History of Human Population: Stationarity, growth, and the demographic transition

Econon/Demog c175
Prof. Goldstein
Week 1, Lecture B
UC Berkeley
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Agenda

- The exponential model
  (what we didn't get to last time)
- Generation Ratios and annual growth rates
  (Activity: brothers and sisters)
- The Demographic Transition
  - Some facts

  (Activity: Sweden and Taiwan)
  - Some explanations and puzzles

Population Growth

The Exponential Model and the History of Humanity

Class activity: Generational Population Growth (We’ll try this on Thursday in break out rooms)

- We’ll simulate generational growth, with each row of class a generation.
- Everyone gets out a piece of paper.
- Each person computes generational growth implied by their own family.
- Let’s see what happens.

Format of sheet

Generation	# of kids	"per parent"	cumulative product
	N	N/2	multiply
0	3	1.5	1.5
1	1	.5	.75
2	2	1	.75
3	…	…	…

Discussion

- What happened?
- If we shift order of generations, would it matter?
- Is this a good statistical estimate of your parent's generations growth rate? What might be wrong?

World Population Growth

An overview of all of humanity's past and its future

World Population Size

Year	Millions	Growth rate (persons per yr)	Growth rate (%)
-8,000	4		
1	211		
500	200		
1000	290		
1500	473		
1750	764		
2000	6,080		
2015	7,218		

Source of Pop. Estimates: Weeks

World Population Size

Year	Millions	Growth rate (persons per yr)	(%)
-8,000	4	25k	
1	211	-22k	
500	200	180k	
1000	290	366k	
1500	473	1,160k	
1750	764	21,000k	
2000	6,080	75,000k	
2015	7,218		

World Population Size

Year	Millions	Growth rate (persons per yr)	(% per yr)
-8,000	4	25k	~ 0
1	211	-22k	~ 0
500	200	180k	0.1
1000	290	366k	0.1
1500	473	1,160k	0.2
1750	764	21,000k	0.8
2000	6,080	75,000k	1.1
2015	7,218		

Which should we model?

The change in absolute numbers

OR

The proportional change?

A good rule-of-thumb is to model the phenomenon which seems the most constant.

Analogy with interest rate

If population is growing at 2% per year, then after 100 years,

$$N(100) = N(0)\, e^{(100)(.02)} = N(0)\, e^{2} \cong N(0) \times 7.4$$

If growth rate is changing, then we can still calculate constant growth within each time period. That's what we do next

Calculating a constant exponential growth rate

Exponential Model

$$N(t) = N(0)\, e^{Rt}$$

To rewrite in terms of *R*, take natural logs (when I write "log", I mean "ln") and rearrange

$$\log N(t) = \log N(0) + R\, t$$

$$R = [\, \log N(t) - \log N(0) \,] \;/\; t$$

This is slope (rise-over-run) of graph of logarithm of population

Let's practice

R = *slope of log graph*

= *rise / run*

= *change in log(pop) / time*

$R = [\, \log N(t) - \log N(0) \,] \,/\, t$

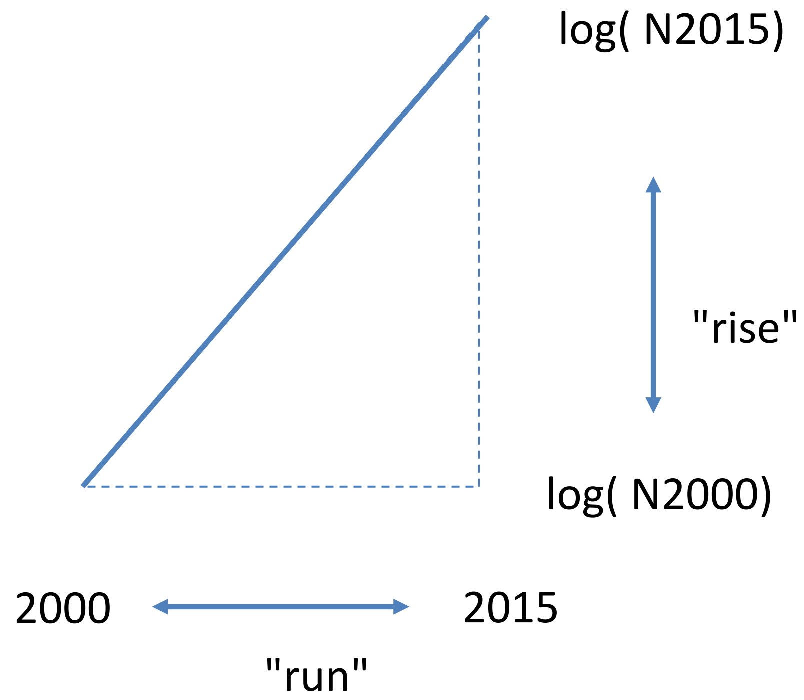
R (2000 to 2015) =

[*log*(N2015) – *log*(N2000)] /

(2015- 2000)

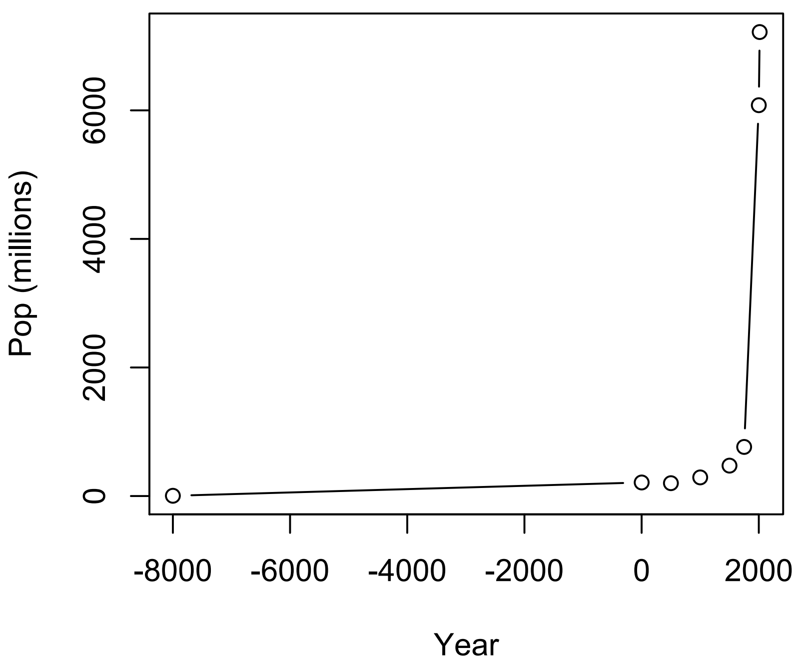
= [*log*(7,218) – *log*(6,080)] / 15

= ?

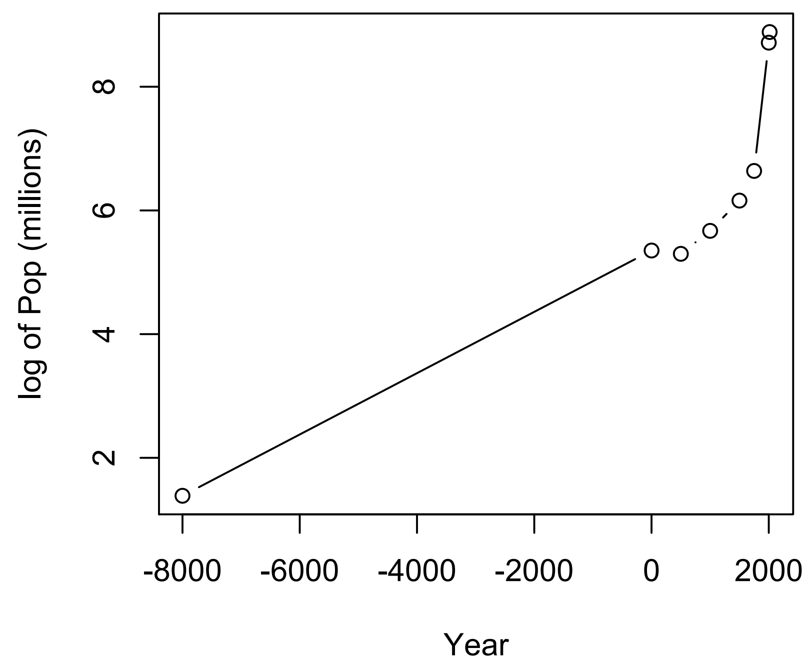


Seeing World Population Growth

Original scale



Log-scale



What is closest to exponential growth rate over last 10,000 years?
A. 1/100 = 1%.   B. 1/1000 = 0.1%. C. 1/10000 = 0.01%.

Has the growth rate last 2000 years been constant or increasing?
A. Constant B. Increasing C. Impossible to tell D. It's complicated

Conclusions

- Most of human history, <u>no population growth</u>
- Then, a period of <u>accelerating growth rate</u>
- We'll see in lab that *most recently*, <u>slowing growth rate</u>

  (Future of humanity may depend on pace of this slowing)

Understanding each of these phases is one of our goals. First, the Demographic Transition, and then in a few weeks we’ll study pre-modern times (Malthus).

Measuring fertility

- Total Fertility Rate (TFR)

  Most common summary measure of fertility: average number of children per surviving woman
- In the United States, now about 1.9
- Prior to Demographic Transition TFR > 6
- In Taiwan (2014) , TFR = 1.1 (!)

(Note: period vs. cohort)

From TFR to growth rate

- To get generational growth
  - Account for sex
  - Account for mortality
- To get annual growth from generational growth
  - Account for generation length
- A good approximation is:

$$R \approx \log [\ TFR * .4886 * \text{survival to age 30}] \quad / \ 30$$

(Note: log is base e, use "ln" on calculator, "log" in R)

Examples

$R \approx \log [\, TFR * .4886 * \text{survival to age 30}] \quad / \ 30$

Let's say TFR = 4, and survival to 30 = 0.7.

$R \approx \log(4 * .4886 * .7) / 30 = \log(1.37) / 30 = 0.01$

What is R(2010, Nigeria)?

TFR = 6, survival to age 30 = 0.8

$R \approx ?$

Crude birth and death rates

- Crude Birth Rate (CBR) or b

  CBR = Annual Births/Pop

(note: denominator has women and men)

- Crude Death Rate (CDR) or d

  CDR = Annual Deaths/Pop

- Crude Growth Rate (when no migration)

  $R = b - d$

The Demographic Transition

A story of changing birth and death rates

The puzzle of the demographic transition

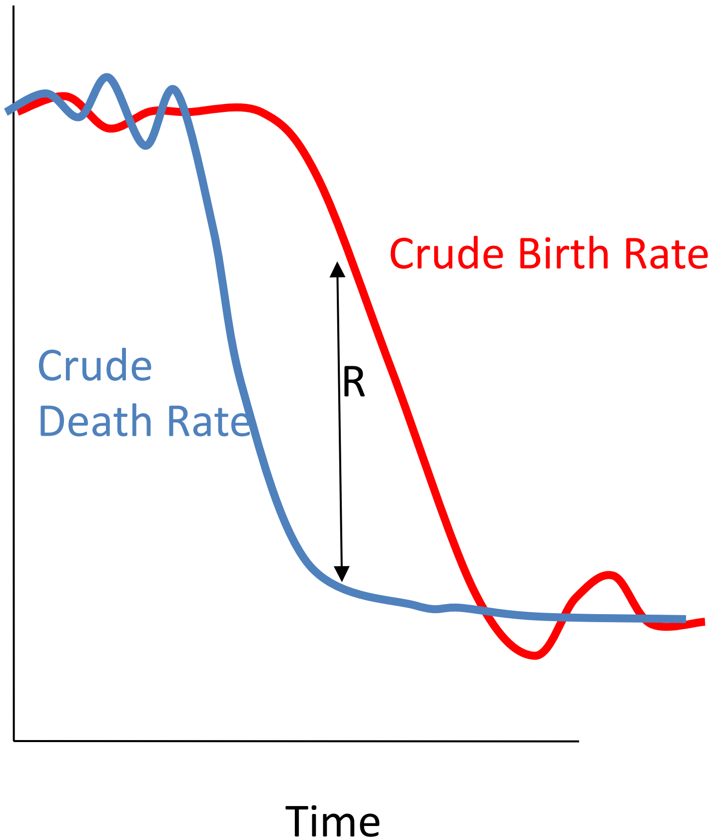
- The Demographic Transition may seem obvious now
  - Birth and death rates used to be high, now both low
- Put ourselves in the position of 1970s
  - World population growth accelerating
  - Energy prices skyrocketing
  - Environmental worries
  - Economic slowdown
- What is the next number in the sequence
- 1, 1, 1, 1, 2, 3, …?

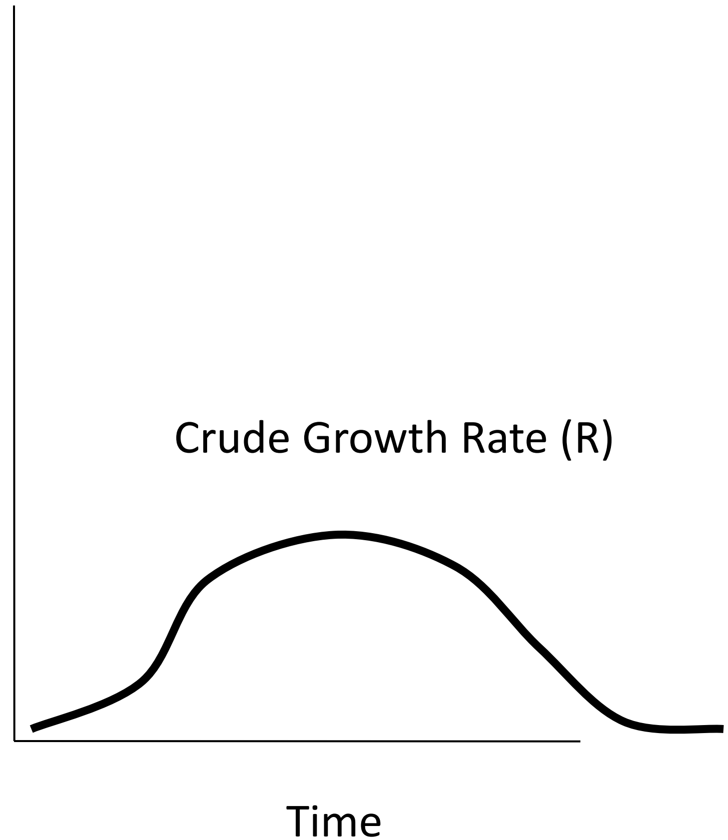
Systems thinking

- Population growth a function of births and deaths
- But what do births and death rates depend on?
  - Perhaps income: $b(y)$ & $d(y)$?
  - Perhaps population size: $b(N)$ & $d(N)$?
  - Perhaps mortality is exogenous: $b(d)$?
- Understanding system crucial to predicting future 1, 1, 1, 2, 3, ….

An idealized portrayal of the D.T.

Note crude rates are per capita (e.g., CBR = births / population)

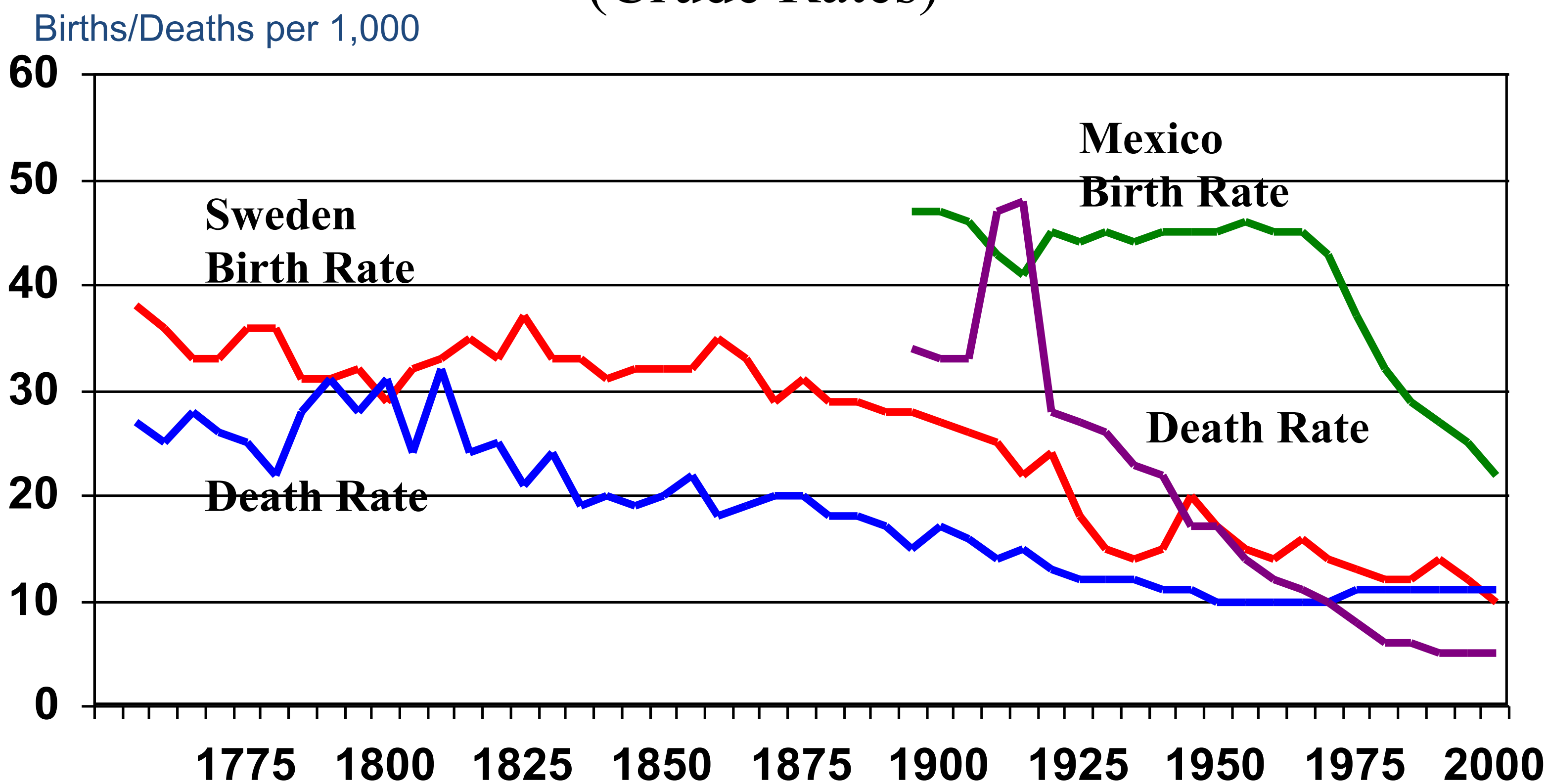




Idealized description

- Pre-transition
  - High fertility, high mortality
  - mortality fluctuating due to random shocks
- Transition
  - Mortality falls first, fertility decline lags
  - Result is “transitional growth”
- Post-transition
  - Fertility finally falls
  - Fluctuations in growth are due to fertility
  - Sub-replacement demography?

Demographic Transition in Sweden and Mexico (Crude Rates)



Sources: B.R. Mitchell, *European Historical Statistics 1750-1970* (1976): table B6; Council of Europe, *Recent Demographic Developments in Europe 2001* (2001): tables T3.1 and T4.1; CELADE, *Boletin demografico* 69 (2002): tables 4 and 7; Francisco Alba-Hernandez, *La poblacion de Mexico* (1976): 14; and UN Population Division, *World Population Prospects: The 2002 Revision* (2003): 326.

Source: PRB

Exercise: How much did Swedish pop grow from 1800 to 1900? Mexico from 1920 to 2000? Answer can be approximate. We want a number, e.g 600%. Hint: approximate average growth rate and use exponential formula.

Discussion of break-out room exercise

Sweden

1900 2.3 million

2000 5 million

Increase ~ a bit more than 2-fold

Mexico

1920 14 million

2000 100 million

Increase ~ 7-fold

Transition statistics

- Pre-transition
  - TFR greater than 6
  - life expectancy about 40 to 50
  - Korea (1950): CBR – CDR = .037 - .032 = .005
- Transitional growth
  - crude growth rates reach 1-2% in historical Europe, 3-4% in Africa
  - Iraq (1985): CBR – CDR = 42/1000 – 8/1000 = .034
- Post-transition
  - TFR about 2
  - life expectancy 70 or 80
  - Belgium (1984): CBR – CDR = .012 - .011 = .001

Crude Death Rate (CDR)

CDR (year t) = deaths (t) / person-years lived (t)

~ deaths(t) / population (t)

- In ancient Rome, about 40/1000
- In modern Japan, about 10/1000
- In modern USA, about 8/1000

(Is it really more dangerous to be born in Japan than USA?)

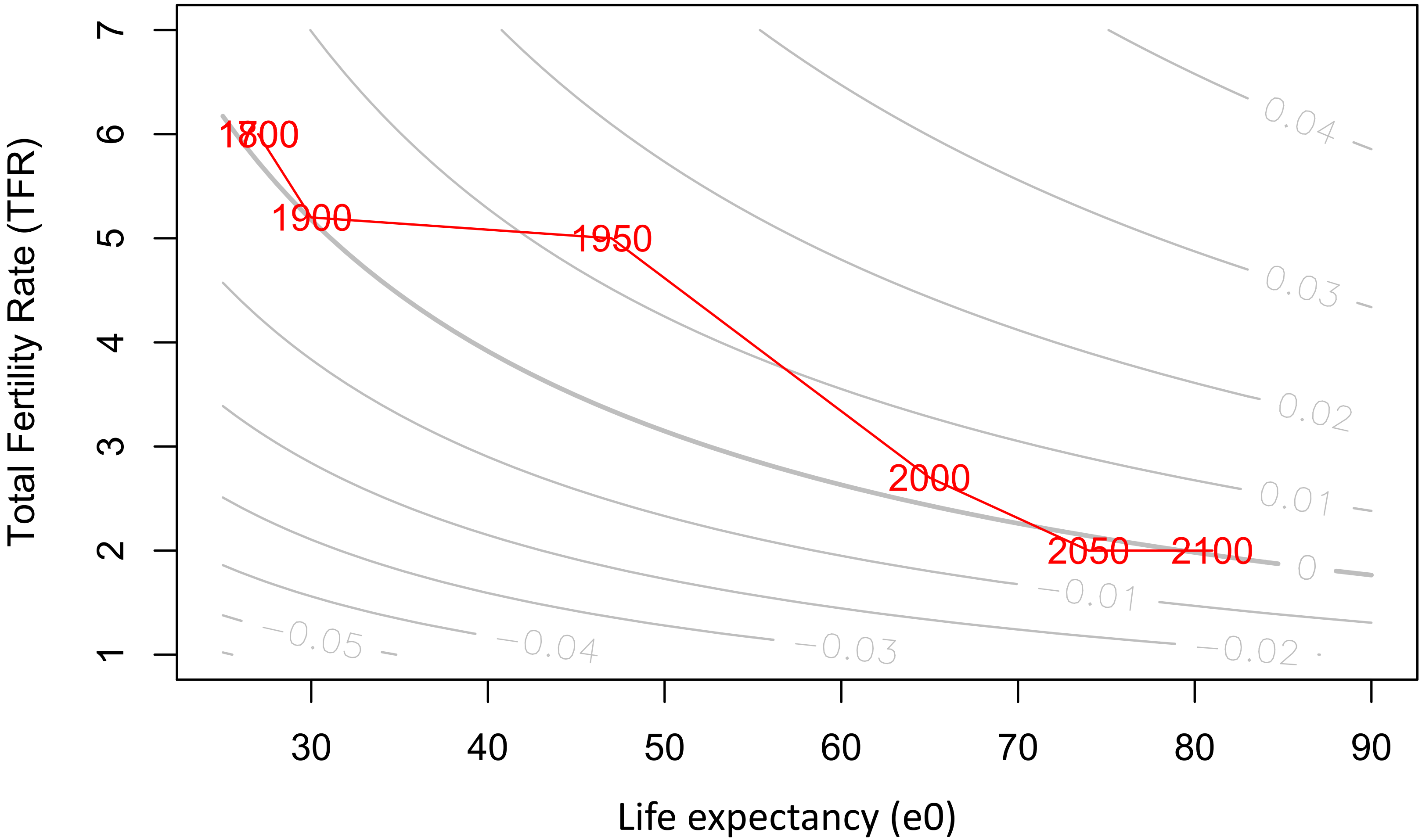
What happened?

Table 1
Global Population Trends Over the Transition: Estimates, Guesstimates and Forecasts, 1700–2100

	Life Expectancy (Years at Birth)	*Total Fertility Rate (Births per Woman)*	*Pop Size (Billions)*	*Pop Growth Rate (%/Year)*	*Pop < 15 (% of Total Pop)*	*Pop > 65 (% of Total Pop)*
1700	27	6.0	.68	0.50	36	4
1800	27	6.0	.98	0.51	36	4
1900	30	5.2	1.65	0.56	35	4
1950	47	5.0	2.52	1.80	34	5
2000	65	2.7	6.07	1.22	30	7
2050	74	2.0	8.92	0.33	20	16
2100	81	2.0	9.46	0.04	18	21

From Lee, Three Centuries of Demographic Transitio

The same table as a picture



(i) Can see ***transitional*** growth (ii) can see relationship between e0, TFR, R

Conclusions

- Today was mostly description and measurement. The stylized facts we want to explain:

  stationarity → transitional growth → stationarity(?)

- Next week: more normative, what population size is "optimal" (and how it depends on who is asking the question).
- Week 3: Malthus, his "trap", and why neither the population or the economy grew much for thousands of years.