:** potential future mothers starting life in a cohort
- **Output:** baby daughters in the next generation
- The essential feature of an input-output ratio is that input must be measured in the same units as output

Same unit for input and output

- Since we are measuring input as a count of females, we need to measure output as a count of females
  - We have women as input, so we need daughters as output, not sons plus daughters
- Furthermore, we have newborn women as input
  - We count the size of the cohort at birth, not at some later age
  - We count newborn daughters as output, not daughters at some later age

Considering mortality

- Mortality comes into the *NRR*, but only once, through the mortality of potential mothers
  - Some members of a cohort die before beginning or completing childbearing
  - Their deaths reduce the eventual total number of daughters and so affect the *NRR*

- *NRR* is a measure of reproduction net of the effects of mortality
  - That is, remaining reproduction after mortality has been taken into account

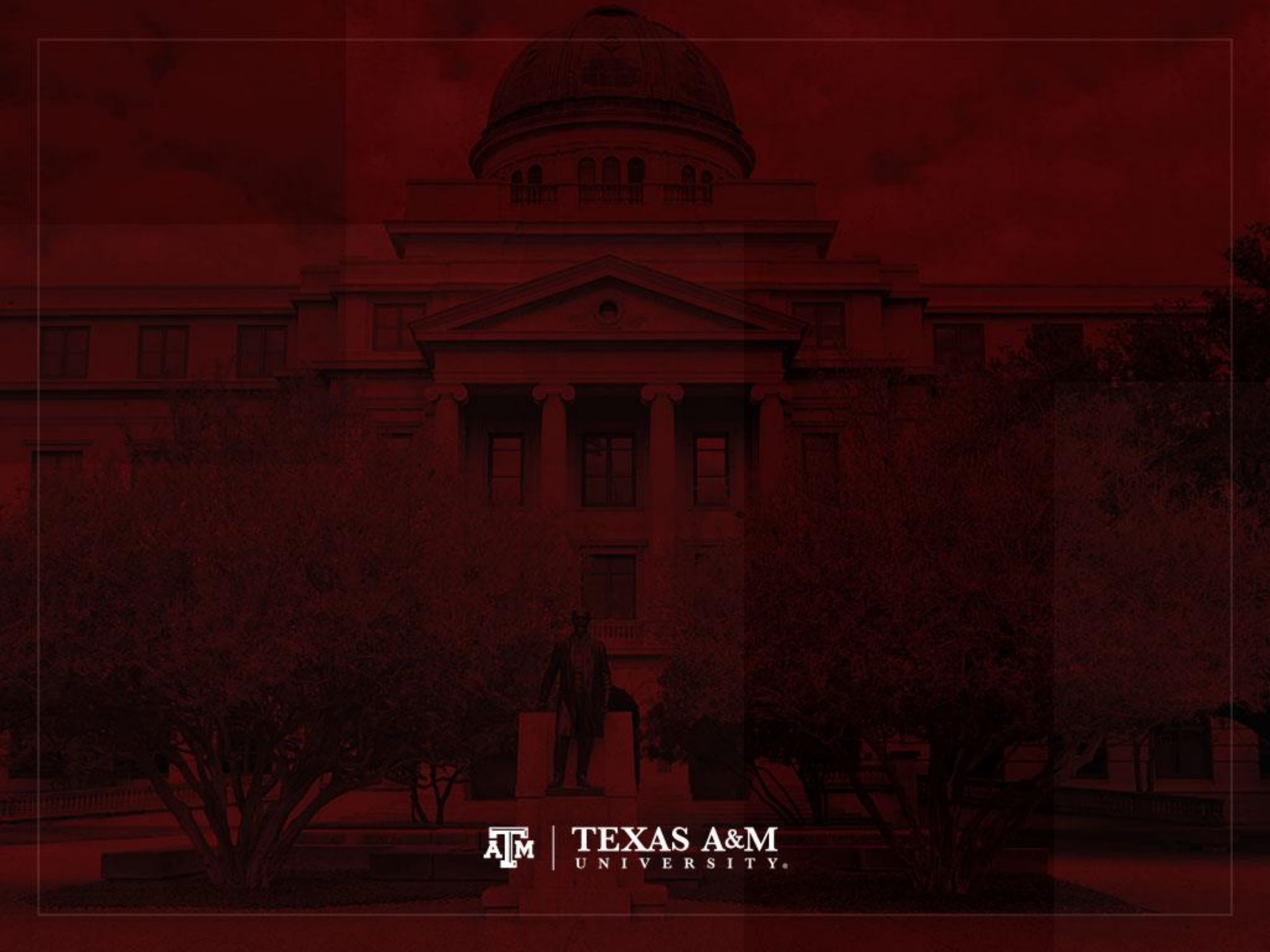
Analogy with income

- Mortality diminishes a cohort’s production of offspring just as taxes diminish a person’s spendable income
- The Net Reproduction Ratio is like a person’s net income after taxes
- There is also a Gross Reproduction Ratio
  - It is like gross, pre-tax income and excludes losses due to mortality (does not consider mortality)

Formal definition of *NRR*

- The Net Reproduction Ratio is the shining measure of demography
  - The word “net” derives from a Latin root meaning “shining”
  - It is one of the most important quantities demographers study

- The Net Reproduction Ratio (*NRR*) is
  - The number of daughters per newborn prospective mother who may or may not survive to and through childbearing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Age-specific fertility

- The presentation of the *NRR* as a ratio of generation sizes (daughters divided by mothers) is easy to understand conceptually

- In practice, however, the common method for calculating the *NRR* makes use of age-specific fertility rates

Age-specific fertility and *CBR*

- Age-specific fertility rate is like a Crude Birth Rate
  - It has babies in the numerator and person-years in the denominator

- But it is different than the Crude Birth Rate
  - The babies are only the babies born to women in a particular age range
  - The person-years are only person-years lived by the women within that age range

Restrictions on person-years

- There are two restrictions on the person-years
- They have to be lived within the particular range of ages
- They have to be lived by women, not (as with the Crude Birth Rate) by men and women

Cohort age-specific fertility rate

- We take an age interval from x to $x+n$
- For a cohort age-specific fertility rate (${}_nf_x$)
  - We divide babies of both sexes born to women in the cohort while the women are between ages x and $x+n$
  - By the cohort person-years lived by women in the cohort between those ages

Formal definition of *ASFR*

- The abbreviation "*ASFR*" stands for age-specific fertility rate

- The cohort age-specific fertility rate (*ASFR*) ${}_nf_x$ is the number of children born by women in the cohort between ages x and $x+n$ per person-year lived by women in the cohort between ages x and $x+n$

Period age-specific fertility rate

- For a period age-specific fertility rate (${}_nF_x$)
  - We divide babies born to women aged *x* to *x*+*n* in the period
  - By the period-person-years lived by women between those ages

Age groups for *ASFR*

- Births rates of women according to their ages

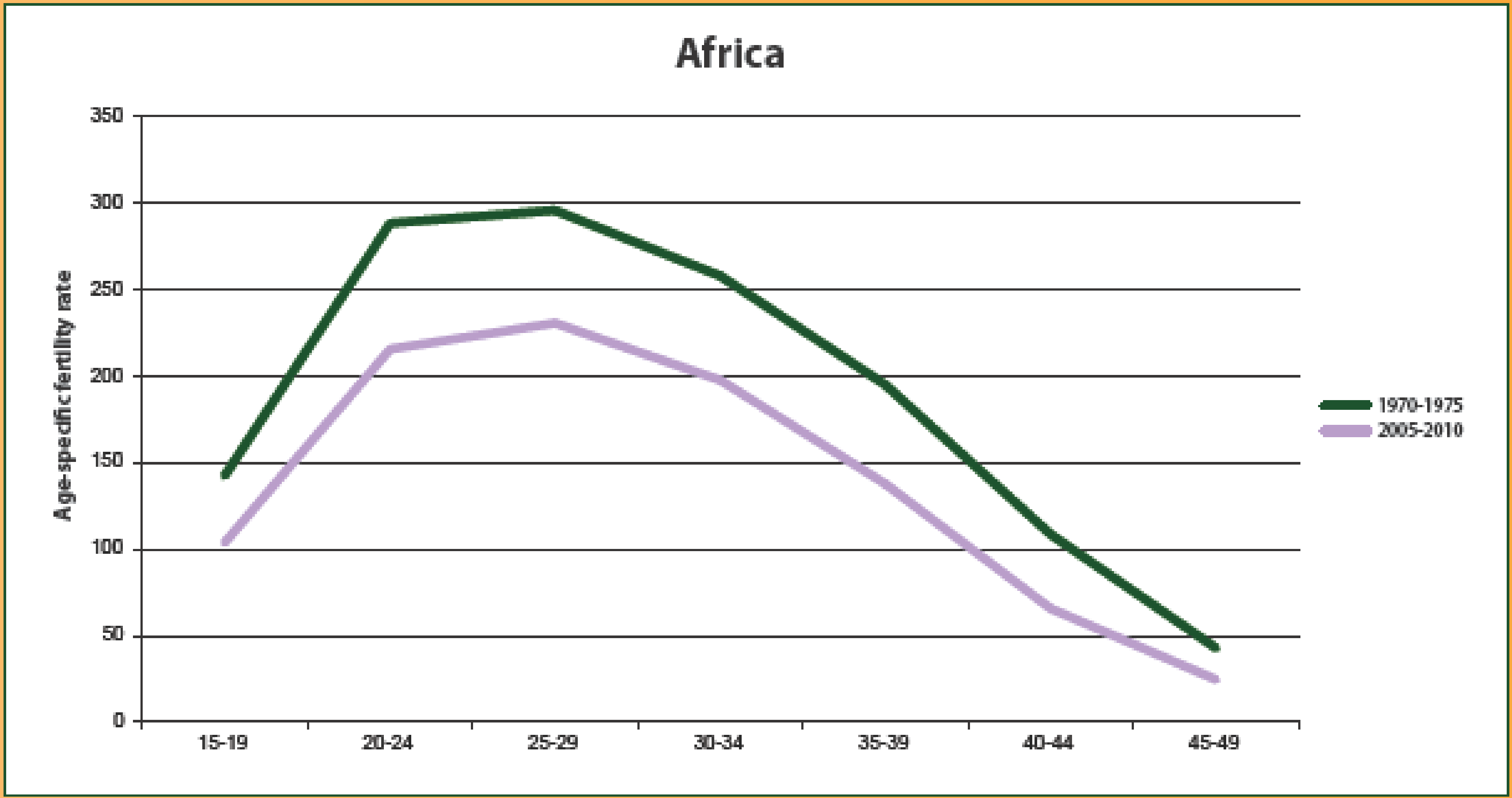
- Usually calculated for women in each of the seven 5-year age groups
  - 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49
  - Sometimes 35 single-year age groups are used
  - ${}_nASFR_x$ means *ASFR* for age group x to $x+n$

$${}_nASFR_x = {}_n\text{births}_x \,/\, {}_n\text{females}_x * 1{,}000$$

- Age curve of fertility: the seven plotted *ASFRs* usually have an inverted U shape

ASFR

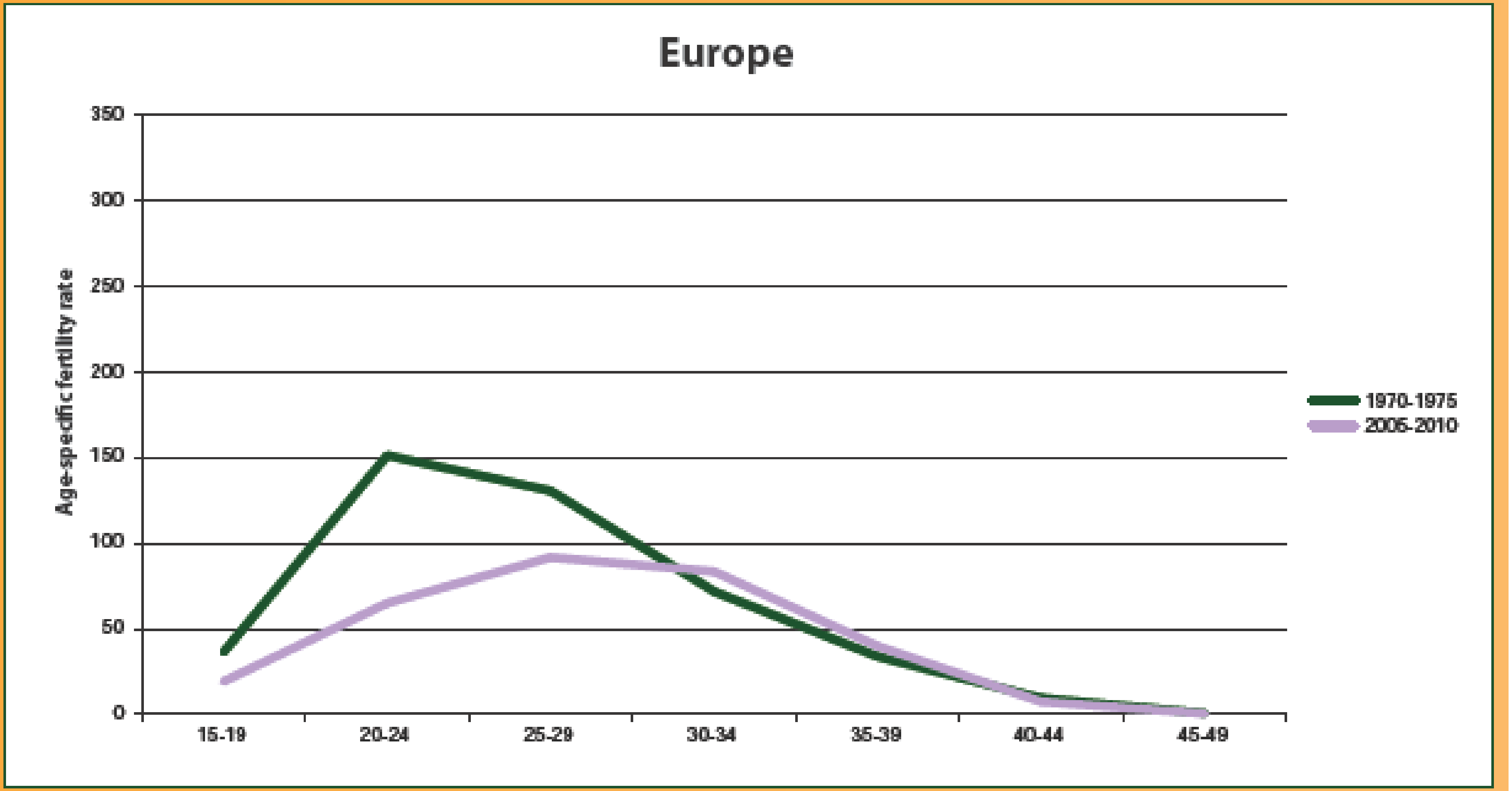
Age-specific Fertility Rates, Africa, 1970-75 and 2005-10



Source: United Nations, 2014a.

ASFR

Age-specific Fertility Rates, Europe, 1970-75 and 2005-10



Source: United Nations, 2014a.

Rates, not probabilities

- Age-specific fertility rates are rates, not probabilities
  - They have units of 1/time
- Babies are persons
  - So the babies in the numerator cancel the persons part of the person-years in the denominator, leaving 1/years
- Doubling the width of the age interval
  - It would increase both the numerator and the denominator and would not drastically change the rate

Analogy with mortality

- An age-specific fertility rate ${}_nf_x$ is the counterpart for fertility of the age-specific mortality rate ${}_nm_x$ in the lifetable
- ${}_nm_x$ has the same denominator but a numerator with deaths in place of births

Focus on female fertility

- It is usual to concentrate on age-specific fertility rates for women
  - Women's age is a more obvious determinant of fertility
- We can count births by age of father and divide by person-years-lived by men in the age interval
  - Such male *ASFRs* are rarely used
  - Ages of fatherhood are less narrowly restricted biologically and socially
  - Data on fathers' ages are rarely tabulated

Note on female fertility

- “Female” *ASFRs* pertain to female parents, but to both male and female babies
  - Sons and daughters enter into the numerator
  - Person-years for mothers into the denominator
- If the numerator is further restricted to daughters
  - The resulting rate should be labeled as a “daughters-only” *ASFR* (${}_nf_x^{\text{daughters}}$)
  - Or by multiplying ${}_nf_x$ by the fraction female at birth

Restrictions sometimes not clear

- Mathematical demographers often work with daughters-only rates

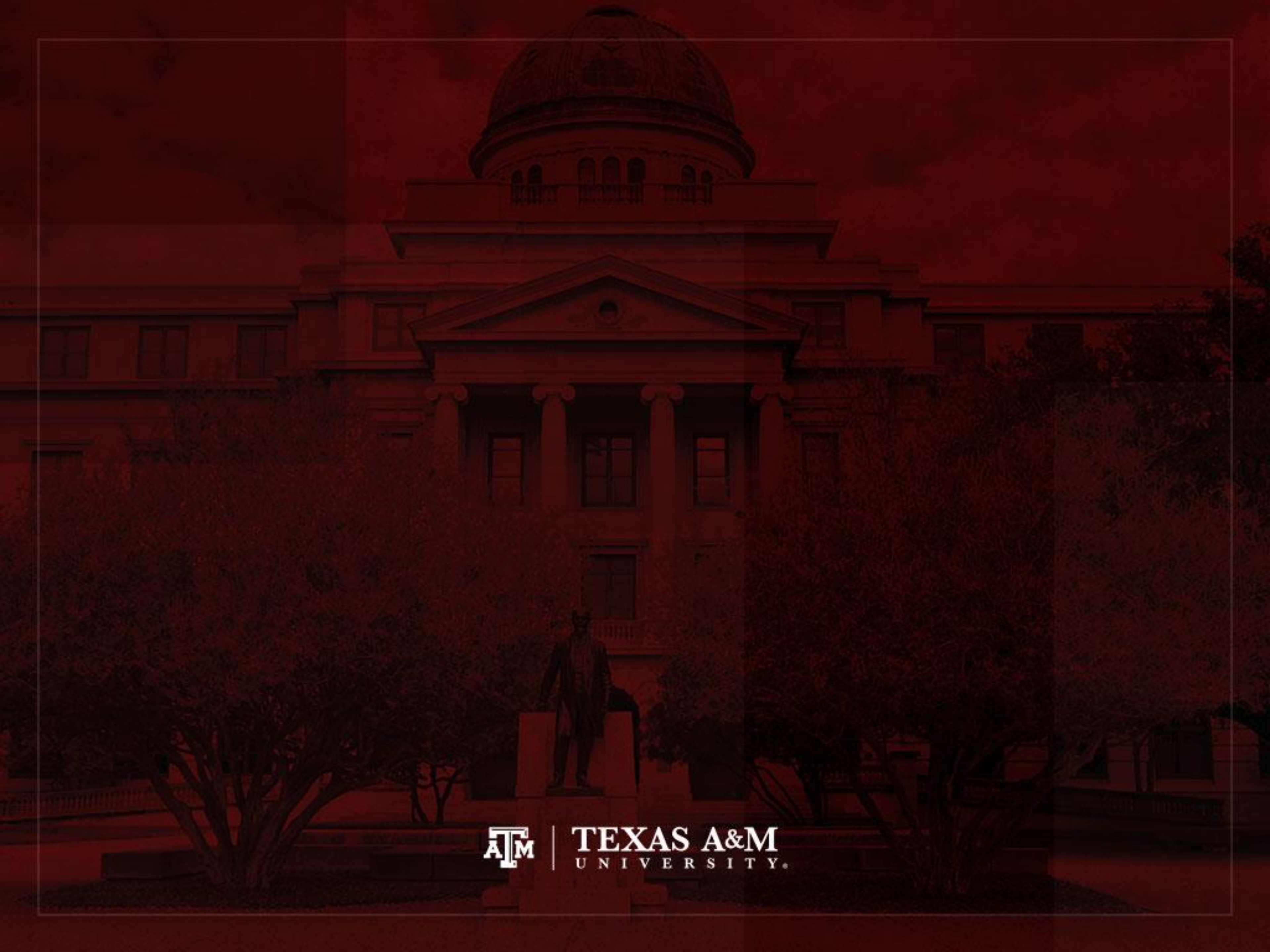
- Sometimes this restriction is mentioned in the text but omitted from the notation

Differentiating rates

$$Birth\,rates = \frac{Daughters + Sons}{Women + Men}$$

$$Fertility\,rates = \frac{Daughters + Sons}{Women}$$

$$Reproduction\,rates = \frac{Daughters}{Women}$$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ASFRs and the *NRR*

- A Net Reproduction Ratio is most often calculated from a table of age-specific fertility rates

- Later, we will be able to calculate this ratio from period-based rates, as we do now with cohort-based rates

Steps to estimate *NRR*

- ${}_nf_x$ has babies divided by person-years
  - We need to multiply back by person-years to recover a count of babies
  - These are person-years lived by the female members of the cohort
  - We get them from the ${}_nL_x$ column of the female cohort lifetable

$$ {}_nf_x * {}_nL_x $$

Age-based formula for the *NRR*

- Need to add them up over all ages of childbearing
  - Σ (sigma) means add up over all the age intervals with different starting ages *x*
- Need to convert from babies to daughters
  - Multiply by f_{fab}
- Divide by the initial cohort size (l_0)

$$NRR = \sum {}_n f_x \, {}_n L_x \; f_{fab} / \ell_0$$

Example of *NRR* calculation

- Sample of 1,000 U.S. women randomly selected from the cohort born in 1934 (Table 4.2)
- Obtain the number of babies
  - Multiply the age-specific fertility rates (${}_nf_x$)
  - By the lifetable person-years lived (${}_nL_x$) (radix of 1,000)
- The sum of the column for babies is 3,063
- Multiply the sum by the fraction $f_{\text{fab}} = 0.4877$
- Divide by the radix

$$NRR = 3{,}063 * 0.4877 / 1{,}000 = 1.494$$

Table 4.2 A cohort *NRR* from U.S. age-specific rates

x	${}_5f_x$	${}_5L_x$	Babies
0	0	4770	0
5	0	4726	0
10	0	4712	0
15	0.0811	4698	381
20	0.2384	4681	1116
25	0.1969	4662	918
30	0.1033	4637	479
35	0.0313	4604	144
40	0.0046	4561	21
45	0.0009	4503	4
			3,063

Two other measures of fertility

- Total Fertility Rate (*TFR*)
- Gross Reproduction Ratio (*GRR*)
  - They are usually calculated from period rather than cohort data
  - However, the concepts of the *TFR* and *GRR* are cohort concepts, just like the concept of the *NRR*
  - They are measures of fertility rather than generational renewal
- *TFR* and *GRR* exclude the effects of mortality
  - They indicate how many babies or daughters a cohort would produce in the absence of mortality

TFR and *GRR* formulas

- In the absence of mortality, each member of a cohort would live *n* person-years in the interval from *x* to *x*+*n*
  - Replace ${}_nL_x / l_0$ by *n*
- If we keep babies of both sexes, we get the *TFR*

$$TFR = \sum ({}_n f_x)(n)$$

- If we restrict to daughters by multiplying by the fraction female at birth (f_{fab}), we get the *GRR*

$$GRR = \sum ({}_n f_x)(n)(f_{\text{fab}})$$

Same *n* for all age intervals

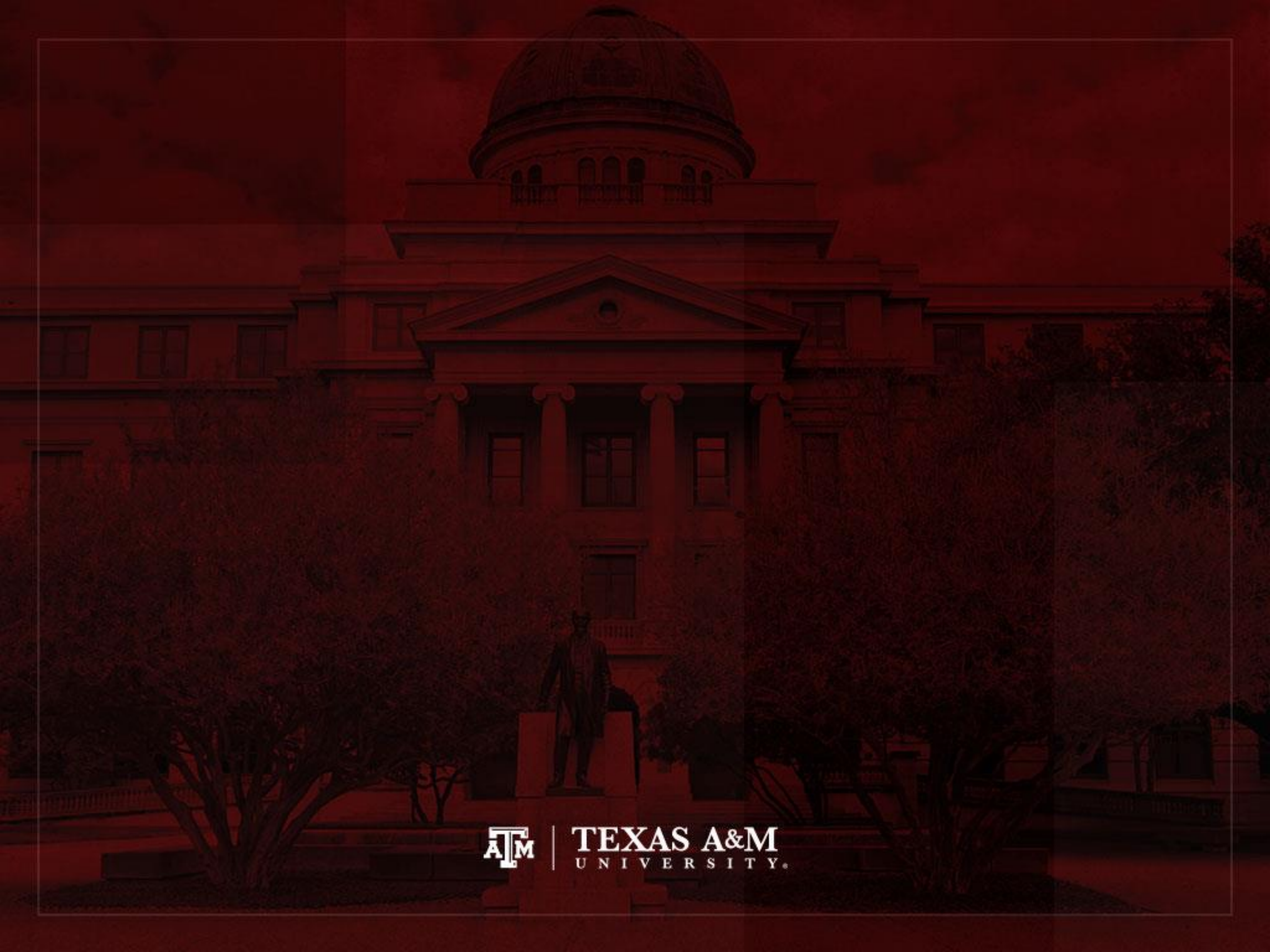
- When all the age intervals in a data table have the same width *n*

- We can add up the $_nf_x$ column and multiply by *n* at the end to obtain the *TFR* (Table 4.2)
  - $TFR = \Sigma(_nf_x) * n = 0.6565 * 5 = 3.283$

- We multiply by f_{fab} to obtain the *GRR* (Table 4.2)
  - $GRR = \Sigma(_nf_x) * n * f_{fab} = 0.6565 * 5 * 0.4877 = 1.601$

Some notes about *TFR*

- *TFR* is not the same as expected total of children for women who do live through childbearing ages
- Women who survive to 50 might not be a typical subset of all women
  - They might have had lower fertility in their twenties than women with poorer prospects for survival
- When we compute a *TFR*, we use the fertility for
  - All women in their twenties
  - Those who will and will not survive to older ages
  - Every age group



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Cohort parity

- The discussed age-specific rates track childbearing across the lifecourse
  - As women in a cohort reach the end of their years of childbearing, we can estimate completed cohort fertility
- Data can come as distribution of children ever born
  - This allows a third way to calculate the *NRR*
  - The leading use for measures based on parity is the study of fertility limitation across history and around the world

Parity term

- Number of live births that a women has had is known as her parity
- “Parturition” means childbirth
- “Post partum” means “after childbirth”
- A woman is “nulliparous” when she has never had children

$w(j)$

- $w(j)$ is the count (tally) of women in a cohort who have parity j
- Parities are measured after all members of the cohort have completed childbearing
  - $w(0)$ cohort members have born no children
  - $w(1)$ have born one child
  - $w(2)$ have born two children

Estimate *NRR* with *w*(*j*)

- If we are given a tally of women by parity for a cohort, we can find the *NRR* by the following formula

$$NRR = \frac{(0 * w(0) + 1 * w(1) + 2 * w(2) + 3 * w(3) \ldots)(f_{\text{fab}})}{w(0) + w(1) + w(2) + w(3) \ldots}$$

  - Each woman at parity 1 contributes one child
  - Each woman at parity 2 contributes two children...
- Multiply by f_{fab} to convert from children to daughters and divide by initial cohort size

Example: *NRR* with cohort parity

- Completed parity for a sample of 1,000 women from the U.S. cohort born in 1934
  - $f_{fab} = 0.4877$

Table 4.3 Completed parity for U.S. women born in 1934

j	0	1	2	3	4	5	6	7	8	9	10
$w(j)$	76	97	233	241	166	90	47	30	12	5	3

$$NRR = (0*w(0) + ... + 10*w10)\ (f_{fab})\ /\ w(0) + ... + w(10)$$

$$NRR = (0*76 + 1*97 + 2*233 + ... + 10*3) * (0.4877) / 1{,}000$$

$$NRR = 1.494$$

Parity Progression Ratio: $PPR(j)$

- $PPR(j)$: fraction of women in a cohort who, having reached parity j, go on to have another baby
  - They reach at least parity $j + 1$
  - End at some parity greater than j
- If $w(j)$ women are ending up at parity j
  - $w(j) + w(j+1) + w(j+2)$... women reached at least parity j, ending up at parity j or more
  - $w(j+1) + w(j+2)$... of these women went on at least to parity $j+1$

Formula for *PPR*(*j*)

- The fraction progressing from *j* to *j*+1 is the ratio *PPR*(*j*) given by

$$PPR(j) = \frac{w(j+1) + w(j+2) + \ldots}{w(j) + w(j+1) + w(j+2) \ldots} = \sum_{j+1}^{\infty} w(i) / \sum_{j}^{\infty} w(i)$$

  - *PPR* is always labeled by the starting parity
  - In sigma notation, the starting index is written below the sigma symbol and the ending index above it
  - These sums go up to the highest parity observed, above which *w*(*i*)=0

Example: *PPR*(*j*)

Table 4.3 Completed parity for U.S. women born in 1934

j	0	1	2	3	4	5	6	7	8	9	10
$w(j)$	76	97	233	241	166	90	47	30	12	5	3

- *PPR*(0) = 924 / 1,000 = 0.924
  - All 1,000 women reach at least parity 0
  - 1,000 – 76 = 924 reach at least parity 1
  - This is the ratio that goes from 0 to 1
- *PPR*(1) = (924–97)/924 = 827/924 = 0.895
- *PPR*(2) = (827–233)/827 = 594/827 = 0.718

Data specificities

- Data in Table 4.3
  - Obtained by following girls born in 1934 as they grow, die or survive, and have children
  - This data considers cohort mortality
  - So, we compute cohort *NRR*
- Other data might inform number of children ever born from women who have survived to a specific age (such as 50)
  - Mean completed parity for these surviving women would estimate cohort *TFR*
  - Multiplying by f_{fab} would estimate cohort *GRR* (not *NRR*)

Example: *PPR*(*j*), survivors data

- Parity for 50-year-old Dutch women in 2009
  - Survivors of the 1-year birth cohort from 1959

Table 4.4 Dutch women age 50 by parity, 2009

j:	0	1	2	3	4	5	6+
$w(j)$:	22,275	15,151	49,972	22,897	6,378	1,690	1,207
$j+$:	119,570	97,295	82,144	32,172	9,275	2,897	1,207
$PPR(j)$:	0.814	0.844	0.392	0.288	0.312	0.417	

Source: Human Fertility Database (HFD) (May 2013).

  - We know that *w*(6+)=1,207 and *w*(5)=1,690
    - Add up from the right to find the row for *j*+
    - 5+ women = 1,207 + 1,690 = 2,897
  - *PPR*(5) = 1,207 / 2,897 = 0.417
  - *PPR*(0) = 97,295 / 119,570 = 0.814

Trends of *PPR*(*j*)

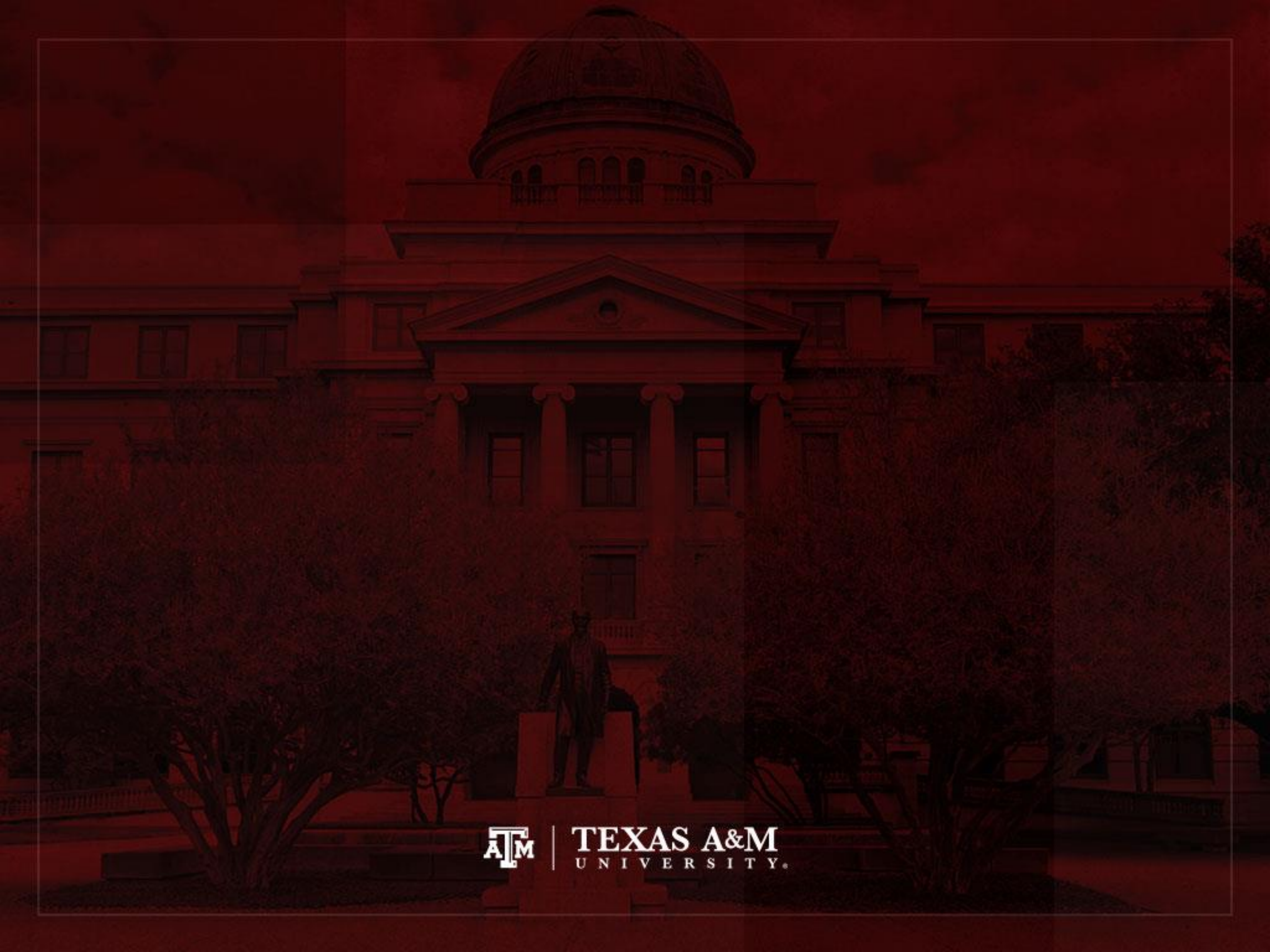
- In the example, PPR drops abruptly after *PPR*(1)
  - Many couples want no more than two children
- *PPR* increases at higher parities
  - Subset of women and spouses who want large families
  - Parities 5+ or 6+ are largely represented by them
- Some European countries are known for lowest-low fertility far below replacement levels
  - Whether fertility in these societies will rebound is a subject for lively debate

PPR for Malawi

- 2004 Demographic and Health Survey (DHS)
  - 770 women aged 45 to 50 interviewed
  - *PPR*(0) = 0.978
  - *PPR*(1) = 0.976
  - *PPR*(2) = 0.940
  - *PPR*(9) > 0.600
  - *PPR*(11+) ≈ 0.300
- Sustained high *PPR* constitute evidence that family limitation practices are not widespread

Estimate *w*(*j*), based on *PPR*

- Example of Malawi: 770 women
  - Women who reach at least parity 1
    - Women 1+ = 770 * *PPR*(0) = 770 * 0.978 = 753
  - Women at parity 0
    - *w*(0) = 770 – 753 = 17
  - Women who reach at least parity 2
    - Women 2+ = 753 * *PPR*(1) = 753 * 0.976 = 735
  - Women at parity 1
    - *w*(1) = 753 – 735 = 18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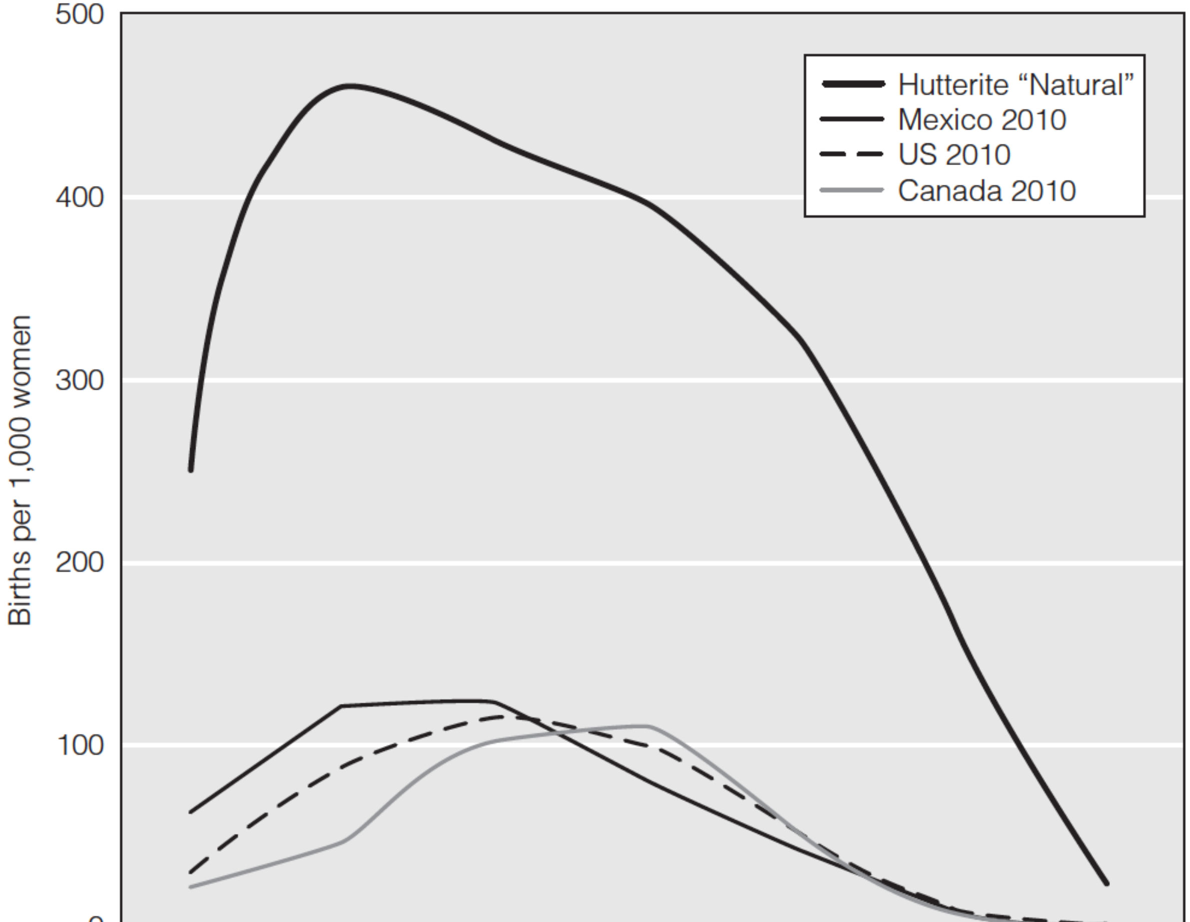
Natural fertility

- Natural fertility (Henry 1961, Coale and Trussell 1974)
  - Level of reproduction in the absence of deliberate fertility control
  - Closer to 6 or 7 live births per woman
  - 25% of completed fertility is due to genetics (same as mortality)
- Hutterites had 11 children per woman (1930s)
  - Ethnoreligious group formed in the early 16th century
  - Early age at marriage, good diet, good medical care, regularly engage in intercourse without contraception or abortion
  - Nowadays, almost all live in South Dakota, North Dakota, Montana, and Western Canada

Source: Weeks, 2015.

Age-specific fertility rates



		15–19	20–24	25–29	30–34	35–39	40–44	45–49	TFR
1930	Hutterite "Natural"	250	460	431	396	321	167	24	11.0
	Mexico 2010	63	121	123	80	42	9	2	2.2
	US 2010	31	88	115	99	50	10	1	2.0
	Canada 2010	15	47	102	110	51	8	0	1.7

Source: Weeks, 2015.

Conscious fertility limitation

- Demographers have devoted sustained attention to develop measures to track fertility decline and conscious fertility limitation
  - Modern study of fertility limitation began with Louis Henry at the Institut National d’Études Démographiques (INED) in Paris
  - Extended by Peter Laslett, Anthony Wrigley, Rogers Schofield in the Cambridge Group for the History of Population and Social Structure in England
  - Continued at the Office for Population Research at Princeton University under Ansley Coale

Louis Henry

- To understand the onset of fertility limitation in a society, it was paramount to describe the pattern of fertility before these practices started
  - Conscious, intentional fertility limitation
  - Family planning
- Analyze data to distinguish between absence and presence of practices by which couples
  - Attempt to stop childbearing
  - After desired family-size targets have been achieved

Signs of fertility limitation

- Data on couples' intentions do not exist to any extent for previous centuries
  - Henry looked for signs that would appear in existing fertility data to indicate conscious family limitation
    - He focused on parity
    - Parity-specific control: when further childbearing is made to depend on the number of previous children
  - Leading signs of parity-specific control
    - Drop in Parity Progression Ratios at some parity
    - Whether age-specific fertility rates differ according to women's parities

Natural fertility and PPR

- Natural fertility is the fertility in the absence of parity-specific control
- Parity-specific control can be inferred from
  - Parity Progression Ratios (PPR)
  - Fertility rates specific to parity and age
- We can use this information to measure whether fertility is "natural fertility" in Henry's sense

Numerator and denominator

- Each combination of age and parity specifies a group of women and an interval
  - e.g., women at parity 3 between ages 30 and 35
  - Numerator: births at parity 3 before age 35
    - Births at parity 3 move women to parity 4
  - Denominator: person-years lived at parity 3 between ages 30 and 35
- For marital fertility rate
  - Numerator only includes births to married women
  - Denominator only includes years lived while married

Example

- Age- and parity-specific fertility rates
  - Women between 30 and 35 years of age in 1990
  - Cohort born between 1955 and 1960
  - In Nigeria
    - At parity 0, 60 first births and 220.4 person-years over age 30
      - 60 / 220.4 = 0.272
    - At parity 1, 101 second births from 448.2 person-years
      - 101 / 448.2 = 0.225

Table 4.5 Fertility rates specific for age and parity

Parity	0	1	2	3	4	5	6+
Nigeria	0.272	0.225	0.257	0.244	0.279	0.284	0.233
Netherlands	0.146	0.221	0.079	0.075	0.090	NA	NA

Interpretation of example

- For Nigeria, fertility rates for women of the same age are close to each other, regardless of parity
  - Evidence of natural fertility
  - Estimates subject to sampling error
- For Netherlands, fertility rates drop by nearly a factor of 3 from parity 1 to parities 2+
  - Few women at parities 5+ (not available estimates)
- This is a contrast between absence and presence of parity-specific control

Limitation of measures

- Parity Progression Ratios and fertility rates specific to parity and age
  - Supply evidence about deviations from natural fertility
  - Do not summarize the strength of fertility limitation

- Demographers use measures from period rather cohort rates to measure strength (chapter 6)

Family reconstitution

- Many of the innovative measures applied to contemporary populations were pioneered by historical demographers (Wringley et al. 1997)
  - Data from local records of baptisms, marriages, and burials from parish churches in England, France, and other European countries
  - Technique builds small family genealogies one by one
  - Estimate age-specific mortality and age- and parity-specific fertility
  - Data are incomplete due to migration

Biology perspective

- Biologists observe that differences in age-specific fertility rates between species are greater than within species
  - This perspective implies that levels of fertility for humans subject to natural fertility would be the same from person to person and society to society
  - Differences would appear with conscious fertility limitation
- Louis Henry discovered that this expectation is wrong

Biology, environment, culture

- If one takes natural fertility to mean the absence of parity-specific control
  - There are variations in level of fertility in human societies from time to time and place to place
- Biological and environmental factors affects fertility levels
  - Without introducing parity-specific patterns
  - These factors interact with different cultural practices
  - Not all forms of family limitation are parity specific

Technical distinctions

- Fecundity
  - Biological capacity for childbearing
- Fecundability
  - Probability of conceiving for a woman subject to a continuous exposure to the risk of pregnancy
- Fertility
  - Outcome level of childbearing
  - It depends on fecundity
  - It also depends on decisions and behaviors of couples within their social, cultural, and environmental context

Technical terms for infertility

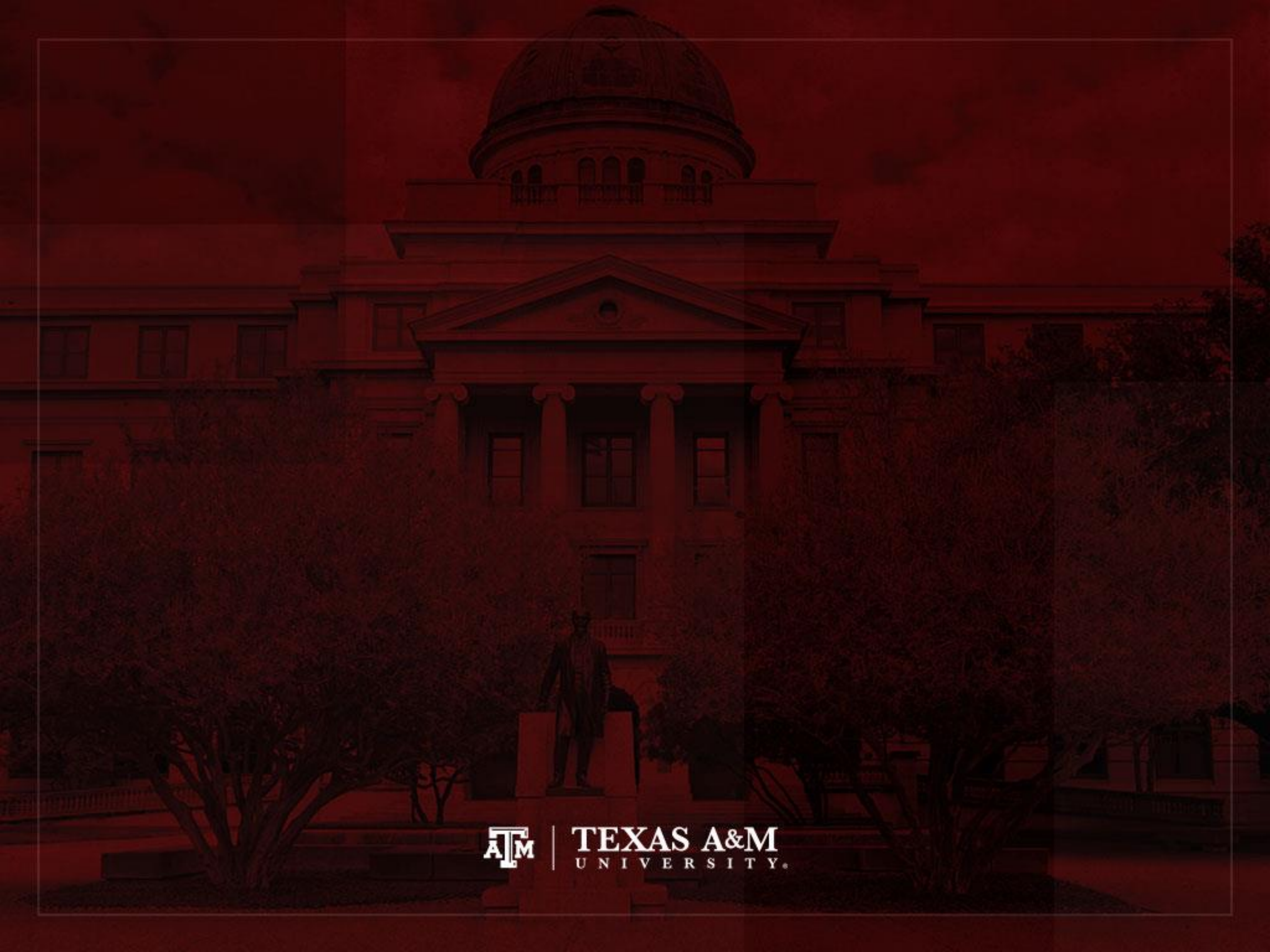
- Primary sterility
  - Lack of capacity ever to have children, either for individuals or for couples
- Secondary sterility
  - Loss of capacity to have children, after some children have been born
- Post-partum amenorrhoea
  - Temporary infecundity for women following childbirth
- Lactational amenorrhoea
  - Temporary infecundity due to breastfeeding, which reduces when breast milk is replaced by other food

Variation in natural fertility

- Previous terms help explain reasons for various fertility levels in societies with natural fertility
  - Cultures have different norms about nursing and breast milk replacement
    - It affects lactational amenorrhoea
  - Post-partum abstinence varies by cultures
    - It does not depend on parity (not parity-specific control)
    - But it affects birth interval, infant survival, mother’s health
  - Nutrition affects fecundity in extremes of malnutrition
    - In famines, women stop ovulating
    - Unequal improvements in nutrition over the last centuries have been a major driver of economic development and indirectly of population growth

Homeostatic mechanisms

- Homeostatic mechanisms regulate population growth in relation to resources (Malthus)
  - Homeostatic means maintaining the same state
  - When resources are plentiful, growth rates rise
  - When resources are scarce, growth rates drop
- This process operates through mortality or fertility
  - Effects on fertility may operate through biological fecundity or through social practices
  - Main historical homeostatic mechanisms come from economic arrangements, culture, and social institutions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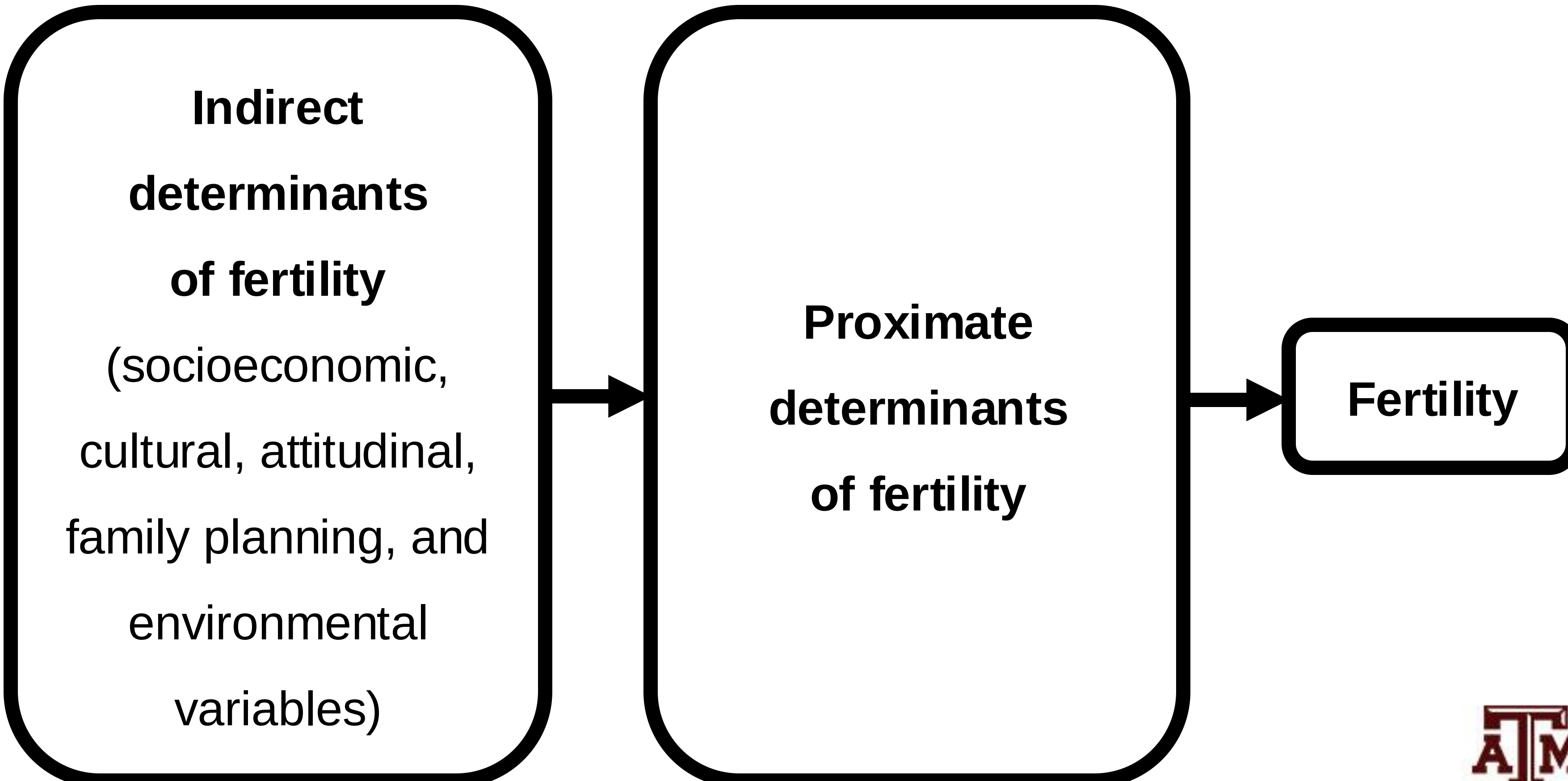
Proximate determinants

- Economic, social, and cultural factors do not themselves prevent births
  - Distinction between background causes and pathways that influence biological processes of having children
- The pathways are called proximate determinants
  - Proximate determinants are the nearest causal factors to the actual fertility outcomes that can be measured from ordinary demographic sources
    - i.e., surveys without special medical examinations
    - Examples: contraception, induced abortion, post-partum infecundity, marriage, sexual activity

Framework for predicting fertility

Major variables operate through proximate determinants in predicting fertility



Source: Bongaarts (1978, 1982).

Intermediate variables & proximate determinants of fertility

- Means for regulating fertility have been popularly labeled the **intermediate variables** (Davis, Blake 1955)
  - 11 variables through which any social factor influencing the level of fertility will operate
  - 3 phases to fertility (intercourse, conception, gestation)

- **Proximate determinants of fertility** (Bongaarts 1978, 1982)
  - 4 of these variables account for differences in fertility between populations
  - Their importance varies across time and space

Table 6.1 The Proximate Determinants of Fertility—Intermediate Variables through which Social Factors Influence Fertility

Most Important of the Proximate Determinants	Proximate Determinants or Intermediate Variables
	I. Factors affecting exposure to intercourse (“intercourse variables”).
	A. Those governing the formation and dissolution of unions in the reproductive period.
✔	1. Age of entry into sexual unions
	2. Permanent celibacy: proportion of women never entering sexual unions.
	3. Amount of reproductive period spent after or between unions.
	a. When unions are broken by divorce, separation, or desertion.
	b. When unions are broken by death of husband.
	B. Those governing the exposure to intercourse within unions.
	4. Voluntary abstinence.
	5. Involuntary abstinence (from impotence, illness, unavoidable but temporary separations).
	6. Coital frequency (excluding periods of abstinence).
	II. Factors affecting exposure to conception (“conception variables”)
✔	7. Fecundity or infecundity, as affected by involuntary causes, but including breastfeeding.
✔	8. Use or nonuse of contraception.
	a. By mechanical and chemical means.
	b. By other means.
	9. Fecundity or infecundity, as affected by voluntary causes (sterilization, medical treatment, and so on).
	III. Factors affecting gestation and successful parturition (“gestation variables”).
	10. Fetal mortality from involuntary causes (miscarriage).
✔	11. Fetal mortality from voluntary causes (induced abortion).

Sources: Adapted from Kingsley Davis and Judith Blake (1955); and John Bongaarts (1982).

Source: Weeks 2015, p.214.

Intermediate variables

- Intermediate variables proposed by Kingsley Davis and Judith Blake (1956)
  - Behavioral and biological variables directly influencing fertility
  - Other social, economic, cultural, and environmental factors influence fertility by operating through the intermediate variables

Intercourse, conception, gestation

- Davis and Blake identified a set of 11 intermediate variables, which directly affect fertility and are grouped into three factors
  - **Intercourse** is affected by
    - Proportion of persons who marry
    - Length of time married
    - Frequency of sexual intercourse while married
  - **Conception** is affected by
    - Contraception
    - Voluntary or involuntary infecundity
  - **Gestation/parturition:** birth probability depends on
    - Likelihood of miscarriage and abortion

Proximate determinants of fertility

- Proximate determinants of fertility proposed by John Bongaarts (1978, 1982)
  - Operationalized proximate determinants of fertility to incorporate them into quantitative reproductive models
  - Designed to facilitate quantitative specification of variables
  - One of the most useful frameworks for studying fertility

Seven proximate determinants

- Marriage and marital disruption
- Contraceptive use and effectiveness
- Prevalence of induced abortion
- Duration of postparturm infecundability
- Waiting time to conception
- Risk of intrauterine mortality
- Onset of permanent sterility

Source: Bongaarts (1978, 1982).

Main proximate determinants

- Proportion married (limiting exposure to intercourse)
  - Younger woman (less sexual intercourse)
  - Household with both mother and father (closer surveillance)
  - Mother well-educated (awareness of costs of pregnancy)
  - Later age at marriage (lower levels of fertility)
- Use of contraceptives
- Induced abortion (Hodgson 2009)
- Involuntary infecundity
  - Breastfeeding prolongs postpartum amenorrhea and suppresses ovulation

Framework for proximate determinants of fertility

Indirect determinants of fertility

- Socioeconomic
- Cultural
- Attitudinal
- Family planning
- Environmental

→

Proximate determinants of fertility

- Proportion married
- Contraception
- Induced abortion
- Involuntary infecundability (postpartum)
- Time to conception (frequency of intercourse)
- Intrauterine mortality
- Sterility

→

Fertility

Source: Bongaarts (1978, 1982).

Indices

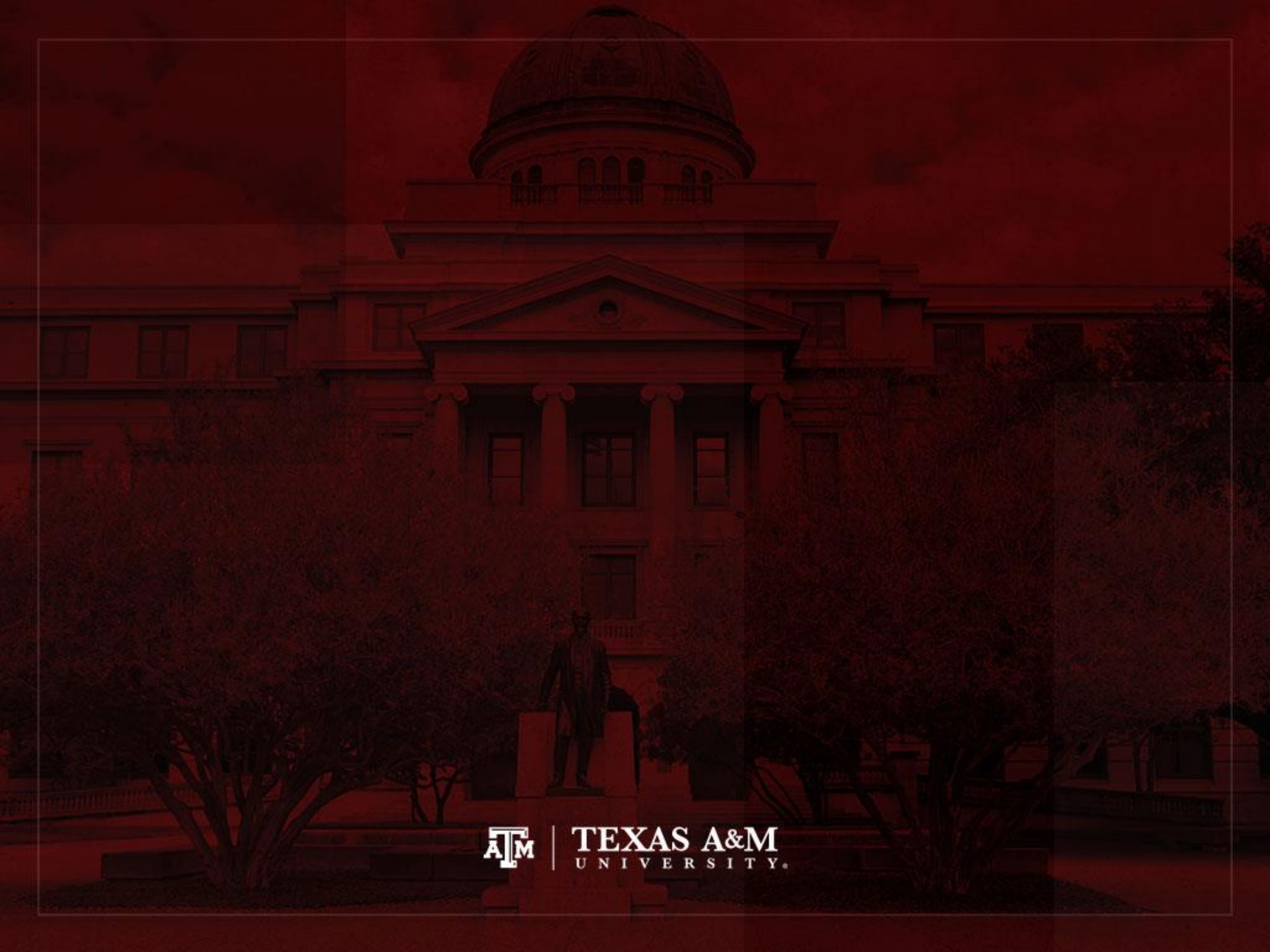
- Indices of the first four proximate determinants for women in their reproductive years
- Indices range from 0 (the greatest inhibiting effect on fertility) to 1 (no inhibiting effect)
  - **Marriage-pattern index (*Cm*)**: 1 when all women are married and 0 when none are married
  - **Contraception index (*Cc*)**: 1 when no contraception is used and 0 when all women are using effective contraceptives
  - **Abortion index (*Ca*)**: 1 when there is no induced abortion and 0 when every pregnancy is aborted
  - **Postpartum-infecundability index (*Ci*)**: 1 when no women are in the period of postpartum infecundability and 0 when all women are

Stover

- Stover's (1998) modifications and extensions to the Bongaarts model to consider demographic realities of modern societies
- Use of sexual activity instead of marriage as the indicator of exposure to pregnancy
- Extension of the sterility index to measure infecundity from all causes
- Revision of the contraception index to consider the fact that users of sterilization could become infecund before the age of 49
- Change of the estimate of total fecundity

References

Wachter KW. 2014. Essential Demographic Methods. Cambridge: Harvard University Press. Chapter 4 (pp. 79–97).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