Lecture 10

The differences between cities, inequality and dynamical processes

10.1 Statistical Distributions of Urban Quantities, Inequality, stochastic processes

IUS 4.2

Happy “World Cities Day 2024”

ArchDaily > Articles > World Cities Day 2024: Transforming Urban Futures Through Preservation, Innovation, and R

World Cities Day 2024: Transforming Urban Futures Through Preservation, Innovation, and Resilience

Save

Written by **Nour Fakharany** Published on October 31, 202 .

In honor of World Cities Day, which concludes Urban October, this year's theme, *"Youth Leading Climate and Local Action for Cities,"* reflects a growing momentum for sustainable urban solutions

Print Edition

DownToEarth

Health Agriculture Water Waste Climate Air Africa Data Centre Video Ga

Urbanisation

World Cities Day: Clock ticking for India’s urban areas; act now, say experts

The time has come for active policies to make sustainable modes work for all income levels, they say

The 2024 World Cities Day China Observance (Shanghai) Opens, Unveiling Practices, Indicators for Sustainable Urban Development

Provided by GlobeNewswire
Oct 31, 2024 10:04am

SHANGHAI, Oct. 31, 2024 (GLOBE NEWSWIRE) -- As an event to mark the World Cities Day, the 2024 World Cities Day China Observance (Shanghai) and 2024 SDG Cities Global Conference, themed "Building People-centered Cities for Better Life," was held on Thursday at the Shanghai World Expo Exhibition and Convention Center.

A Media Snippet accompanying this announcement is available by clicking on this link.

We want to explain why deviations from scaling for each city

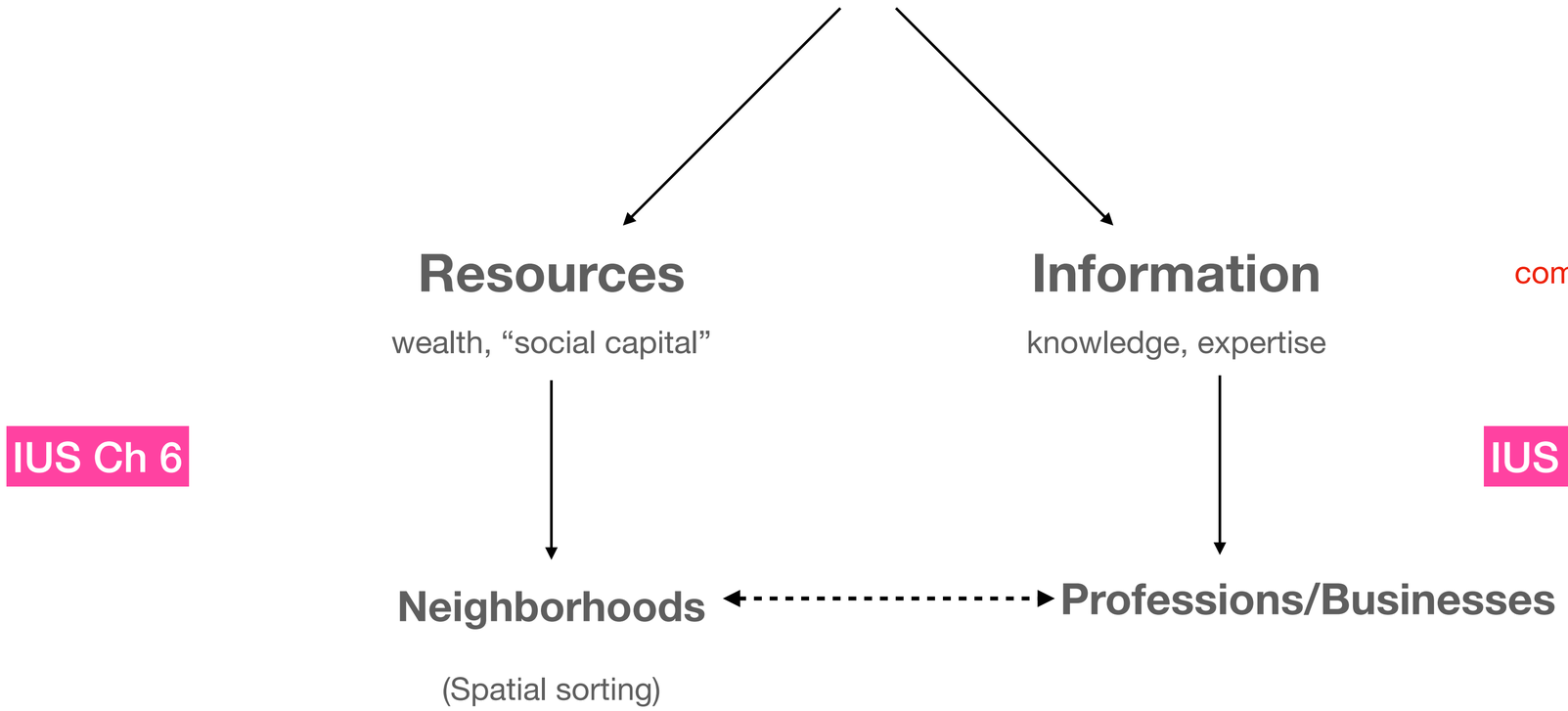
have the observed distribution (~lognormal)

Bell-curve in logs

This is connected to how **resources and information** are used, at the individual and firm levels

and brings in the problems of **growth and inequality**

Inequality and statistics of variation in cities



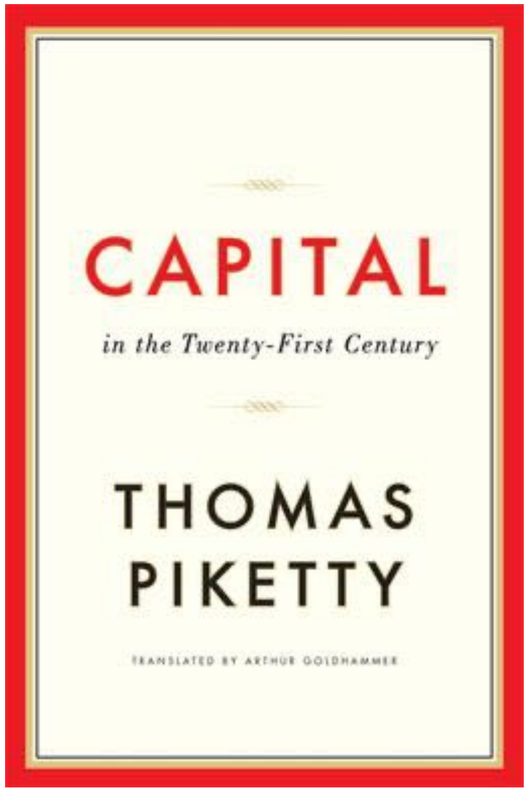
common problem in all complex systems

Inequality by:

Ethnicity, Race, SES

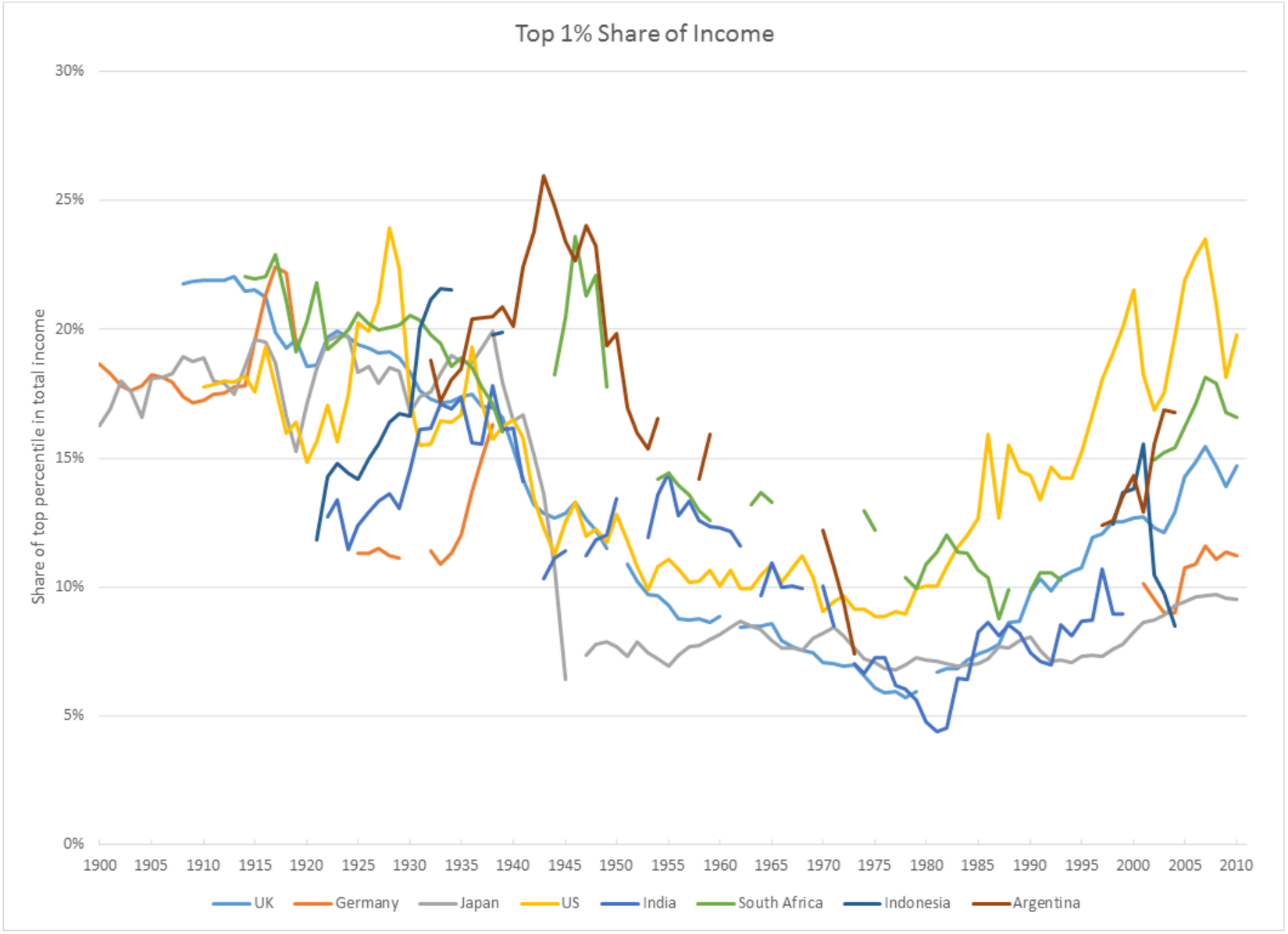
Class, Caste, Income

The Classic Approach to Economic Inequality

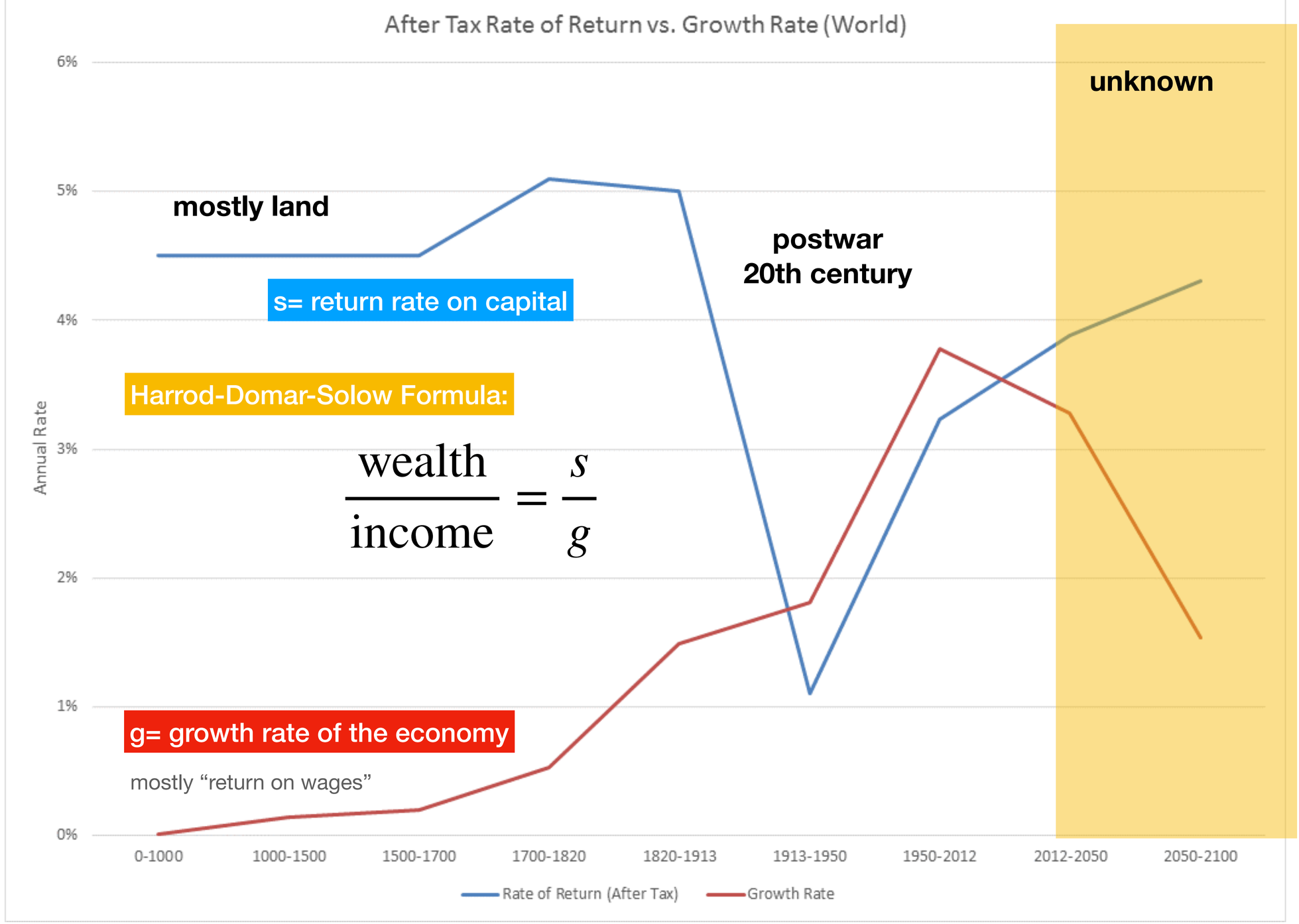


2013

nations



Thomas Picketty


After Tax Rate of Return vs. Growth Rate (World)
6%
5%
4%
3%
2%
1%
0%
Annual Rate
unknown
mostly land
postwar
20th century
s= return rate on capital
Harrod-Domar-Solow Formula:
$\frac{\text{wealth}}{\text{income}} = \frac{s}{g}$
g= growth rate of the economy
mostly “return on wages”
0-1000
1000-1500
1500-1700
1700-1820
1820-1913
1913-1950
1950-2012
2012-2050
2050-2100
Rate of Return (After Tax)
Growth Rate

But many sources and forms of inequality…

SCIENTIFIC AMERICAN®

POLICY & ETHICS

The American Economy Is Rigged

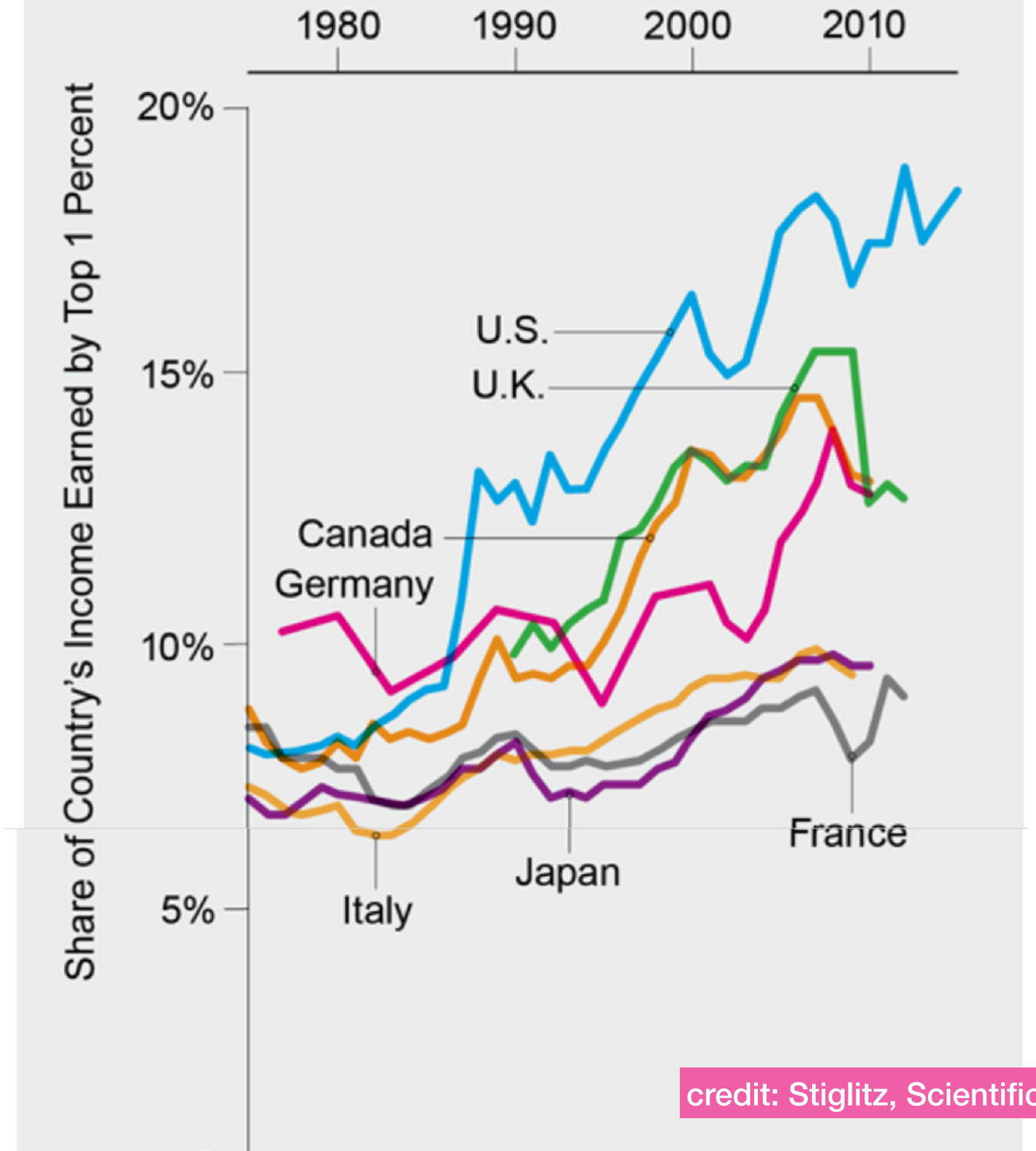
And what we can do about it

By Joseph E. Stiglitz | Scientific American November 2018 Issue

Joseph E. Stiglitz

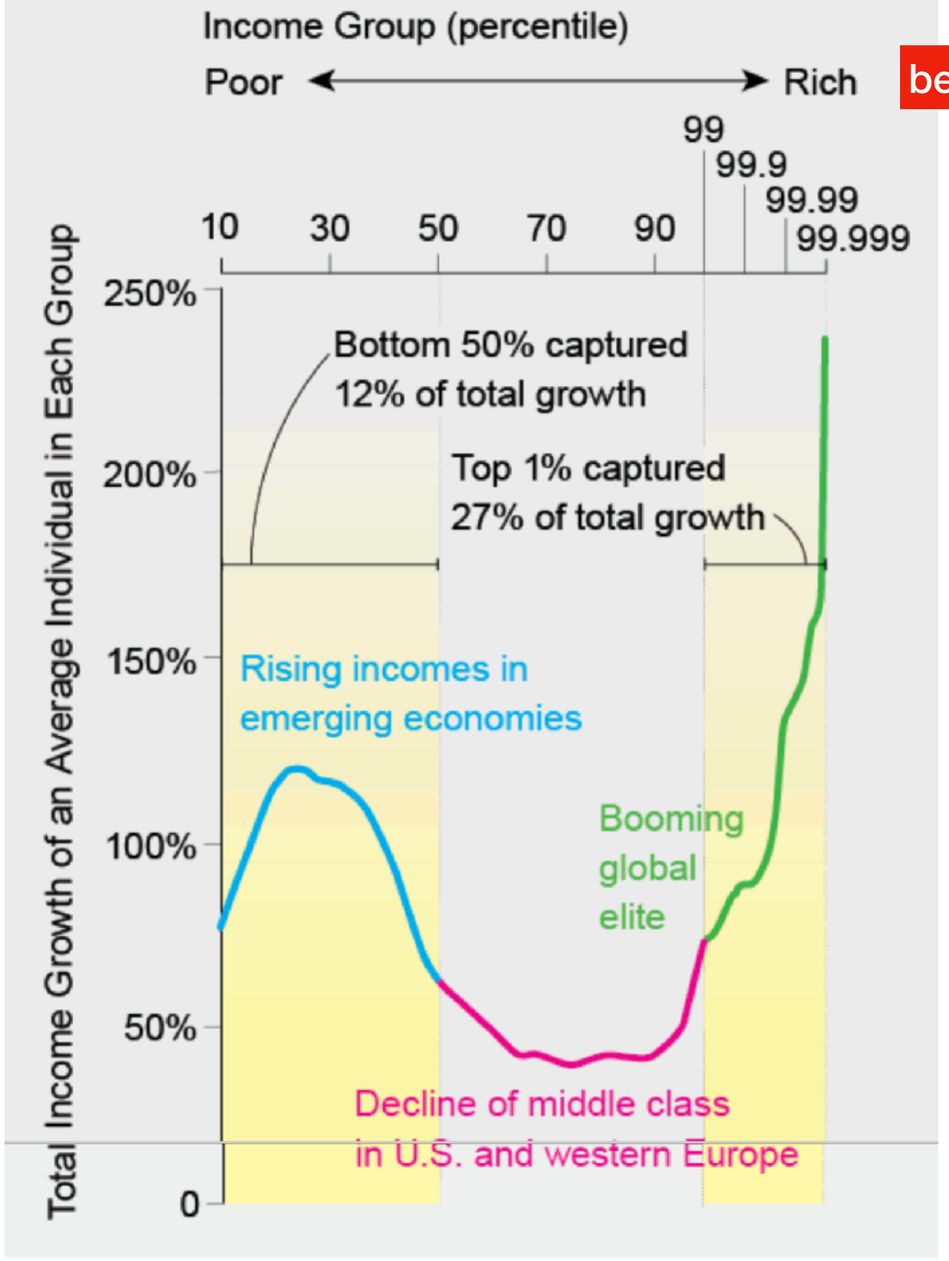
Joseph E. Stiglitz is a University Professor at Columbia University and Chief Economist at the Roosevelt Institute. He received the Nobel prize in economics in 2001. Stiglitz chaired the Council of Economic Advisers from 1995–1997, during the Clinton administration, and served as the chief economist and senior vice president of the World Bank from 1997–2000. He chaired the United Nations commission on reforms of the international financial system in 2008–2009. His latest authored book is *Globalization and Its Discontents Revisited* (2017).

Credit: Nick Higgins



credit: Stiglitz, Scientific American (2018)

between 1980-2016



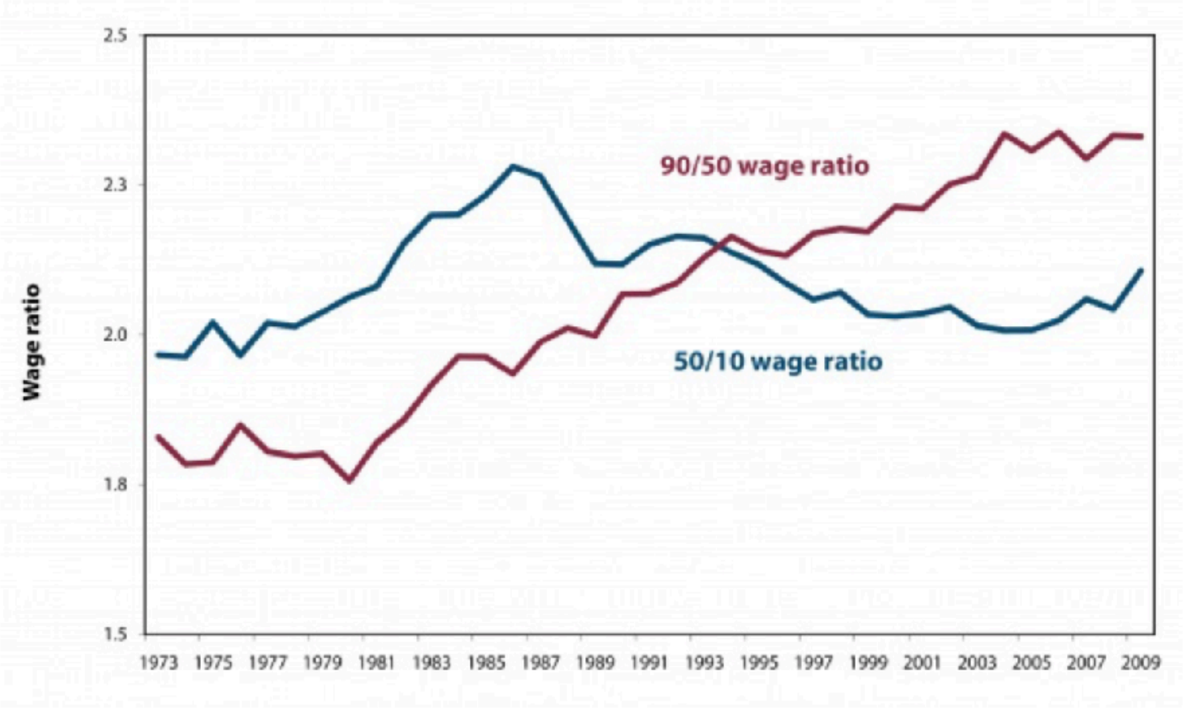
income = wages + capital rents

credit: Stiglitz, Scientific American (2018)

1. Wage Inequality

Over the last 30 years, wage inequality in the United States has increased substantially, with the overall level of inequality now approaching the extreme level that prevailed prior to the Great Depression. This general characterization of the inequality trend oversimplifies, though, the actual pattern of change: The chart below shows that the trend at the top of the income distribution (the "upper tail") is not exactly the same as the trend at the bottom of the distribution (the "lower tail"). "Lower-tail" inequality is measured here by taking the ratio of wages at the middle of the income distribution (i.e., the 50th percentile) to those near the bottom of the distribution (i.e., the 10th percentile); "upper-tail" inequality is measured by taking the ratio of wages near the top of the distribution (i.e., the 90th percentile) to those at the middle of the distribution (i.e., the 50th percentile of workers). We find that lower-tail inequality rose sharply in the 1980s and contracted somewhat thereafter, while upper-tail inequality has increased steadily since 1980.

Men's wage inequality



Nation wide

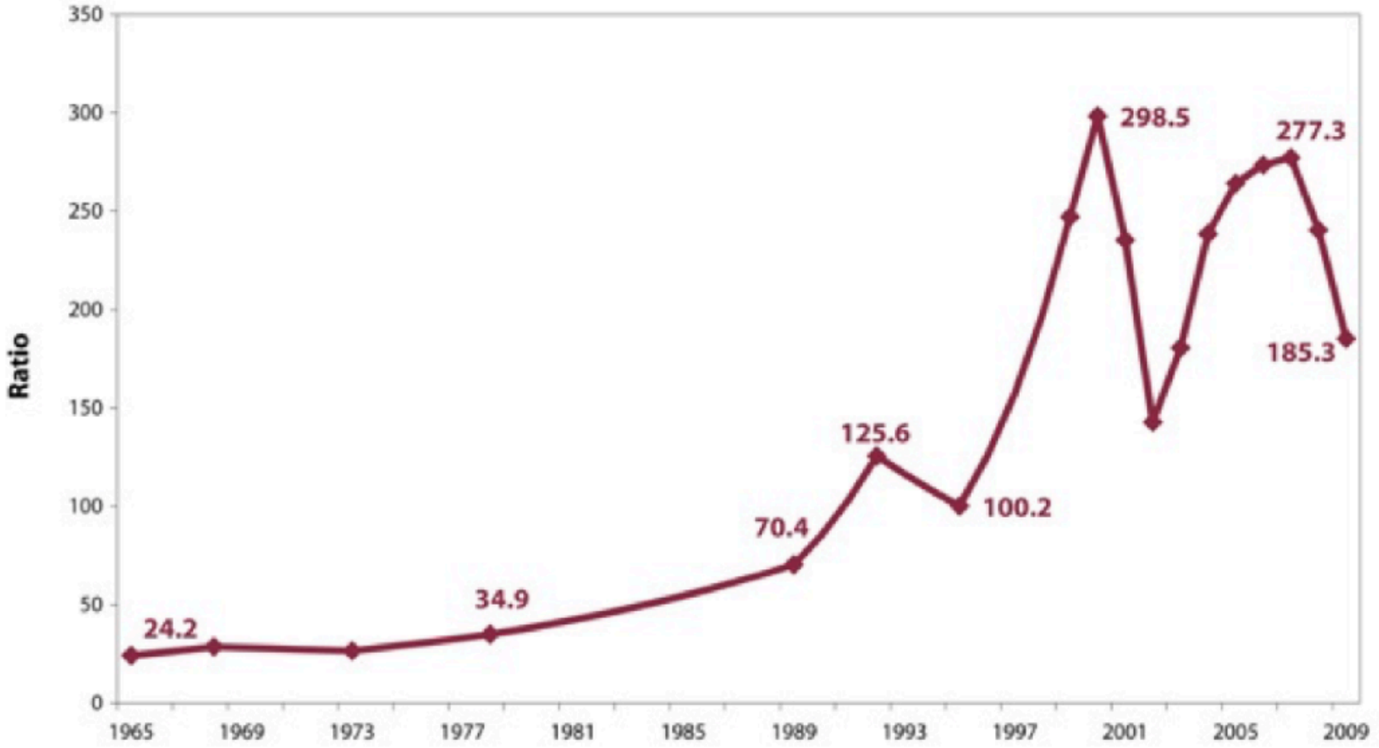
Source: Economic Policy Institute. 2011. "Upper Tail" inequality growing steadily: Men's wage inequality, 1973-2009. Washington, D.C.: Economic Policy Institute. May 11, 2011. <http://www.stateofworkingamerica.org/charts/view/192>.

20 Facts About U.S. Inequality that Everyone Should Know

2. CEO pay

Recent decades have seen a clear increase in the difference between CEO compensation and that of the average worker in manufacturing ("production." CEOs in 1965 made 24 times more than the average production worker, whereas in 2009 they made 185 times more. This cha shows how this ratio between the compensation of CEOs and production workers took off in the 1980s.

U.S. CEO pay in relation to the average production worker's compensation



Within firms

Source: Economic Policy Institute. 2011. More compensation heading to the very top: Ratio of average CEO total direct compensation to average production worker compensation, 1965-2009. Washington, D.C.: Economic Policy Institute. May 16, 2011. <http://www.stateofworkingamerica.org/charts/view/17>.

from: 20 Facts About U.S. Inequality that Everyone Should Know

FIGURE A

CEOs make 344 times as much as typical workers

CEO-to-worker compensation ratio, 1965–2022

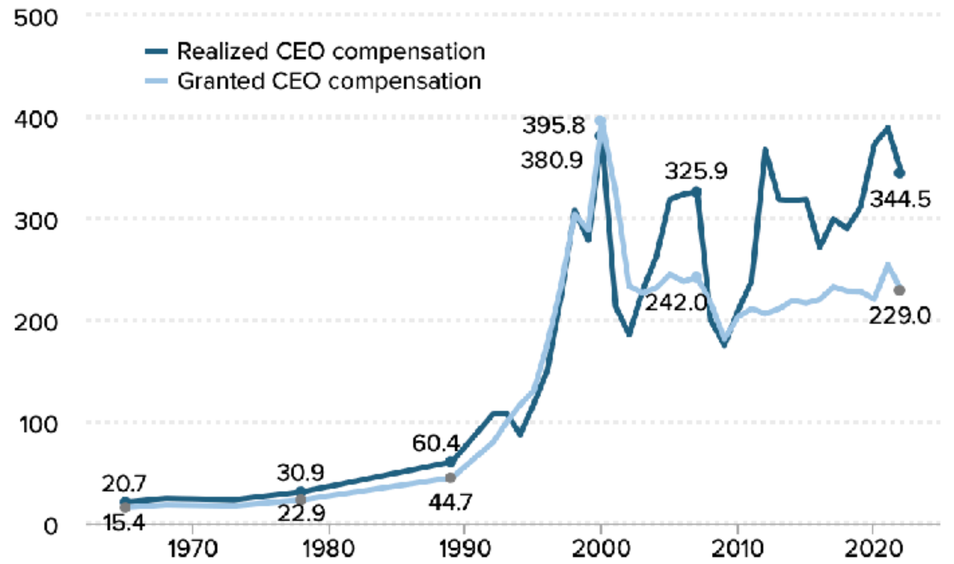


Chart | Data

Notes: Average annual compensation for CEOs is for CEOs at the top 350 U.S. firms ranked by sales. Typical worker compensation is the average annual compensation (wages and benefits of a full-time, full-year worker) of production/nonsupervisory workers in the industries that the top 350 firms operate in. ...

Source: Authors' analysis of data from Compustat's ExecuComp database, the Bureau of Labor Statistics' Current Employment Statistics data series, and the Bureau of Economic Analysis NIPA tables.

Economic Policy Institute

The gap between productivity and a typical worker's compensation has increased dramatically since 1979

Productivity growth and hourly compensation growth, 1948–2024

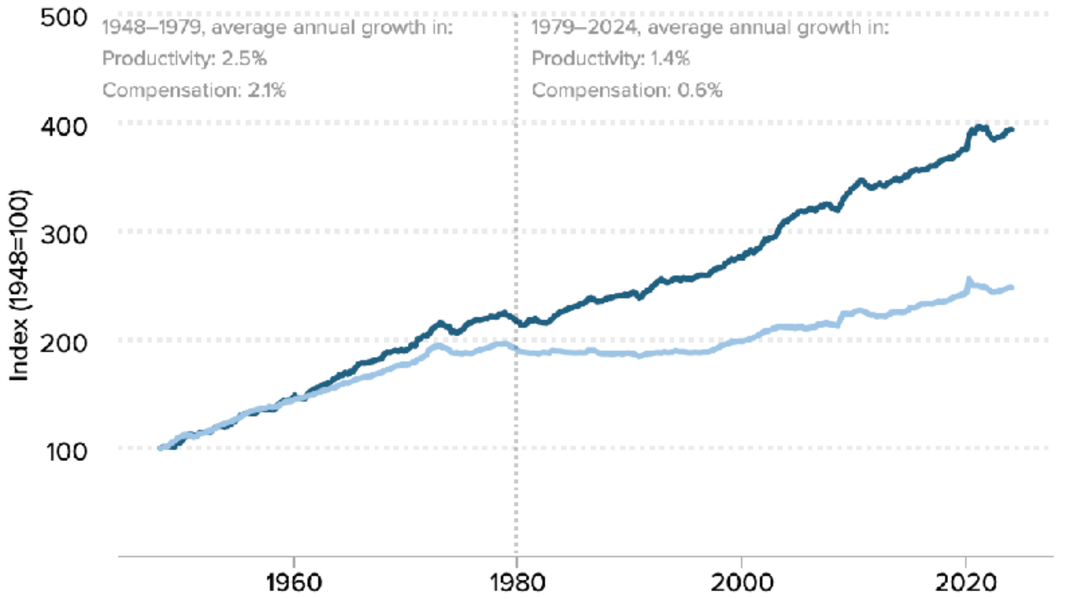


Chart | Data

Notes: Data are for compensation (wages and benefits) of production/nonsupervisory workers in the private sector and net productivity of the total economy. "Net productivity" is the growth of output of goods and services less depreciation per hour worked.

Source: EPI analysis of unpublished Total Economy Productivity data from Bureau of Labor Statistics (BLS) Labor Productivity and Costs program, wage data from the BLS Current Employment Statistics, BLS Employment Cost Trends, BLS Consumer Price Index, and Bureau of Economic Analysis National Income and Product Accounts.

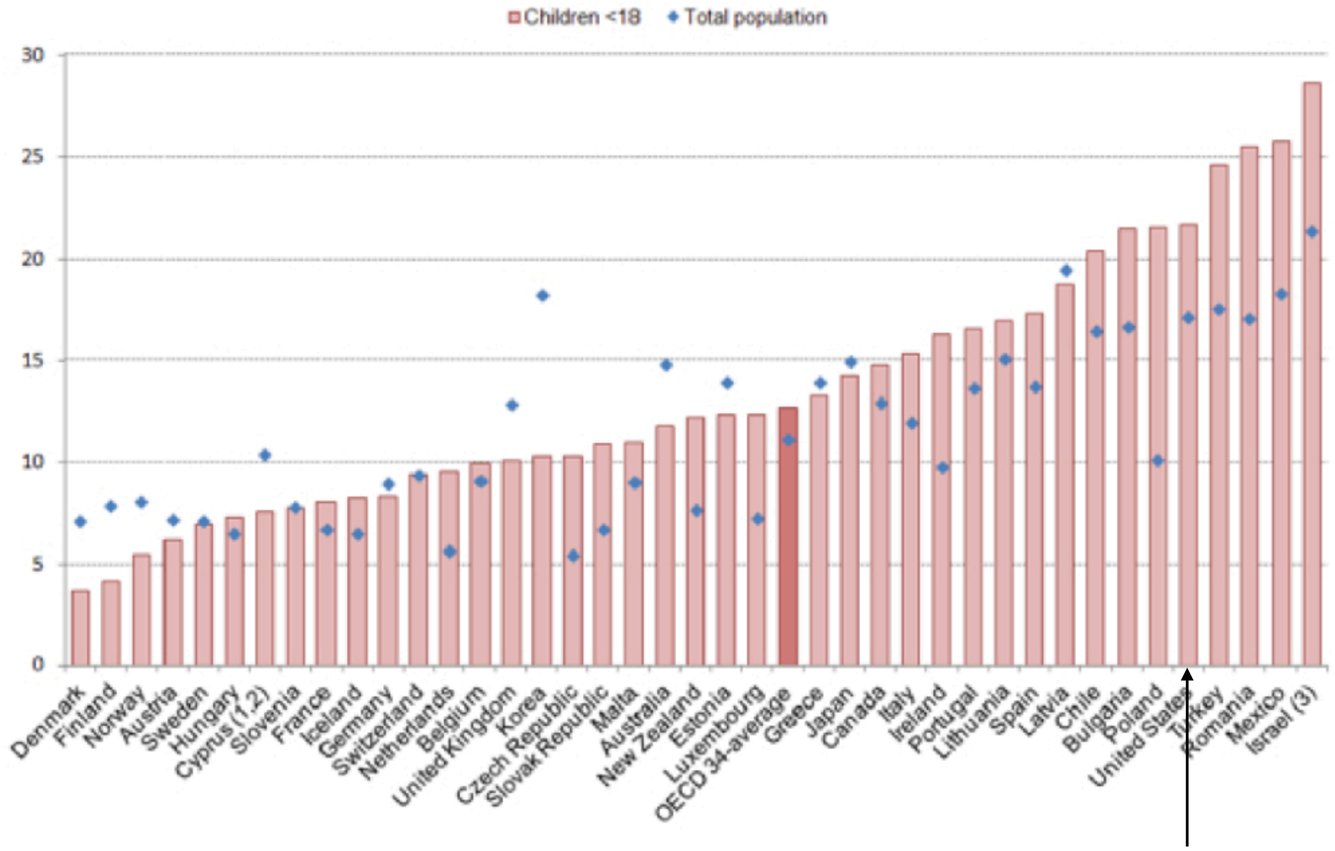
Economic Policy Institute

https://www.epi.org/publication/ceo-pay-in-2022/#fig-a

9. Child Poverty

In the United States, 21 percent of all children are in poverty, a poverty rate higher than what prevails in virtually all other rich nations.

Relative Poverty Rates in Forty Nations in the Mid-to-Late 2000s



Intergenerational

Source: OECD Income Distribution questionnaire, February 2011. Data refer to 2008 for Germany, Israel, Italy, Korea, Mexico, Netherlands, New Zealand, Norway, Sweden and the United States; 2007 for Canada, Denmark and Hungary; 2006 for Chile, Estonia, Japan and Slovenia; 2005 for France, Ireland, Switzerland and the United Kingdom; 2004 for Australia, Austria, Belgium, Czech Republic, Finland, Greece, Iceland, Luxembourg, Poland, Portugal, the Slovak Republic, Spain and Turkey.

from: 20 Facts About U.S. Inequality that Everyone Should Know

If you are interested in the general moral philosophy of inequality, I recommend:

In **1998**, Sen received the Prize in Economic Sciences in Memory of Alfred Nobel for his theoretical, field, and ethics work in welfare economics and for his research advancing the understanding of social-choice theory, poverty, and the measurement of welfare. Jun 3, 2021

Equality of What?

AMARTYA SEN

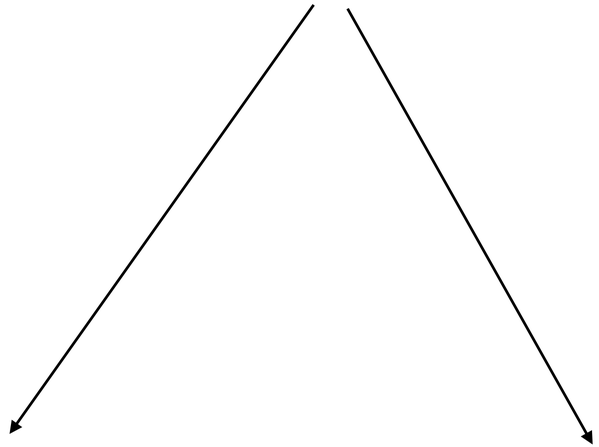
THE TANNER LECTURE ON HUMAN VALUES

In your reading list (optional)

https://www.ophi.org.uk/wp-content/uploads/Sen-1979_Equality-of-What.pdf

Origins of wealth inequality

Two Different Issues:



Piketty, Bowles,…

Marx, Stieglitz, …

Transmission of wealth over time

Allocation of production returns as Income

wealth “dynamics”

income: labor vs capital

Policy solutions :

depreciation, expropriation
government: inheritance taxes

firms
government: redistribution, social services

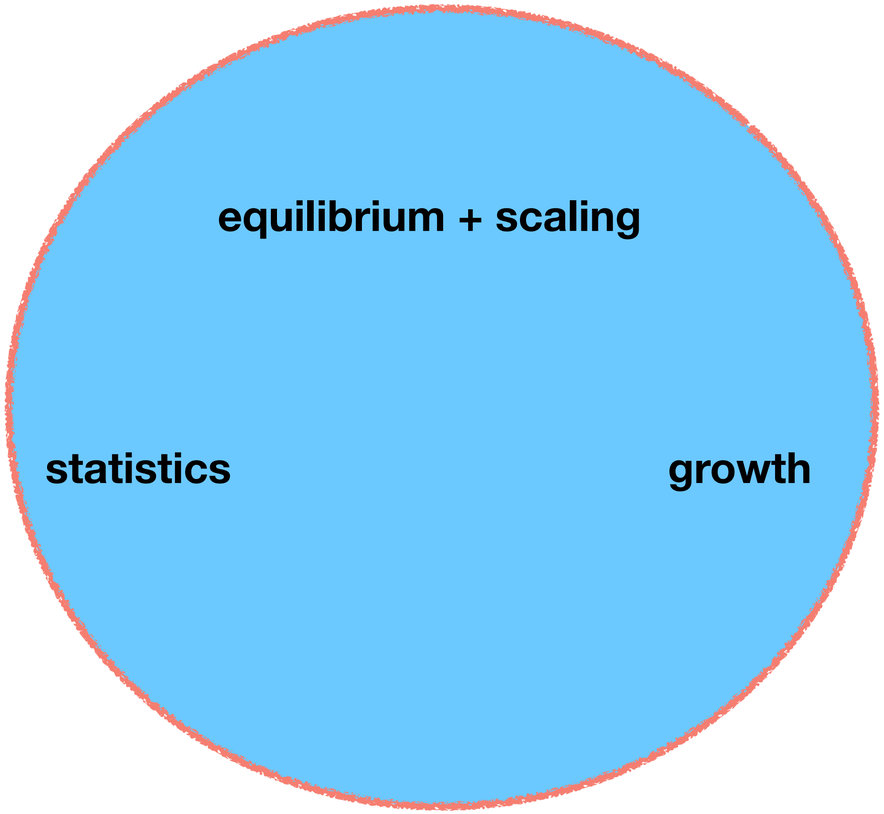
News

Stone Center Premieres "The Inequality Podcast"

New podcast discusses the causes and consequences of inequality and strategies to promote economic mobility.

https://harris.uchicago.edu/research-impact/centers-institutes/stone-center

Where does this all fit with Cities?



Economic Growth and Cities: Surplus from spatial “equilibrium”

budget: $Y(N) - C(N)$ → Surplus → **growth**

interactions — **costs**

transportation, housing

1. The Problem of Statistics

diversity, inequality: broad distributions of wealth

2. The Problem of Growth

cities are not static: they grow at a few percent a year!! good or bad?

Recall:

Economic Growth

where do economic growth rates come from?

$$\frac{dY}{dt} = \eta Y$$

Exponential Growth: 2-3% a year for USA

noisy, scale dependent, variable

inequality

A Simple Model of Resource Dynamics

flows: **income** **costs**

$$\frac{dr(t)}{dt} = y(t) - c(t) = \eta_r(t) r(t)$$

"one-good wealth accumulation model"

in economics

change in *resources*

stock: wealth, energy

"spatial equilibrium"

savings rate = growth rate

growth

$$\eta_r(t) \equiv \frac{y(t)}{r(t)} - \frac{c(t)}{r(t)}.$$

definition

Solution:

$$\ln \frac{r(t)}{r(0)} = \left(\bar{\eta}_r - \frac{\sigma_r^2}{2} \right) t + \Theta(t),$$

noise: $\Theta(t) = \sum_{l=1}^{t} \varepsilon_r(t_l),$ → **Normal "bell curve"**

because of the central limit theorem

The counter intuitive consequences of stochastic geometric growth

Consequences:

zero average, standard deviation: $\sigma_\Theta = \sigma_r\sqrt{t}$

1.

$$\ln\frac{r(t)}{r(0)} = \left(\bar{\eta}_r - \frac{\sigma_r^2}{2}\right)t + \Theta(t), \qquad \Theta(t) = \sum_{l=1}^{t}\varepsilon_r(t_l) \quad \sim \sigma_r\sqrt{t}$$

Central Limit Theorem -> Gaussian

lognormal statistics !!

2.

$$\frac{1}{t}\ln\frac{r(t)}{r(0)} = \gamma_r + \frac{\Theta(t)}{t} \to \gamma_r,$$

The average growth rate over long times becomes a simple number

ergodicity

3.

$$t_* = \frac{\sigma_r^2}{\left(\bar{\eta}_r - \frac{\sigma_r^2}{2}\right)^2},$$

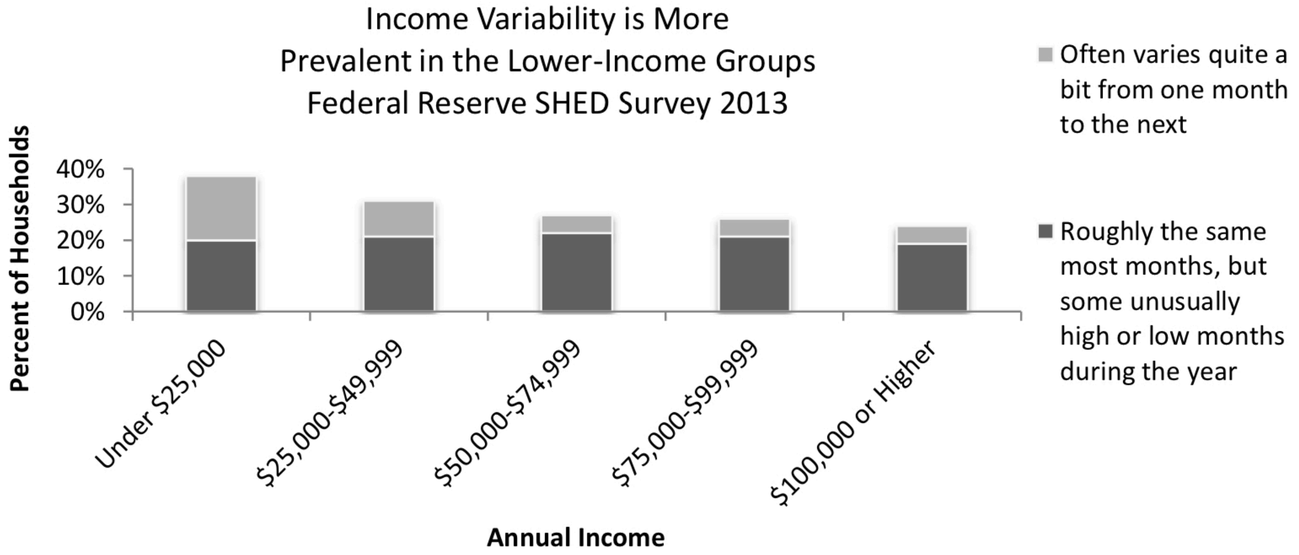
There is a minimum time to see through the "fog" of sort term fluctuations.

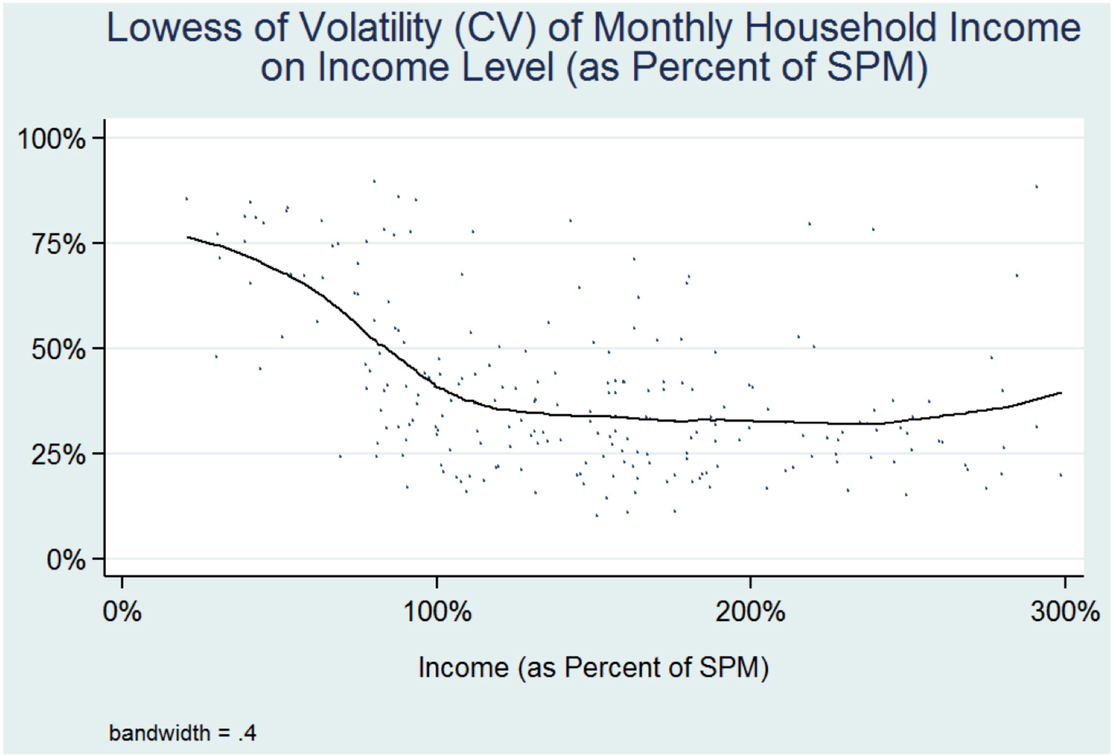
proportional to the uncertainty (volatility, std) between relative income and costs

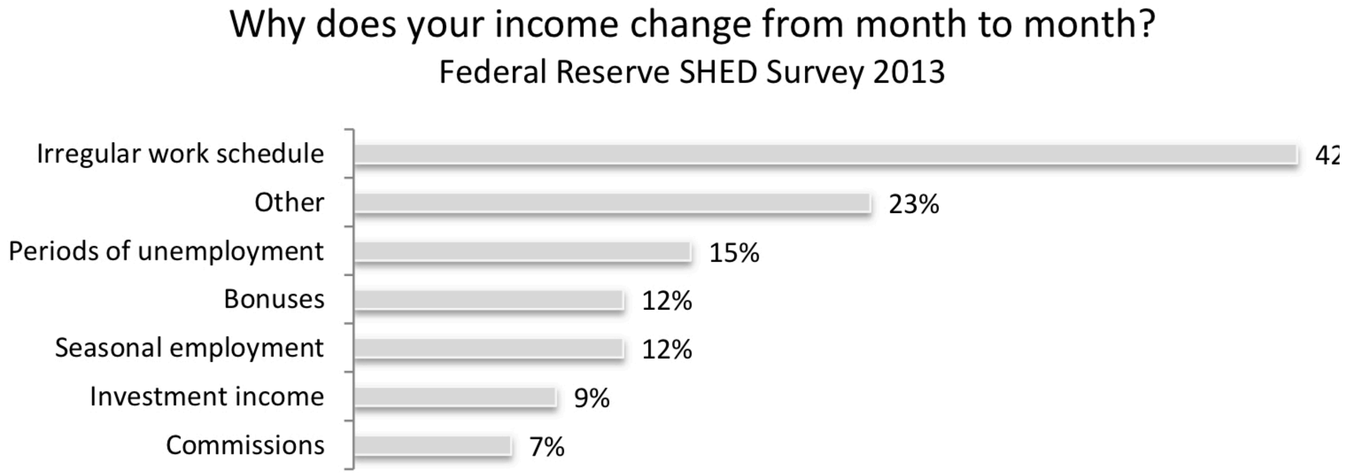
people with a lot if uncertainty do not see growth as a possibility

The working poor experience much more volatility

lower effective growth rates, unclear horizons

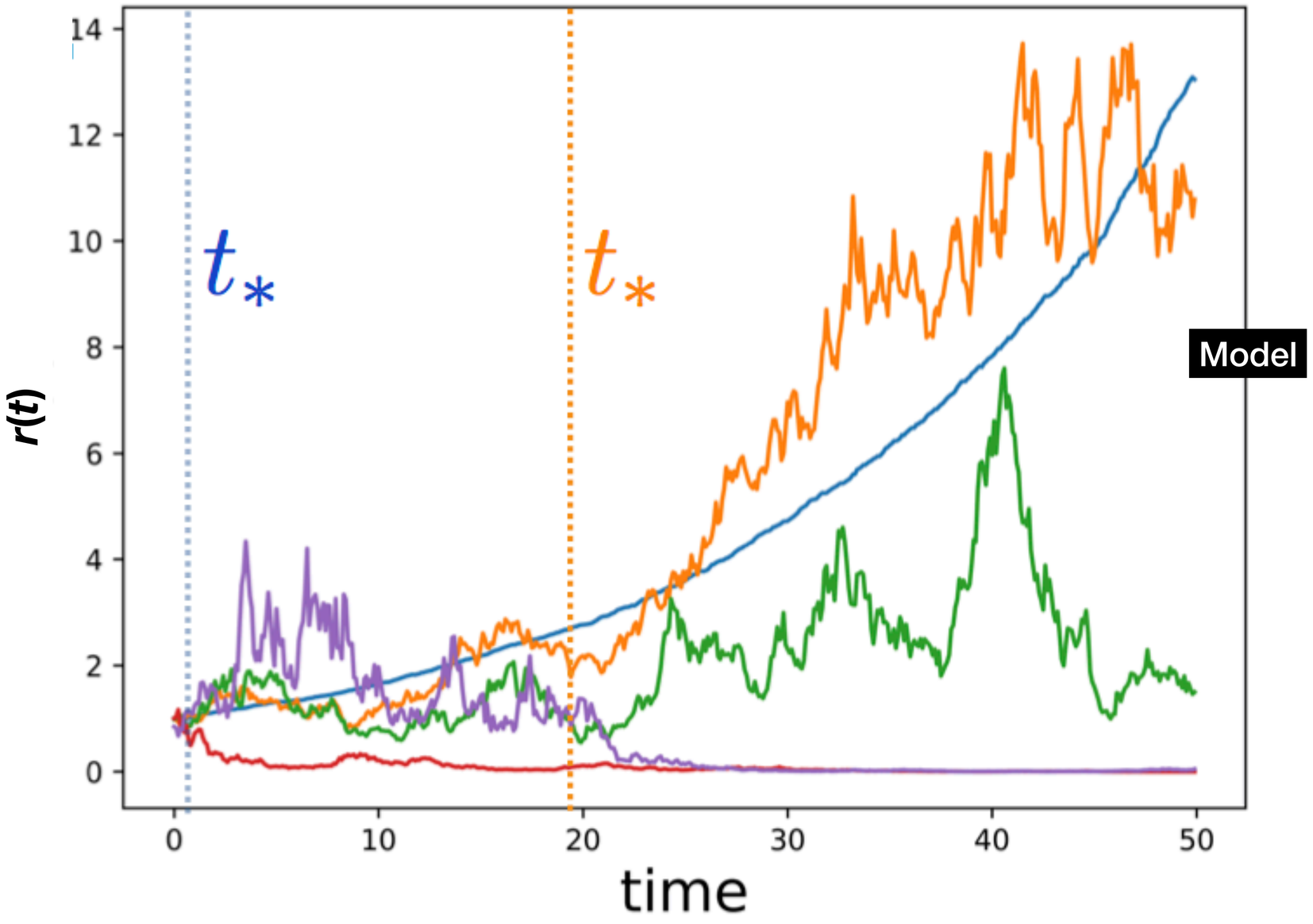




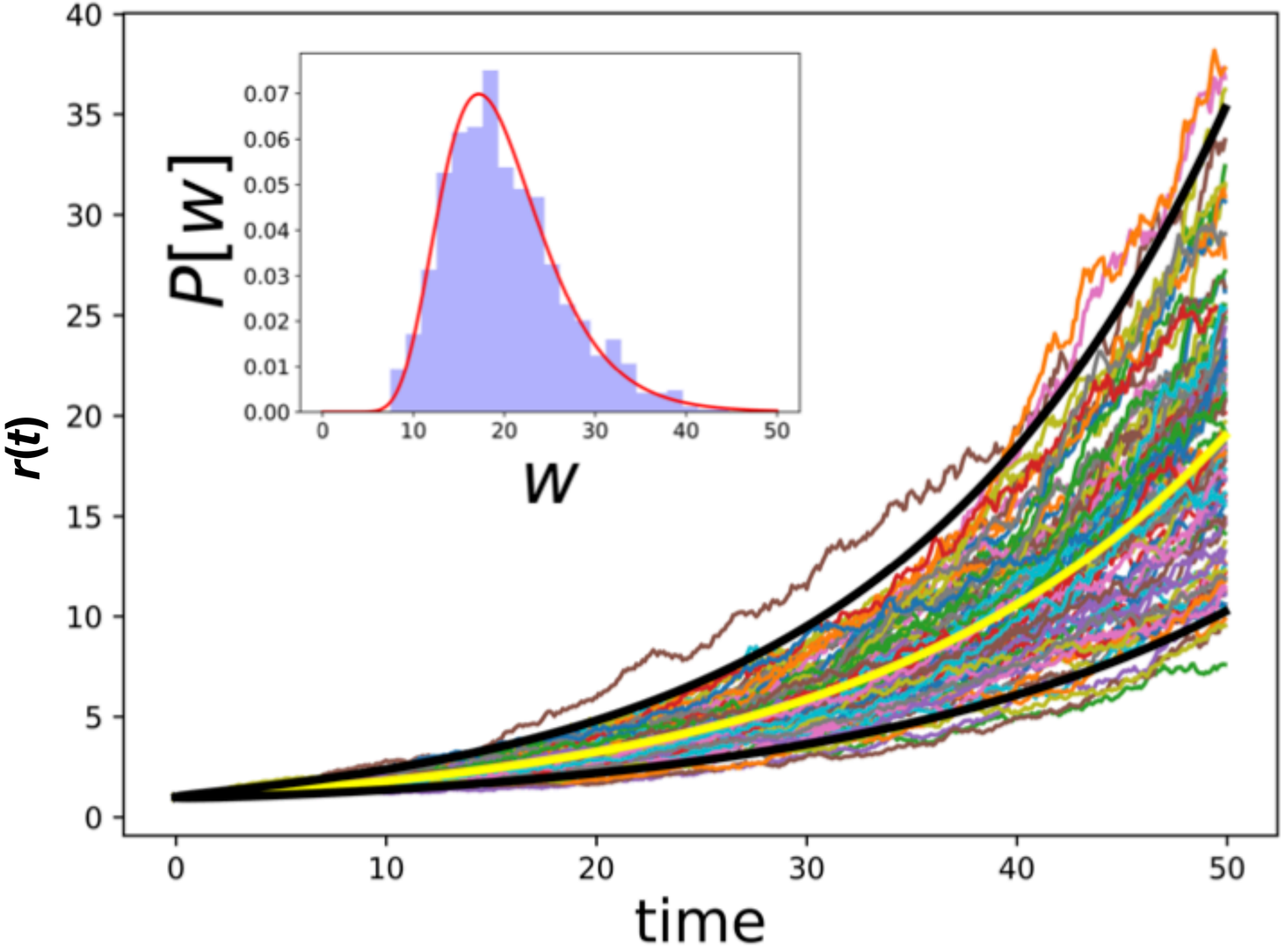


from: Income Gains and Month-to-Month Income Volatility: Household evidence from the US Financial Diaries, Hannagan + Morduch (2015)

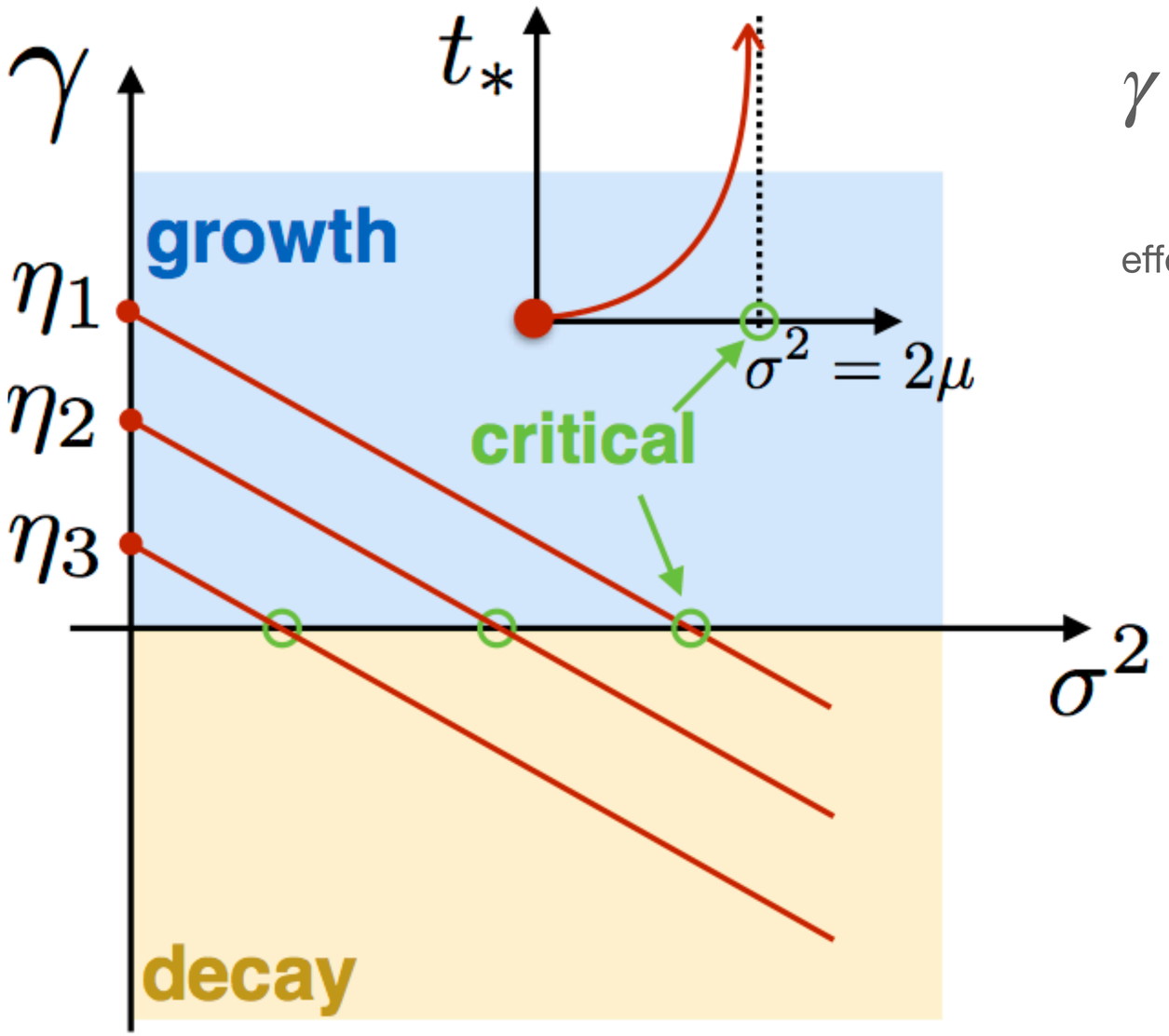
Model Solutions look like this



Log normal statistics



Net Growth Requires Low Fluctuations



$$\gamma = \eta - \frac{\sigma^2}{2}$$

effective growth rate

Want low fluctuations:

$$\eta_r(t) \equiv \frac{y(t)}{r(t)} - \frac{c(t)}{r(t)} = b(t) - a(t) = \bar{\eta} + u(t) - v(t) = \bar{\eta} + \epsilon(t)$$

definition

income fluctuations

choice expenditures

definition

when I have more money can spend more and vice-versa

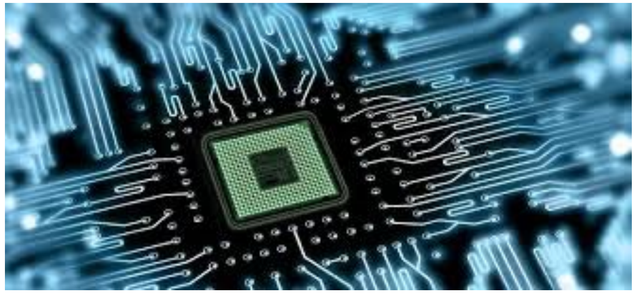
Consumption Smoothing

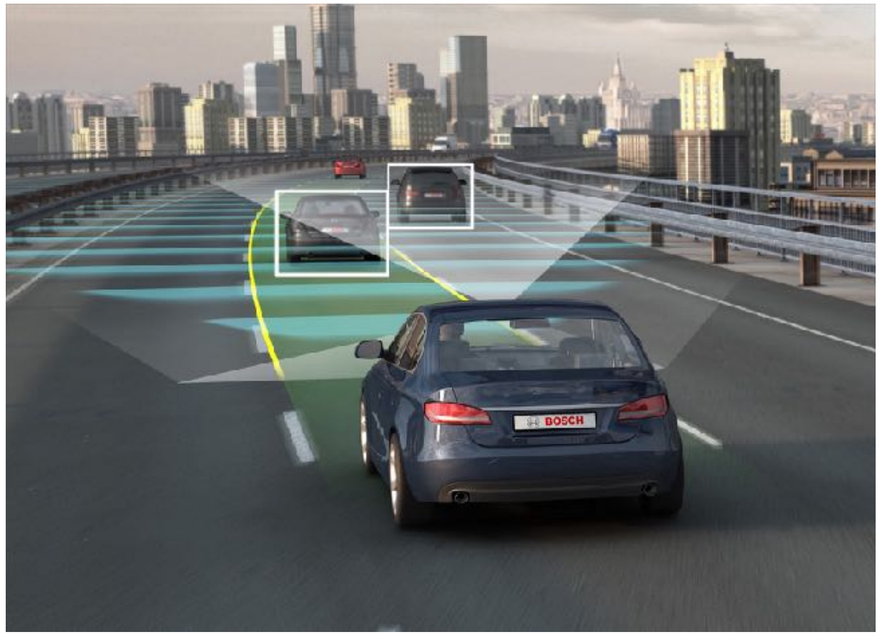
need to average (smoothen) expenditures and incomes over some time
month, season, year

feedback control theory

Feedback Control is a big part of your life

Feedback Control is a big part of your life





How Control theory works:

PID Controller

$$u(t) = k_P \varepsilon_r(t) + k_I \int_0^t \varepsilon_r(t')dt' + k_D \frac{d\varepsilon_r}{dt},$$

Time costs to track income fluctuations

This gives a simple dynamics for errors

$$\frac{d^2\varepsilon_r}{dt^2} + 2\zeta\omega\frac{d\varepsilon_r}{dt} + \omega^2\varepsilon_r = F/m, \qquad m = k_D,\ \omega = \sqrt{k_I/k_D} \text{ and } \zeta = \frac{k_P+1}{2\sqrt{k_D k_I}},$$

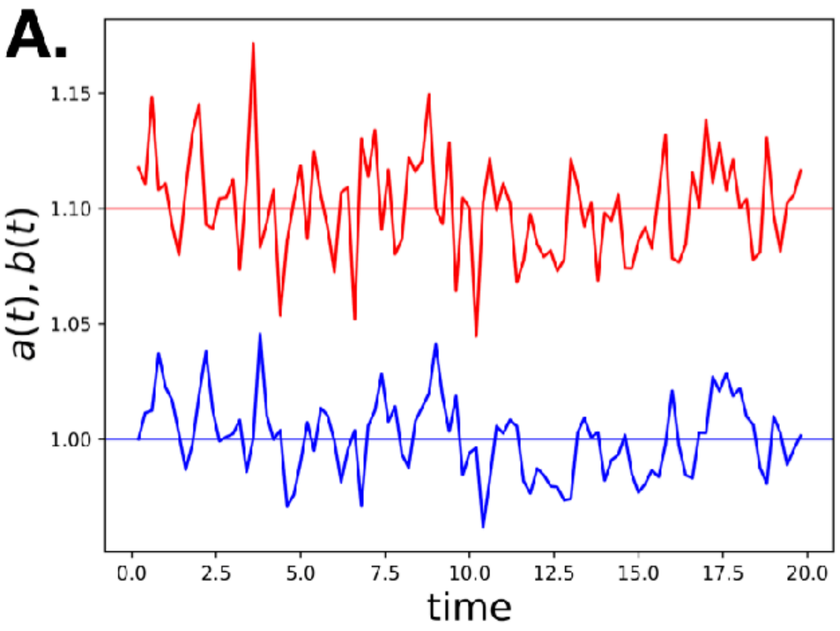
noisy spring

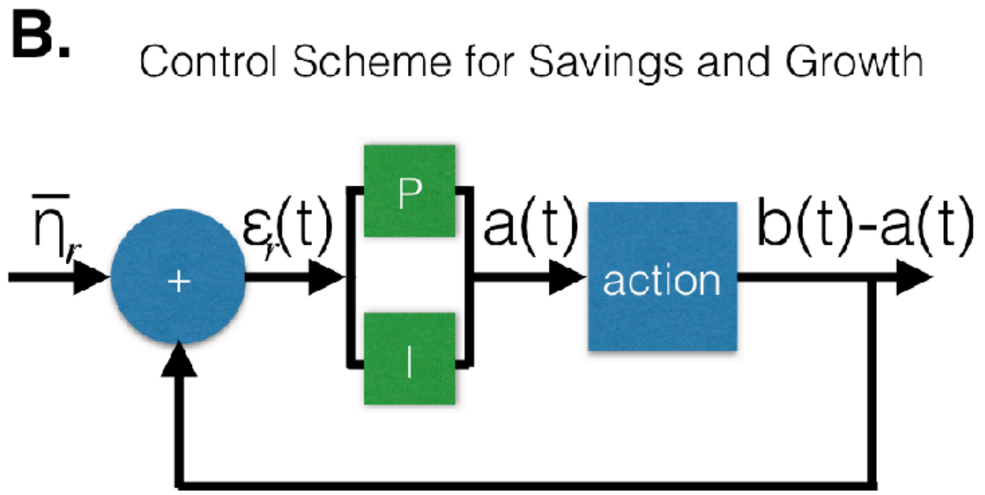
$$d\varepsilon_r = -\frac{M}{2}\varepsilon dt + \Omega dW(t). \qquad M = \omega/\zeta = k_I/[2(k_P+1)]$$

error wants to vanish **noise**

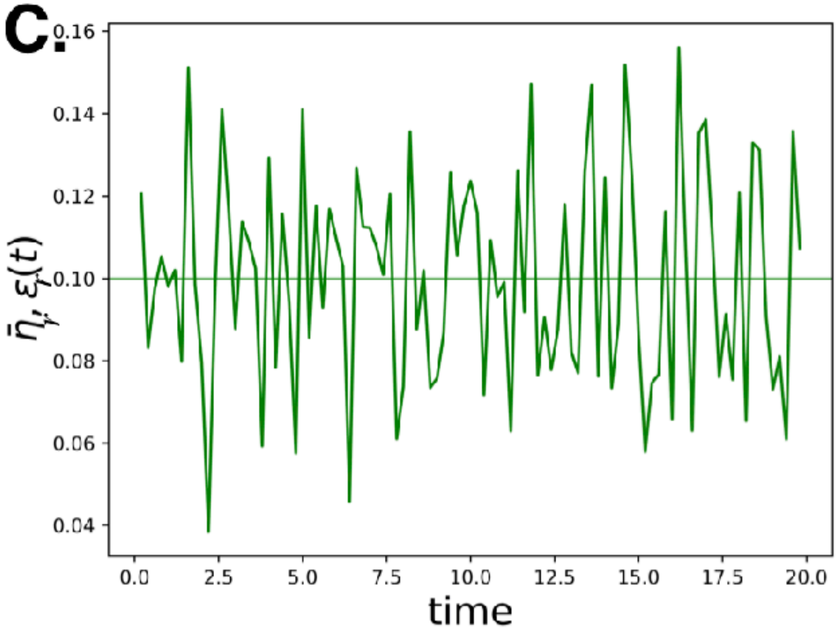
Statistics of error is "under control":

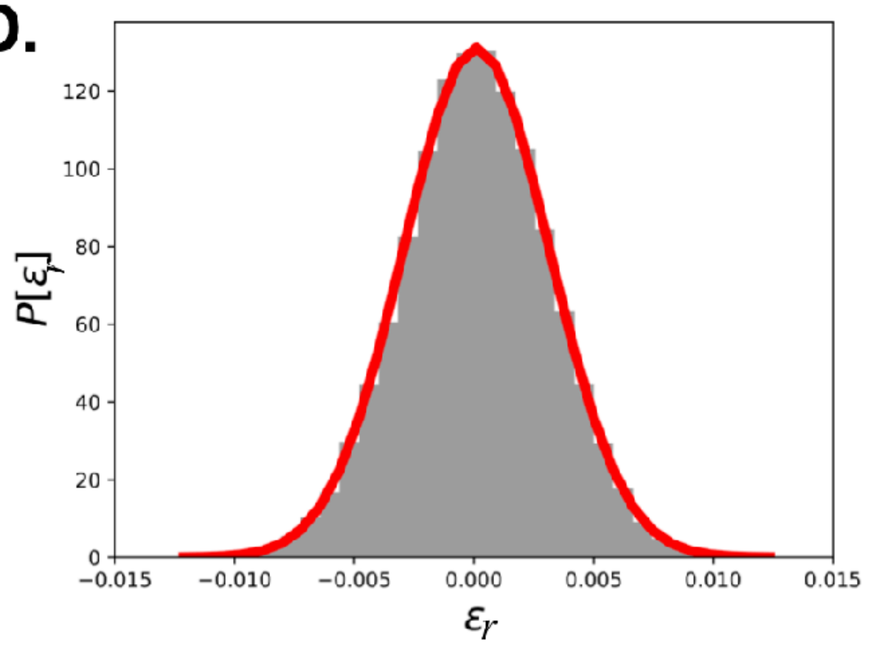
$$P[\varepsilon_r, t|\varepsilon_0] = \sqrt{\frac{M}{2\pi\Omega^2(1-e^{-Mt})}}\, e^{-\frac{M}{2\Omega^2}\left[\frac{(\varepsilon_r - \varepsilon_0 e^{-M/2\ t})^2}{1-e^{-Mt}}\right]} \to \sqrt{\frac{M}{2\pi\Omega^2}}\, e^{-\frac{M}{2\Omega^2}\varepsilon_r^2},$$





"Consumption Smoothing"





Growth rates for individuals and for cities

Is the growth rate for a city the average of the growth rates for individuals?

Not in general:

$$r_G = \frac{1}{G}\sum_{j=1}^{G} r_j$$

average resources

$$\frac{dr_G}{dt} = y_G - c_G = (\eta r)_G,$$

growth of resources per capita in a population

average of product

$$(\eta r)_G = \frac{1}{G}\sum_{j=1}^{G} \eta_j w_j = \eta_G r_G + \mathrm{covar}_G(\eta, r) = [\eta_G + \mathrm{covar}_G(\eta, r/r_G)]\, r_G.$$

average rate

"selection"

Consequences:

$$(\eta r)_G = \frac{1}{G}\sum_{j=1}^{G} \eta_j w_j = \eta_G r_G + \mathrm{covar}_G(\eta, r) = [\eta_G + \mathrm{covar}_G(\eta, r/r_G)]\, r_G.$$

positive: richer people get higher growth rates

correlation between resources and rates

negative: richer people get lower growth rates

anti-correlation between resources and rates

What situation gives the highest overall growth rates?

What situation gives the lowest inequality?

Corrections to scaling exponents

$$Y(N) = Y_0 N^{\beta} e^{\xi} \rightarrow \langle Y(N) \rangle = Y_0 N^{\beta} \langle e^{\xi} \rangle$$

lognormal

$$e^{\frac{\sigma^2(N)}{2}}$$

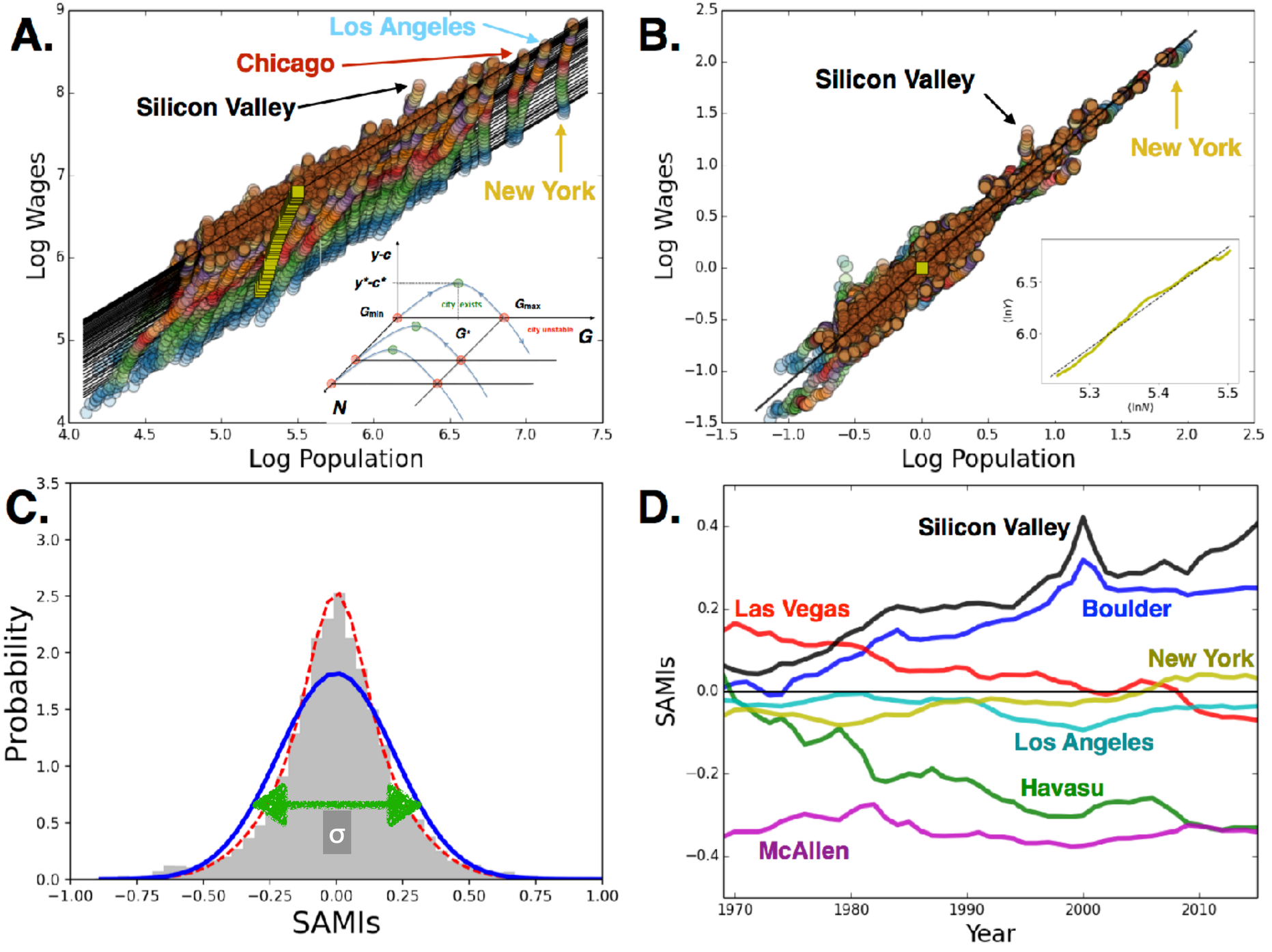
varies with N

scaling exponents become scale dependent

loss of scale invariance

requires a theory for the variances

more complicated statistics


A.
Los Angeles
Chicago
Silicon Valley
New York
Log Wages
Log Population
y-c
y*-c*
Gmin
city exists
Gmax
G*
city unstable
G
N
B.
Silicon Valley
New York
Log Wages
Log Population
⟨lnY⟩
⟨lnN⟩
C.
Probability
SAMIs
σ
D.
Silicon Valley
Las Vegas
Boulder
New York
Los Angeles
Havasu
McAllen
SAMIs
Year

How Long does it take Cities to Catch Up with Others?

In the US, very small randomness

The typical square displacement of

$$\xi^2(t) = \sigma^2 t \simeq 0.054$$

in 50 years !!

Observe:

$$\langle \xi^2(1969) \rangle = 0.043$$

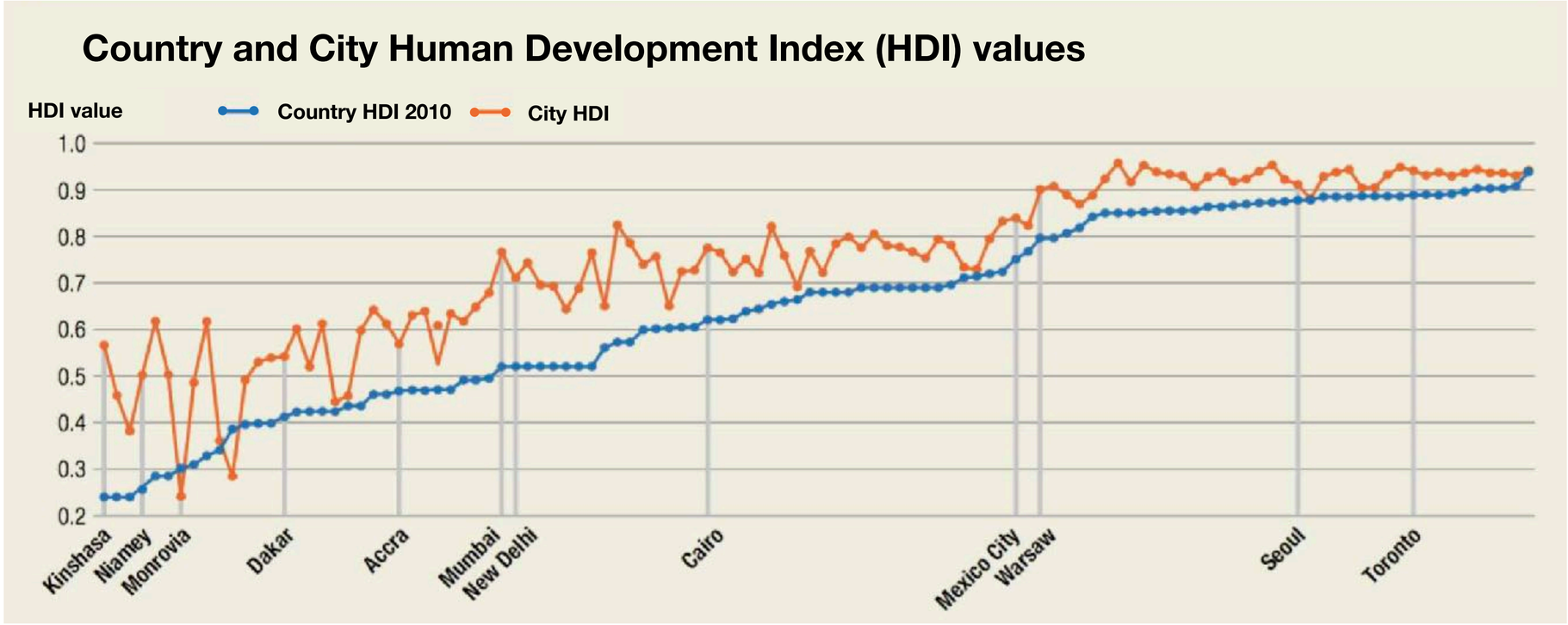
could have been ~ 0 **40 years before: in the 1920s**

How long does it take to create an equitable society? **About a Generation ~ 20-50 years**

slower with slow economic and demographic growth rates

How about human development?

Broad Human Development is a Feature of Larger Cities ！



credit: UNDP Human Development Report 2013

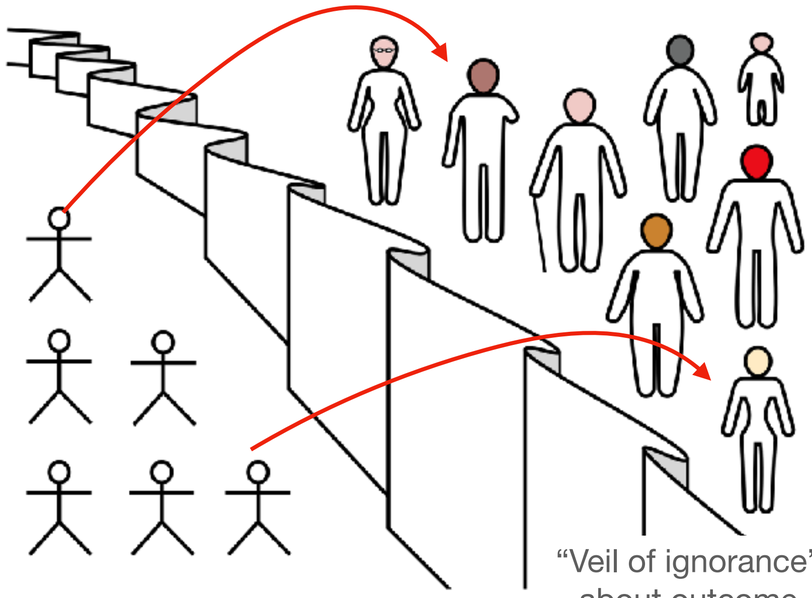
A theory of justice

Problem: how to find a socially just distribution of goods in a society?

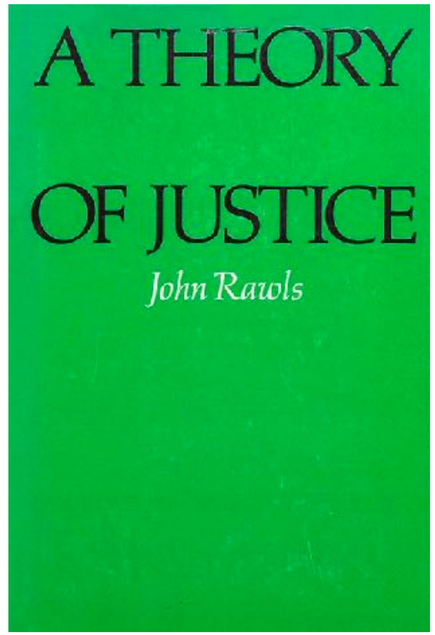
Thought experiment:

What society would you want if you were to be swapped at random with any other person?

Original Position:



"Veil of ignorance" about outcome



https://en.wikipedia.org/wiki/A_Theory_of_Justice

"Preference symmetry invariance"

1. Each citizen is guaranteed a fully adequate scheme of basic liberties, compatible with the same liberties for all

2. Social and economic inequalities are:
   - to the greatest benefit of the least advantaged,
   - attached to offices and positions open to all under conditions of fair equality of opportunity

But can people “pursue their happiness”? That takes more than goods and liberties

Equality of What?

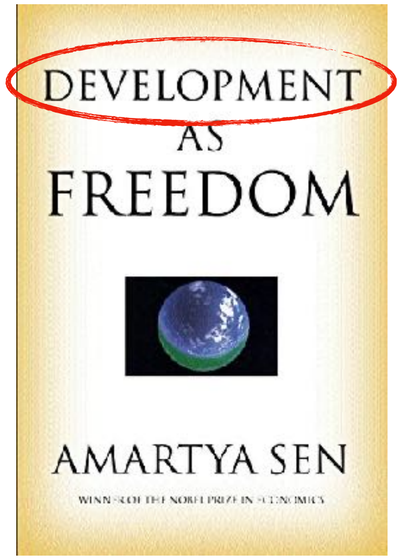
AMARTYA SEN

THE TANNER LECTURE ON HUMAN VALUES

Delivered at
Stanford University

May 22, 1979

https://www.ophi.org.uk/wp-content/uploads/Sen-1979_Equality-of-What.pdf



“capabilities approach”:

basic capabilities **agency** **empowerment** **in context**

processual equalities

not just money, goods, freedom,…

+ Martha Nussbaum

https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=3391&context=flr

Human development as a network process (in cities)

Measuring Human Development across scales


Suraj Sheth

nature › npj urban sustainability › articles › article

Article | Open Access | Published: 20 February 2023

Measuring health and human development in cities and neighborhoods in the United States

Suraj K. Sheth ✉ & Luís M. A. Bettencourt

npj Urban Sustainability **3**, Article number: 7 (2023) | Cite this article

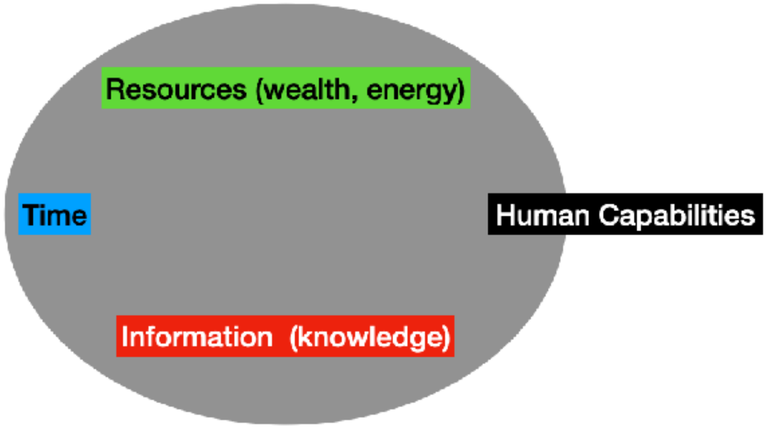
https://www.nature.com/articles/s42949-023-00088-y

Human Development Index

"measures the ability of human populations to lead long, healthy and fulfilled lives"

Mahbub ul Haq

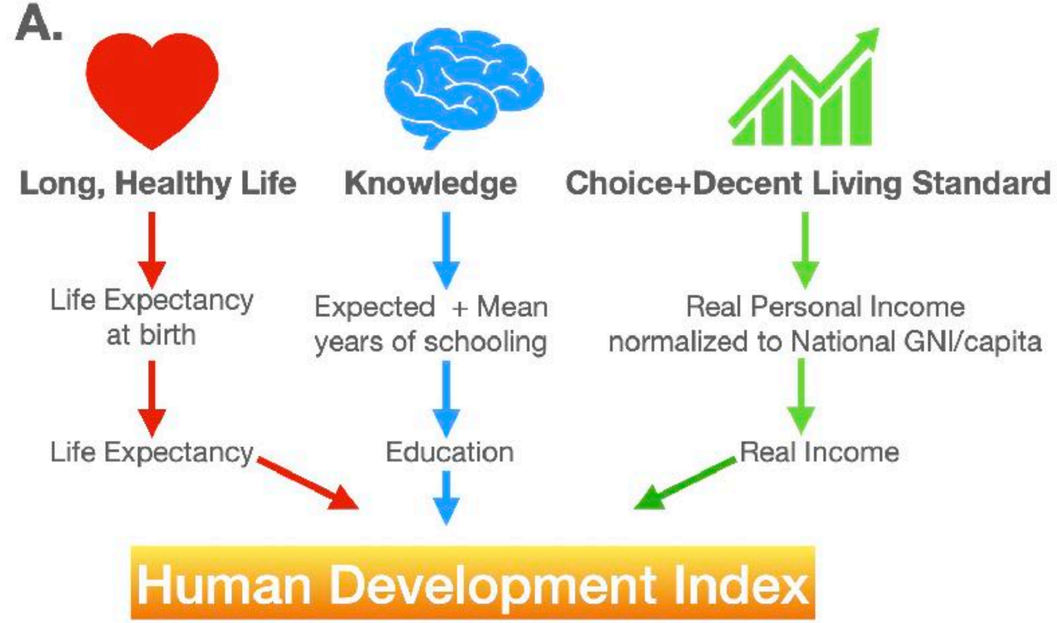
$$\mathrm{HDI}_i = \left(\mathrm{education}_i \,.\, \mathrm{life\ expectancy}_i \,.\, \mathrm{real\ income}_i\right)^{1/3}$$

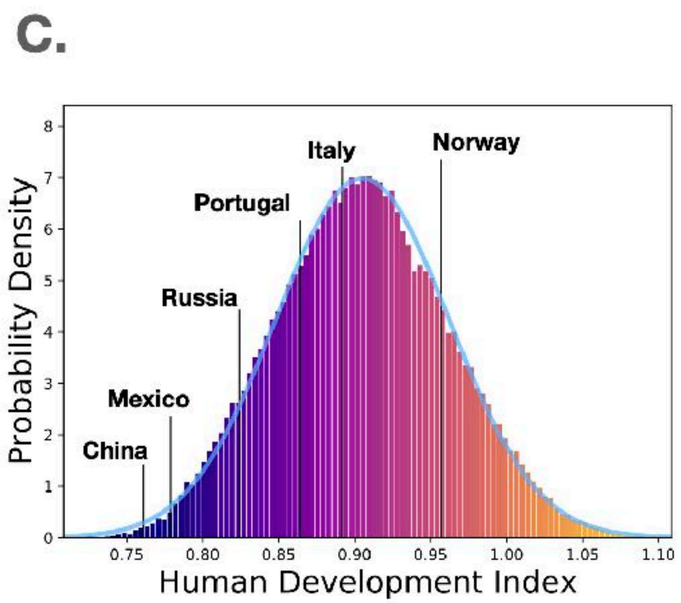


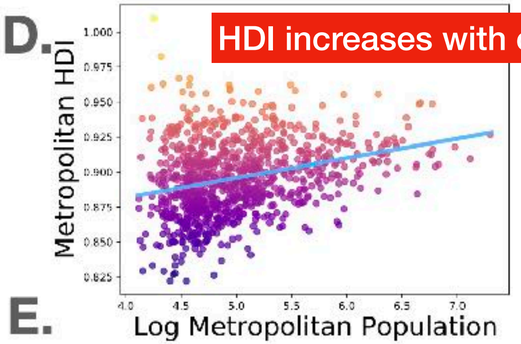
Rank		Country or Territory	HDI	
2019 data (2020 report)[14]	Change over 5 years (2014)[15]		2019 data (2020 report)[14]	Average annual HDI growth (2010-2019)[15]
1	–	Norway	0.957	▲ 0.20%
2	▲ (7)	Ireland	0.955	▲ 0.65%
2	–	Switzerland	0.955	▲ 0.16%
4	▲ (7)	Hong Kong	0.949	▲ 0.54%
4	▲ (4)	Iceland	0.949	▲ 0.62%
6	▼ (3)	Germany	0.947	▲ 0.24%
7	▼ (3)	Sweden	0.945	▲ 0.41%
8	▼ (2)	Australia	0.944	▲ 0.17%
8	▼ (1)	Netherlands	0.944	▲ 0.32%
10	▼ (6)	Denmark	0.940	▲ 0.28%
11	▼ (2)	Finland	0.938	▲ 0.26%
11	–	Singapore	0.938	▲ 0.35%
13	–	United Kingdom	0.932	▲ 0.24%
14	▲ (1)	Belgium	0.931	▲ 0.25%
14	▲ (3)	New Zealand	0.931	▲ 0.30%
16	▼ (1)	Canada	0.929	▲ 0.34%
17	▼ (3)	United States	0.926	▲ 0.12%

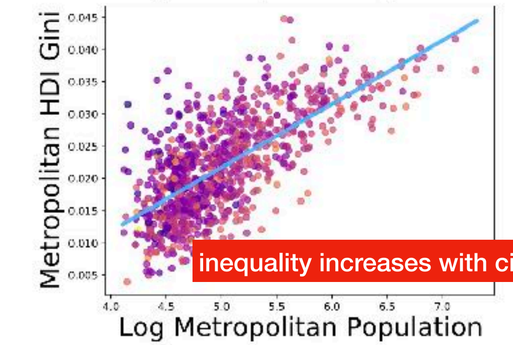
The US is now # 17

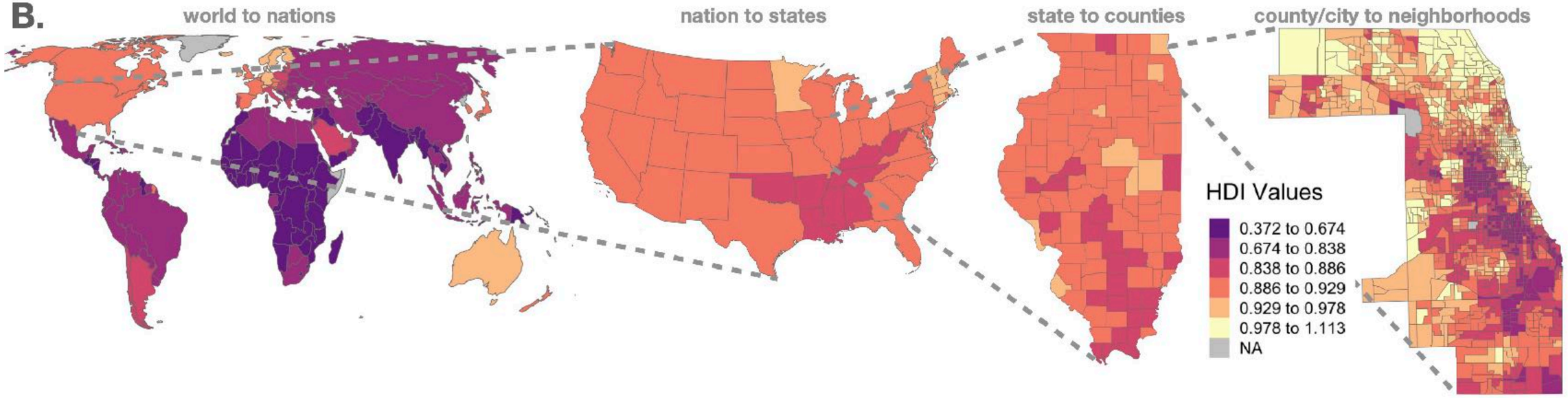
because of health and educational inequality







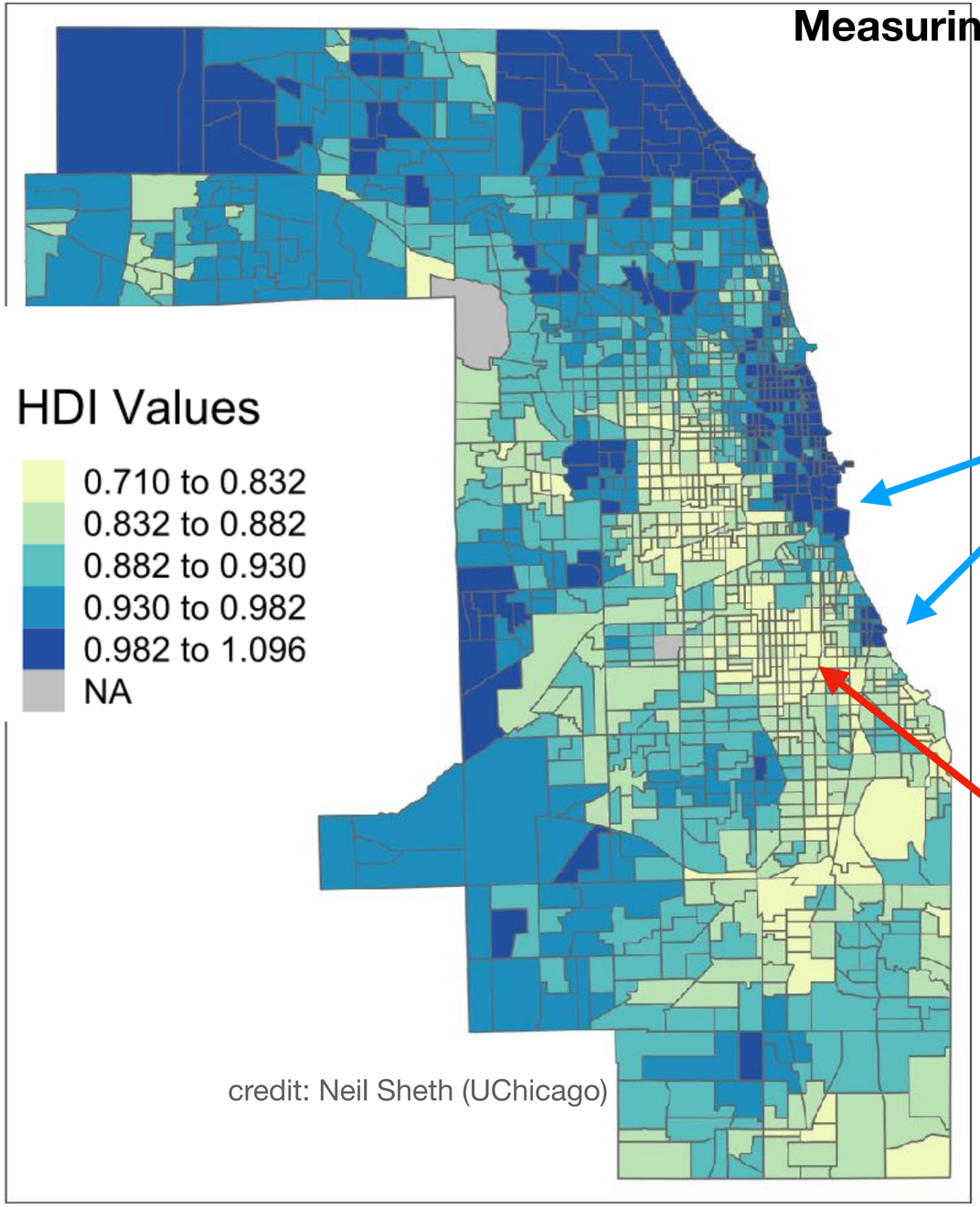




https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3961750

Check out the interactive map at: https://communityhdi.org/

Measuring the Human Development of Chicago neighborhoods



better than Norway

worse than China or Mexico

https://www.nature.com/articles/s42949-023-00088-y

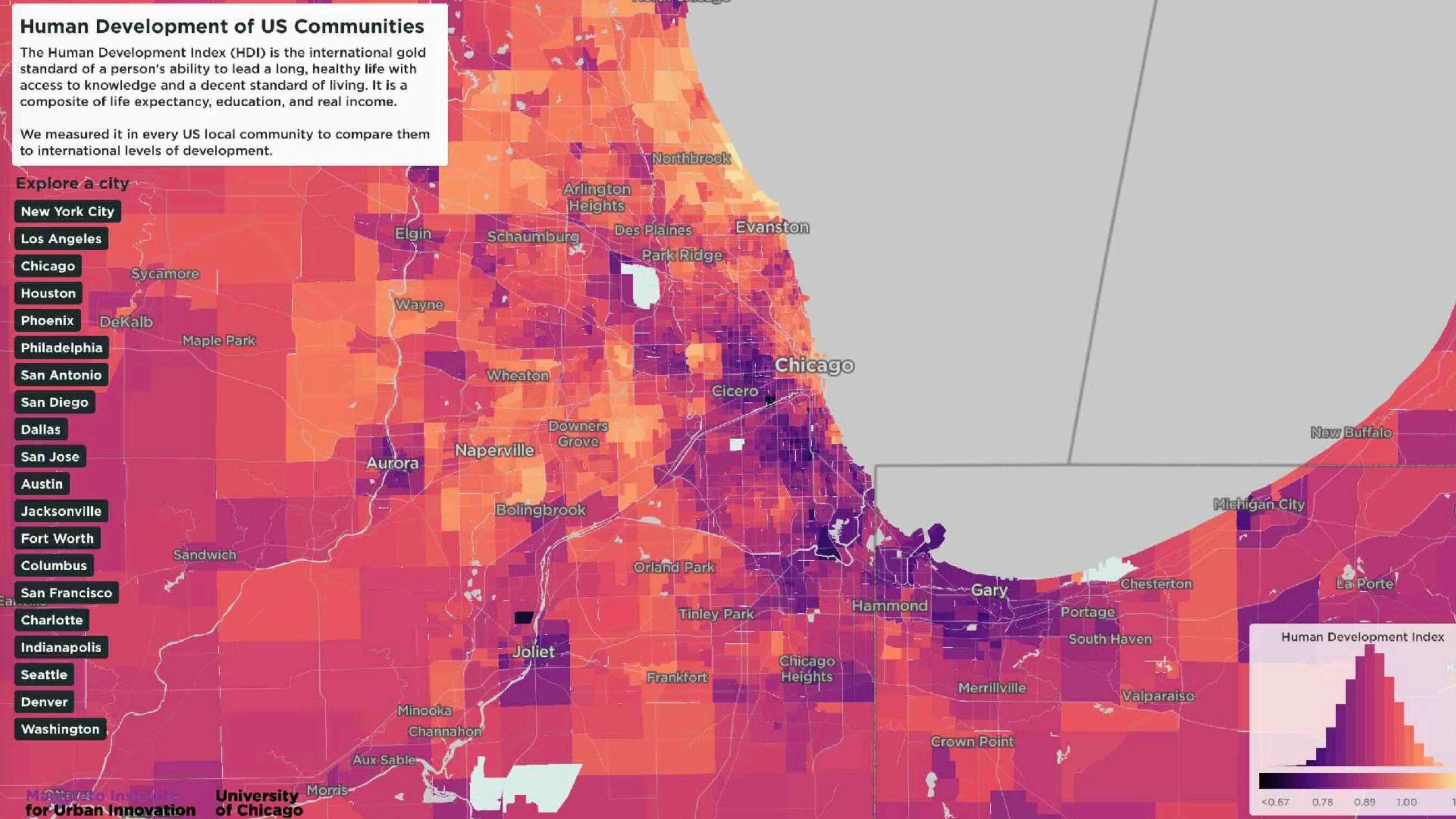
Human Development of US Communities

The Human Development Index (HDI) is the international gold standard of a person's ability to lead a long, healthy life with access to knowledge and a decent standard of living. It is a composite of life expectancy, education, and real income.

We measured it in every US local community to compare them to international levels of development.

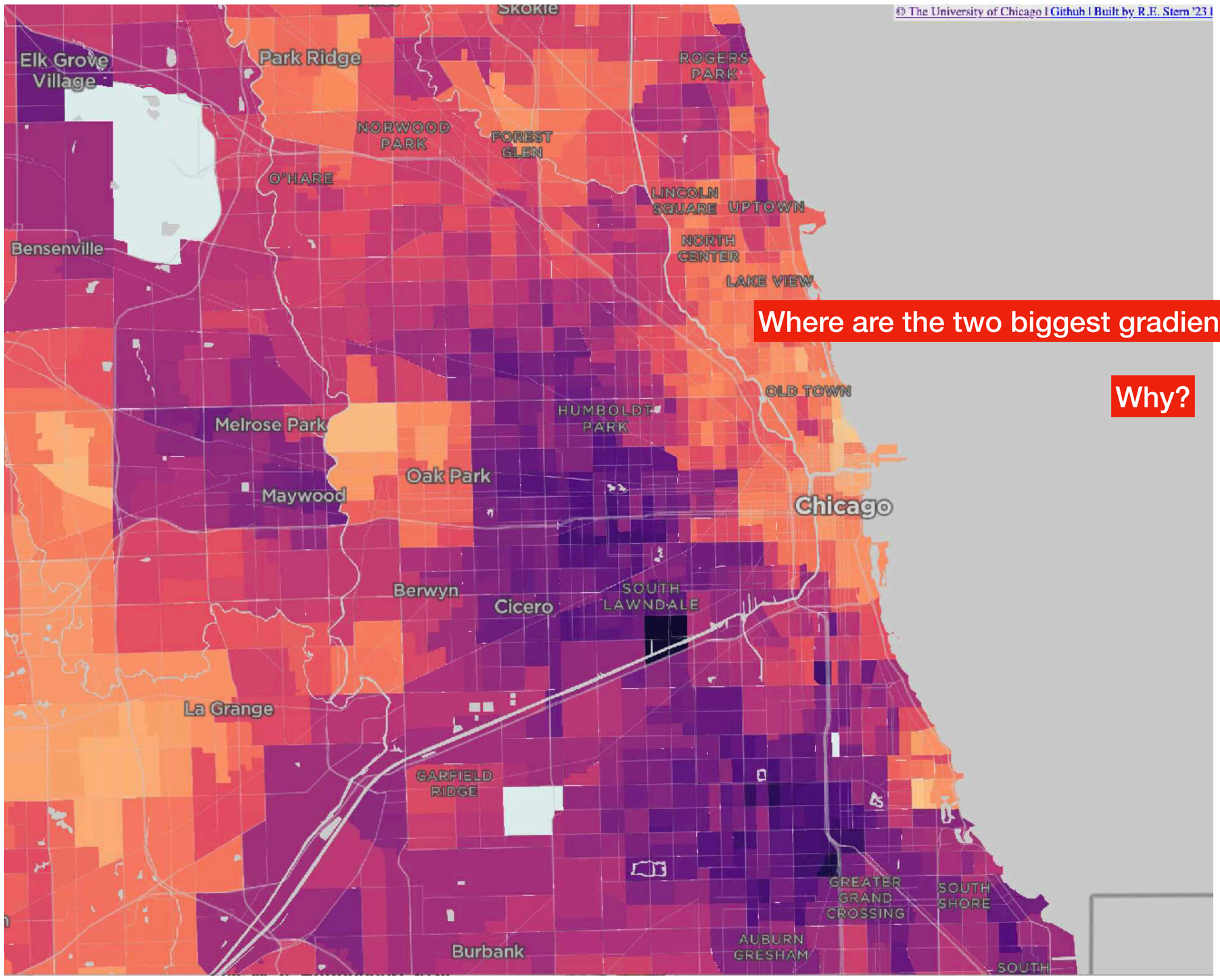
Explore a city

- New York City
- Los Angeles
- Chicago
- Houston
- Phoenix
- Philadelphia
- San Antonio
- San Diego
- Dallas
- San Jose
- Austin
- Jacksonville
- Fort Worth
- Columbus
- San Francisco
- Charlotte
- Indianapolis
- Seattle
- Denver
- Washington



Metropolis Institute for Urban Innovation

University of Chicago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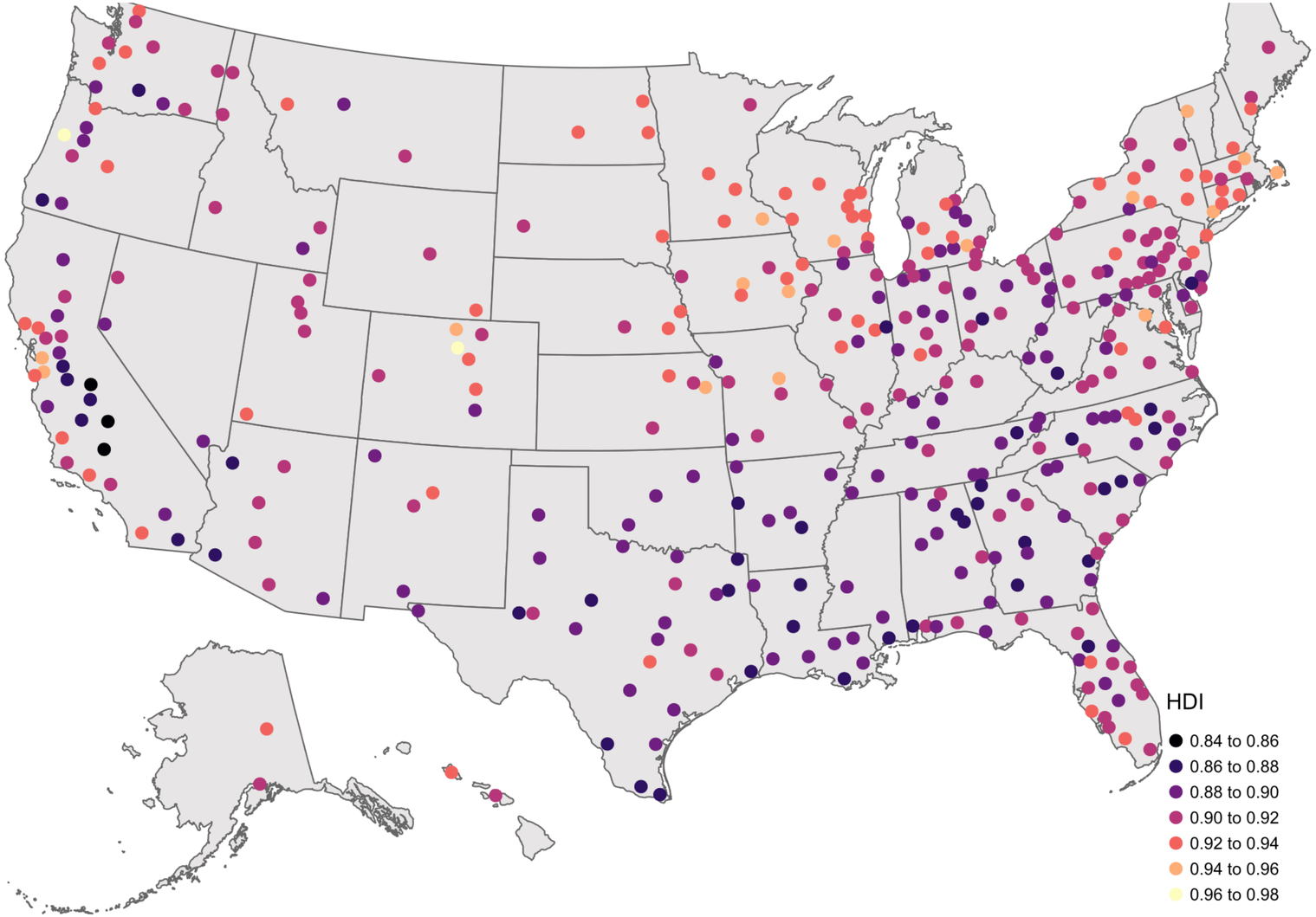
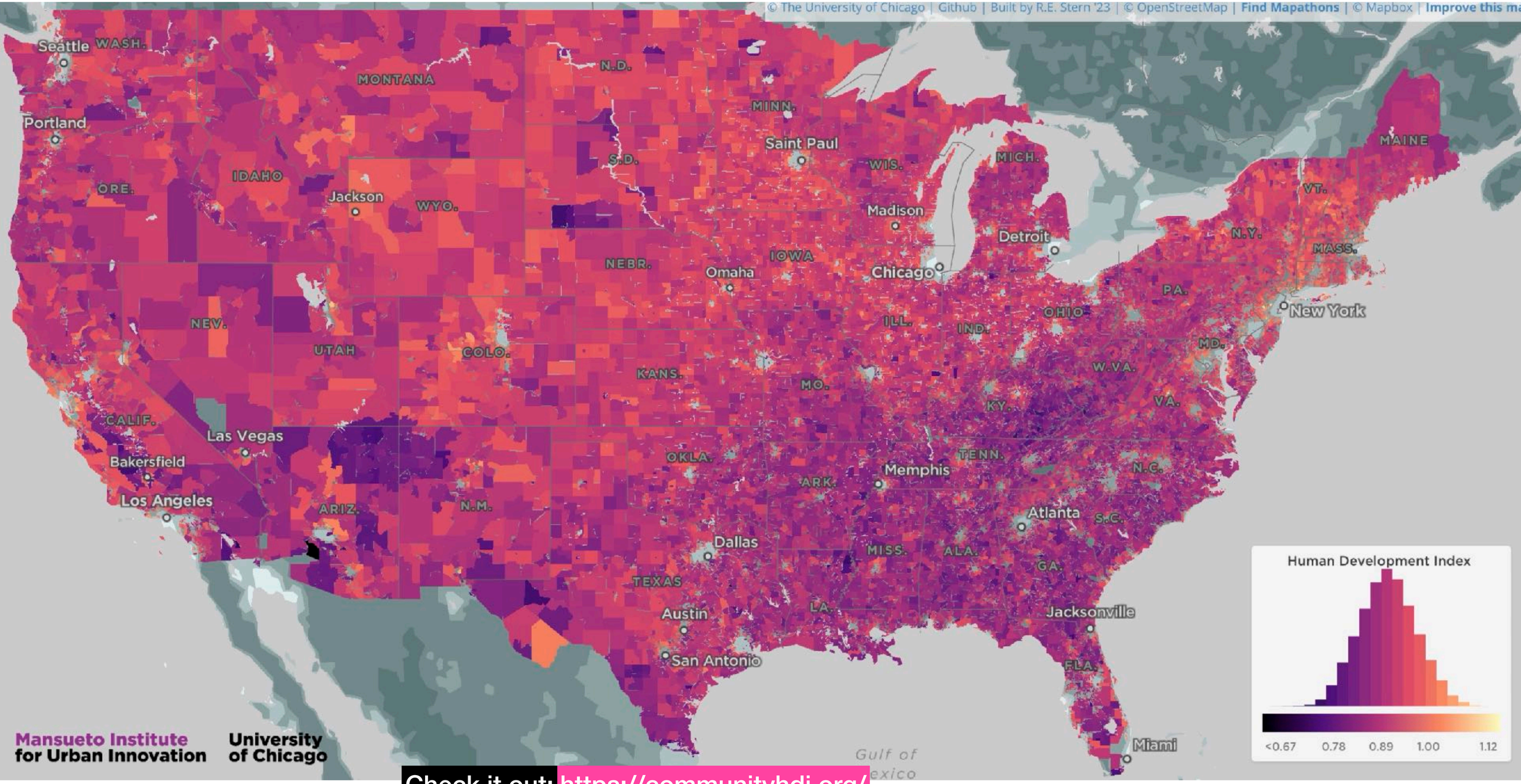
Skokie
Elk Grove Village
Park Ridge
ROGERS PARK
NORWOOD PARK
FOREST GLEN
O'HARE
LINCOLN SQUARE
UPTOWN
Bensenville
NORTH CENTER
LAKE VIEW
Where are the two biggest gradients?
OLD TOWN
Why?
HUMBOLDT PARK
Melrose Park
Oak Park
Maywood
Chicago
Berwyn
Cicero
SOUTH LAWNDALE
La Grange
GARFIELD RIDGE
GREATER GRAND CROSSING
SOUTH SHORE
AUBURN GRESHAM
Burbank
SOUTH



State/Federal District	HDI	Metropolitan Area	HDI
Massachusetts	0.9407	Boulder, CO	0.9624
Connecticut	0.9378	Corvallis, OR	0.9622
Vermont	0.9348	Ann Arbor, MI	0.9570
New Hampshire	0.9345	Iowa City, IA	0.9567
Minnesota	0.9330	San Jose-Sunnyvale-Santa Clara, CA	0.9557
New Jersey	0.9281	Bridgeport-Stamford-Norwalk, CT	0.9553
District of Columbia	0.9273	Ames, IA	0.9532
Maryland	0.9271	Lawrence, KS	0.9496
North Dakota	0.9244	Boston-Cambridge-Newton, MA-NH	0.9491
Colorado	0.9240	San Francisco-Oakland-Hayward, CA	0.9486
Texas	0.8964	Gadsden, AL	0.8647
South Carolina	0.8935	McAllen-Edinburg-Mission, TX	0.8641
Nevada	0.8919	Lake Havasu City-Kingman, AZ	0.8637
Oklahoma	0.8879	Laredo, TX	0.8614
Tennessee	0.8874	Dalton, GA	0.8614
Kentucky	0.8843	Brownsville-Harlingen, TX	0.8605
Alabama	0.8839	Yakima, WA	0.8604
Louisiana	0.8838	Pine Bluff, AR	0.8601
West Virginia	0.8832	Bakersfield, CA	0.8595
Arkansas	0.8798	Visalia-Porterville, CA	0.8579
Mississippi	0.8762	Madera, CA	0.8572

https://www.nature.com/articles/s42949-023-00088-y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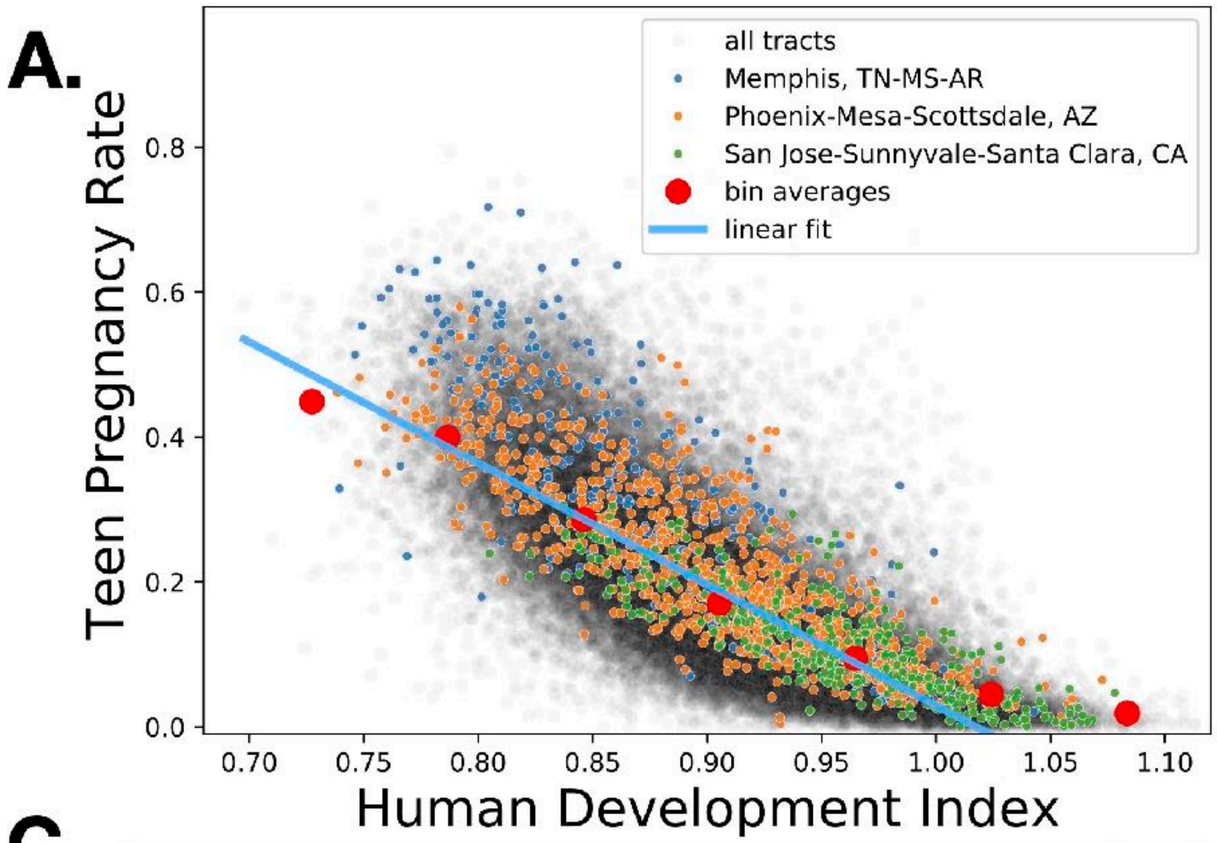
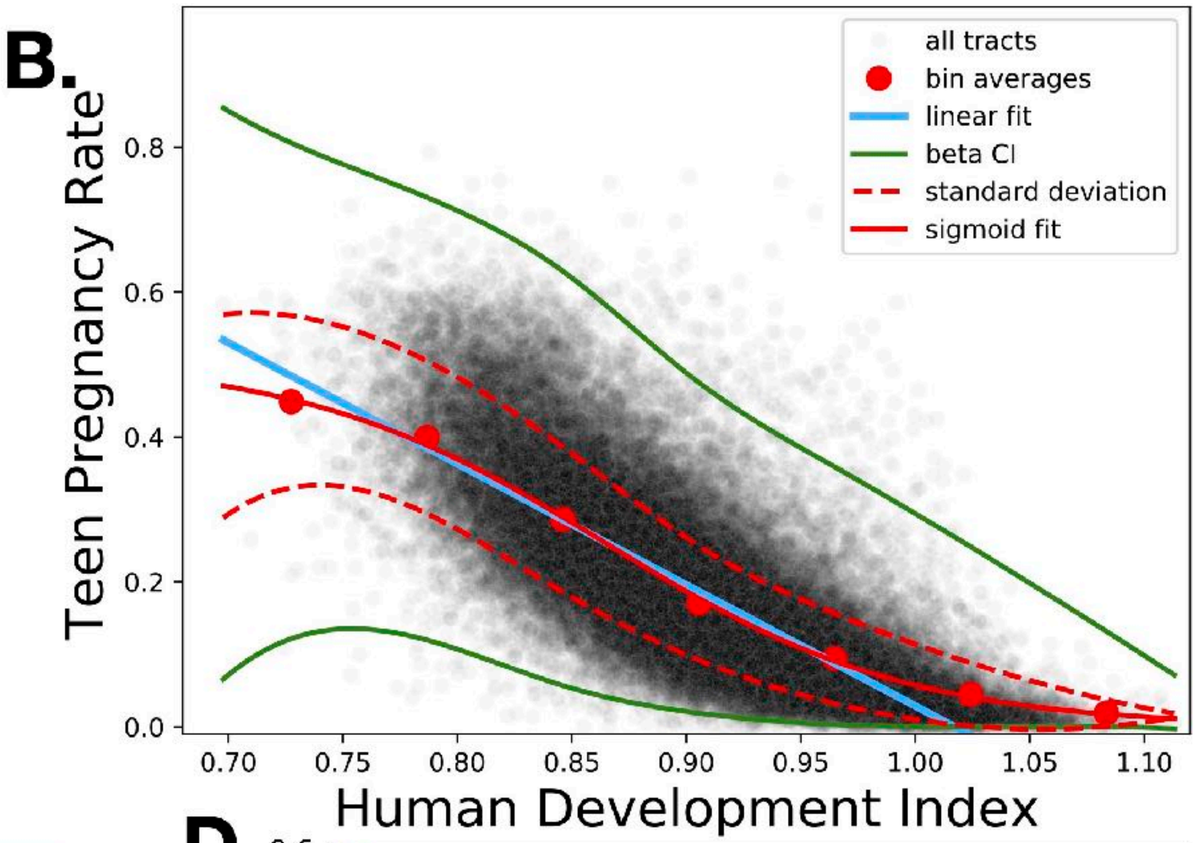
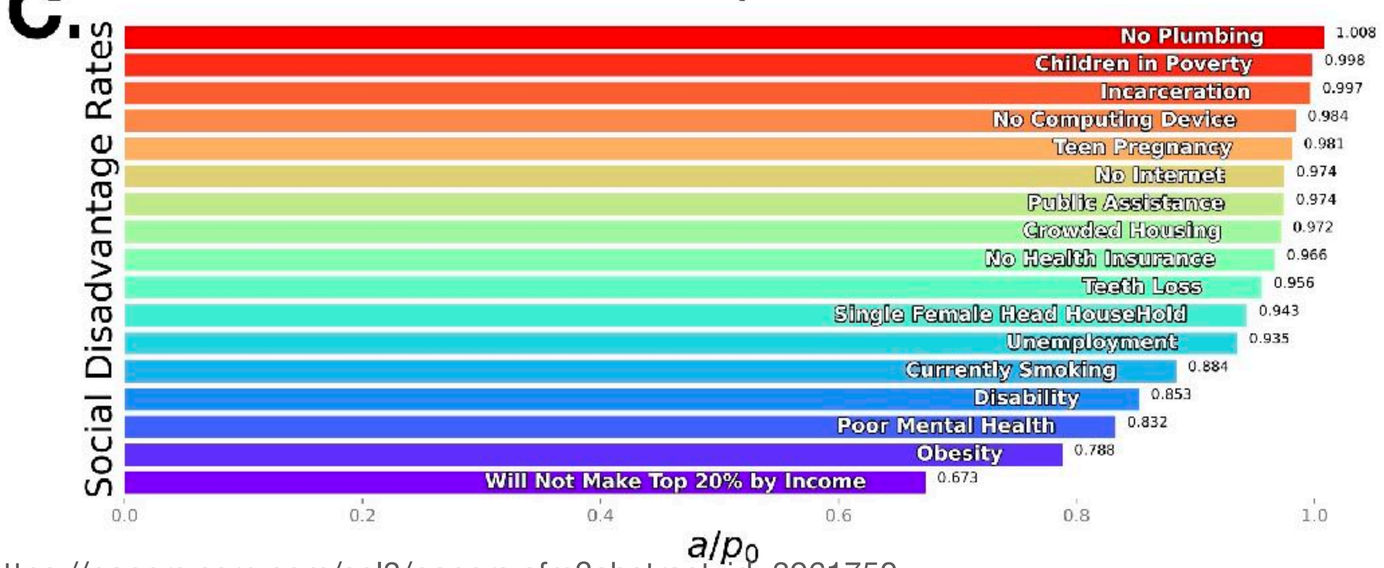
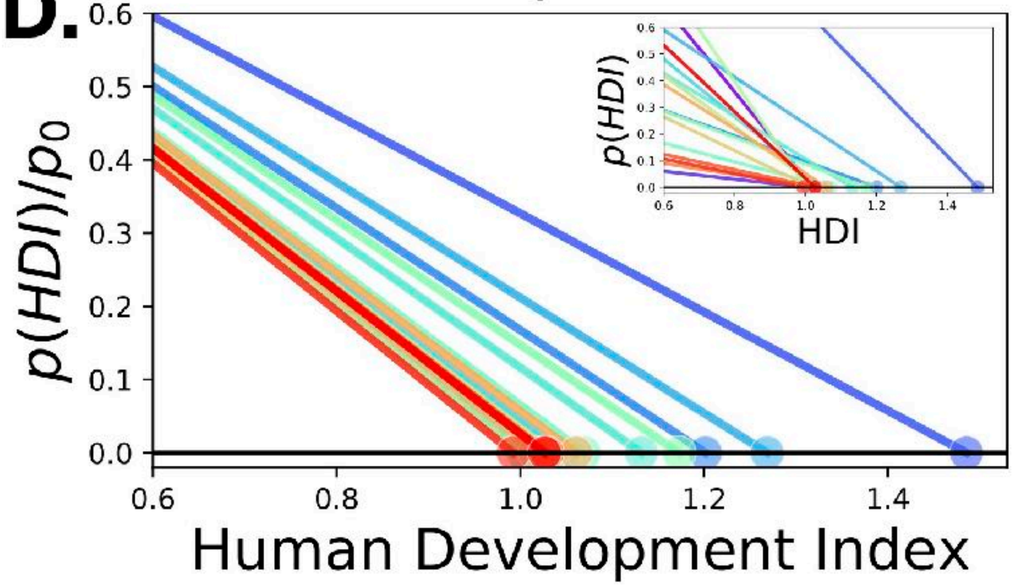
Seattle
WASH.
Portland
ORE.
MONTANA
IDAHO
Jackson
WYO.
N.D.
MINN.
Saint Paul
S.D.
WIS.
MICH.
MAINE
VT.
N.Y.
MASS.
Madison
Detroit
NEBR.
IOWA
Omaha
Chicago
PA.
New York
NEV.
UTAH
COLO.
ILL.
IND.
OHIO
MD.
KANS.
MO.
W.VA.
KY.
VA.
CALIF.
Las Vegas
Bakersfield
Los Angeles
OKLA.
TENN.
Memphis
N.C.
ARK.
ARIZ.
N.M.
Atlanta
S.C.
Dallas
MISS.
ALA.
GA.
TEXAS
LA.
Austin
Jacksonville
San Antonio
FLA.
Miami
Gulf of
exico
Human Development Index
<0.67
0.78
0.89
1.00
1.12
Mansueto Institute
for Urban Innovation
University
of Chicago
Check it out: https://communityhdi.org/









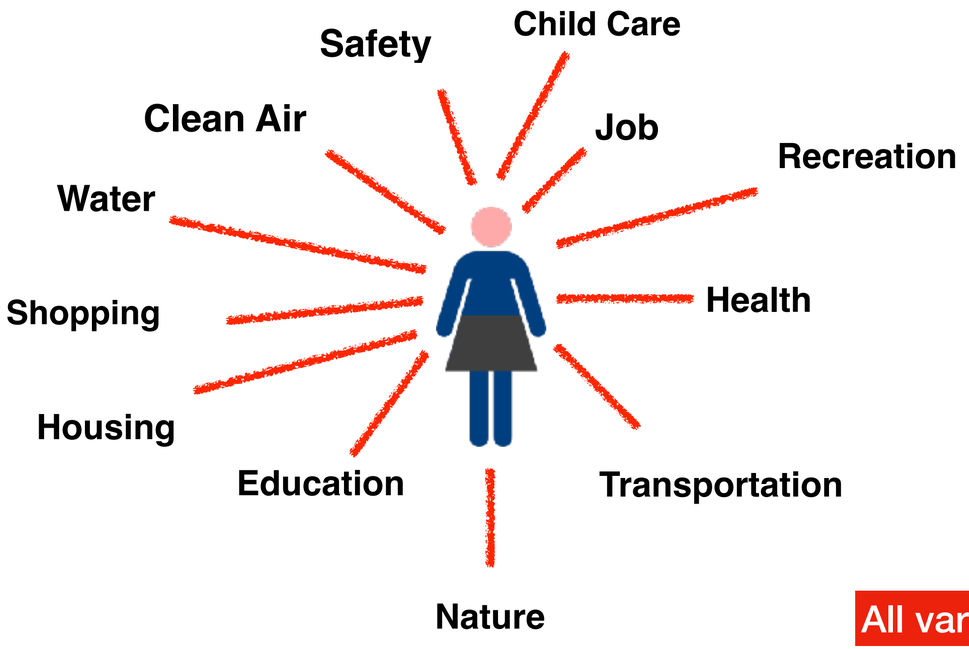
“Anna Karenina Principle” of Human Development

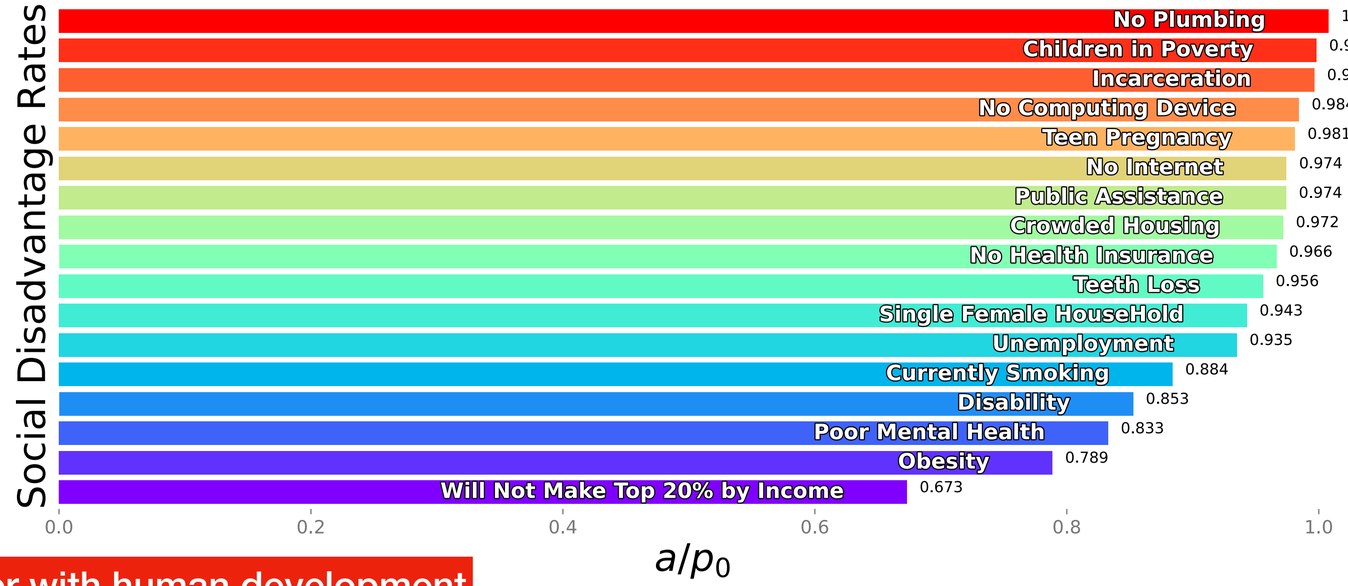
A deficiency in any one of a number of factors dooms an endeavor to failure.

Consequently, a successful endeavor (subject to this principle) is one for which every possible deficiency has been avoided.

https://en.wikipedia.org/wiki/Anna_Karenina_principle

All *high* human development communities are alike (“no problems”); but each *low* human development community is challenged in its own way





All vary together with human development

Solution: ensure systemic human capabilities = education *and* health *and* decent real income