Demographic Methods

Monica Alexander

Week 3: Fertility

Overview

- Demographic transition
- Measures of fertility
- Measures of reproduction
- Fertility models
- Dataset ideas

The demographic transition

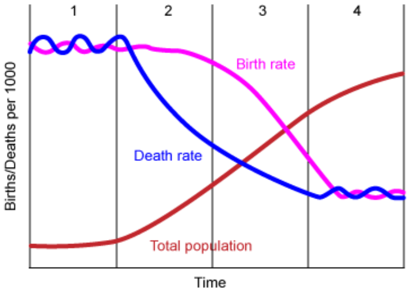
The demographic transition

Over time, human populationsbroadly go through four demographic stages:

1. High mortality / high fertility (Pre-transition)
   - high rate of infectious diseases, poor medical coverage
   - no modern contraception
   - agricultural economies, non-nuclear families
   - population size: low and stable
2. Falling mortality (Early transition)
   - technological progress (vaccinations, modern medicine)
   - improved infrastructure (sanitation)
   - population size: increasing rapidly
3. Falling fertility (Late transition)
   - empowerment of women
   - modern contraception
   - ubranization
   - population size: increasing but deceleration

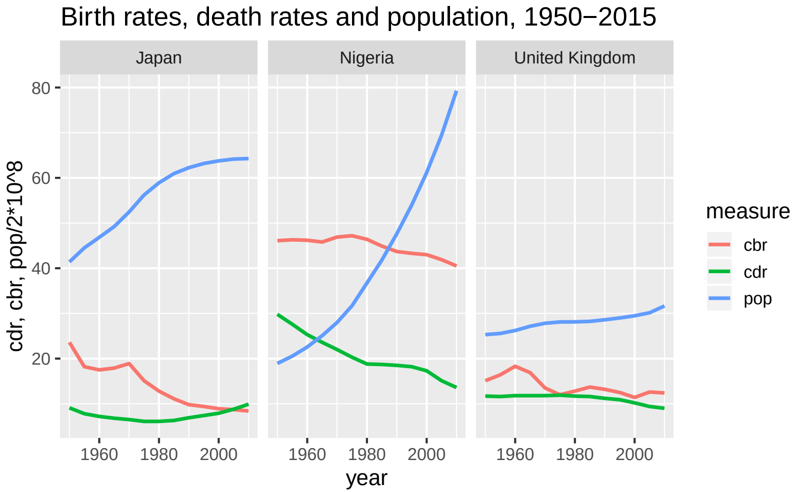
The demographic transition

4. Low mortality and fertility (Post-transition)
   - population size: high and stable
5. (TBD?) fertility $<$ mortality
   - improvements in old-age mortality
   - children are expensive
   - population size: declining



Graph source: IUSSP

Examples



Birth rates, death rates and population, 1950−2015
Japan
Nigeria
United Kingdom
80
60
40
20
cdr, cbr, pop/2*10^8
1960
1980
2000
year
measure
cbr
cdr
pop

Measures of fertility

Note: fertility versus fecundity

- Fertility is studying the outcome (circumstances where live births occur)
- Fecundity is the studying the ability to conceive

Crude measures

Crude birth rate:

$$CBR = \frac{\text{Births to women}}{\text{PY lived by population}}$$

But the population at risk: all women aged 15-49.

General fertility rate:

$$GFR = \frac{\text{Births to women}}{\text{PY lived by women of reproductive age}}$$

Recall discussion about why crude rates are good and bad.

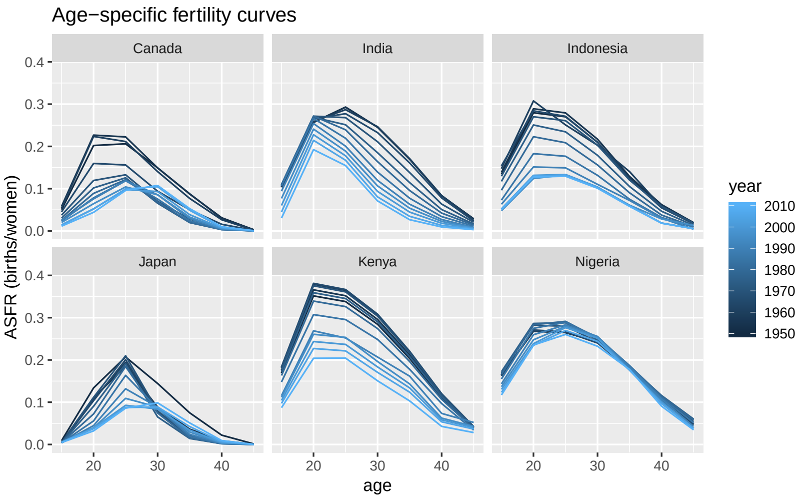
Age-specific fertility rates

$$ {}_nF_x = \frac{\text{Births to women aged } x \text{ to } x+n}{\text{PY lived by women aged } x \text{ to } x+n} $$

Continuous version:

$$ f(x) = \frac{B(x)}{P(x)} $$

Age-specific fertility rates



Total fertility rate

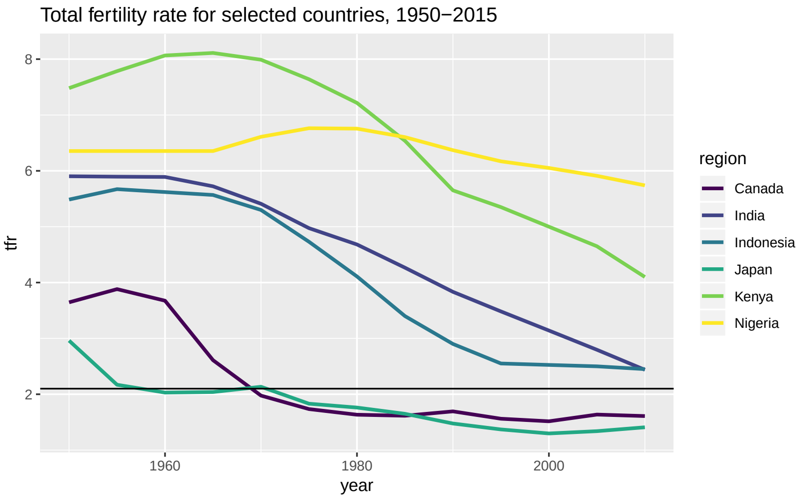
TFR is the average number of babies a women would have if she lived through the entire reproductive lifespan.

$$TFR = n \cdot \sum_{15}^{49} {}_nF_x$$

or

$$TFR = \int_{15}^{49} f(a)da$$

Examples



Total fertility rate for selected countries, 1950−2015
tfr
8
6
4
2
1960
1980
2000
year
region
Canada
India
Indonesia
Japan
Kenya
Nigeria

Parity

- Sometimes we get data in the form of 'children ever born' to a women (common in surveys)
- **Parity** is the number of live births a woman has had.
- A woman is **nulliparious** if they have parity $= 0$.
- Studying fertility by parity gives us an idea of how women are limiting their fertility
- Cohort measure

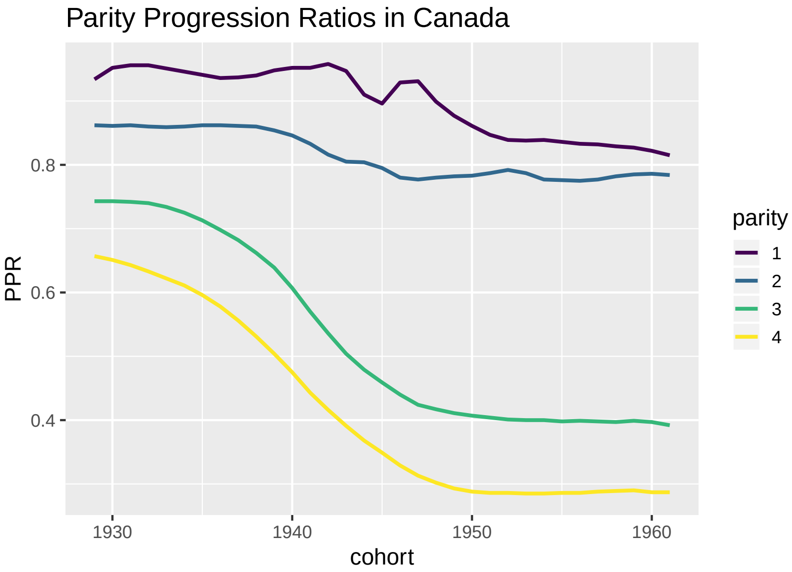
Define $w(j)$ to be the number of women at parity j

Parity progression ratios

Parity Progression Ratio at parity j $PPR(j)$ is the fraction of women who, having reached parity j, go on to have at least another child.

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

Example



Parity Progression Ratios in Canada
PPR
0.8
0.6
0.4
1930
1940
1950
1960
cohort
parity
1
2
3
4

Measures of reproduction

Measures of reproduction

The idea of generational renewel: compare sizes of successive cohorts of women

Only want to consider female babies.

Define fraction female at birth $f_{fab} \approx 0.4886$ i.e. there are slightly fewer girls born c.f. boys.

Gross reproduction ratio

GRR is the average number of **female** babies a women would have if she lived through the entire reproductive lifespan.

$$GRR = n \cdot \sum_{15}^{49} {}_nF_x{}^F$$

Or, if we don't know sex-specific fertility rates

$$GRR = n \cdot \sum_{15}^{49} {}_nF_x \cdot f_{fab}$$

Net reproduction ratio

NRR is the average number of female babies a women would bear if they were subject to the observed age-specific mortality rates.

$$NRR = \sum_{15}^{49} {}_nF_x{}^F \cdot {}_nL_x$$

or

$$NRR = \sum_{15}^{49} {}_nF_x \cdot {}_nL_x \cdot f_{fab}$$

Note the ${}_nL_x$ refers to the survivorship of women.

In continuous form, the product of fertility rates (of female babies) and the survivorship is given its own notation, $\phi(x)$, and called the net maternity function. Then

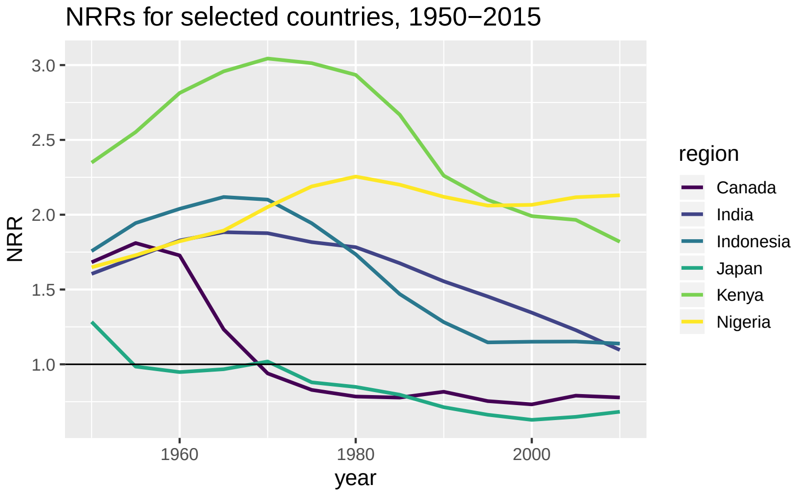
$$NRR = \int \phi(a)da$$

NRR from parity

If we are given data in the form of number of women by parity in a cohort, then we can also calculate the NRR as:

$$NRR = \frac{\sum_0^\infty i \cdot w(i)}{\sum_0^\infty w(i)}$$

Examples


NRRs for selected countries, 1950−2015
NRR
3.0
2.5
2.0
1.5
1.0
1960
1980
2000
year
region
Canada
India
Indonesia
Japan
Kenya
Nigeria

How does NRR relate to population growth?

- NRR > 1 implies?
- NRR < 1 ?
- NRR $= 1$?

More next week (population growth, stable populations)

Fertility models

Fertility distributions are different to mortality

- repeated events
- separated by intervals of non-risk
- individual control

Harder (and less appropriate?) to model at the aggregate level than mortality.

Model fertility schedules

Coale and Trussel (1974). Focus:

- capture the extent to which observed mortality deviates from natural fertility
- use age-specific standards that are empirically derived (similar idea to Brass mortality)
- Parameterize in terms of overall level of fertility and degree of fertility control
- Note: estimating marital fertility. (!)

Model fertility schedules

$$ {}_nF_x = M \cdot n(x) \cdot e^{-m \cdot \nu(x)} $$

- M is the overall level of fertility
- $n(x)$ is the natural fertility age-specific schedule (constant)
- m is the strength of parity-specific limitation
- $\nu(x)$ is the impact of fertility limitation by age (constant)

Natural fertility schedule $n(x)$

Derived from the Hutterites (anabaptists, community of goods, limited use of technology). High fertility rates, closest thing to natural fertility observed (marry young, religious duty)

Interestingly, now evidence Hutterite fertility is declining.

Natural fertility schedule $n(x)$

Age	$n(x)$
15	0.36
20	0.46
25	0.431
30	0.396
35	0.321
40	0.167
45	0.024

What's the implied TFR?

Fertility limitation schedule $\nu(x)$

Derived from empirical data

Age	$\nu(x)$
15	0
20	0
25	0.279
30	0.667
35	1.042
40	1.414
45	1.67

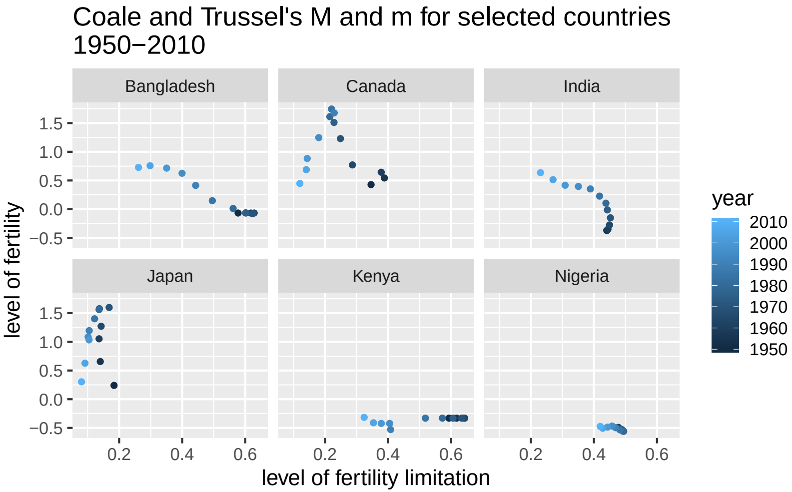
Estimating M and m

$$ {}_nF_x = M \cdot n(x) \cdot e^{-m \cdot \nu(x)} $$

implies

$$ \log\left(\frac{{}_nF_x}{n(x)}\right) = \log M - m \cdot \nu(x) $$

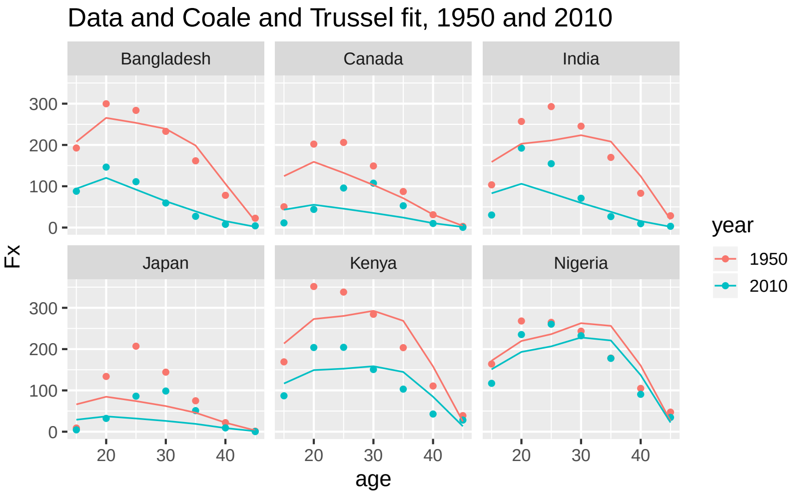
Example



Coale and Trussel's M and m for selected countries
1950−2010
Bangladesh
Canada
India
Japan
Kenya
Nigeria
level of fertility
level of fertility limitation
1.5
1.0
0.5
0.0
−0.5
0.2
0.4
0.6
year
2010
2000
1990
1980
1970
1960
1950

Example

BUT the fits are pretty bad



..ideas for how to do this differently?

Tempo and quantum

Background

Note: shift in focus of research from high to low fertility.

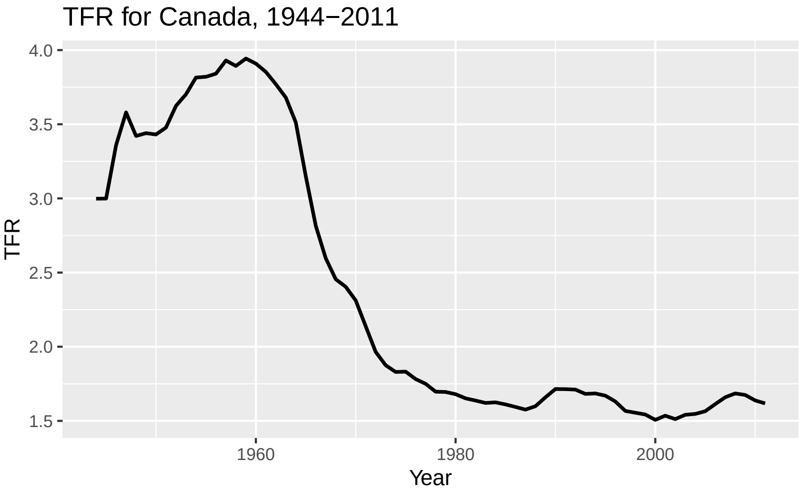
Most common measure of fertility is the period TFR. Is TFR declining because women are having fewer kids or because they are putting it off until later?

In any given year, fertlity rates can decline because of two reasons:

- Quantum: decline in number of children
- Tempo: shift in age at childbearing (delaying having kids to older ages)

Note: this isn't an issue with cohort TFR, just period TFR

Background


TFR for Canada, 1944−2011
4.0
3.5
3.0
2.5
2.0
1.5
TFR
1960
1980
2000
Year

Tempo-adjusted TFR

$$TFR'(t) = \frac{TFR(t)}{1 - \frac{d}{dt}A(t)}$$

$A(t)$ is the average age at child-bearing in period t.

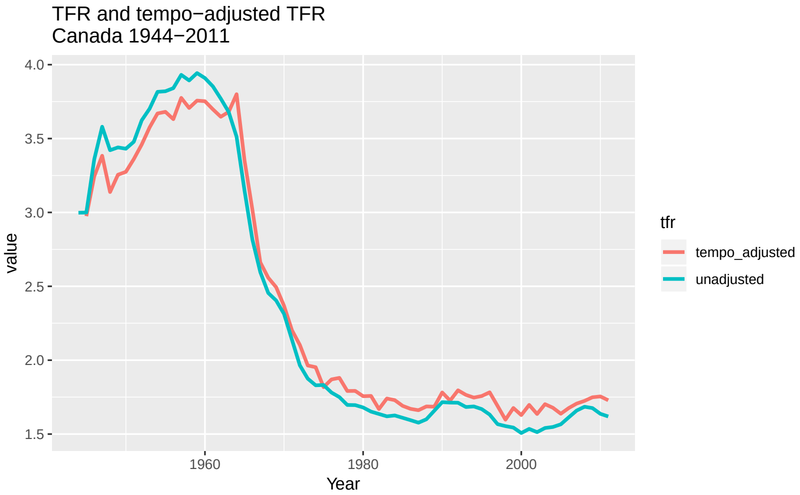
How to calculate this in practice?

Bongaarts and Feeney (1998) calculate the change in the mean age at child-bearing by parity i, r_i:

$$TFR'(t)_i = \frac{TFR_i}{1 - r_i}$$

then $TFR'(t) = \sum_i TFR'_i$

Example



TFR and tempo−adjusted TFR
Canada 1944−2011
value
Year
4.0
3.5
3.0
2.5
2.0
1.5
1960
1980
2000
tfr
tempo_adjusted
unadjusted

Dataset ideas

Dataset ideas

- WPP
- Human Fertility Database
- Current Population Survey (IPUMS)
- DHS (IPUMS)