Explorations at the Interface of Social Epidemiology and Complex Systems: A Theoretical Health Inequality Model (THIM)

Prof Michael Wolfson
& Reed Beall

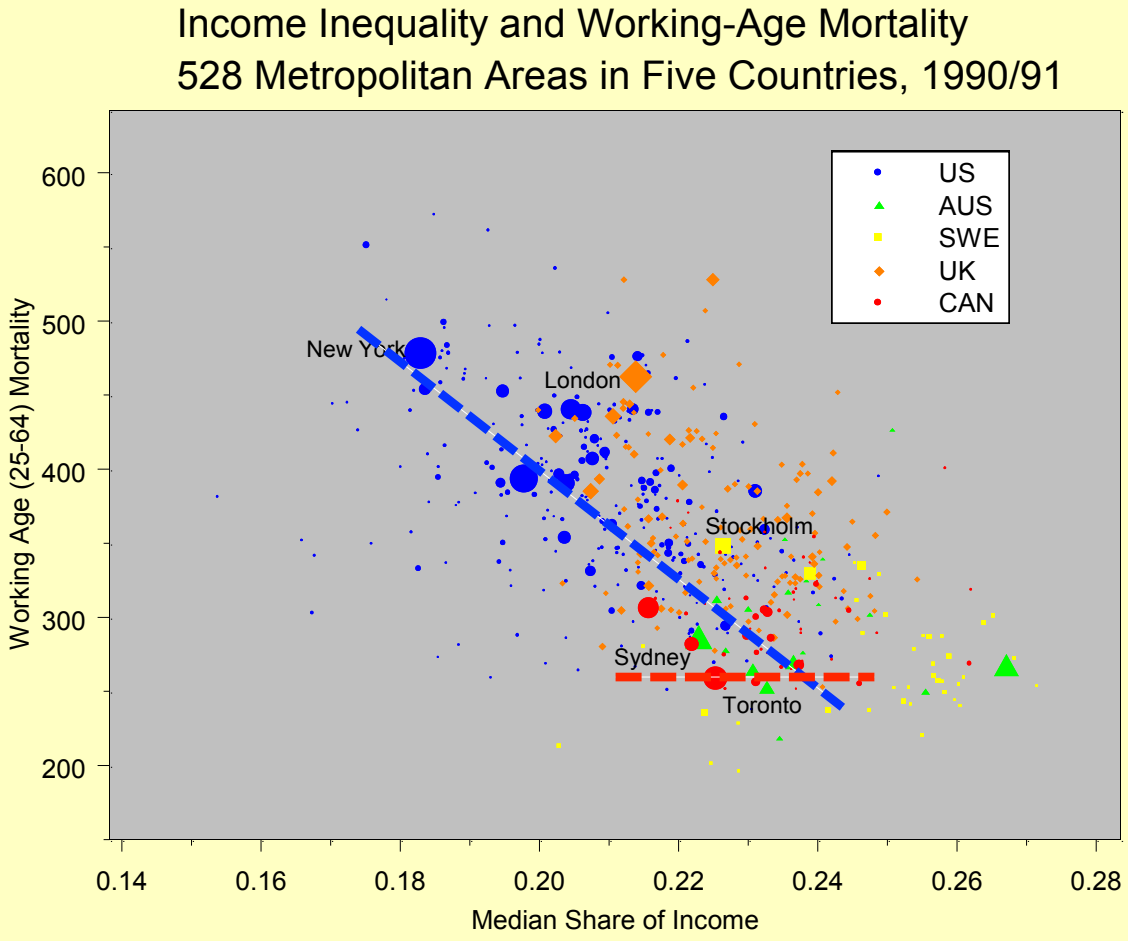
Special thanks to Steve Gribble, George Kaplan and the NIH-funded Network for Inequality, Complexity and Health*

Contrasting income inequality & mortality association in US vs Canada

Nancy Ross et al's 1991 results

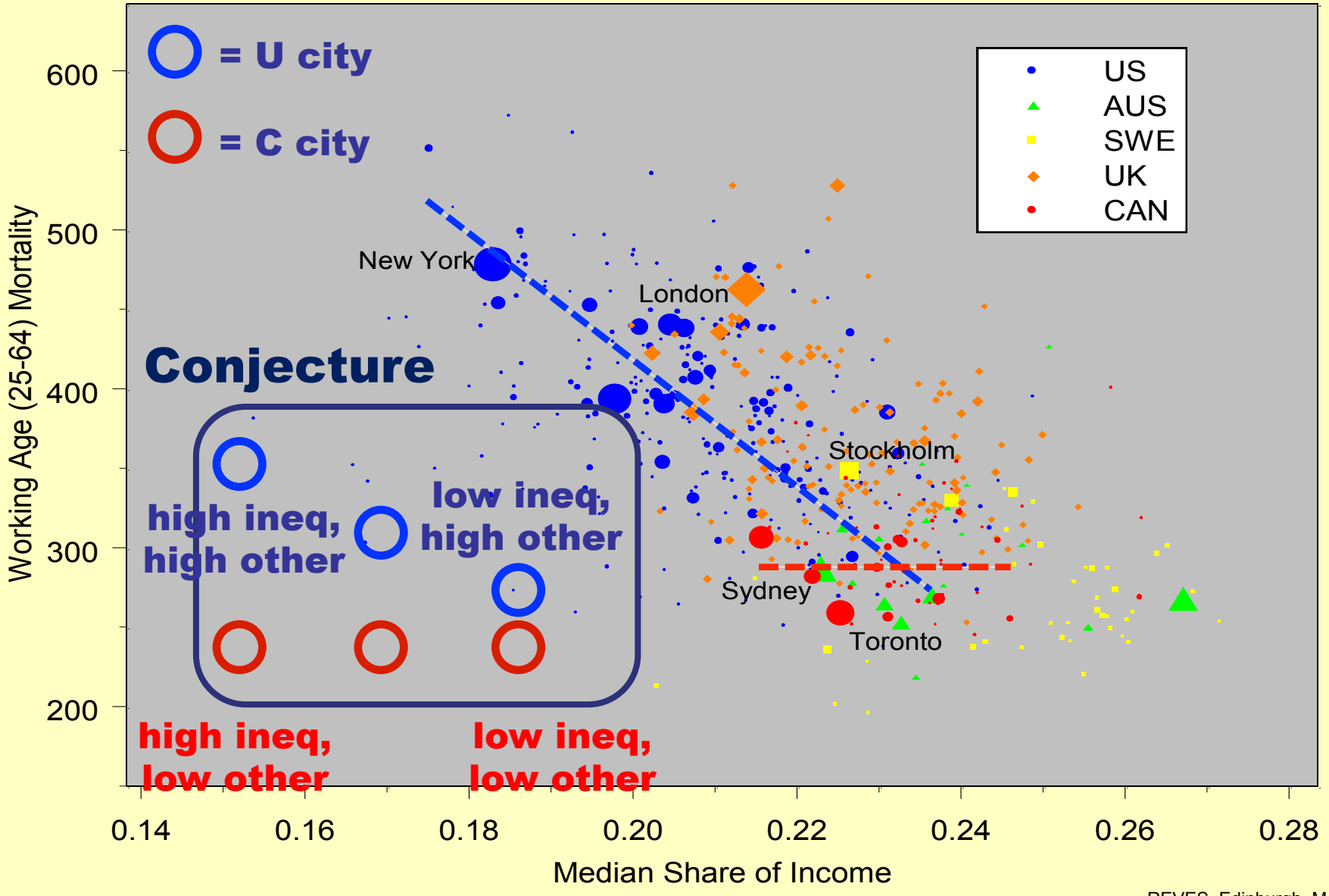
Median share income indicator

- higher inequality = lower median share = smaller share of income going to the bottom 50% of the population



uOttawa

Income Inequality and Working-Age Mortality
528 Metropolitan Areas in Five Countries, 1990/91



Formulate Explanation/Theory & Model Selection

- Main factors to consider
  - overall level of income inequality
  - neighbourhood income segregation
  - parental + neighbourhood influences on children's education / subsequent incomes
  - "returns to education" in terms of future income
  - effects of income on health and mortality

Build Theory: Constructing an Agent-Based Model (ABM)

- Model needs to capture main factors
  - *individual heterogeneity* in income and health
  - parental influences, life course ⇒ *trajectories*
  - neighbourhood (nbhd) factors: education as a major pathway + nbhd sorting ⇒ *multi-level*
- Abstraction (i.e. major simplification) is essential
- Model should reflect "stylized facts"
  - i.e. as simple as possible, but not too simple
- Open to "emergent" phenomena

Some Building Blocks of THIM city

Main agent ("sim") variables:

a = age of the agent = uni-sex "sim"; max a = 100.

Time = measured in "years" (say)

H = health status, a QALY index in the [0,1] interval.

D = dead (Boolean, true or false).

Y = income (dollars, non-negative).

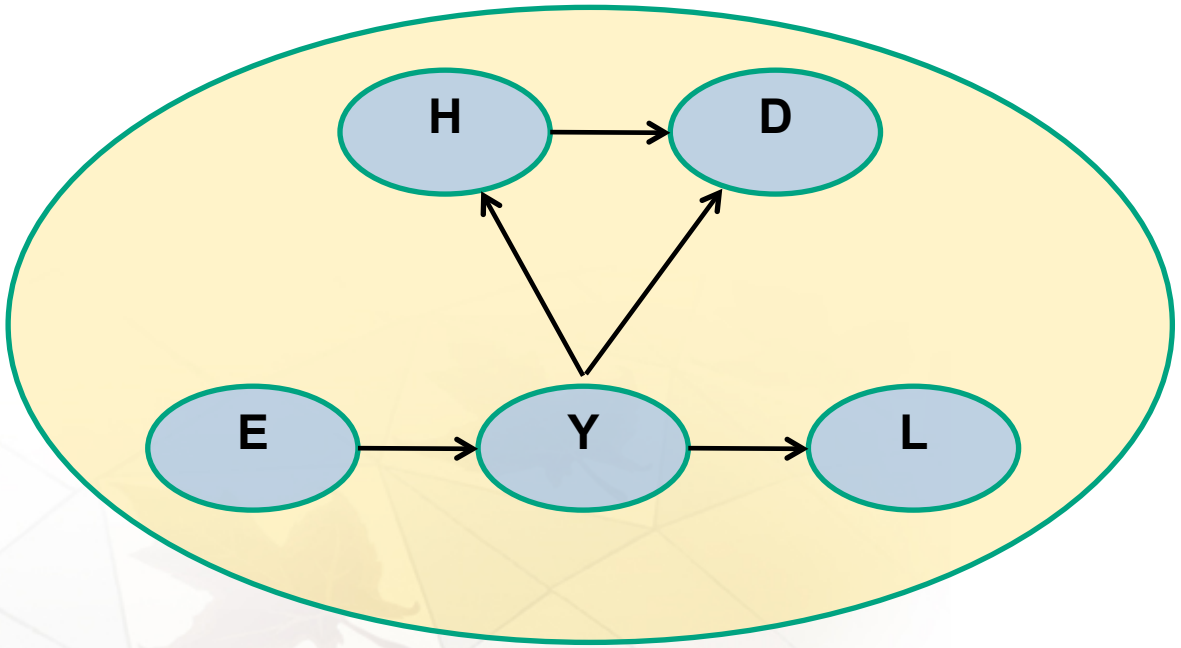
E = "education" measured in years, integer in [1, 20]

L = location in a "city" comprised of many (e.g. 50) nbhds

Multi-level variables (critical component to our conjecture!):

individual agents / families (parent-child dyads) / neighbourhoods (nbhds) / cities

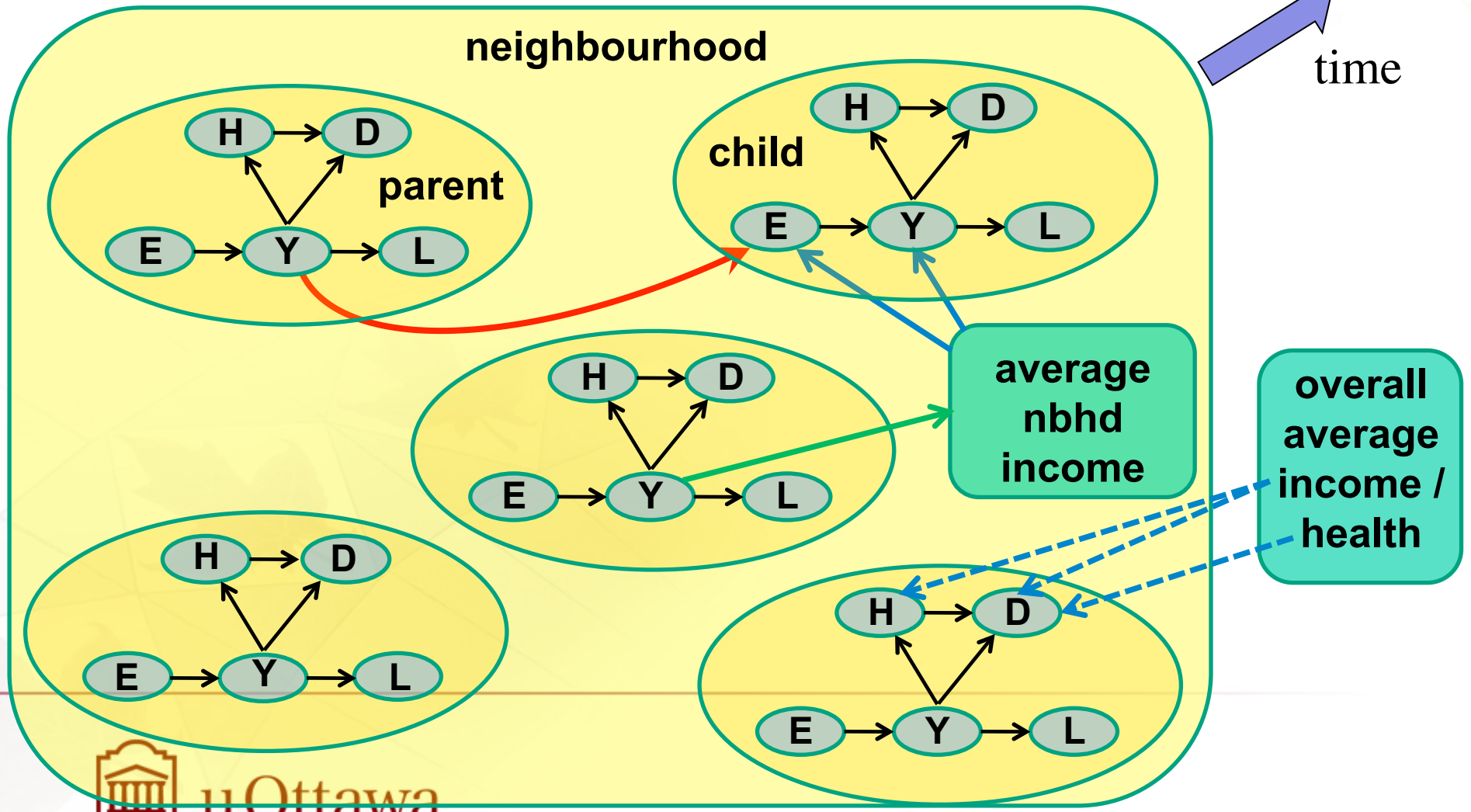
THIM: "Web of Causality" at Individual "Sim" Level



Building Blocks

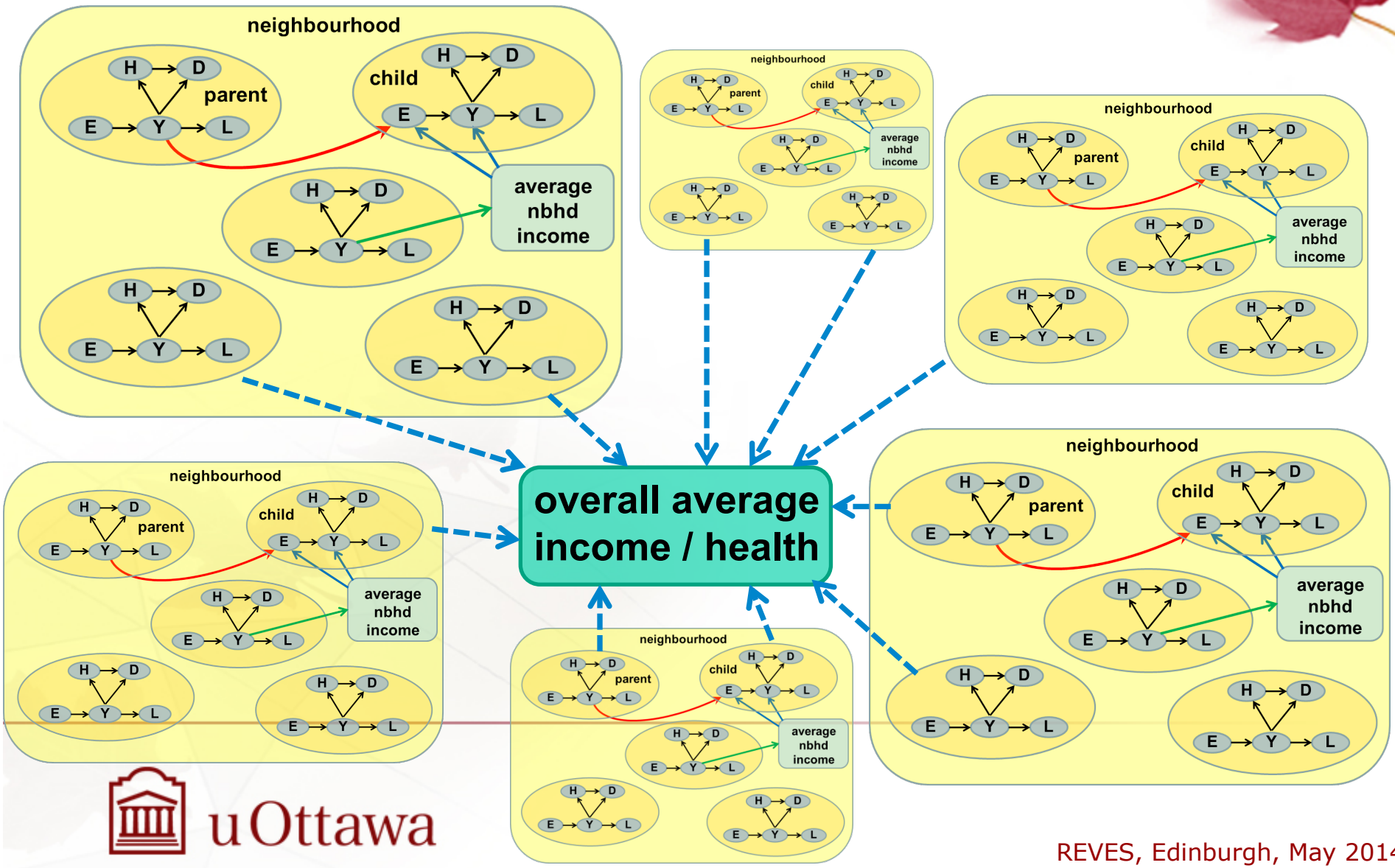
- E = education
- Y = income
- H = health
- D = death
- L = location

THIM – Multi-Level Relationships:
Individual sims -> Parent-child dyads <-> nbhd



THIM: Many Nbhds = "City"

City-wide Factors



uOttawa

THIM Equations

- *colour = level of aggregation*
- *multiple levels increases complexity*

<u>Fixed at birth:</u>

education (E) = fcn (parent's income, average nbhd income, symmetric randomness)

potential income (Y*) = fcn (education, parent's income, average nbhd income, skewed randomness)

<u>Evolving over time / age:</u>

income (Y) = average income for given age x individual's potential income (Y*) x skewed randomness

change in health (H) = random drift (mostly down) + fcn (own income relative to those at similar ages)

mortality risk (D) = average mortality rate for given age x fcn (own income relative to those at similar ages, own health relative to the overall average)

nbhd mobility (ΔL) = fcn (own income, own nbhd average income, other nbhds' average incomes)

Review Data & Stylized Facts to Tailor Simulation Parameters

Data literature review for stylized facts of C and U cities. Some examples…

- OECD PISA studies
- OECD Skills Outlook 2013
- Miles Corak's "Great Gatsby Curve." See Journal of Economic Perspectives, Volume 27, No. 3, 2013

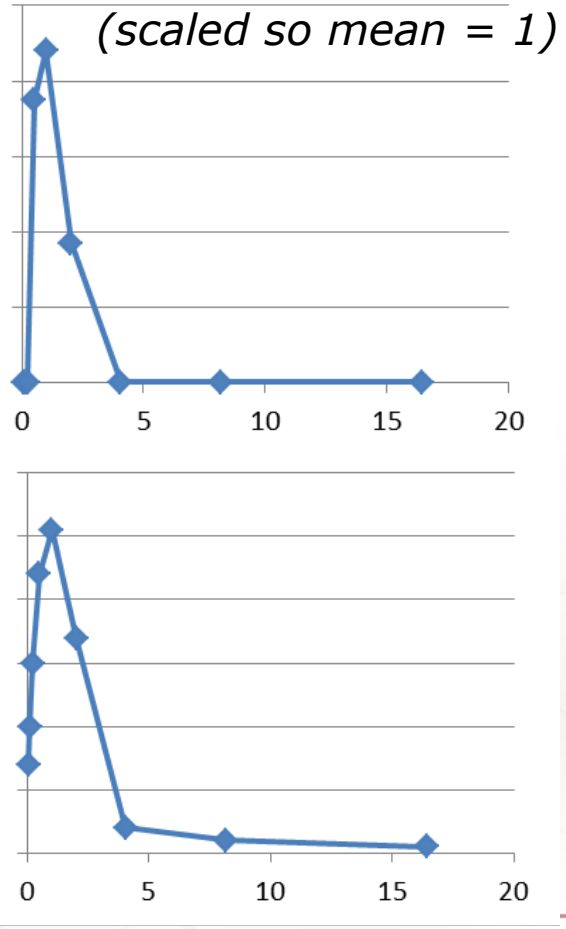
Conclusions from review of stylized facts for simulation parameters. U cities have…

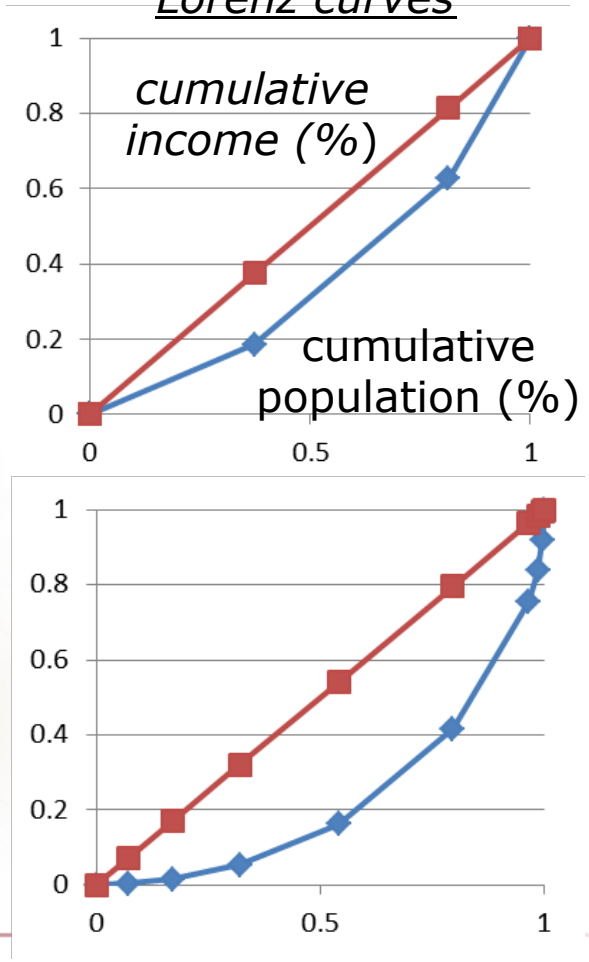
- much higher income sorting by nbhd and more ndhds
- 50% higher parental income impact on child's education and income
- higher impact of nbhd average income on children's education and income
- stronger link between own income and mortality

Simulation experiment set up

- Simulation for a wide range of overall "potential" income inequality levels
- focus on LE and HALE as health outcomes
- questions: are the U cities less healthy than the C cities, and is the slope for U cities steeper?

Input Parameters: High/Low Inequality "Potential (Y*) Income" Distributions





Low Inequality;
Gini = 0.271

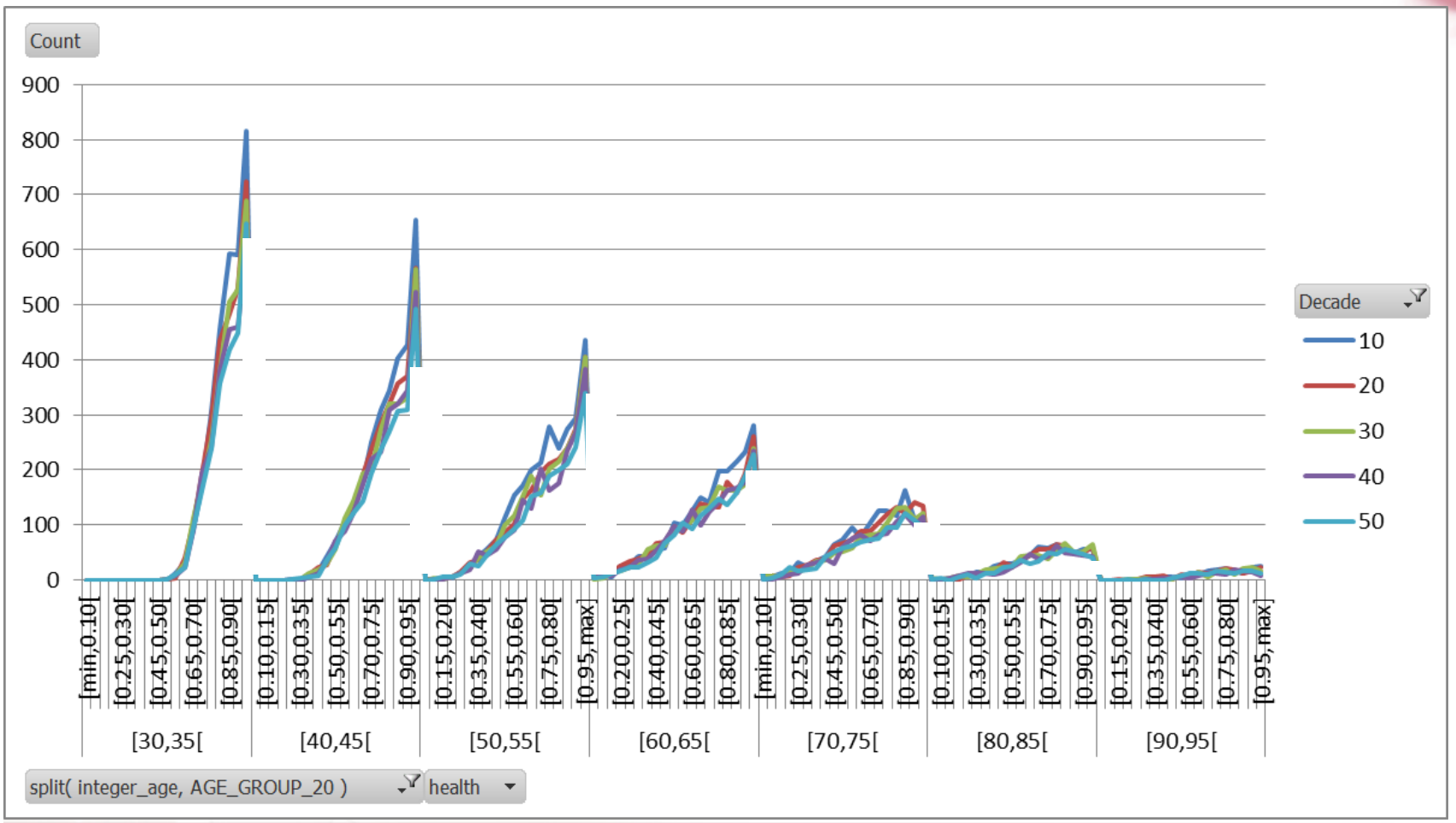
High Inequality;
Gini = 0.534

uOttawa

“Validating” THIM outputs

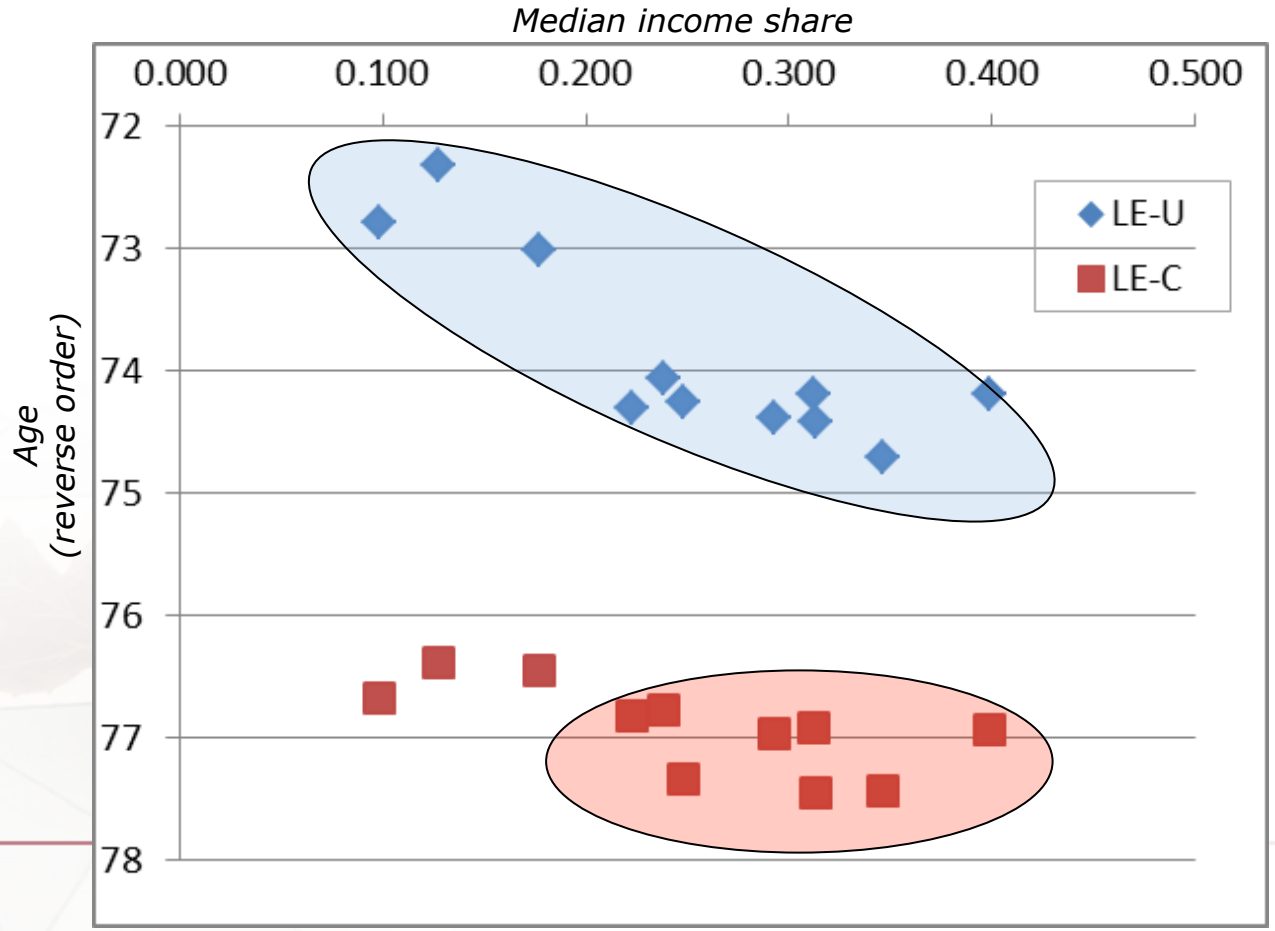
- THIM is a theoretical model ⇒ conventional validation is not appropriate
- look for verisimilitude instead
- especially “emergent” outputs = those outputs not directly connected to inputs, i.e. resulting from the interactions of many inputs

Simulated Health Distributions Within Each Selected 5 Year Age Group



LE and HALE Outputs for City U (blue) & City C (red) and Income Inequality

LE outputs from THIM

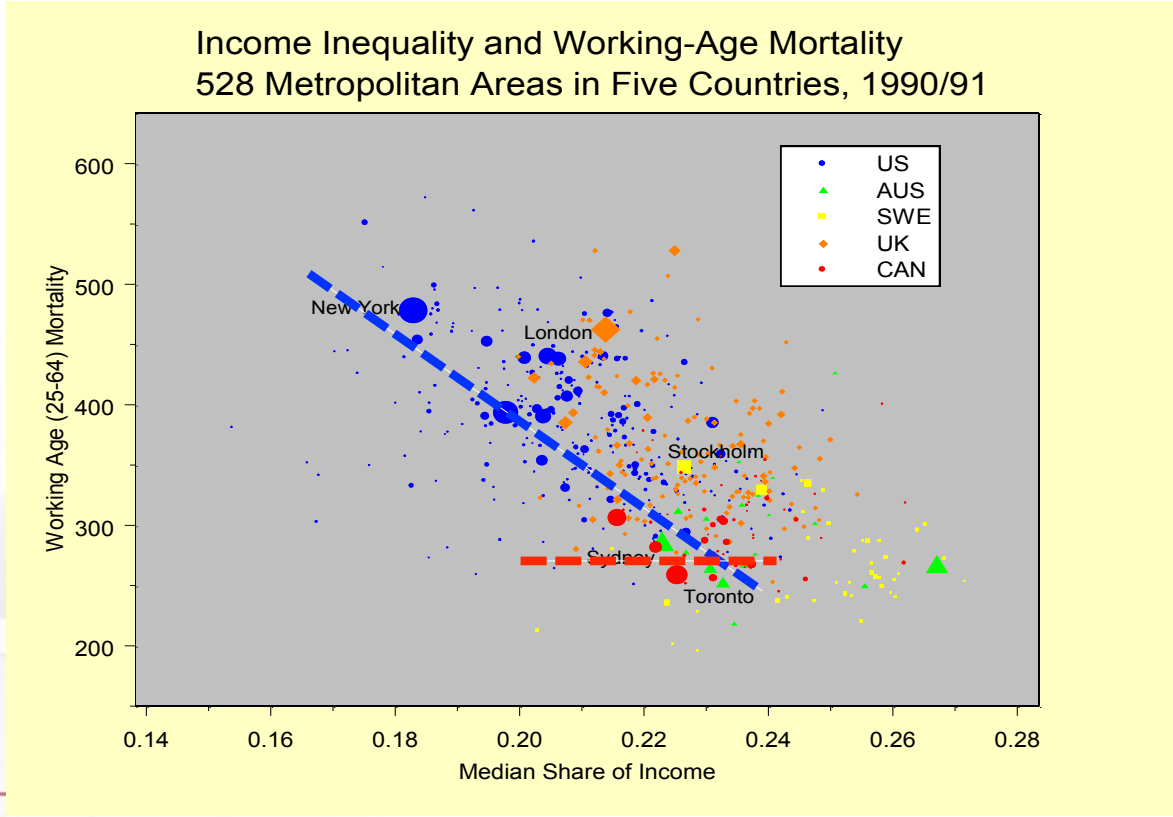


uOttawa

LE and HALE Outputs for City U (blue) & City C (red) and Income Inequality

Ross et al Results

Median income share

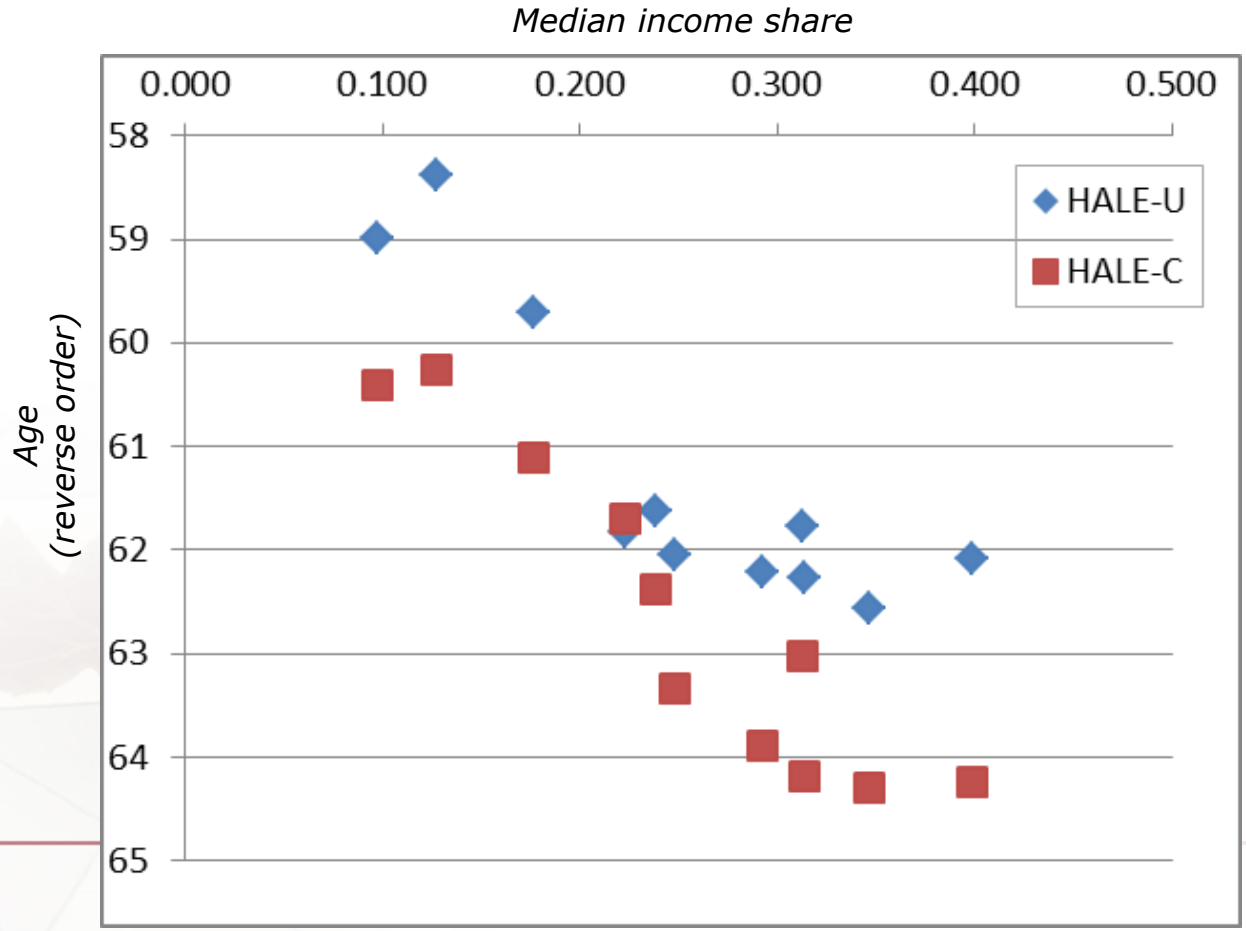


Age (reverse order)

uOttawa

LE and HALE Outputs for City U (blue) & City C (red) and Income Inequality

HALE outputs from THIM



uOttawa

THIM – Concluding Comments

- the realities of individual heterogeneity (including ubiquitous skewedness) + multiple interacting levels of influence (individual ↔ parent ↔ nbhd ↔ city) ⇒ agent-based / complex systems simulation models are needed
- "realistic" behaviours can be generated from a rather simple (albeit complex systems) model
- some Canada-US differences in the (ecological = city) income inequality-mortality relationship, so far, can and others cannot be "explained" by the factors and parameter values tested
- further explorations with THIM plus better internationally comparable data are needed

Questions, Comments & Discussion

Prof Michael Wolfson –
Michael.Wolfson@uOttawa.ca

Reed Beall –
Reed.Beall@gmail.com

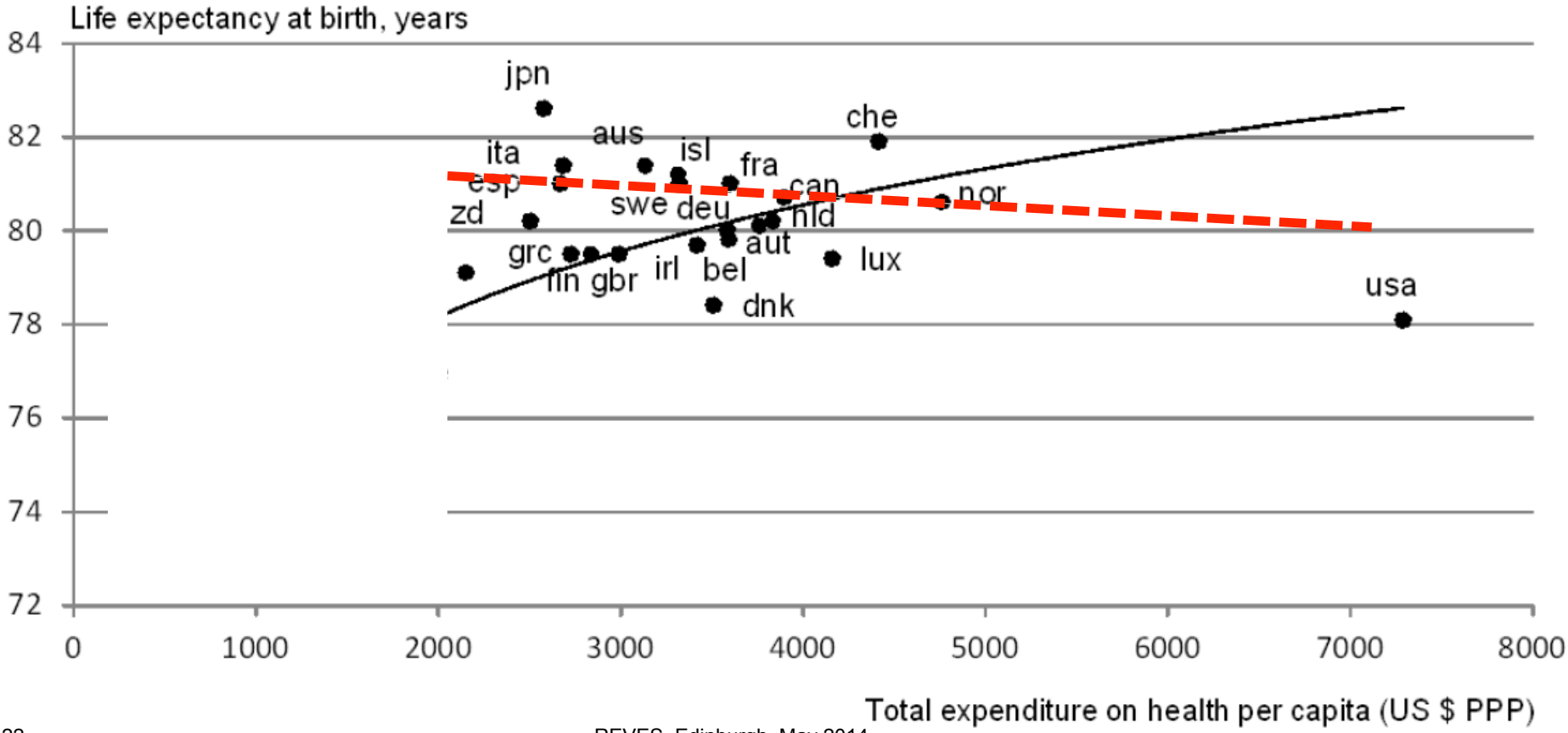
Extra Slides Placeholder

On stylized facts…

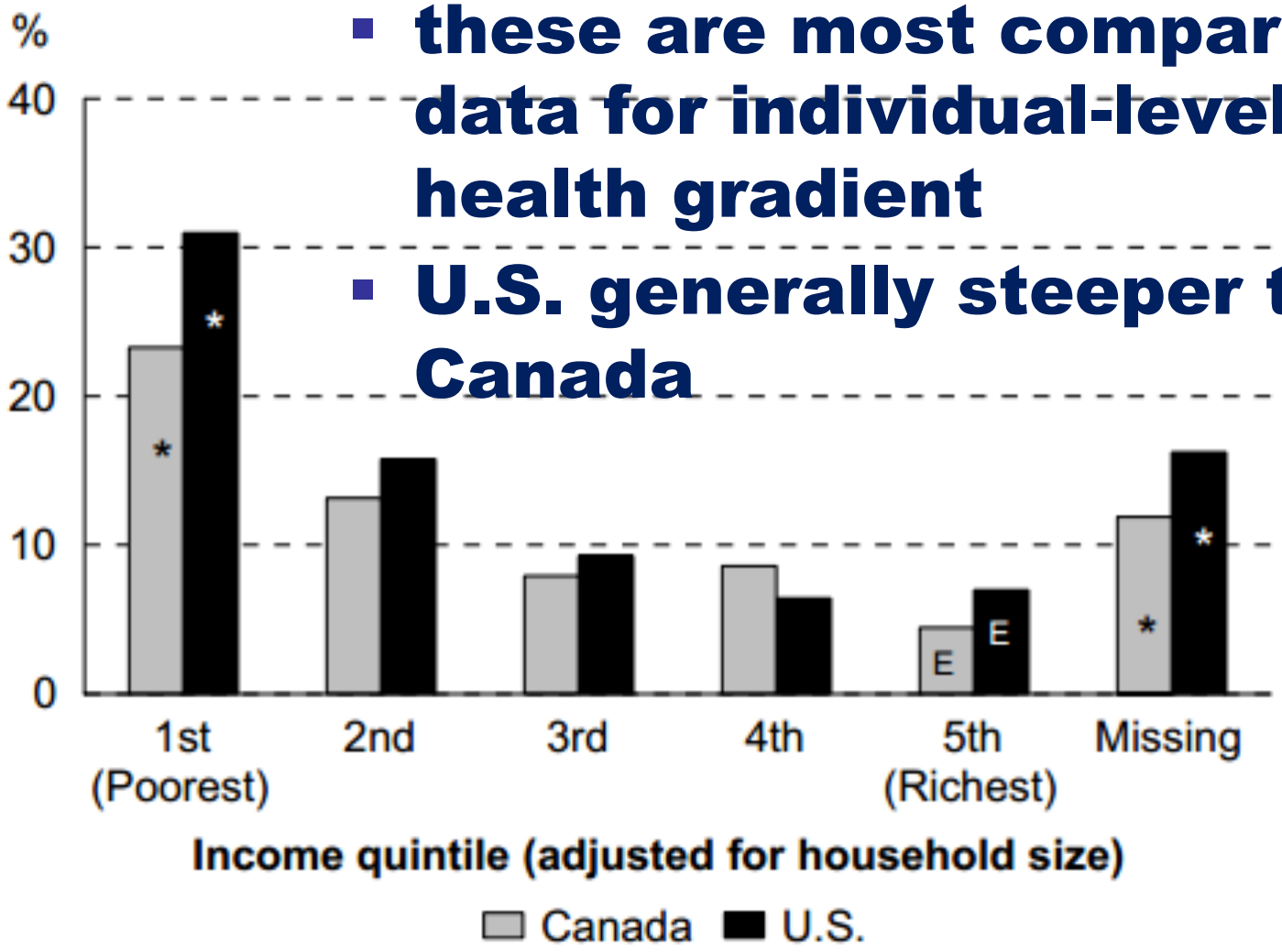
OECD 2010 – Health Care Expenditure Per Capita versus Life Expectancy

Health Care (input) $ ≠ Health

Joumard, I., C. André and C. Nicq (2010), "Health Care Systems: Efficiency and Institutions", *OECD Economics Department Working Papers*, No. 769, OECD Publishing. doi: 10.1787/5kmfp51f5f9t-en



Fair/poor general health by household income quintile, Canada and United States, 2002/03‡

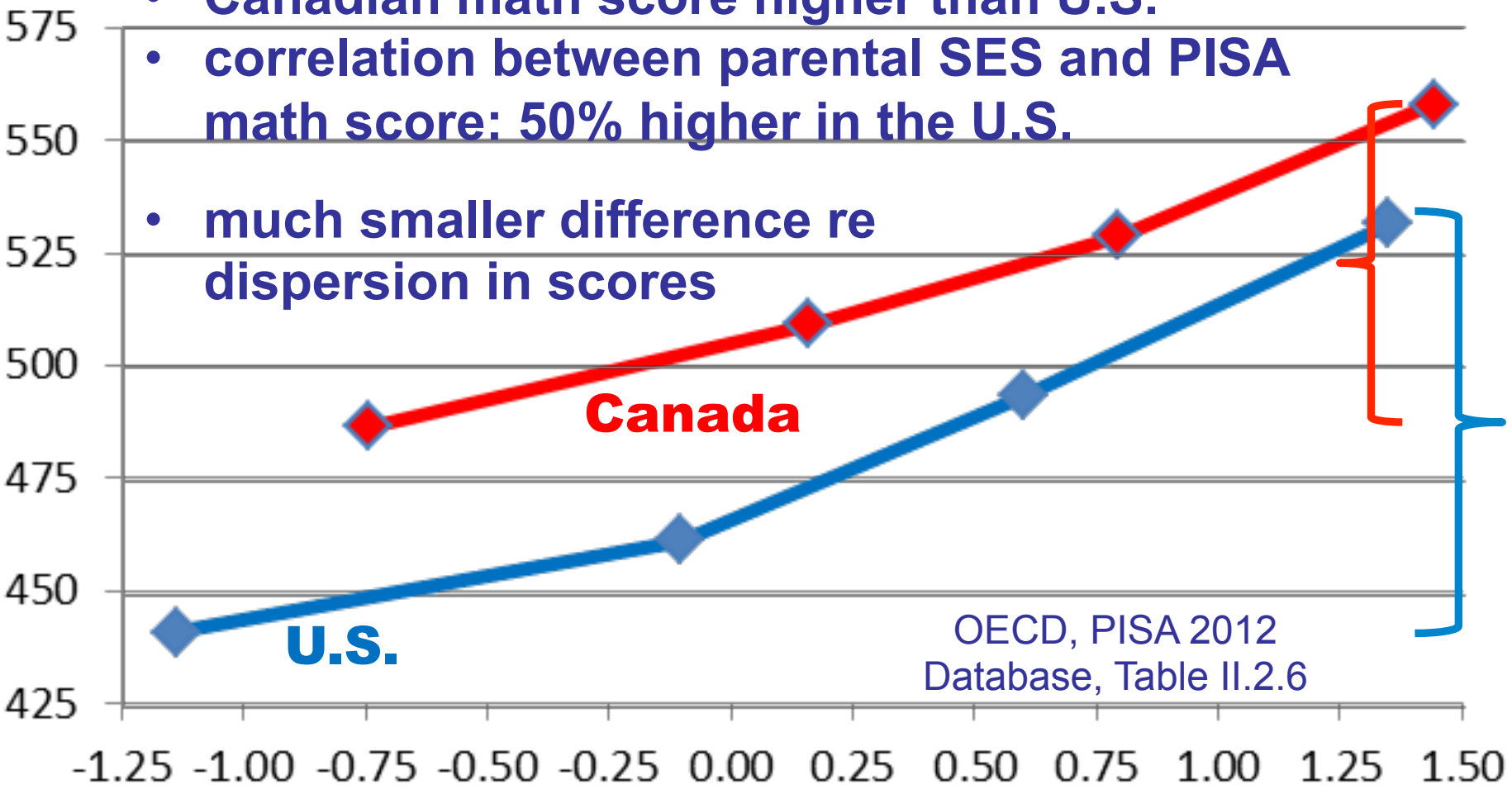


- **these are most comparable data for individual-level health gradient**
- **U.S. generally steeper than Canada**

Data source: *Joint Canada/United States Survey of Health, 2002/03.*
Notes: *Household population aged 18 and over.*

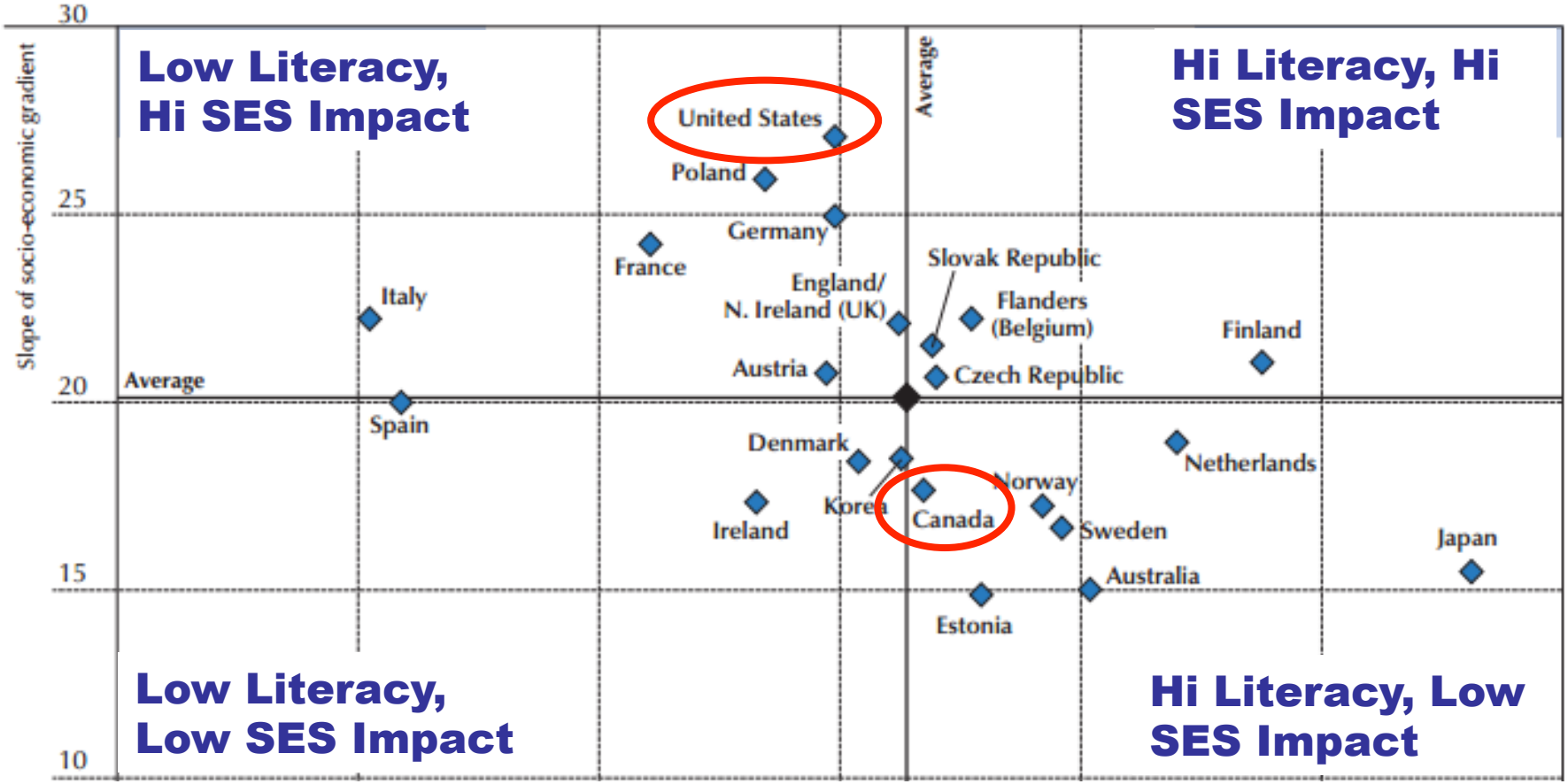
Parental Influence – PISA Math Scores by Parental Socio-Economic Status (SES) Quartiles, OECD 2013

- Canadian math score higher than U.S.
- correlation between parental SES and PISA math score: 50% higher in the U.S.
- much smaller difference re dispersion in scores



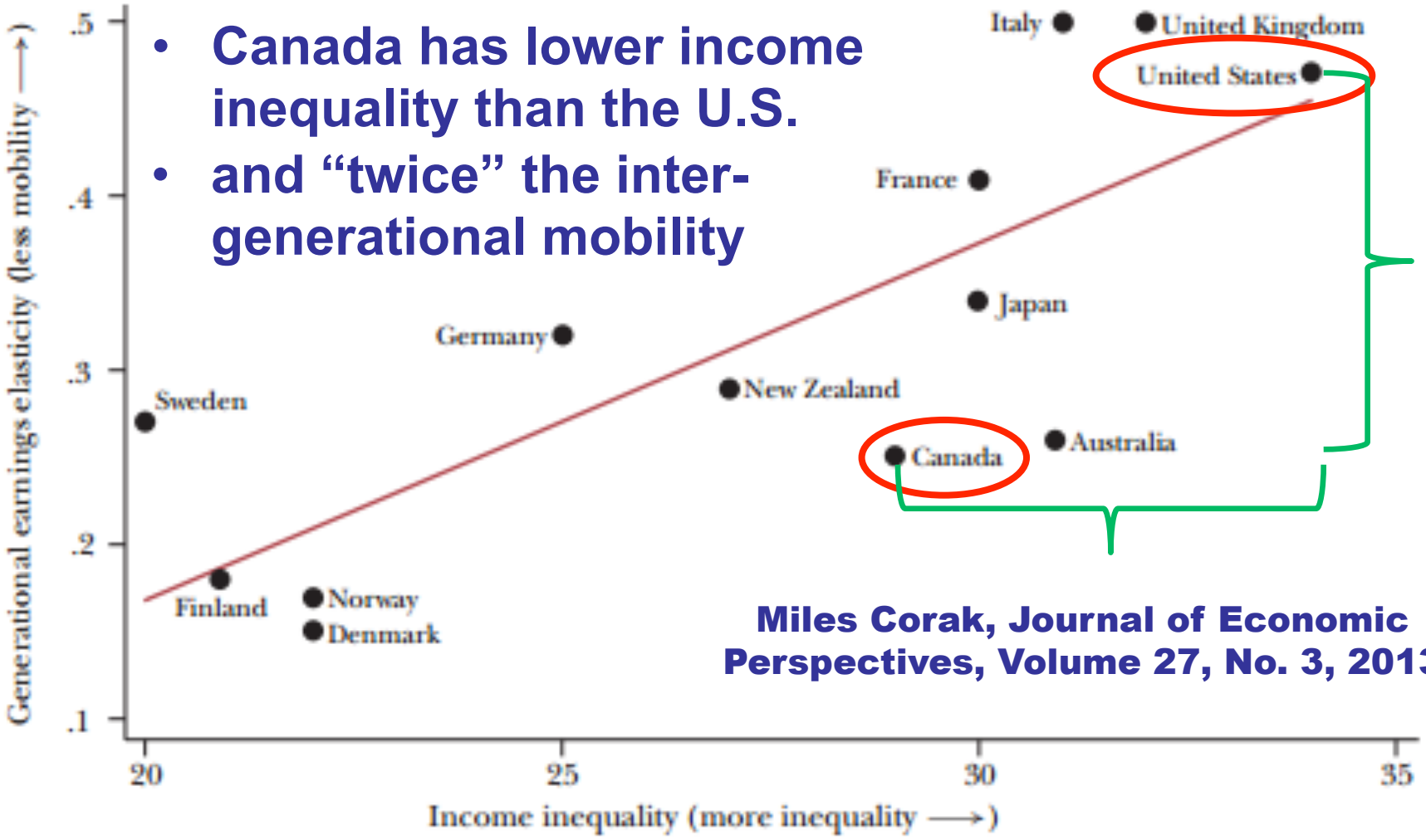
Parental Influence – Adult Literacy Score by Slope of SES Gradient

(OECD Skills Outlook 2013 Figure 3.8c)



Parental Influence – Father-Son Income Elasticities vs Gini

The Great Gatsby Curve: More Inequality is Associated with Less Mobility across the Generations

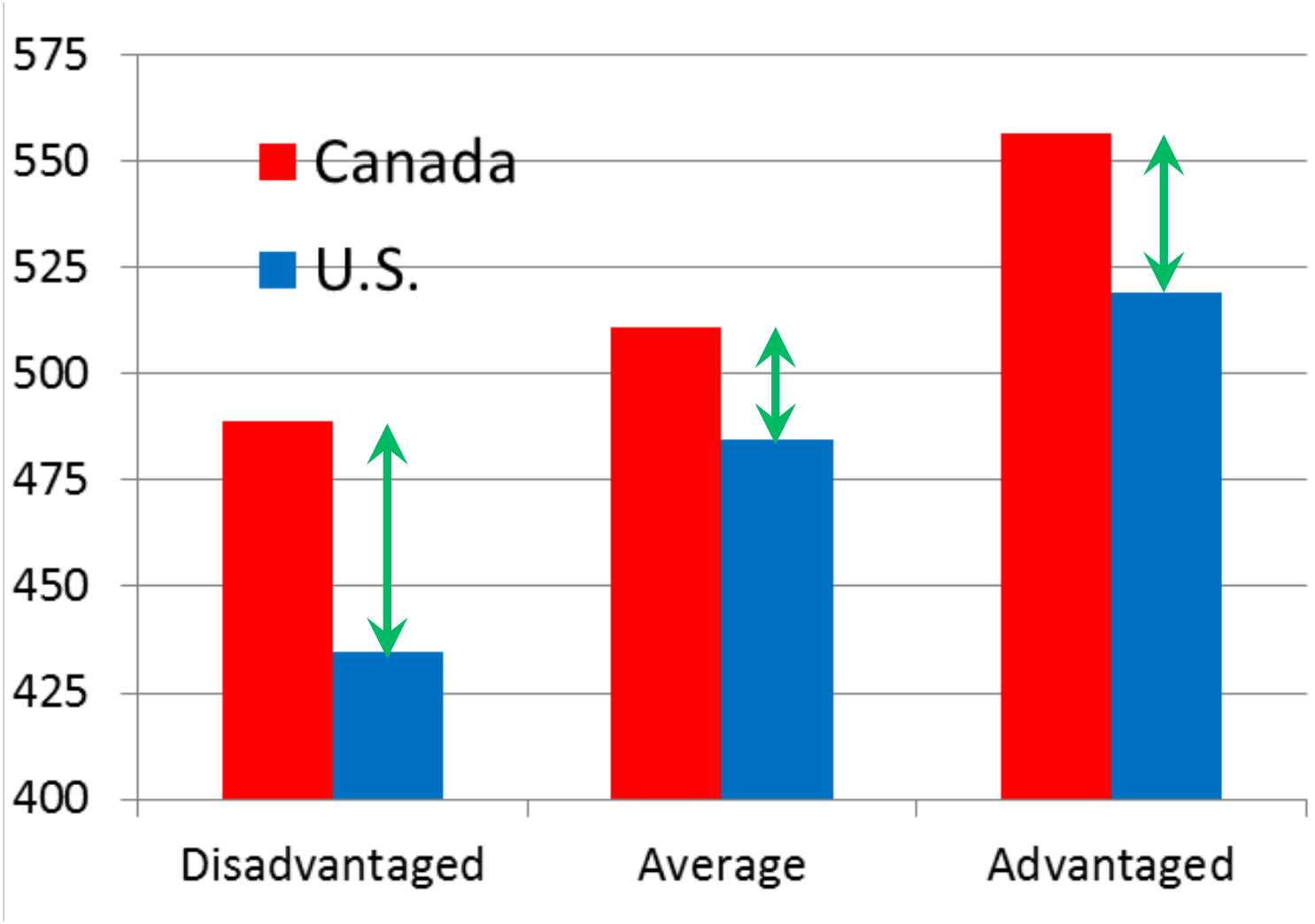


- Canada has lower income inequality than the U.S.
- and "twice" the inter-generational mobility

Miles Corak, Journal of Economic Perspectives, Volume 27, No. 3, 2013

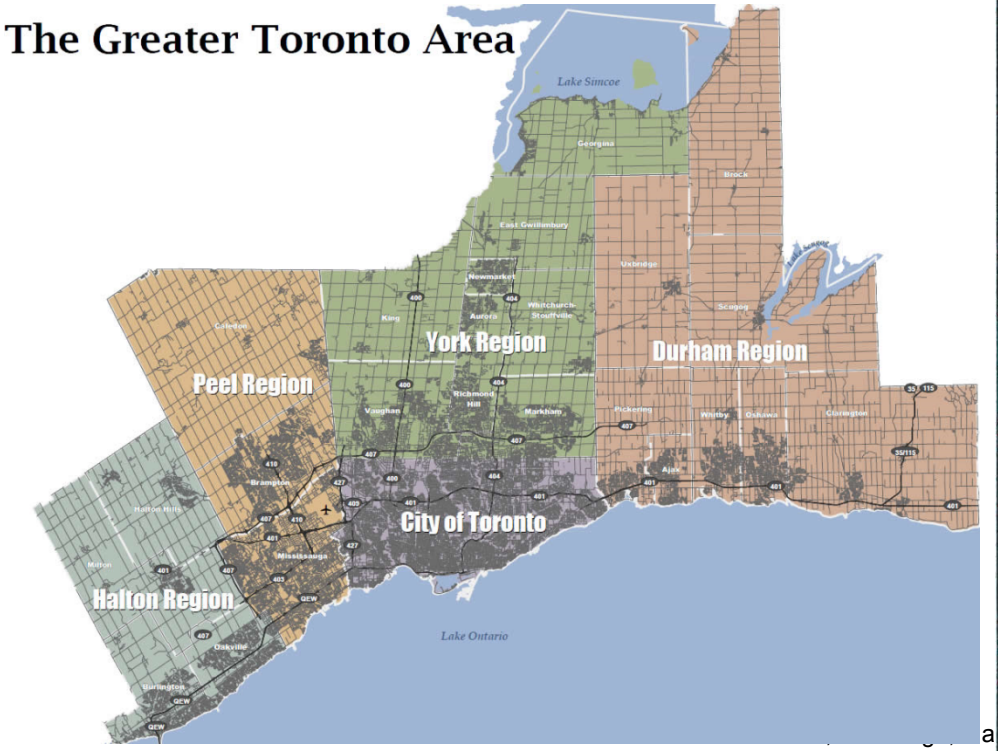
“Neighbourhood” Influence – PISA Math Scores by Average School SES

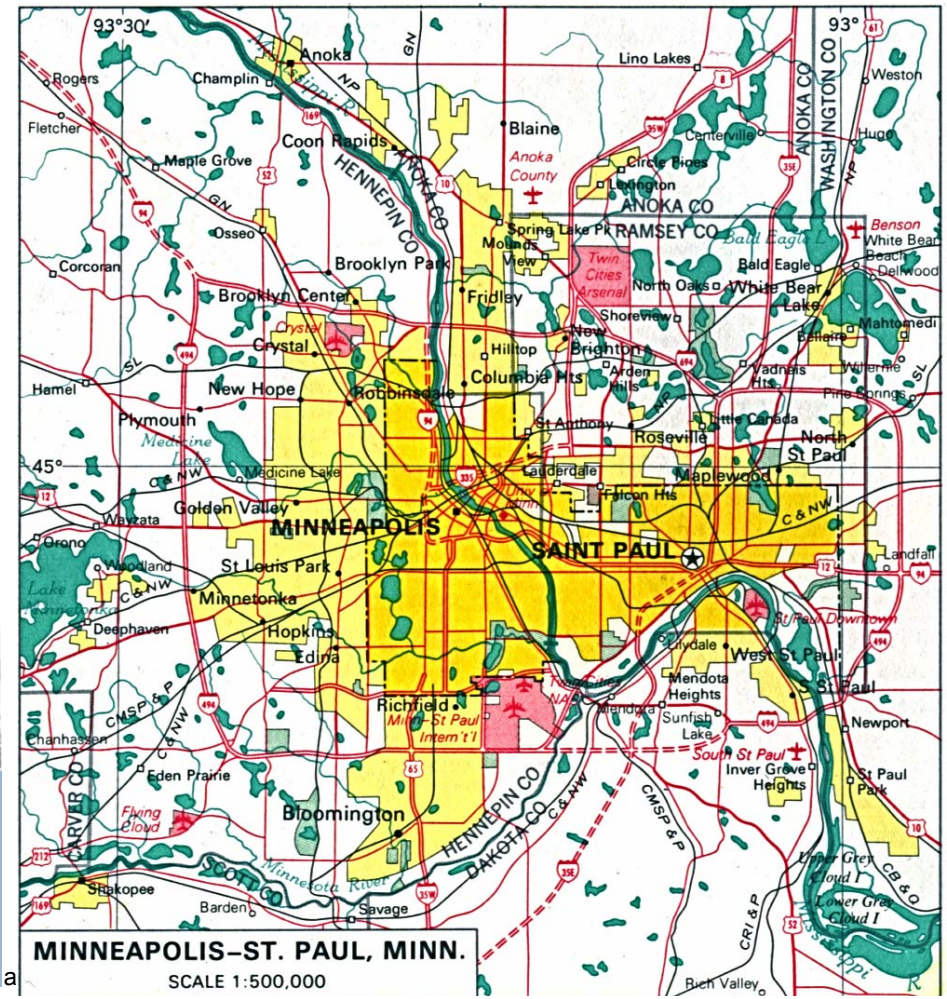
OECD, PISA 2012 Database, Table II.2.10



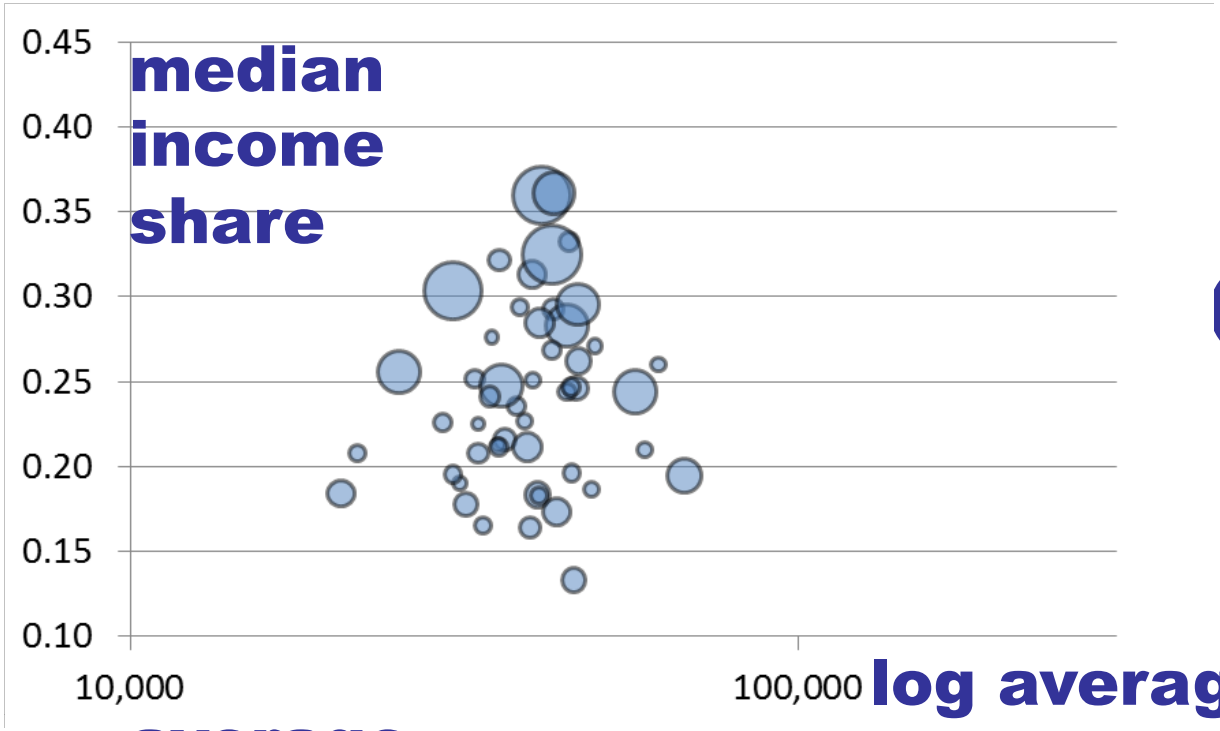
City Structure: e.g. Minneapolis and Toronto

- 200+ versus ~15 elected governments (municipal, school boards, etc.)?
- differing extent of racial / economic segregation?
- comparable data lacking



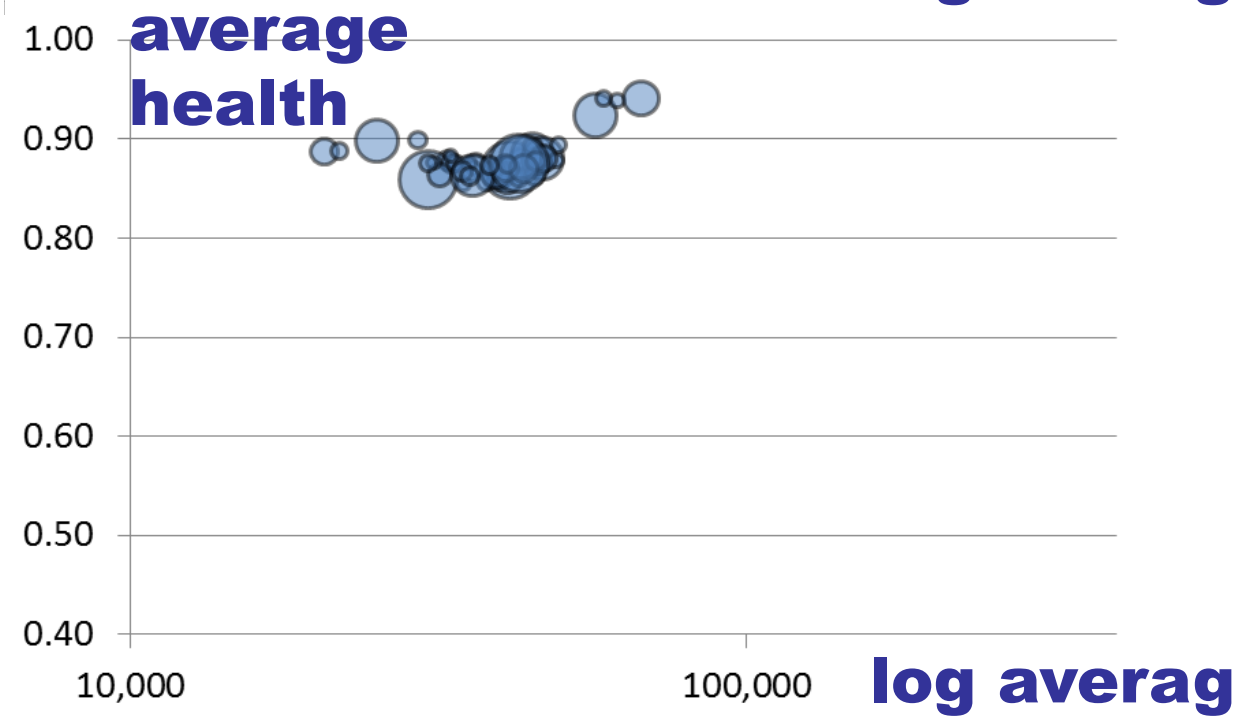


On validation…

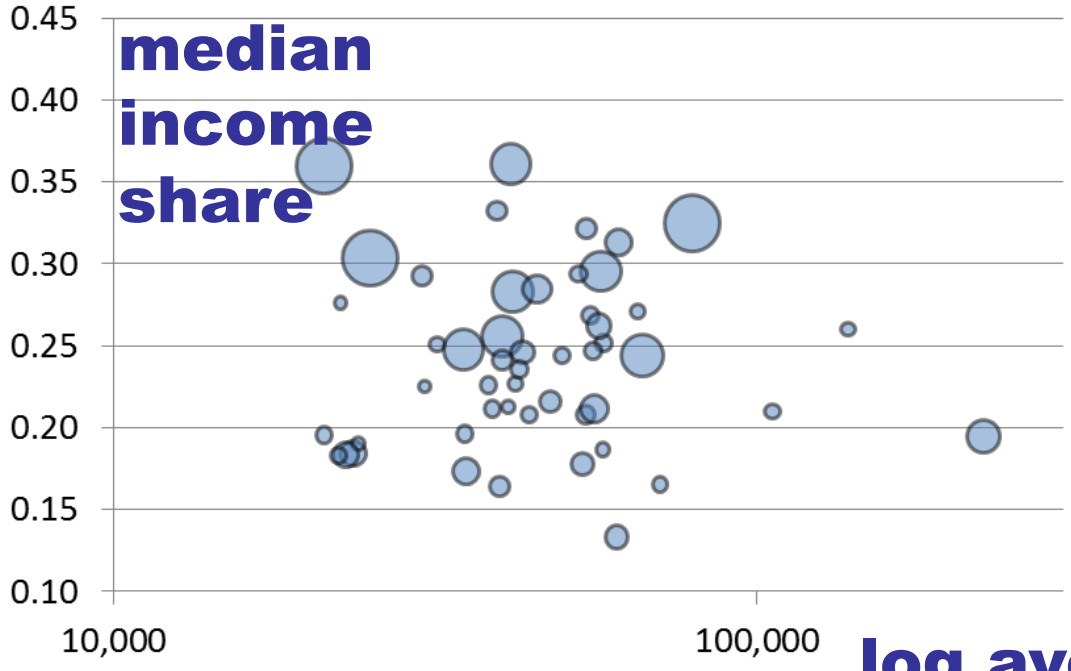


100 Nbhds, Decade 1

(areas proportional to population)

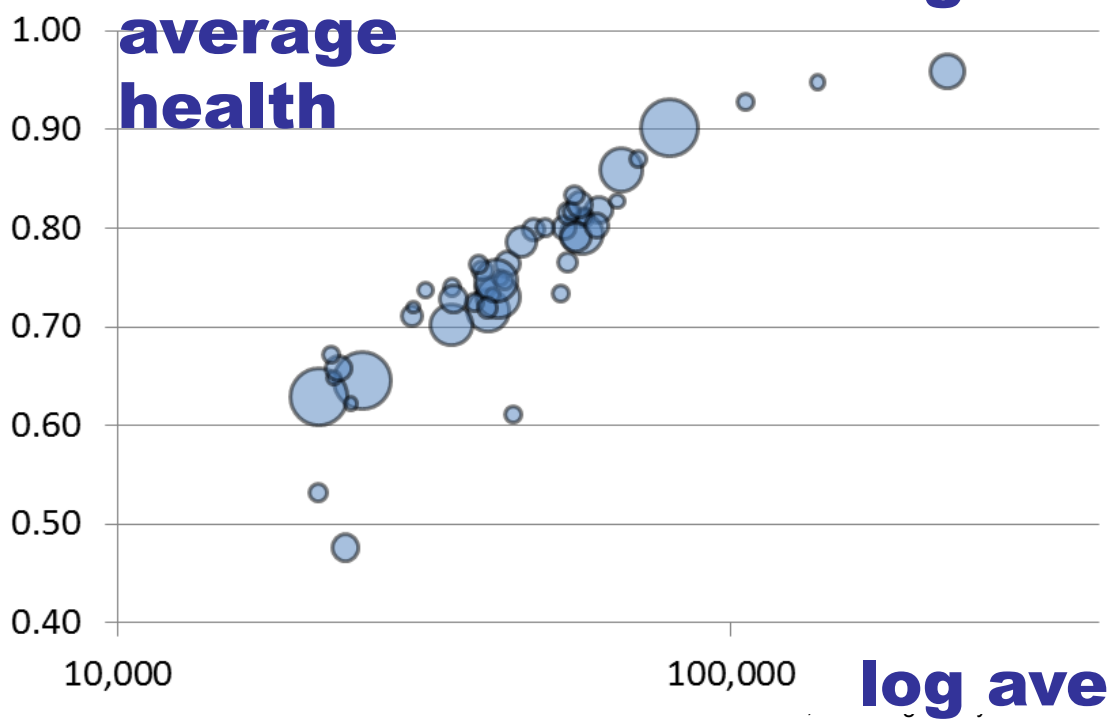


population starts randomly distributed over nbhds and incomes, but all in very good health



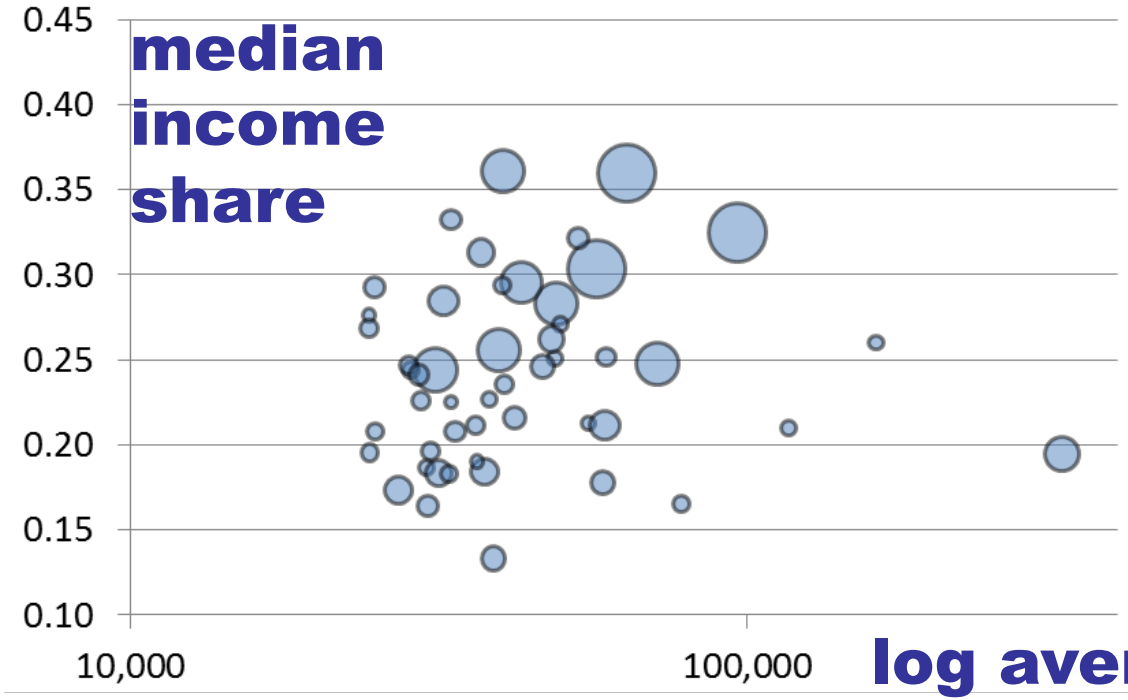
100 Nbhds, Decade 5

(areas proportional to population)



by 5th decade, nbhds spread out in terms of average income,

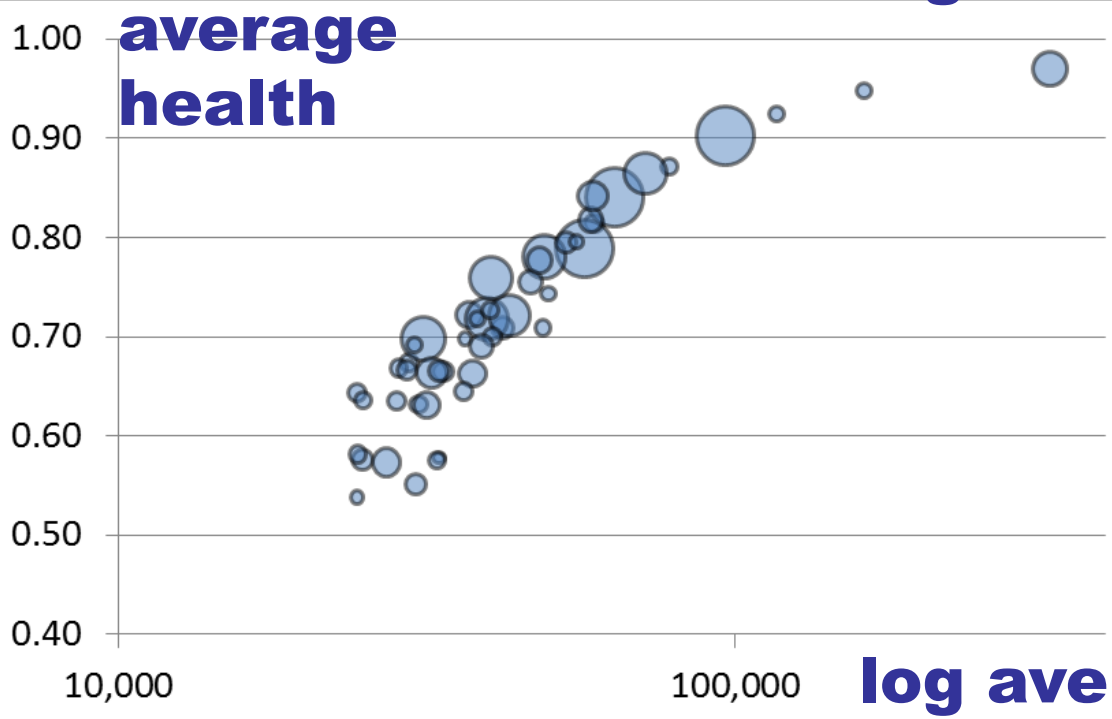
and health ↔ income pattern emerges



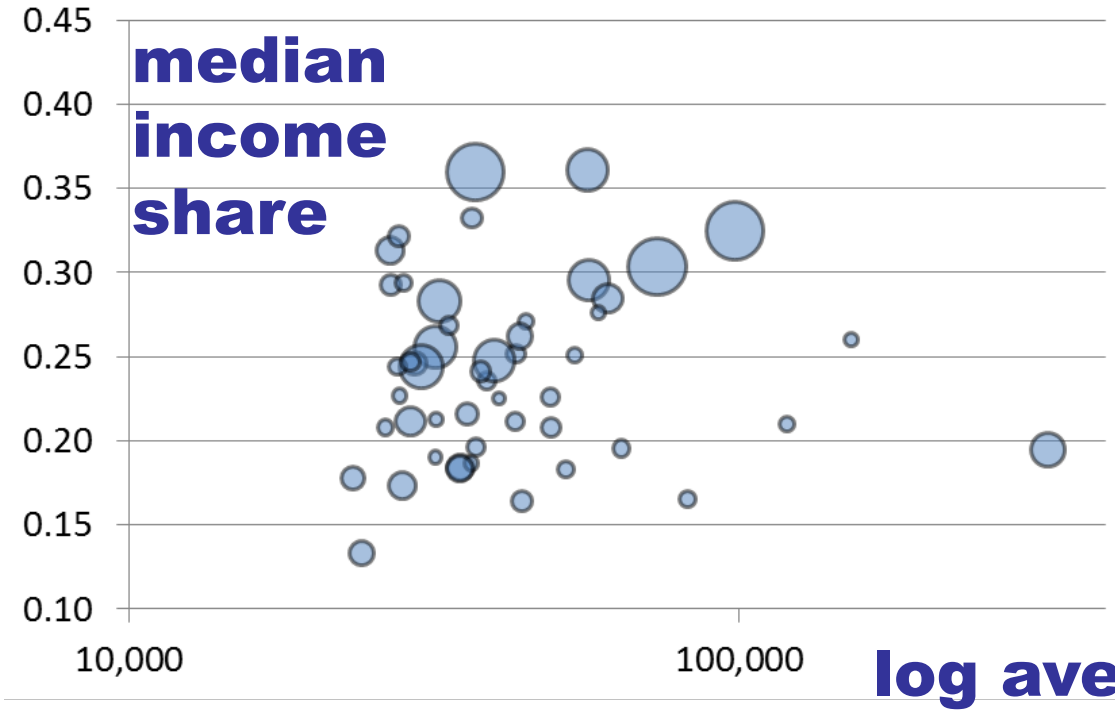
100 Nbhds, Decade 10

(areas proportional to population)

n.b. overall Gini not changing



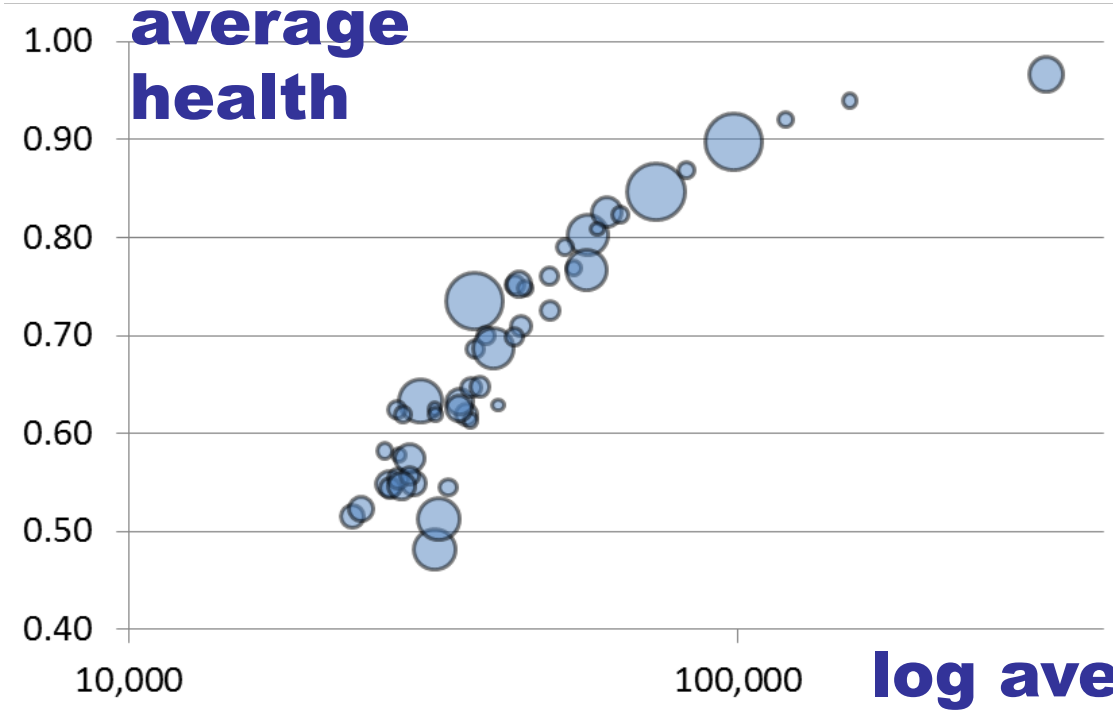
n.b. nbhd health ↔ income gradient becoming steeper



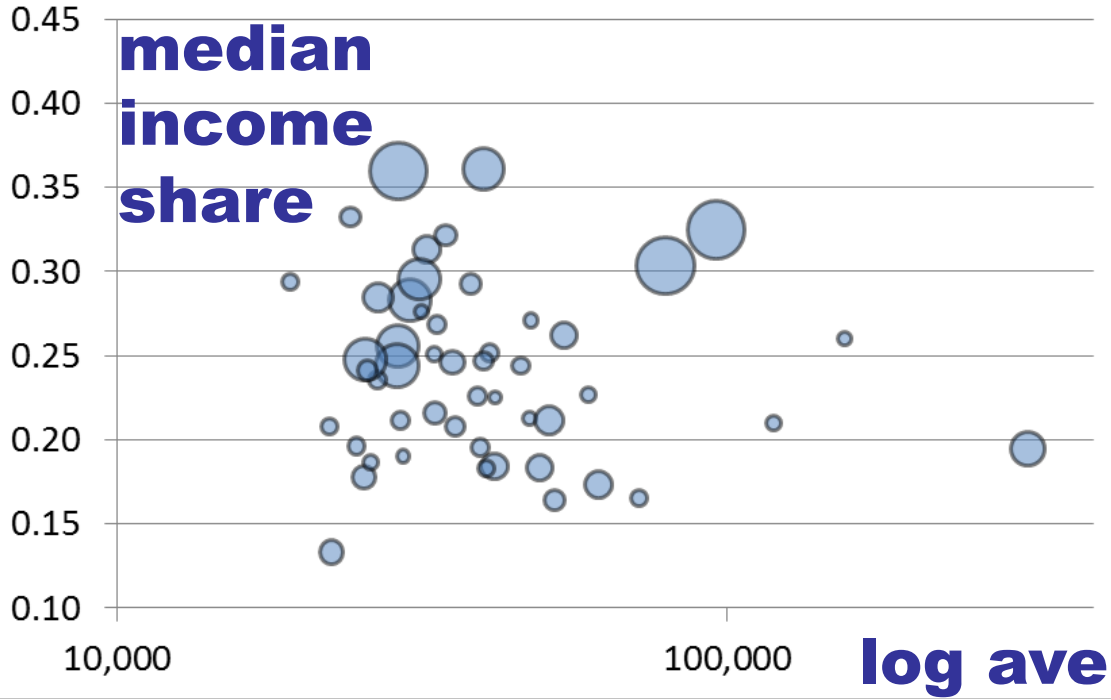
100 Nbhds, Decade 20

(areas proportional to population)

n.b. overall Gini not changing



n.b. nbhd health ↔ income gradient becoming steeper

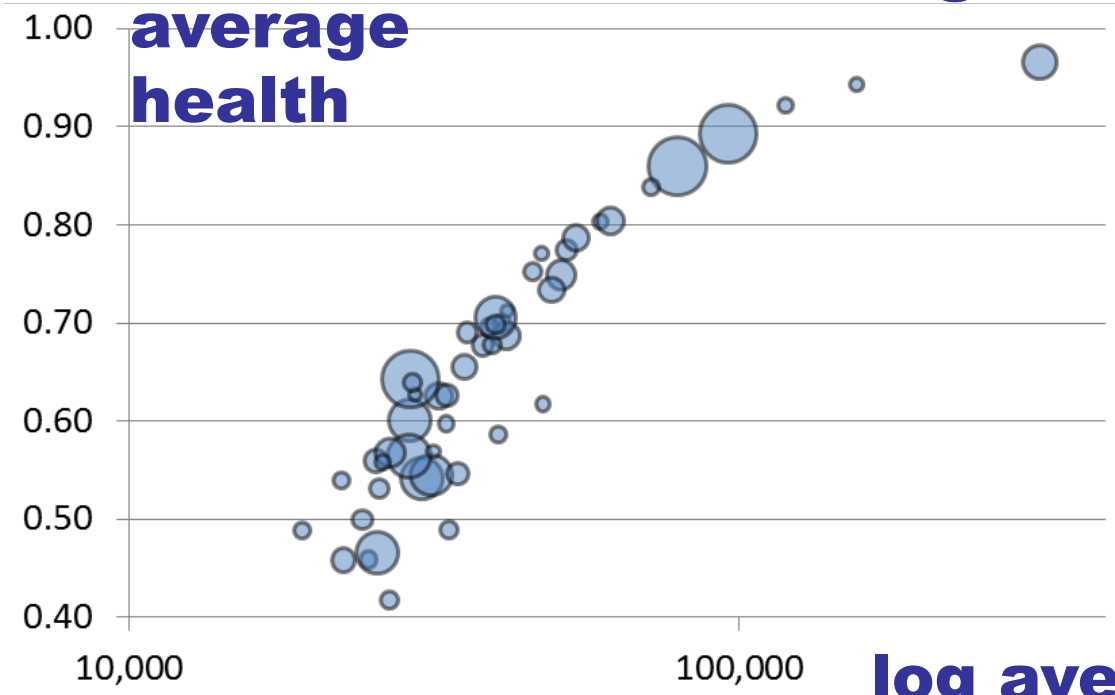


100 Nbhds, Decade 30

(areas proportional to population)

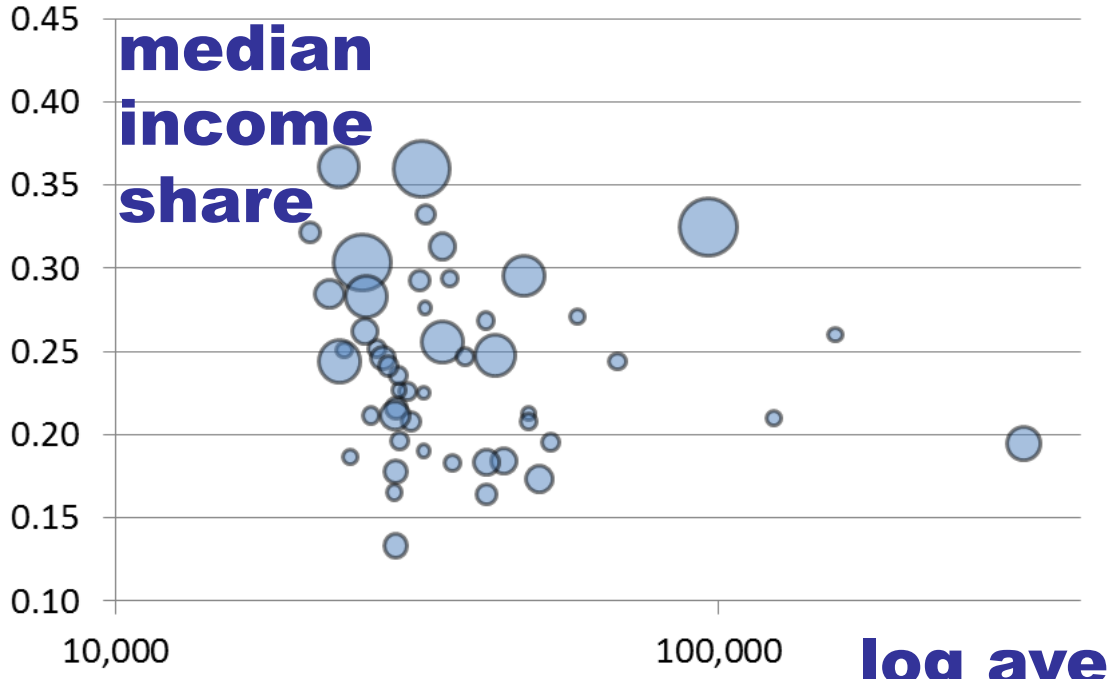
n.b. overall Gini not changing

log average income



n.b. nbhd health ↔ income gradient becoming steeper

log average income

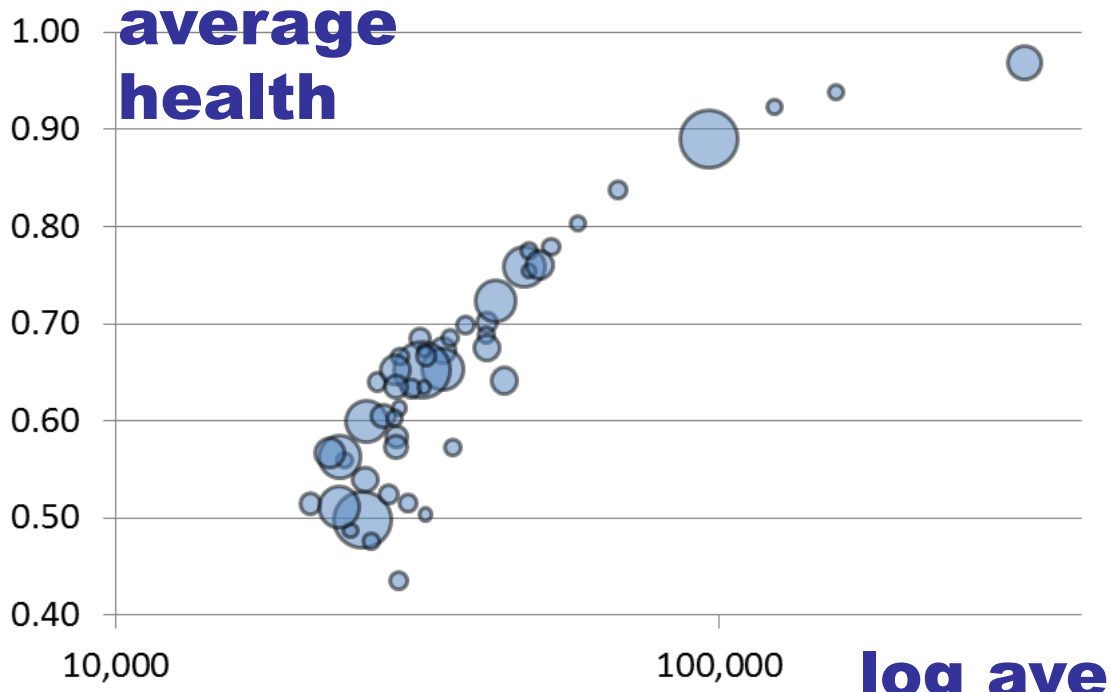


100 Nbhds, Decade 40

(areas proportional to population)

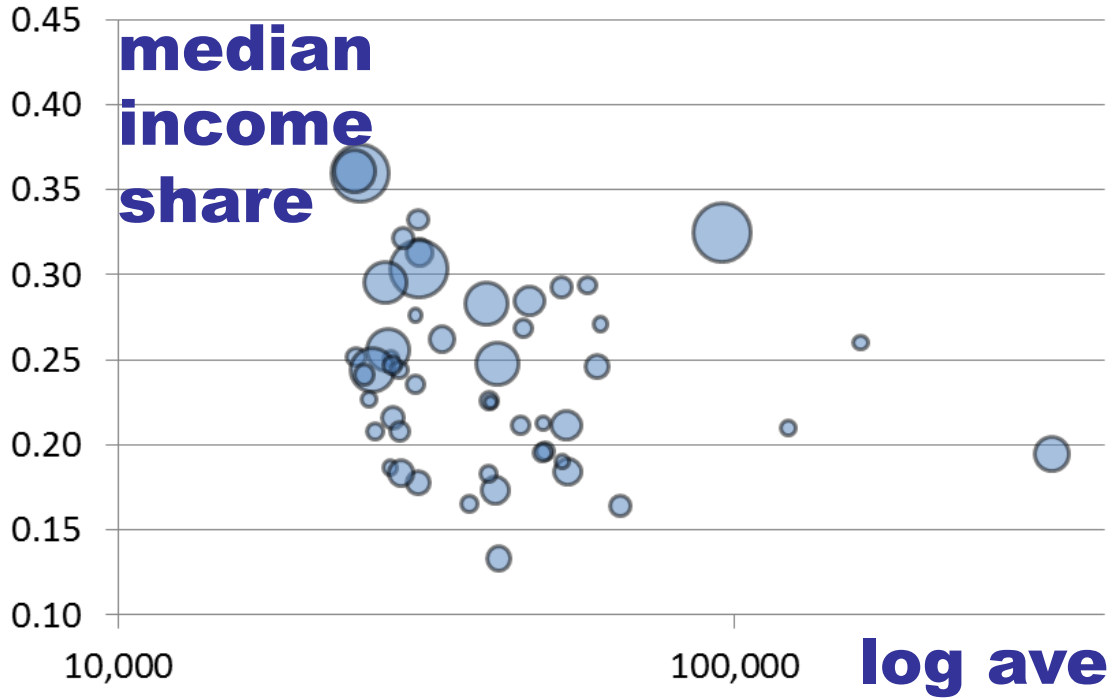
n.b. overall Gini not changing

log average income



n.b. nbhd health ↔ income gradient becoming steeper

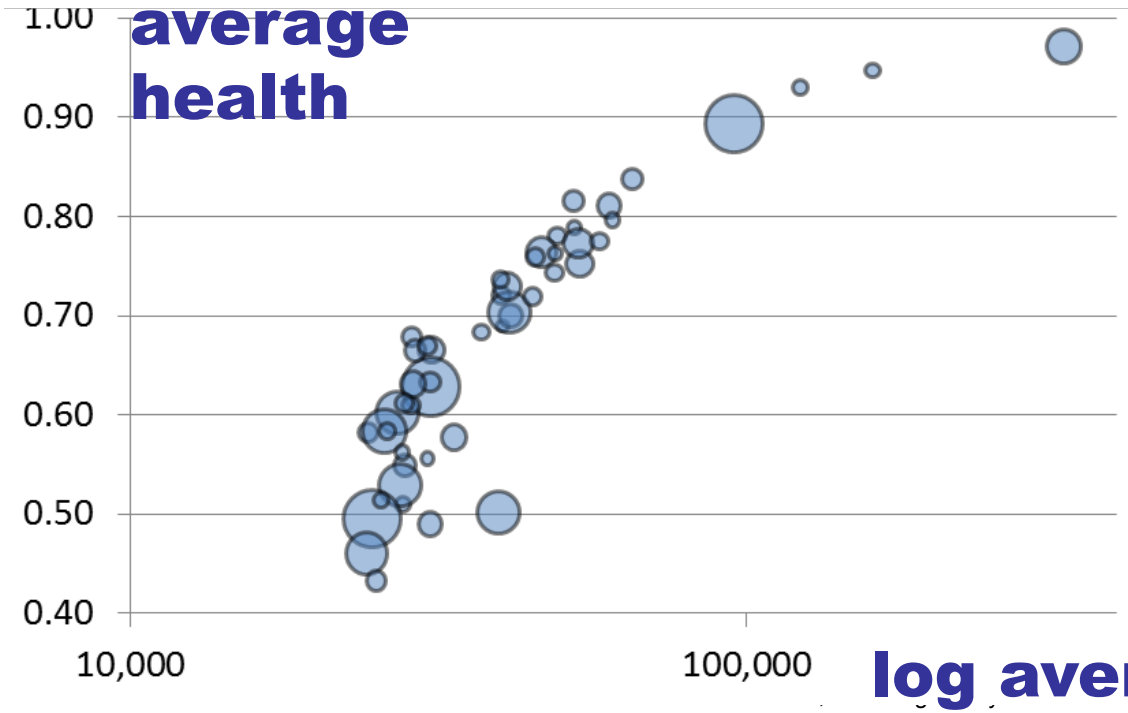
log average income



100 Nbhds, Decade 50

(areas proportional to population)

n.b. overall Gini not changing



n.b. nbhd health ↔ income gradient becoming steeper

On neighborhood dynamics over time…

Simulated Health Gradients by Income and Selected 5 Year Age Groups

- average health declines with age
- gradient becomes steeper with age
- stochastic variation greatest in top age groups