

WHAT WE TALK ABOUT WHEN WE TALK ABOUT CAUSE

CAUSAL VALUES IN GISCIENCE

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Causal Values in GIScience

Regularity and Contextuality

Moving to generative value

Talk outline

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What do we mean by it?

Regularity and Contextuality

Moving to generative value

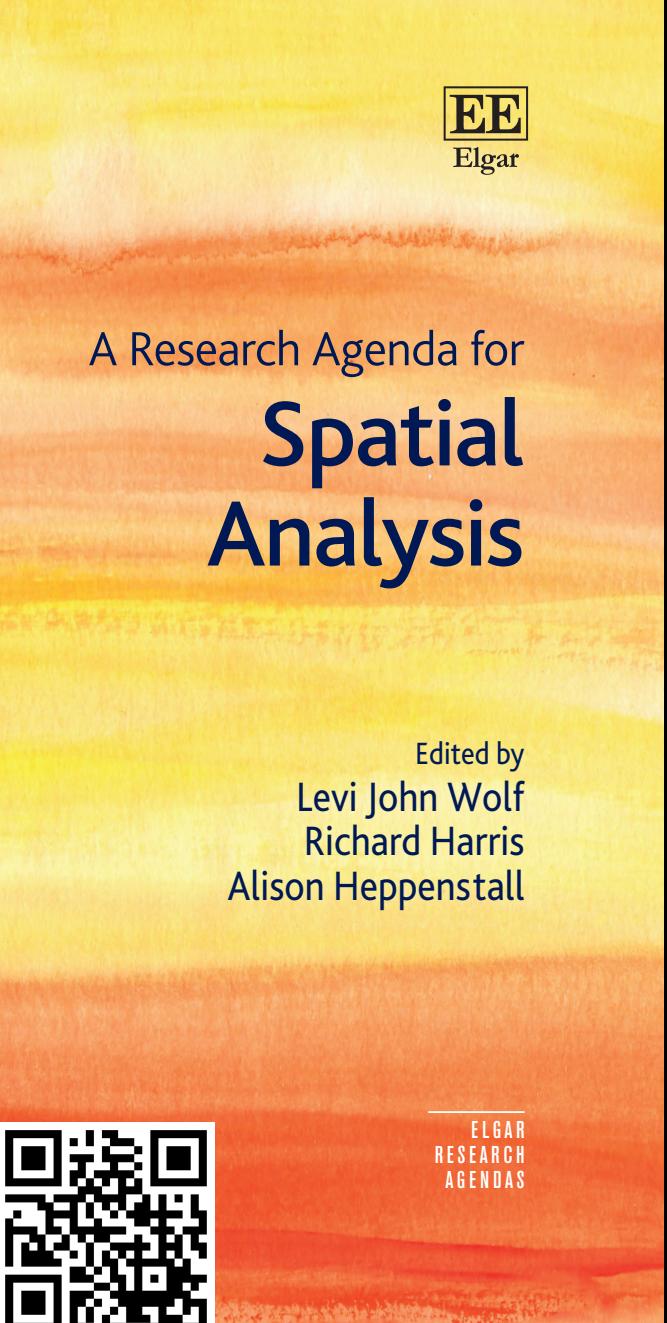
Talk outline

Rethinking Causality in Quantitative Human Geography

Mirah Zhang Levi John Wolf

Many social and physical sciences have entangled their ideas of “law” and “cause” ... causality got evicted from the discipline [of Geography] as collateral damage of theoretical debates about “law.”





A Research Agenda for
**Spatial
Analysis**

Edited by
Levi John Wolf
Richard Harris
Alison Heppenstall



ELGAR
RESEARCH
AGENDAS

A challenge for spatial analysis, as for many areas of applied social science, data science and statistics, is answering the question of causality ... what caused something to happen or arise where and when it did?
(Wolf, Harris, Heppenstall)

generative modelling done right can both contribute to a new form of causal inference and to the larger program of social sciences: the simultaneous search for generalised explanations of social phenomena and recognition of the uniqueness of historical events.
(Cottineau)

there are causal processes operating at a level (or levels) beyond the individual, but if the level included in an analysis does not correspond with the level(s) of the process then it is possible it will be mis-estimated
(Petrovic, Van Ham, & Manley)

regularity value

How often is this true?

contextual value

Where/when is this true?

generative value

How is this true?

Three kinds of “value”
for law-like statements
in GIScience

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Three kinds of “value”
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Causal reasoning can
play a role in each

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City size distributions often
follow Zipf's Law...

... in “coherent” urban
systems ...

... because of within-city
inequality.

Beyond open science: Data, code, and causality

Levi John Wolf

EPB: Urban Analytics and City Science
2023, Vol. 50(9) 2333–2336

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Indeed, city science is relatively unusual in the social sciences, in that one can still often find work seeking ‘laws’



A COMPUTER MOVIE SIMULATING URBAN GROWTH IN THE DETROIT REGION

W. R. TOBLER

University of Michigan

The LAWS of MIGRATION.

By E. G. RAVENSTEIN, Esq., F.R.G.S.

HUMAN BEHAVIOR

AND

THE PRINCIPLE
OF LEAST EFFORT



An Introduction to Human Ecology

GEORGE KINGSLEY ZIPF, Ph.D.

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Tobler's First Law

Gravity Law (of flows)

Zipf's Law (power law)

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Near things are more similar than distant things

Separation decreases flow between cities

The sizes of cities in a “coherent” system will decay in a regular way

regularity value

*Statements
we make that
derive their value
from how often
they're true.*

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City scaling as an example

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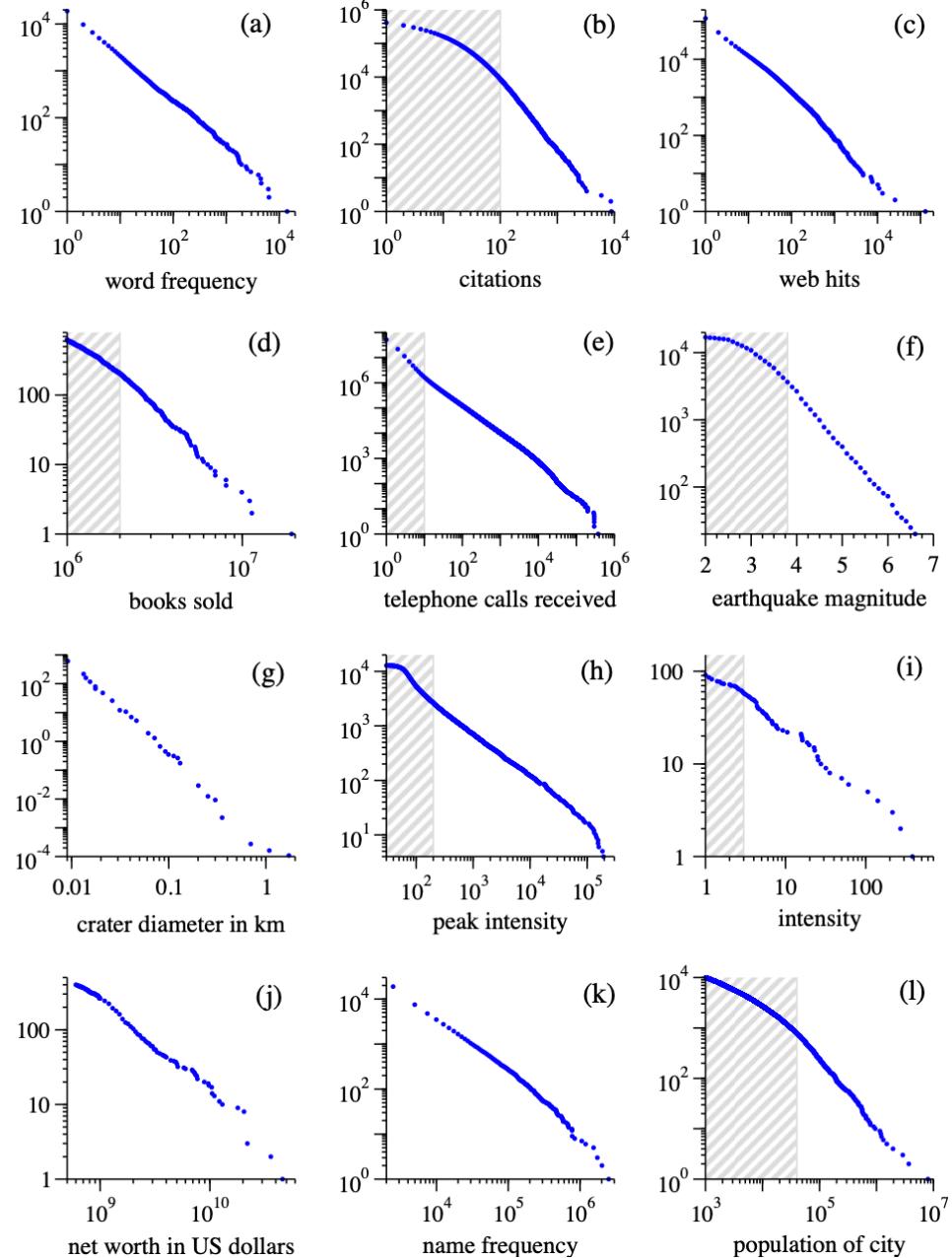
regularity value

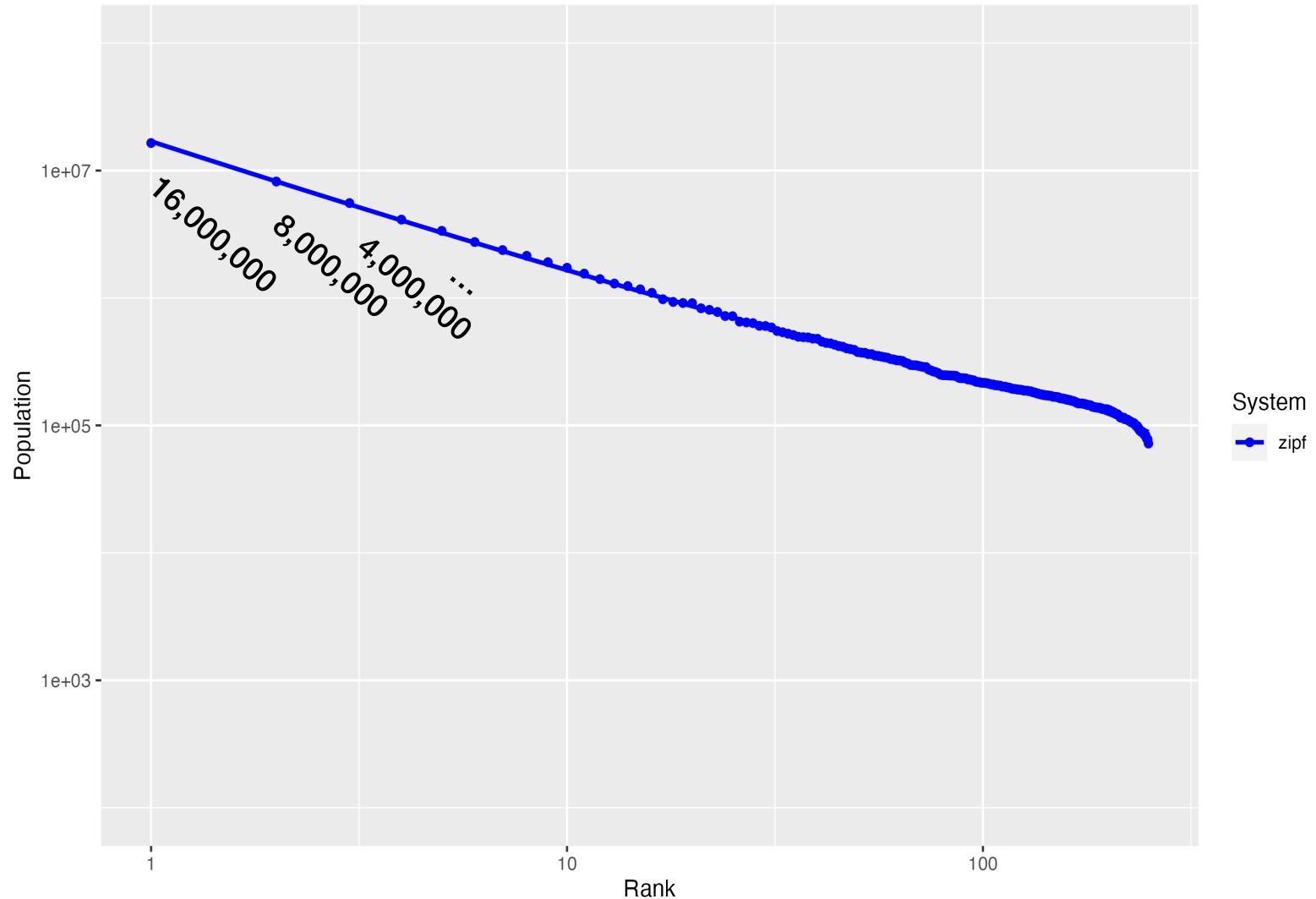
Power laws in plain language

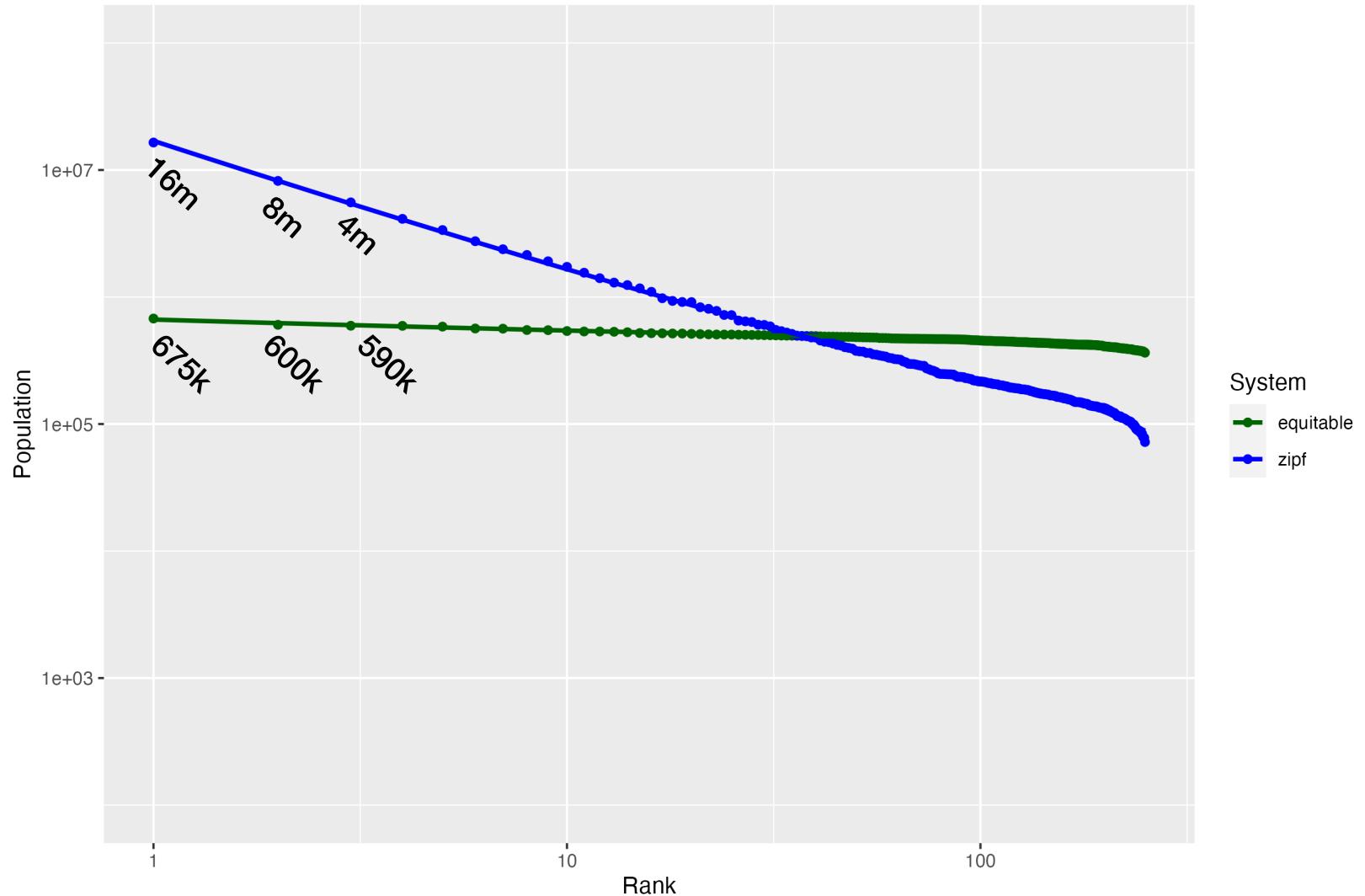
Starting from the biggest item, the next item gets smaller at a consistent ratio

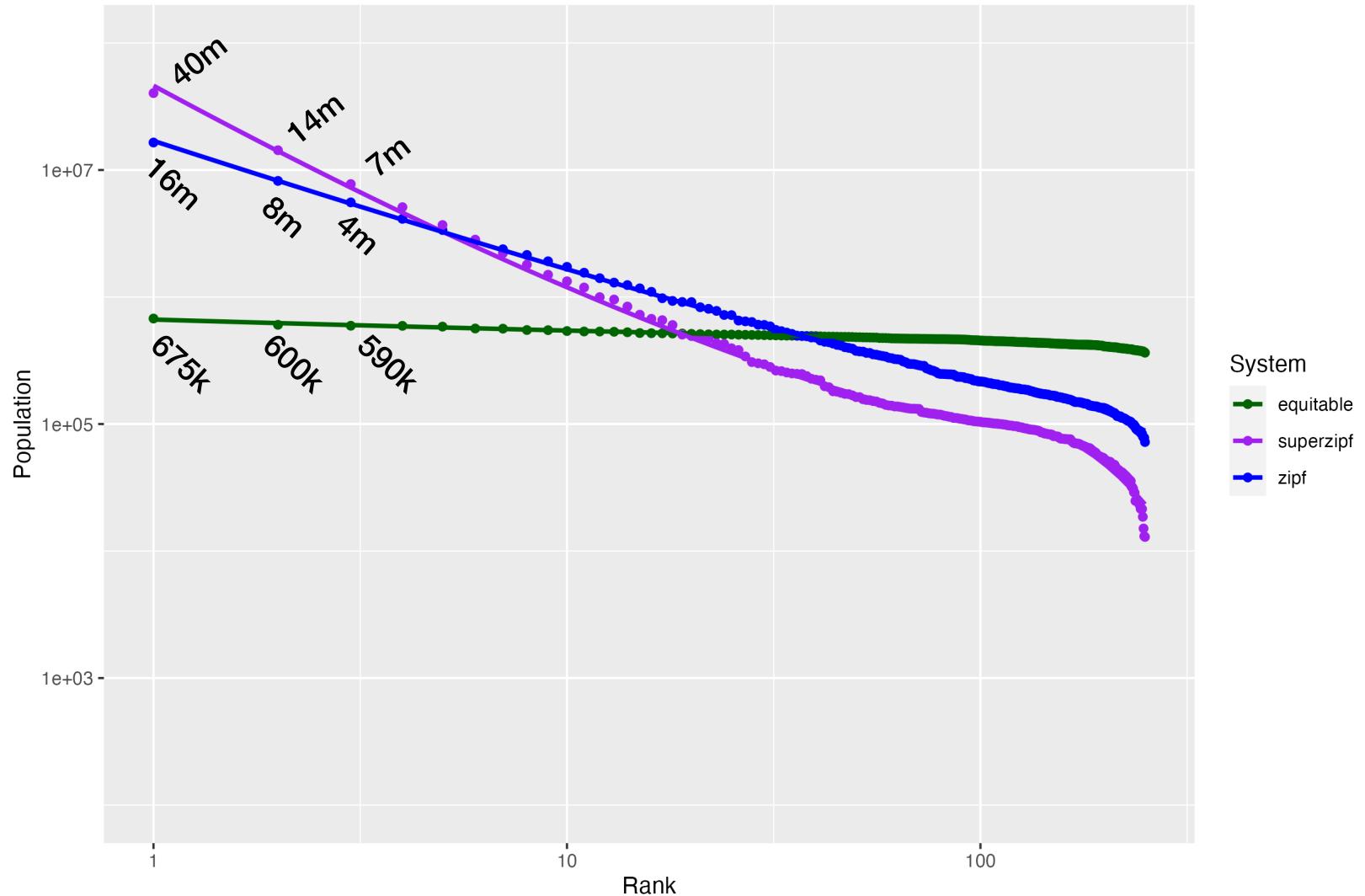
size \propto rank^{-decay}

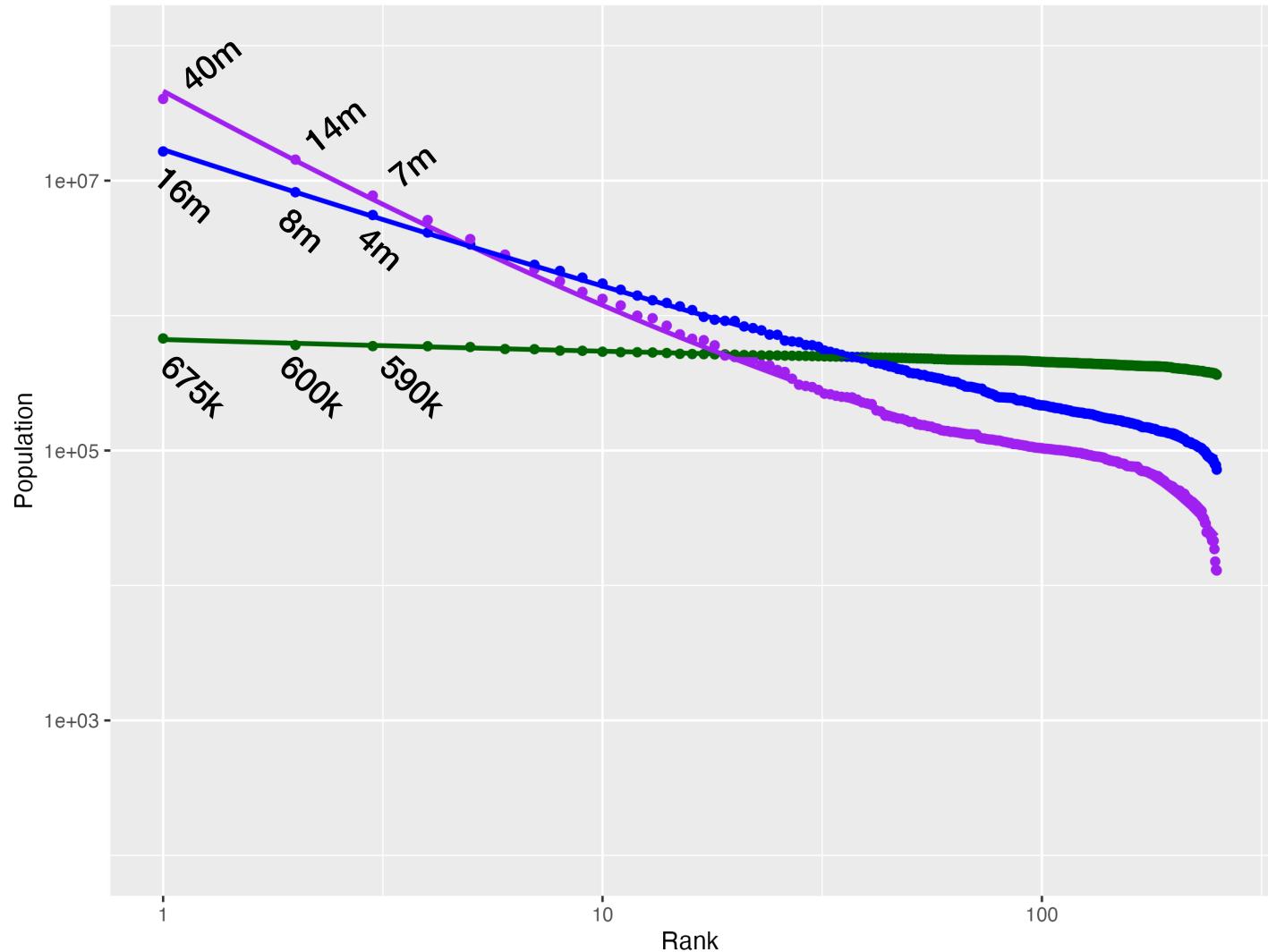
Newman, (2005)







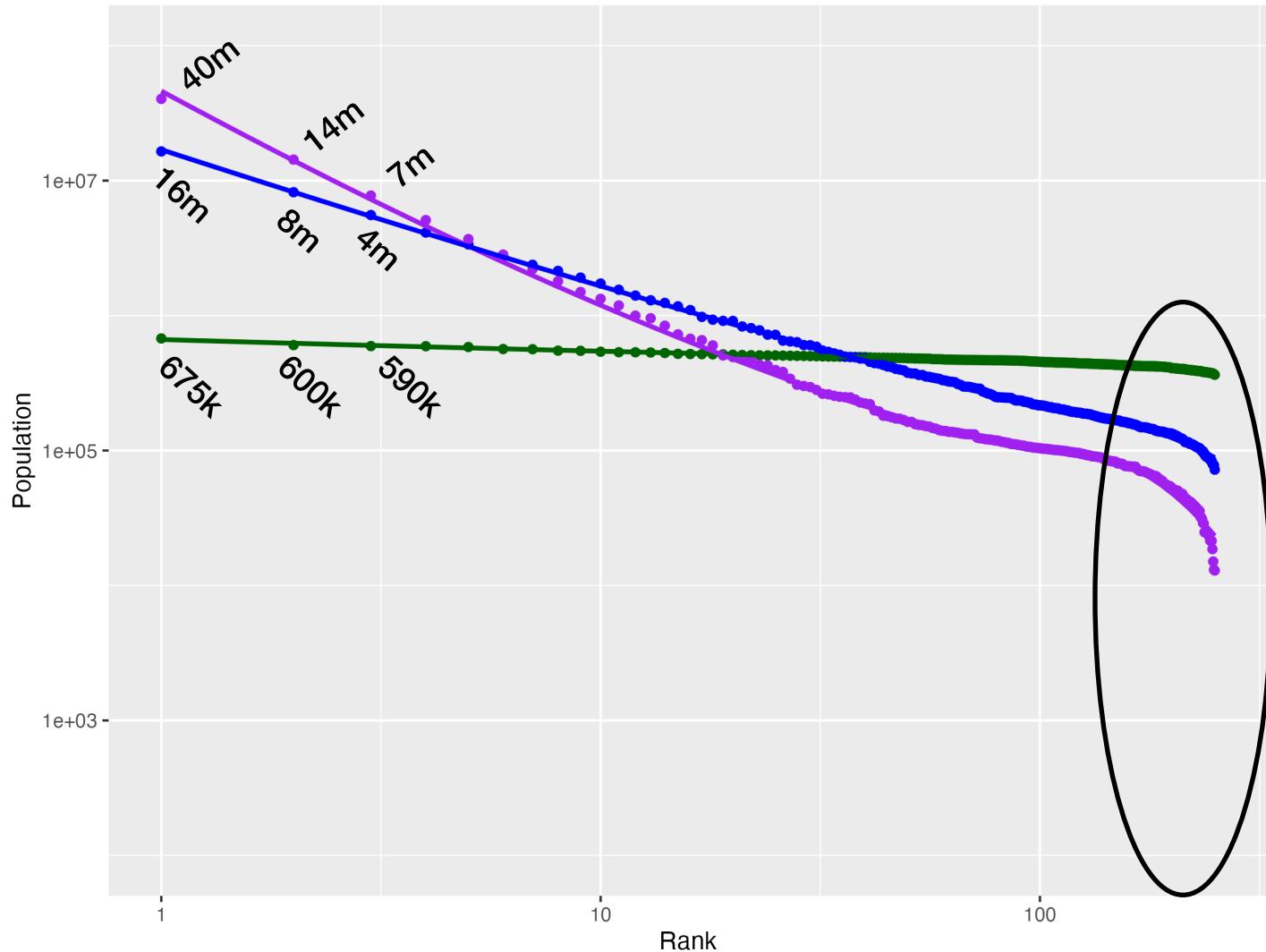




System

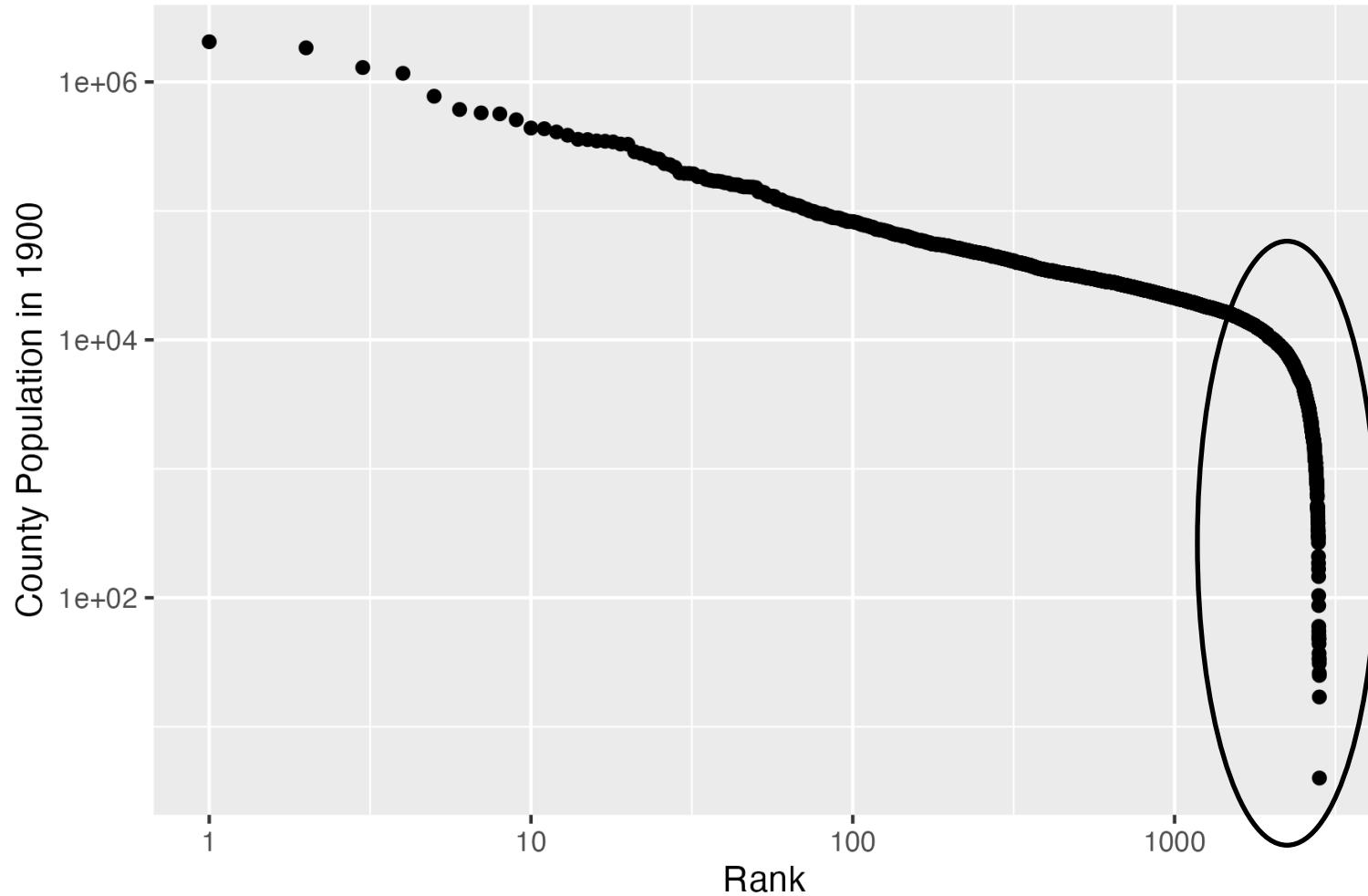
- equitable ($\lambda = .1$)
- superzipf ($\lambda = 1.5$)
- zipf ($\lambda = 1$)

$$y(x) \propto x^{-\lambda}$$



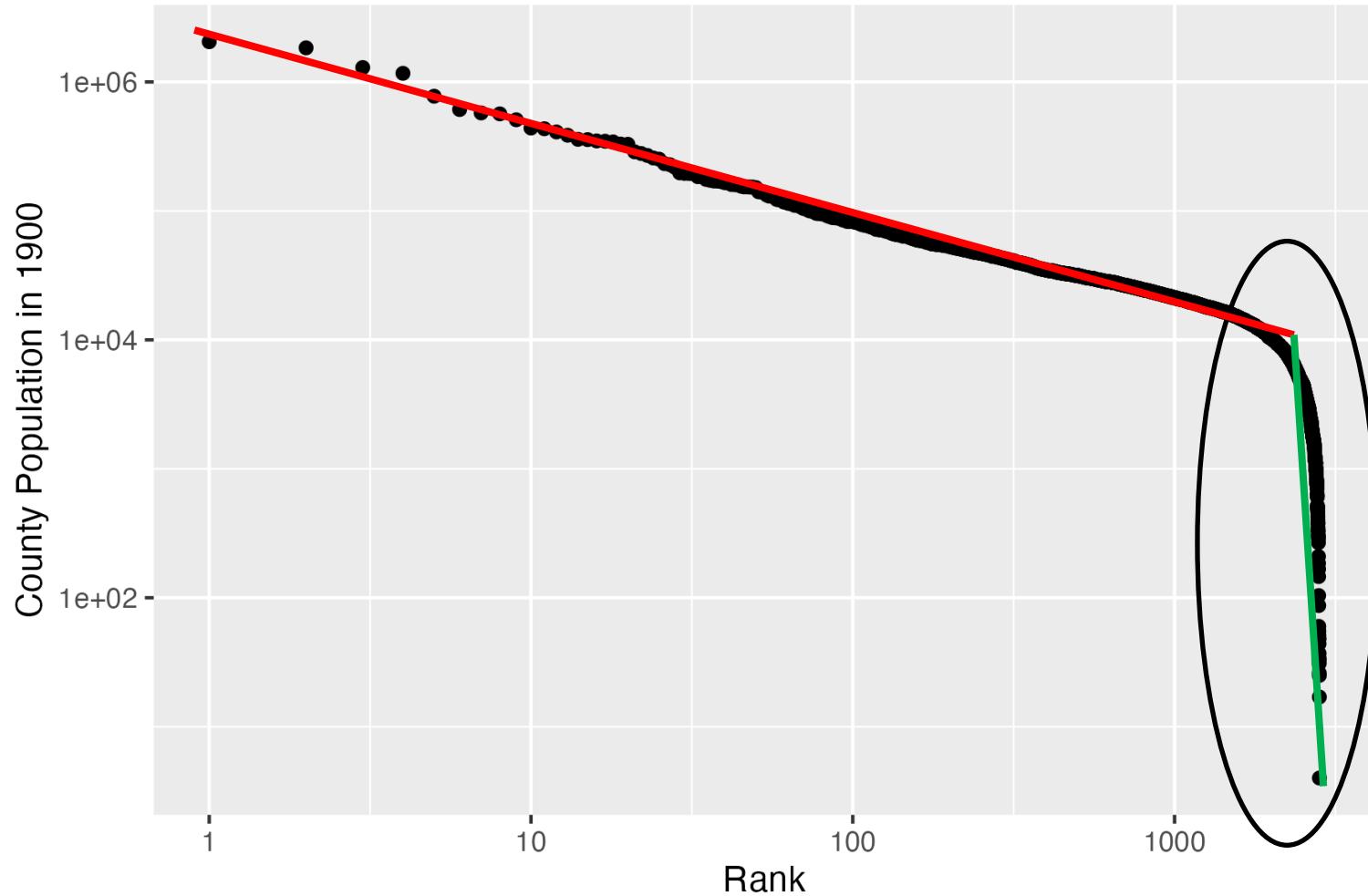
“fall off”
common to many
real-world things with
more small values

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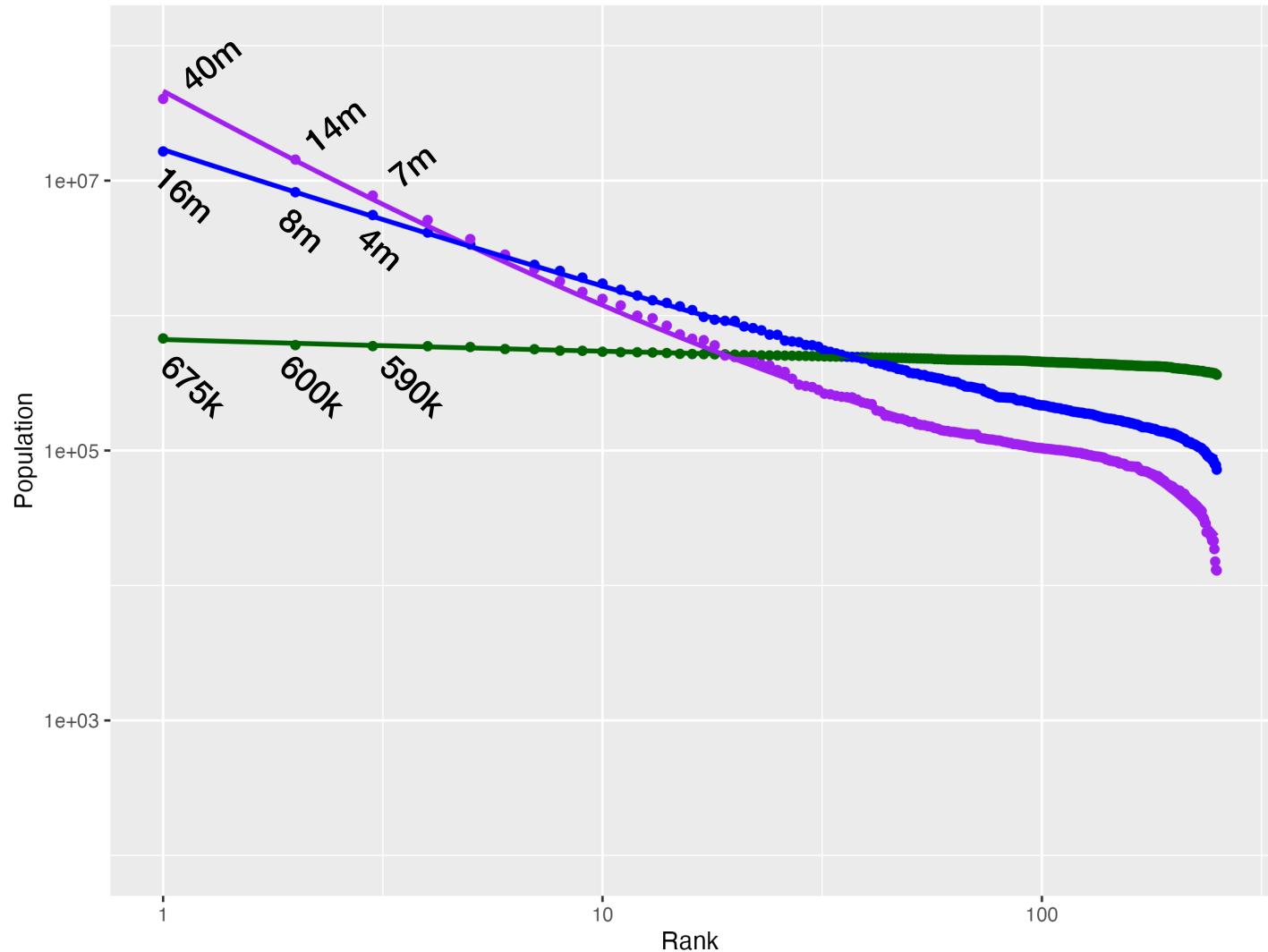
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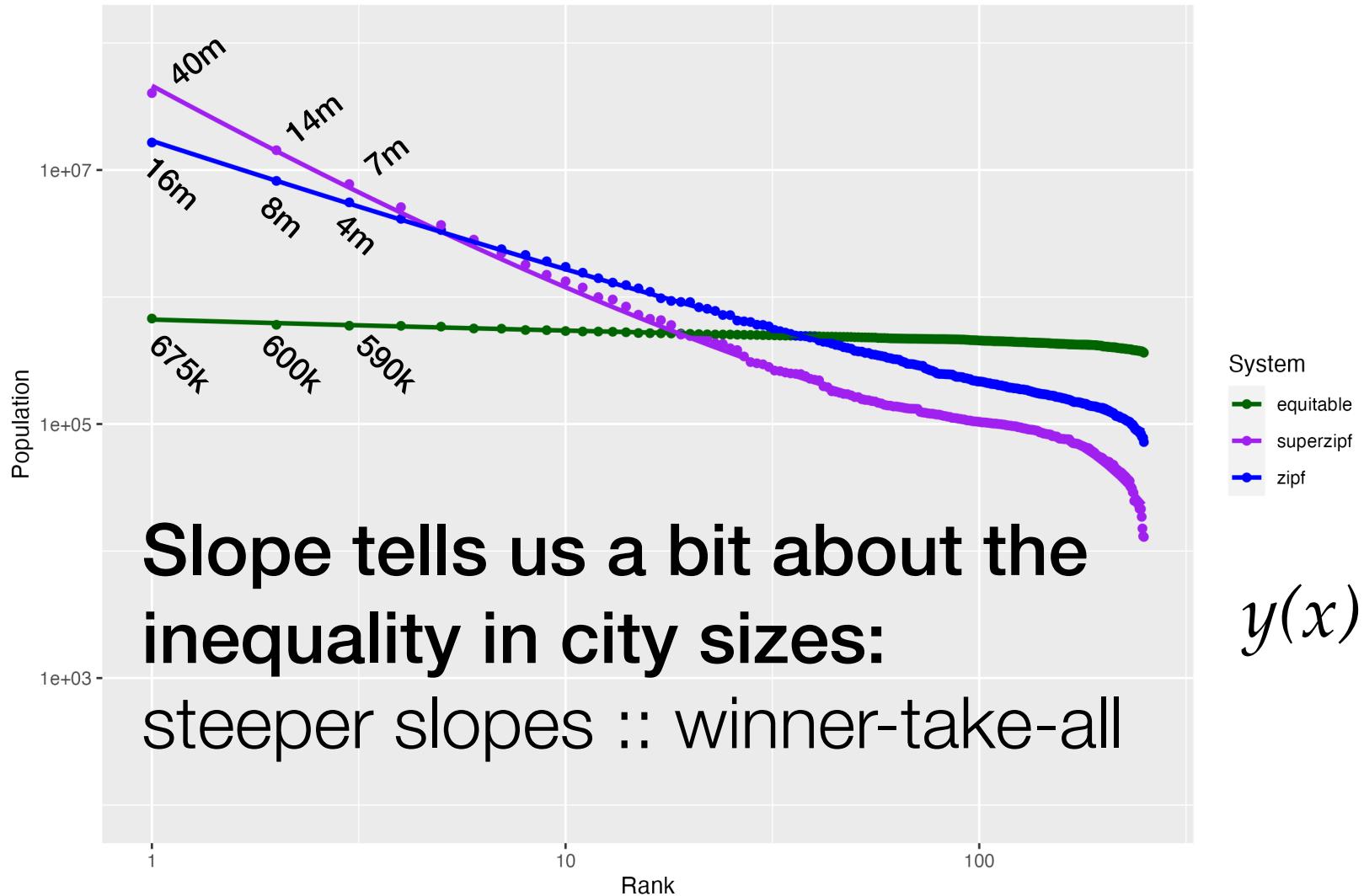
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Critical Truths About Power Laws

Michael P. H. Stumpf¹ and Mason A. Porter²

What genuinely new insights have been gained by having found a robust, mechanistically-supported, and in-all-other-ways superb power law? We believe that such insights are very rare.



$$y(x) \propto x^{-\lambda}$$

Replication across space and time must be weak in the social and environmental sciences

Michael F Goodchild & Wenwen Li

Proceedings of the National Academy of Sciences, 2021

doi.org/10.1073/pnas.2015759118

GEOGRAPHIC INFORMATION SCIENCE II: Mesogeography: social physics, GIScience, and the quest for geographic knowledge

Harvey J. Miller

Progress in Human Geography, 2018

doi.org/10.1177/0309132517712154

[Meso-geographers] occupy “intermediate positions in the longstanding debate between nomothetic [law-seeking] and idiographic” research (Goodchild and Li, 2021).

In this sense, “Mesogeography seeks generalizations, but not universal laws” where generalizations are the “causal relations holding in a range of environments.” (Miller, 2018)

Rethinking Causality in Quantitative Human Geography

Mirah Zhang Levi John Wolf

“Weak replicability” should instead be framed as “strong contextuality”: our specific explanations of why context counts should be sufficient to understand when a given causal mechanism might operate.





There is More than a Power Law in Zipf

Matthieu Cristelli^{1,2}, Michael Batty^{3,4} & Luciano Pietronero^{1,2,5}

SUBJECT AREAS:

STATISTICAL PHYSICS,
THERMODYNAMICS AND
NONLINEAR DYNAMICS
PHYSICS
STATISTICS

¹Department of Physics, University of Rome “La Sapienza”, Piazzale A. Moro 2, 00185 Rome, Italy, ²The Institute of Complex Systems, CNR, Via dei Taurini 19, 00185 Rome, Italy, ³Centre for Advanced Spatial Analysis, University College London, 90 Tottenham Court Road, London W1T 4TJ, UK, ⁴School of Geographical Sciences and Urban Planning, Arizona State University, P.O. Box 875302, Tempe, AZ 85287-5302, ⁵London Institute for Mathematical Sciences, 35 South Street, Mayfair, London W1K 2NY, UK.

In fact, [Zipf's law] cannot be developed without considering ... some kind of optimization in growth processes or of an optimal self-organization mechanism with respect to some (finite) resource.

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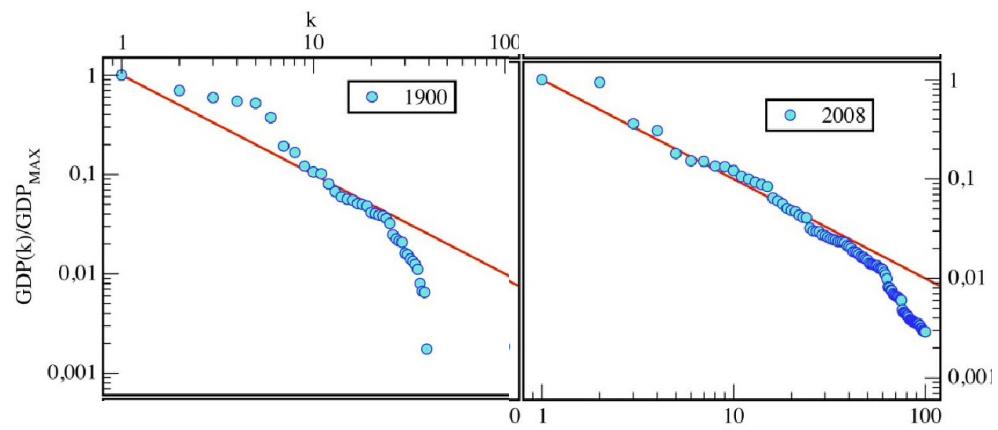
Separation decreases flow between cities

The sizes of cities in a “**coherent**” system will decay in a regular way

While Zipf's Law holds approximately for the city sizes of each European country ... it completely fails in the aggregated sets, that is in the EU.

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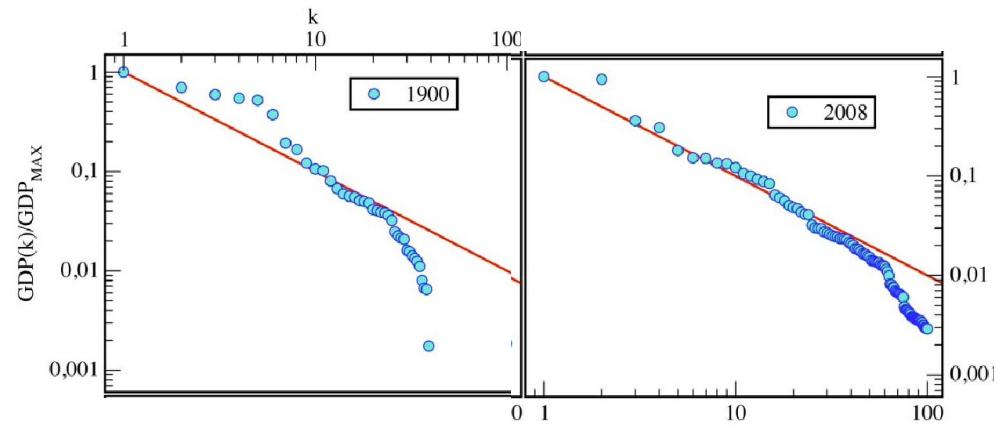
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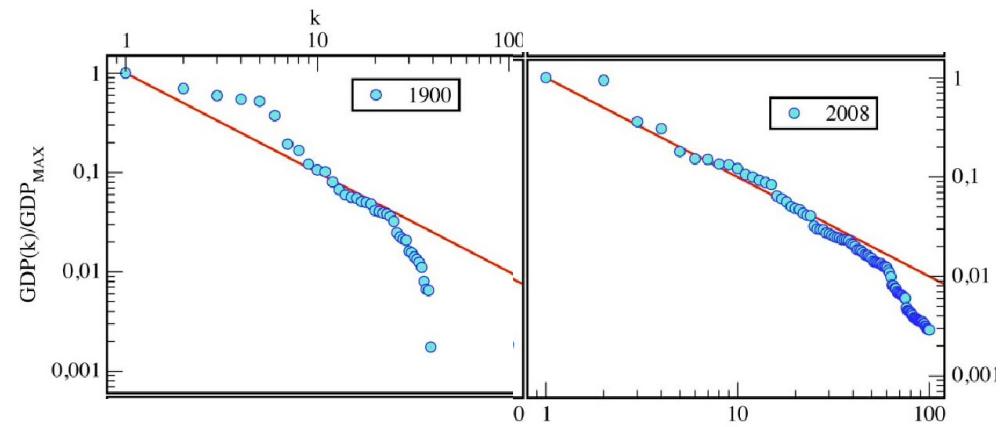
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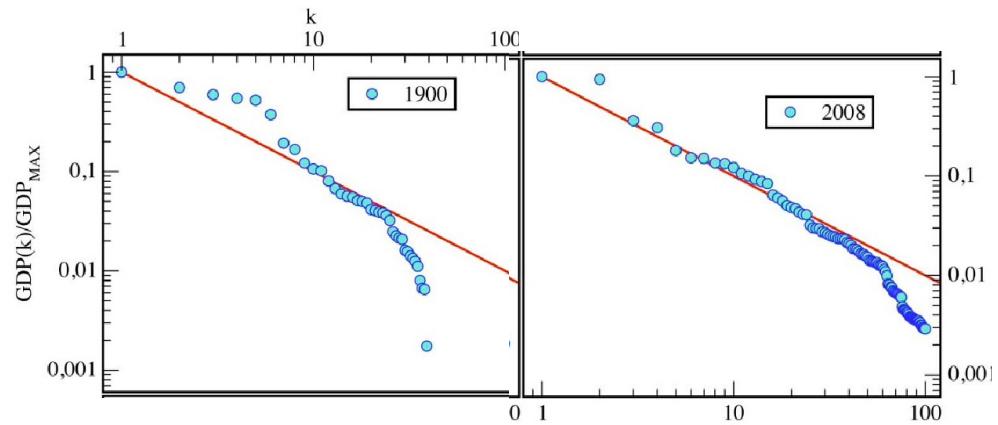
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Contextual value

*Statements
we make that
derive their value
from when/where
they are true
(or are not!)*

There is More than a Power Law in Zipf

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Contextual value

regularity value

How often is this true?

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Where/when is this true?

generative value

How is this true?

City size distributions often
follow Zipf's Law...

... in “coherent” urban
systems ...

... because of within-city
inequality.

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Winner-take-all urbanity

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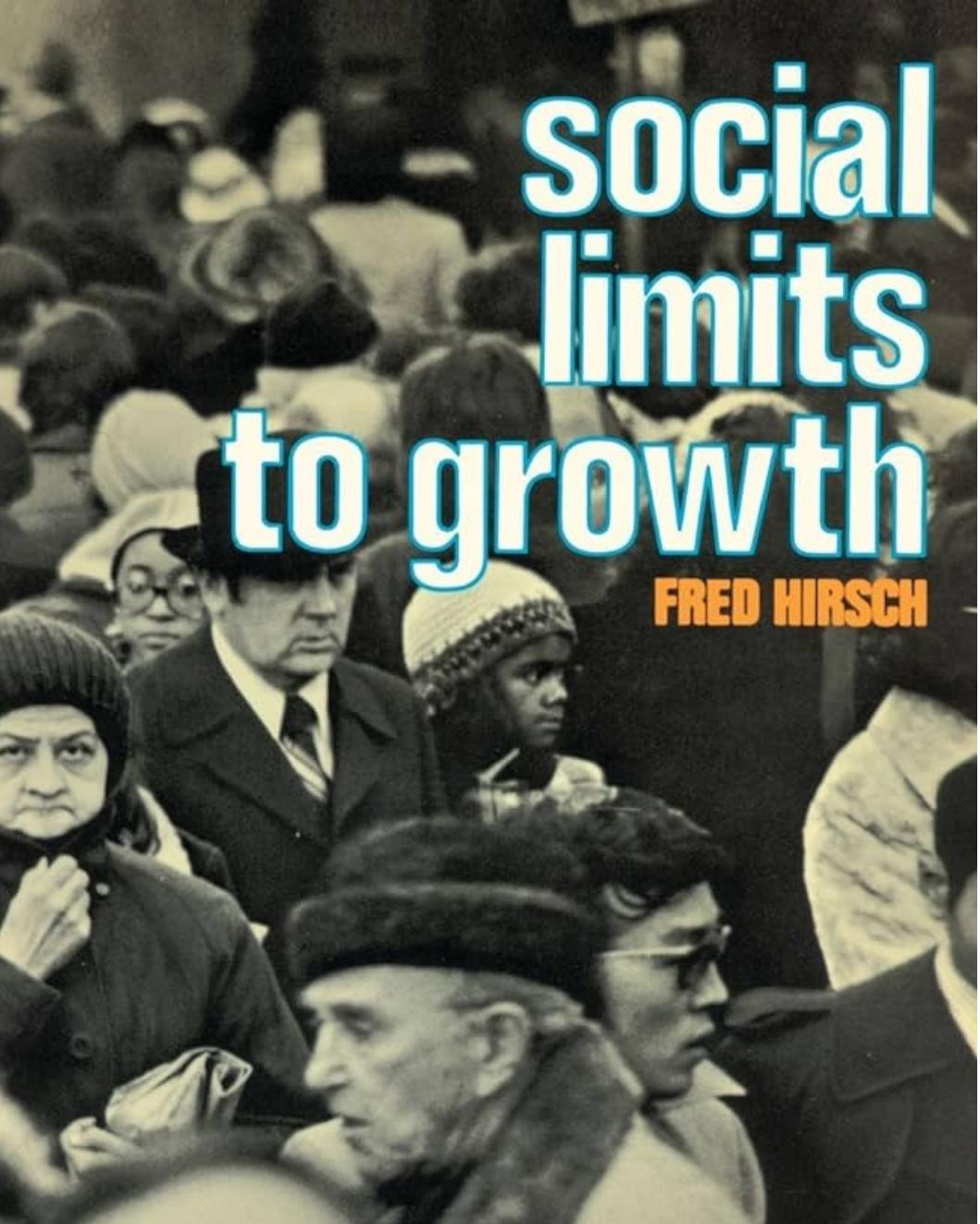
... because of within-city
inequality.

Positional goods derive their value from their relation to other consumers' goods.

“What each of us can achieve, all cannot.”

Examples include luxuries, education, and real estate.

Are cities themselves positional?



Urban scaling laws arise from within-city inequalities

Arvidsson et al. (2023)

City size-dependent cumulative advantage

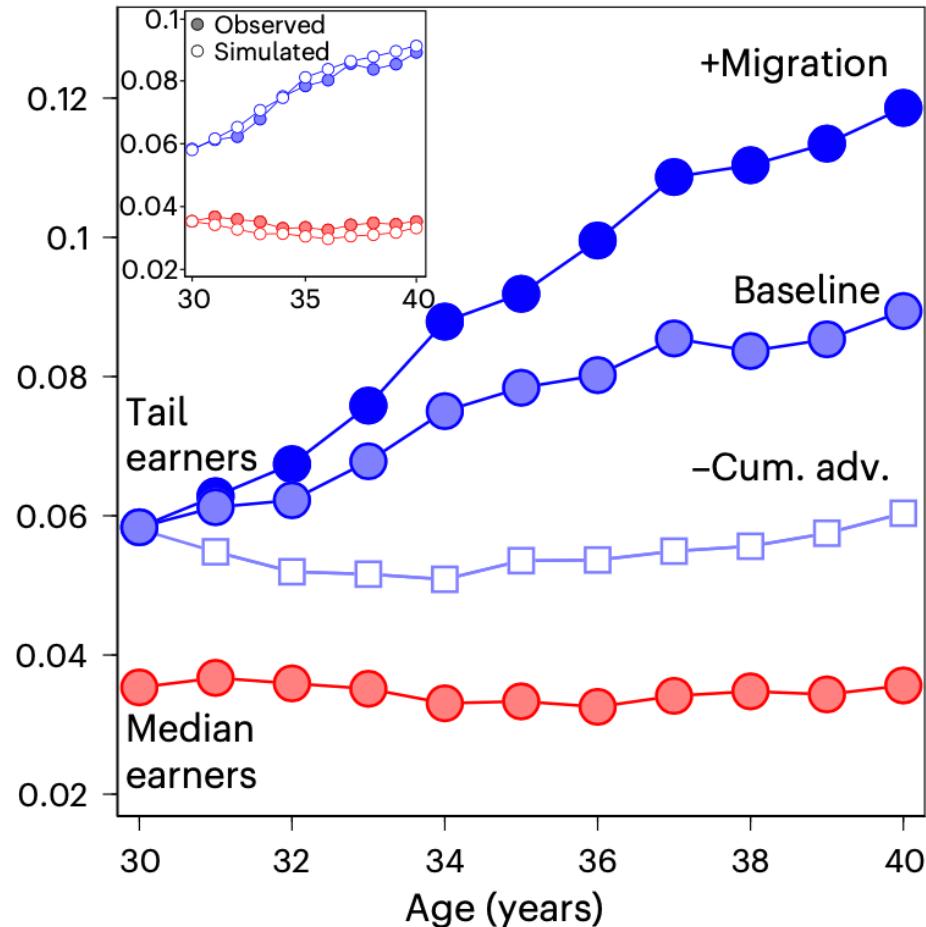
- (1) Cities benefit their inhabitants
- (2) Benefits are unevenly distributed
- (3) In big cities, the top “gets” more from more people
- (4) Disparity compounds over time due to generational transfer and migration
- (5) This top causes scaling to emerge between cities

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Arvidsson et al. (2023)

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Simulation results show the contribution of each mechanism

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Winner-take-all Urbanism: Geographic Divisions in the Modern Era

RICHARD FLORIDA
University Professor
University of Toronto

An Interview with Gray Brakke

The first dimension [of the New Urban Crisis] is the growing divide between the winner cities ... and the rest. I call this winner-take-all urbanism.

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So, if this is true:

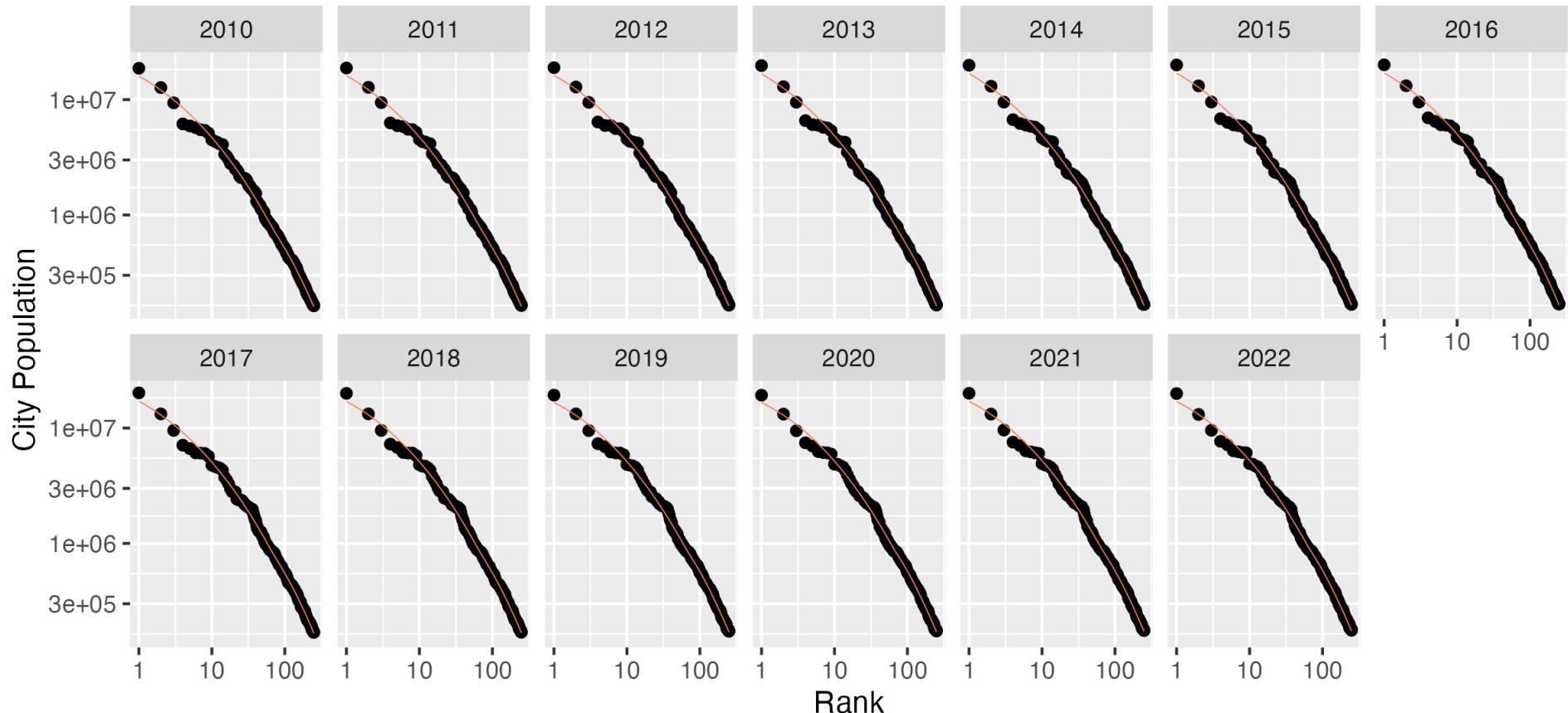
Within-city inequality should go hand-in-hand with pop growth

Between-city inequality should rise as income inequality rises

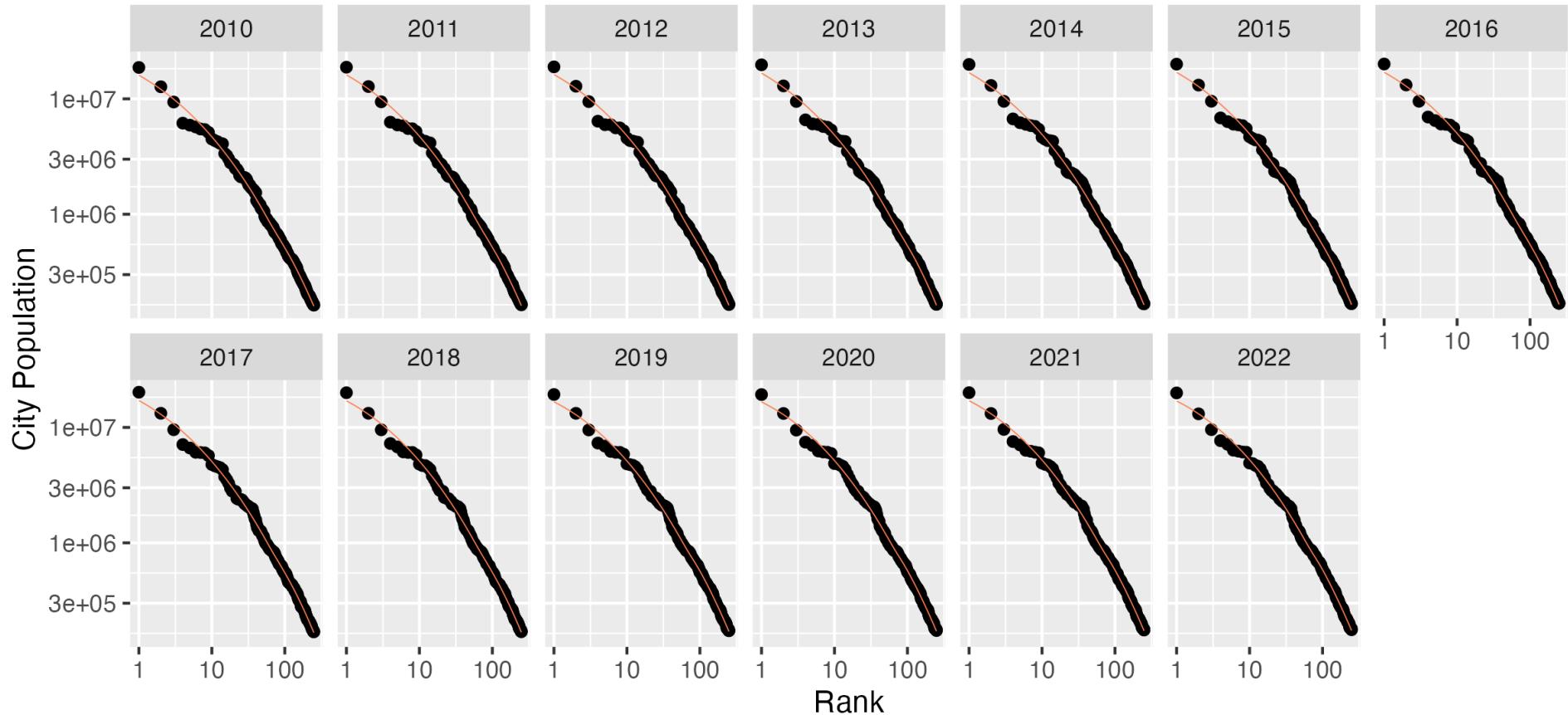
Scaling should get steeper as within-city inequality increases

generative value

Rank Size of Cities by Decade

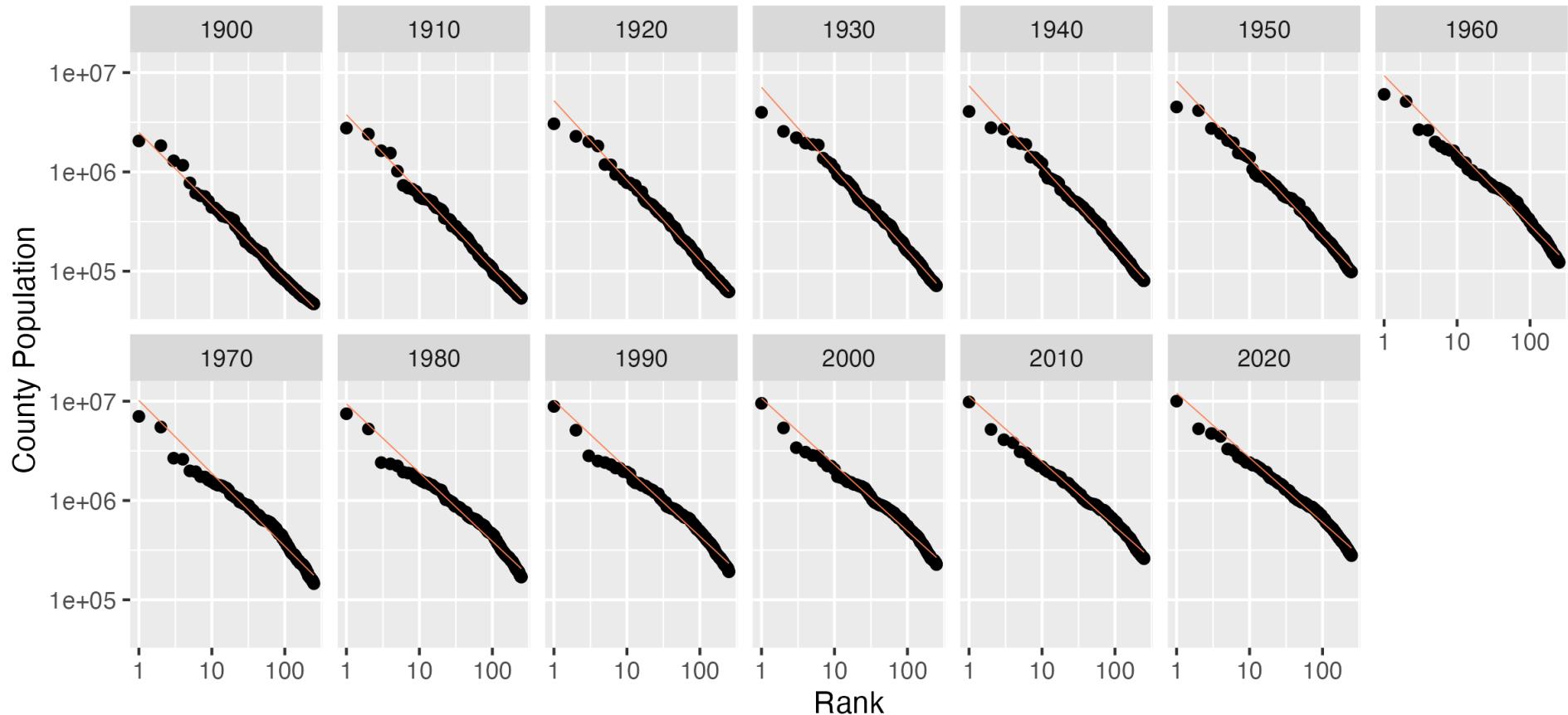


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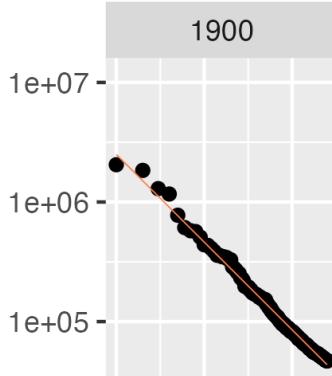
Cities don't really change
substantially on this timescale

Rank Size of Counties by Decade



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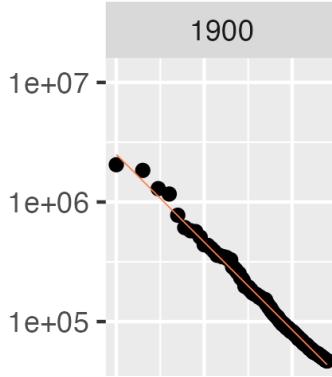
County Population



- NY** (Manhattan)
- Cook** (Chicago)
- Philadelphia**
- Kings** (Brooklyn)
- Allagheny** (Pittsburgh)
- Suffolk** (Central Boston)
- St. Louis**
- Middlesex** (Boston-Cambridge)
- Baltimore**
- Cuyahoga** (Cleveland)
- Erie** (Buffalo)
- Hamilton** (Cincinnati)
- Hudson** (Jersey City)
- Essex** (Newark)
- Essex** (Boston-Salem)
- Wayne** (Detroit)
- Worcester**
- San Francisco**
- Milwaukee**

Rank Size of Counties by Decade

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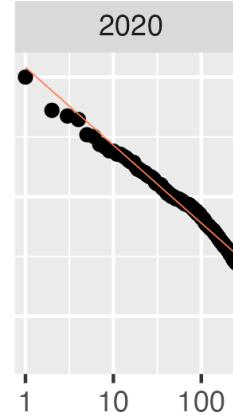


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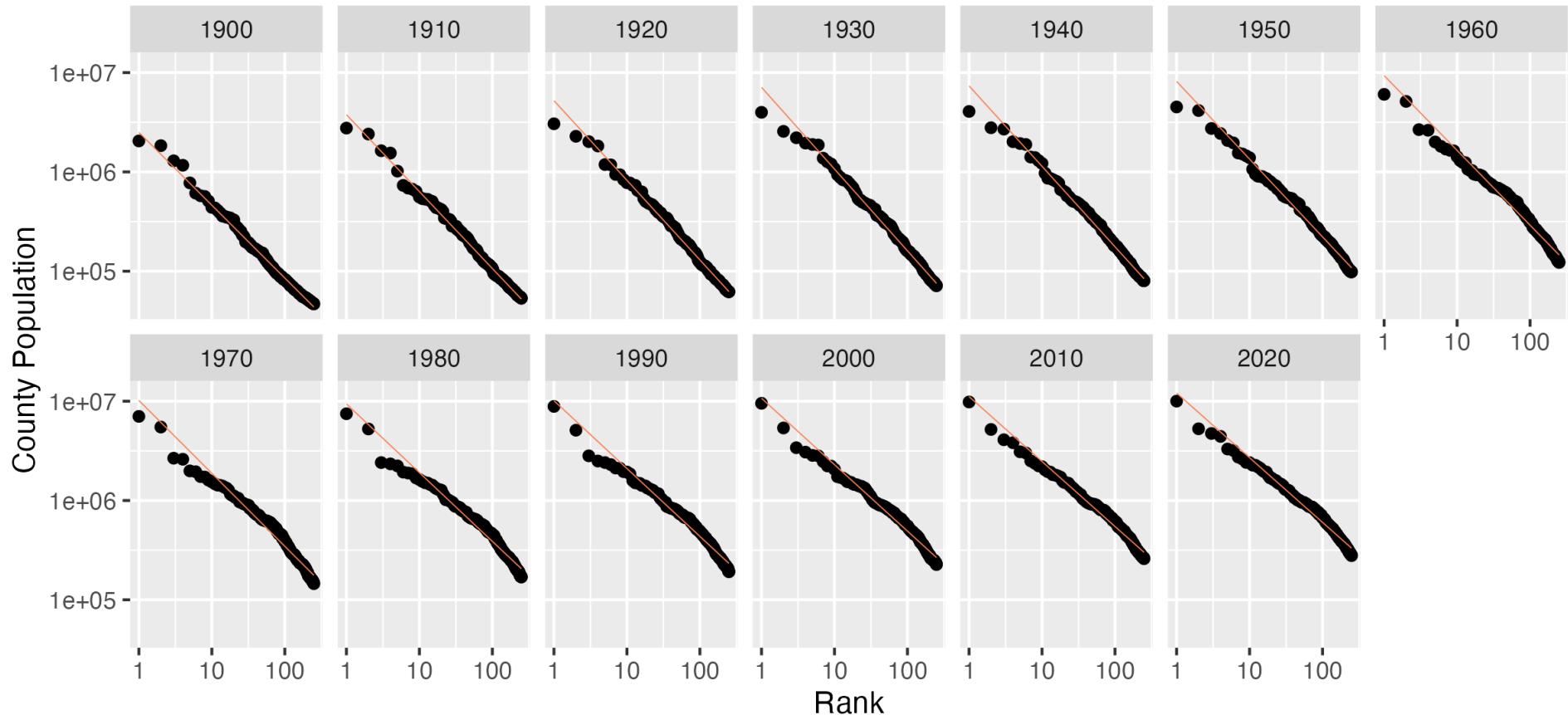
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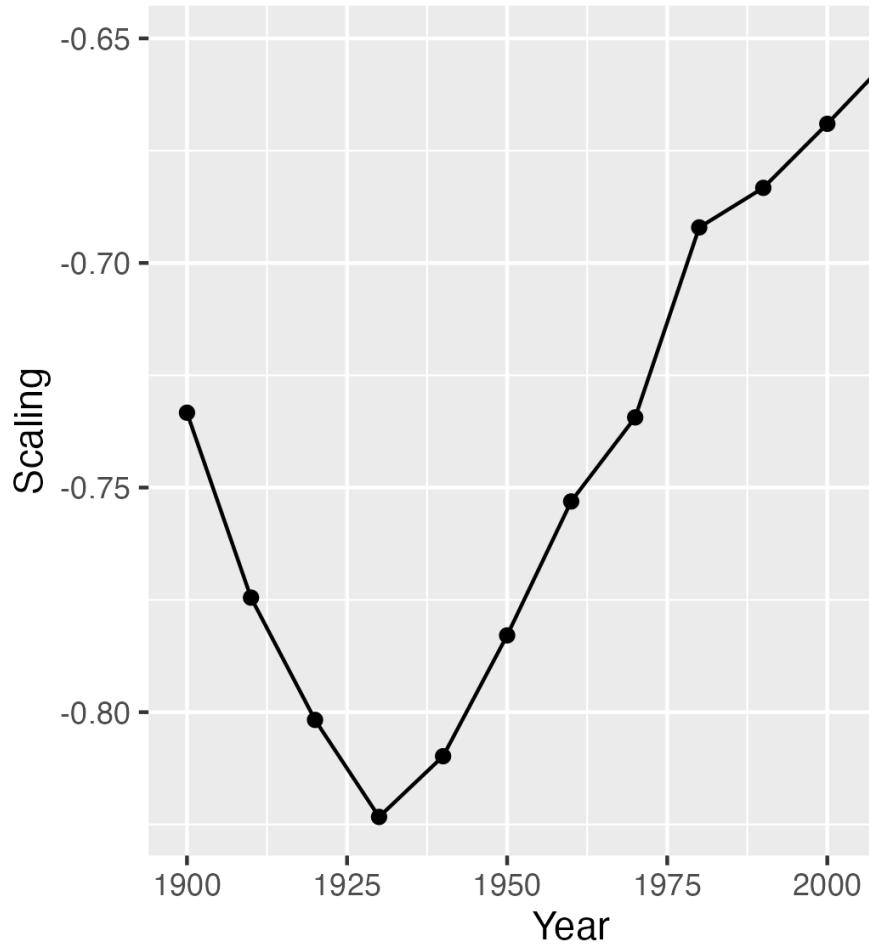
- Los Angeles**
- Cook (Chicago)**
- Harris (Houston)**
- Maricopa (Phoenix)**
- San Diego**
- Orange (Anaheim/Irvine)**
- Kings (Brooklyn)**
- Dallas**
- Riverside (Inland Empire LA)**
- Queens**
- King (Seattle)**
- Clark (Las Vegas)**
- San Bernardino**
- Tarrant (Ft. Worth)**
- Bexar (San Antonio)**
- Broward (Miami)**
- Santa Clara (San Jose/South Bay)**
- Wayne (Detroit)**
- NY (Manhattan)**



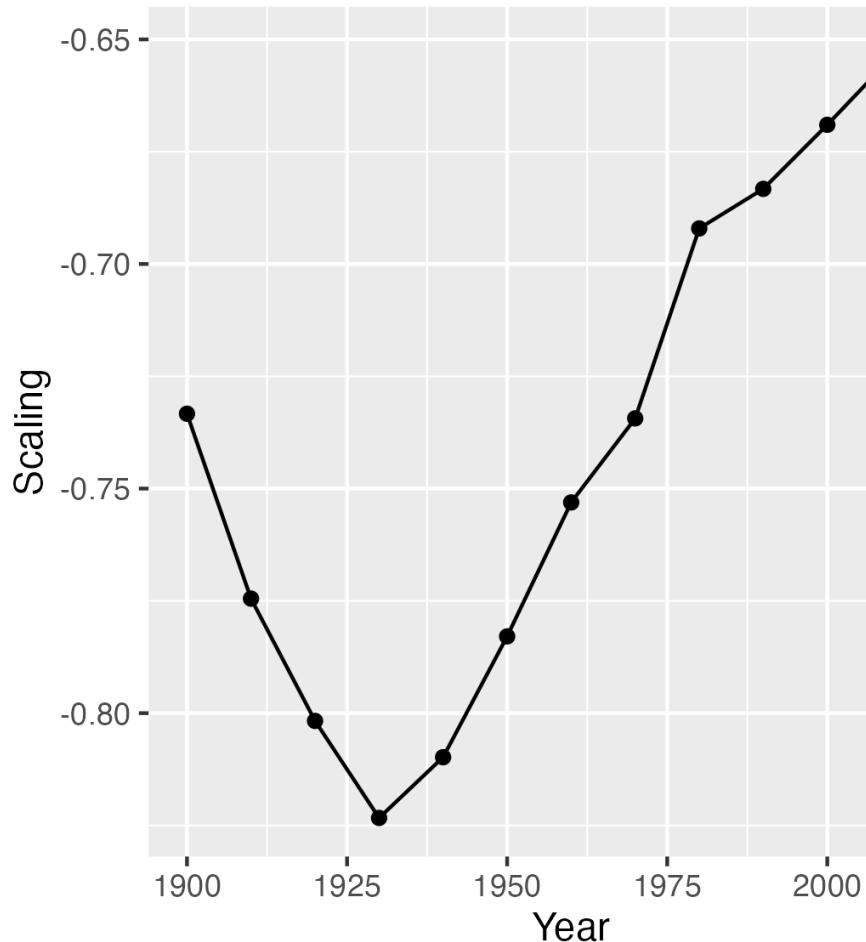
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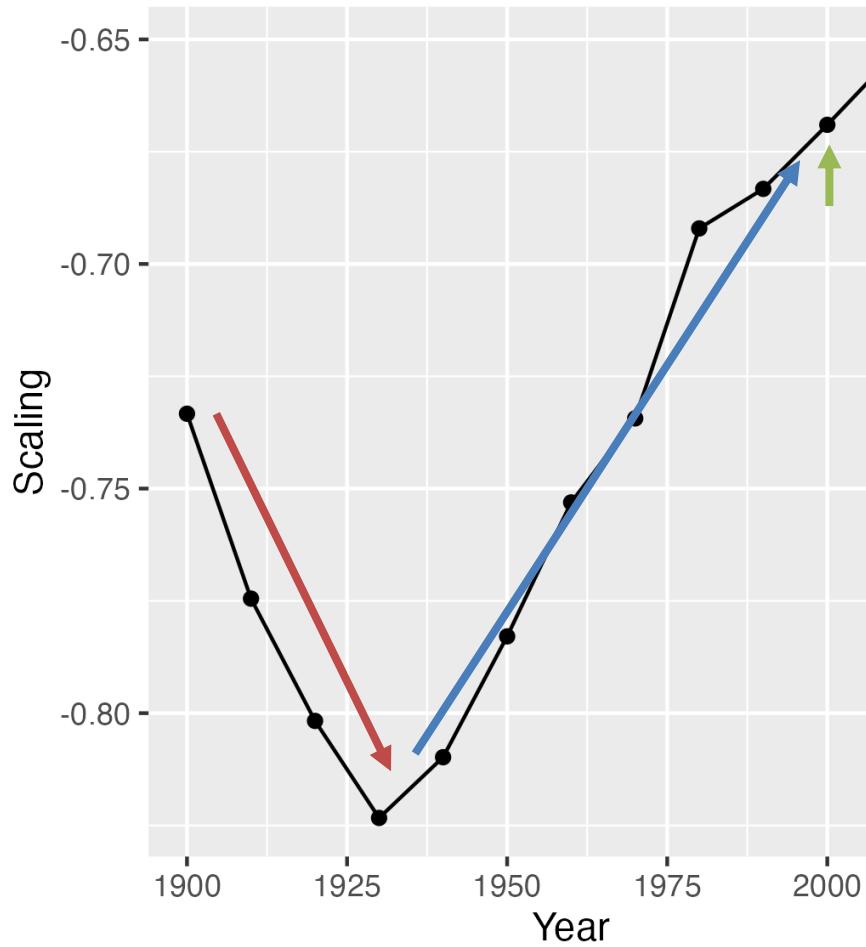


Rank Size of Counties by Decade



US city scaling in the 20th Century

- Increases during the “Gilded Age”
- Rapid reversal during the mid-20th
 - Population transfer west & south
 - Massive growth overall
 - Mass sub-urbanization
- Now, population distribution across cities is more equitable than ever

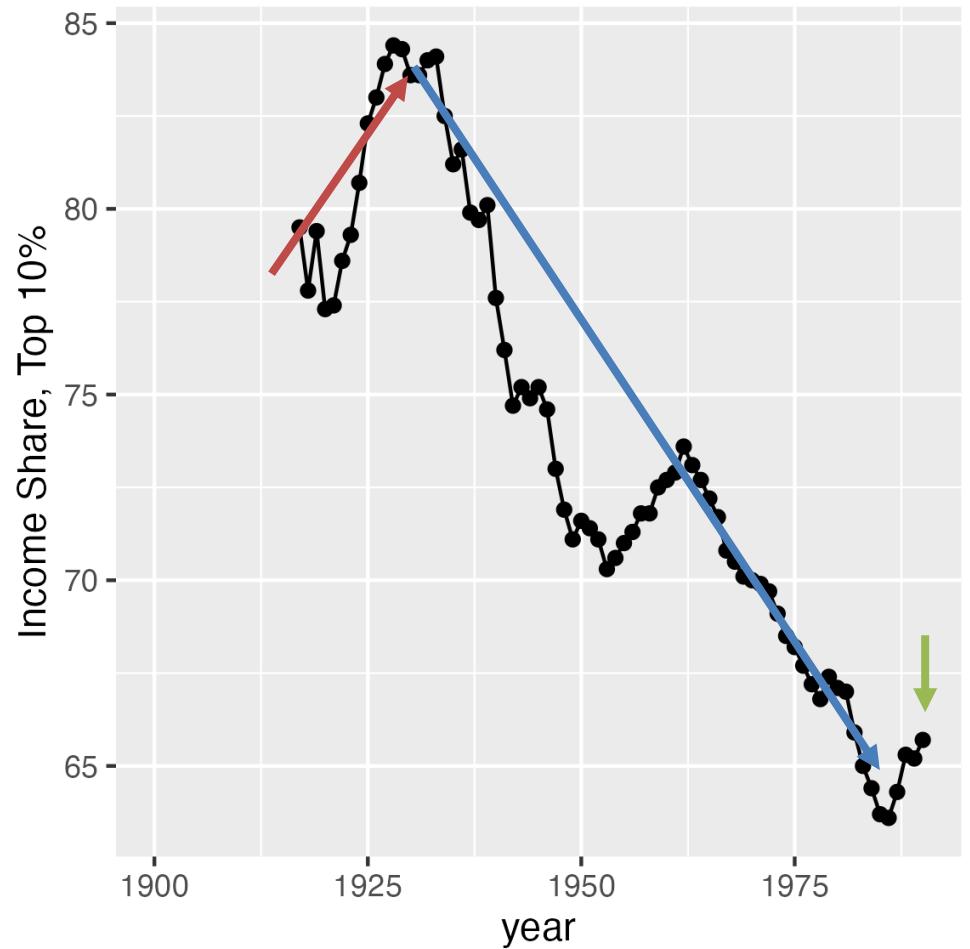


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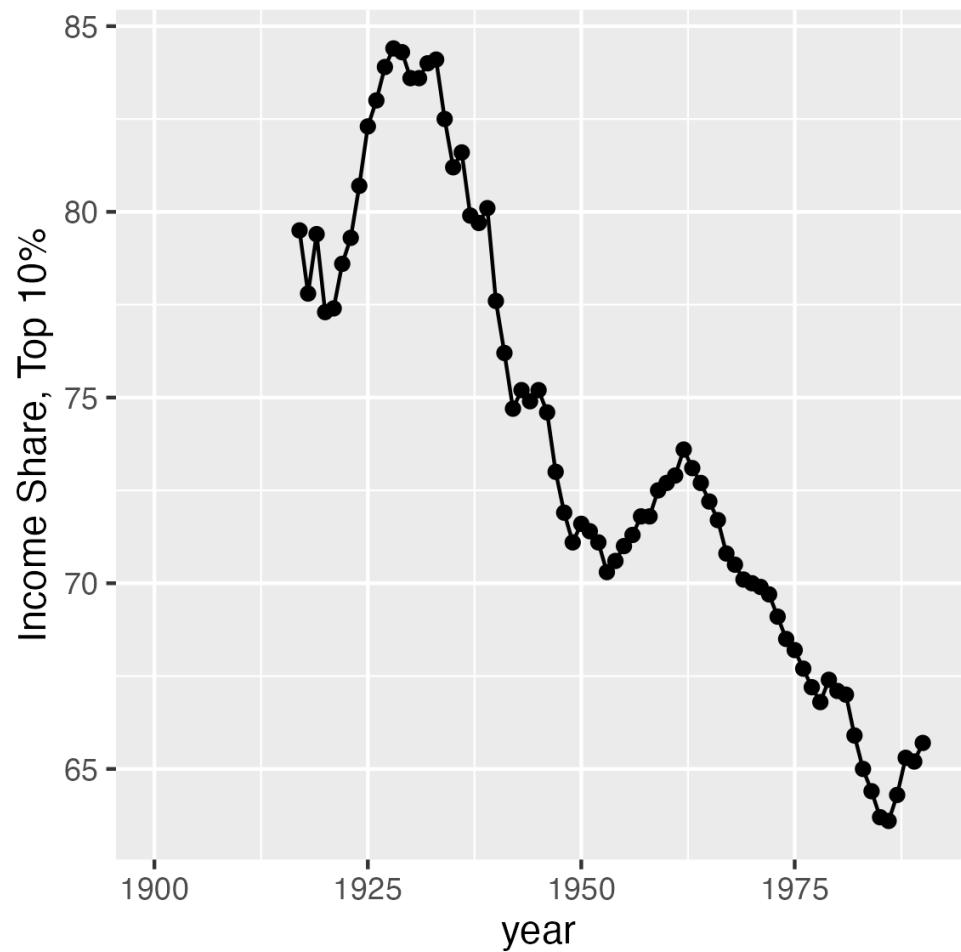
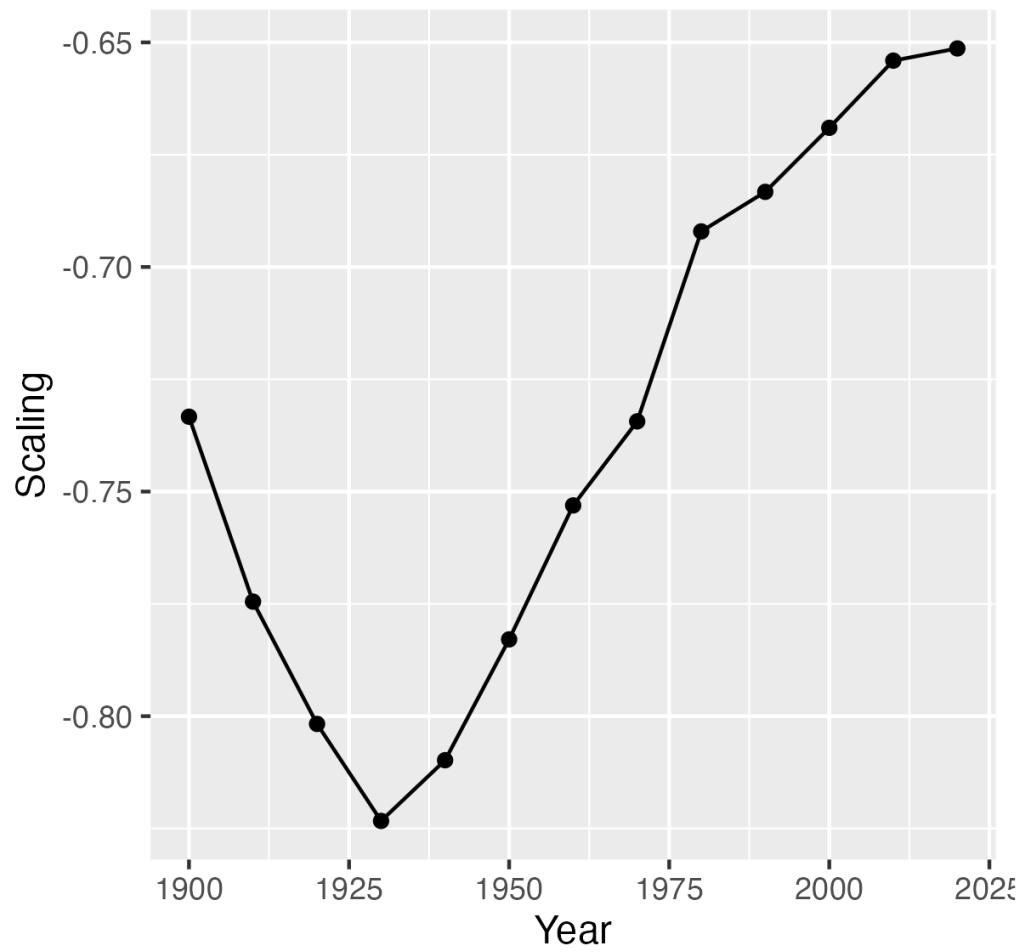
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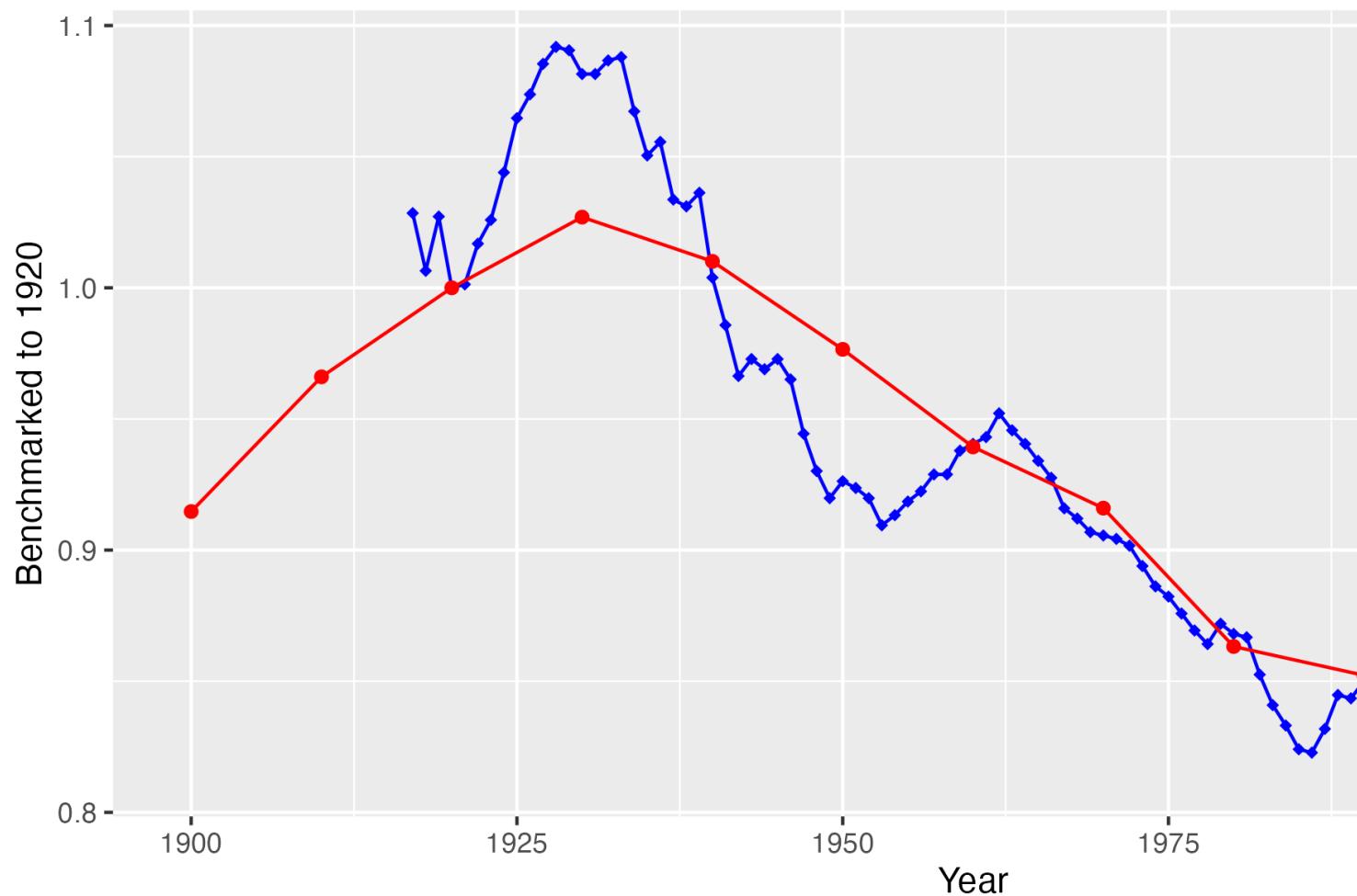
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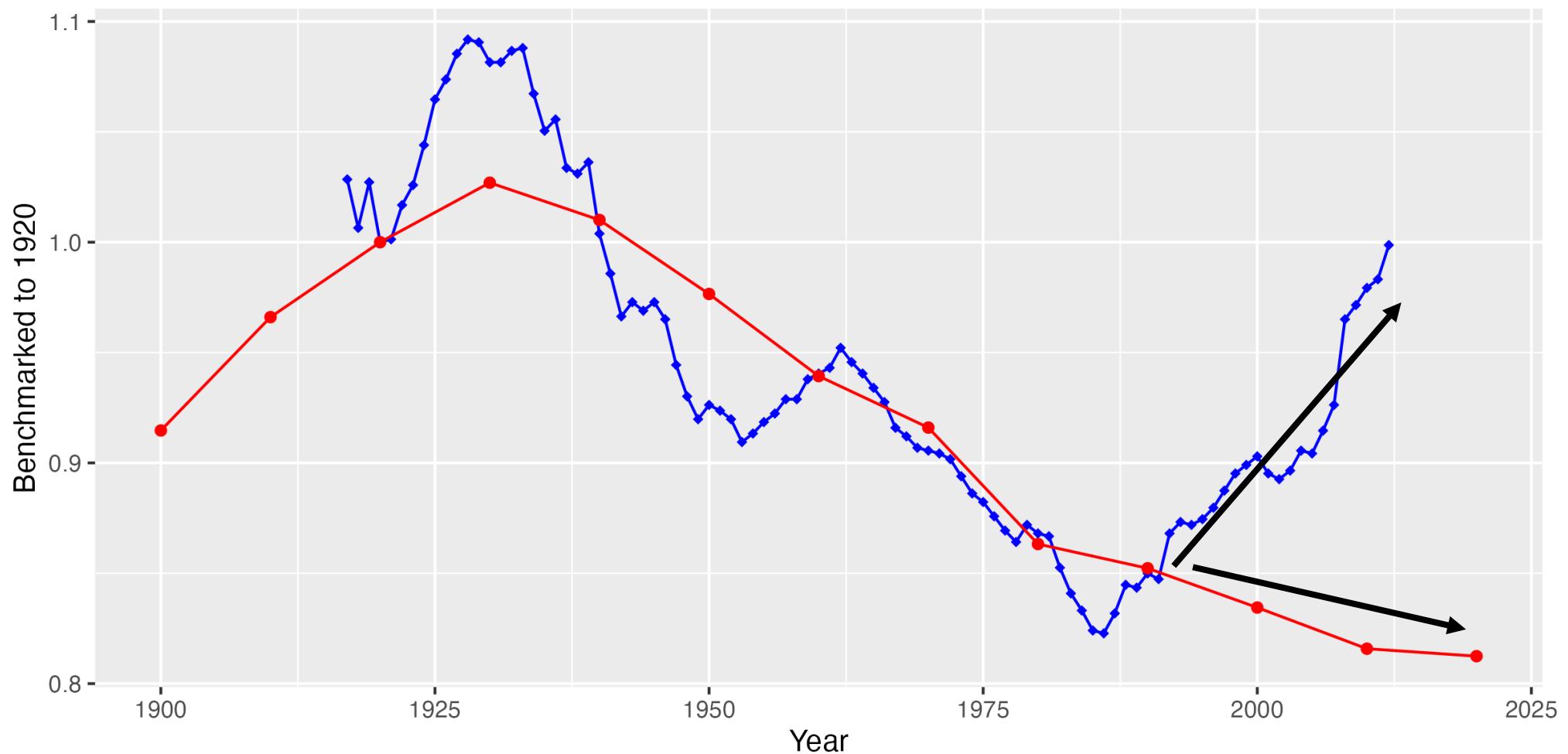


Saez-Zucman (2015)

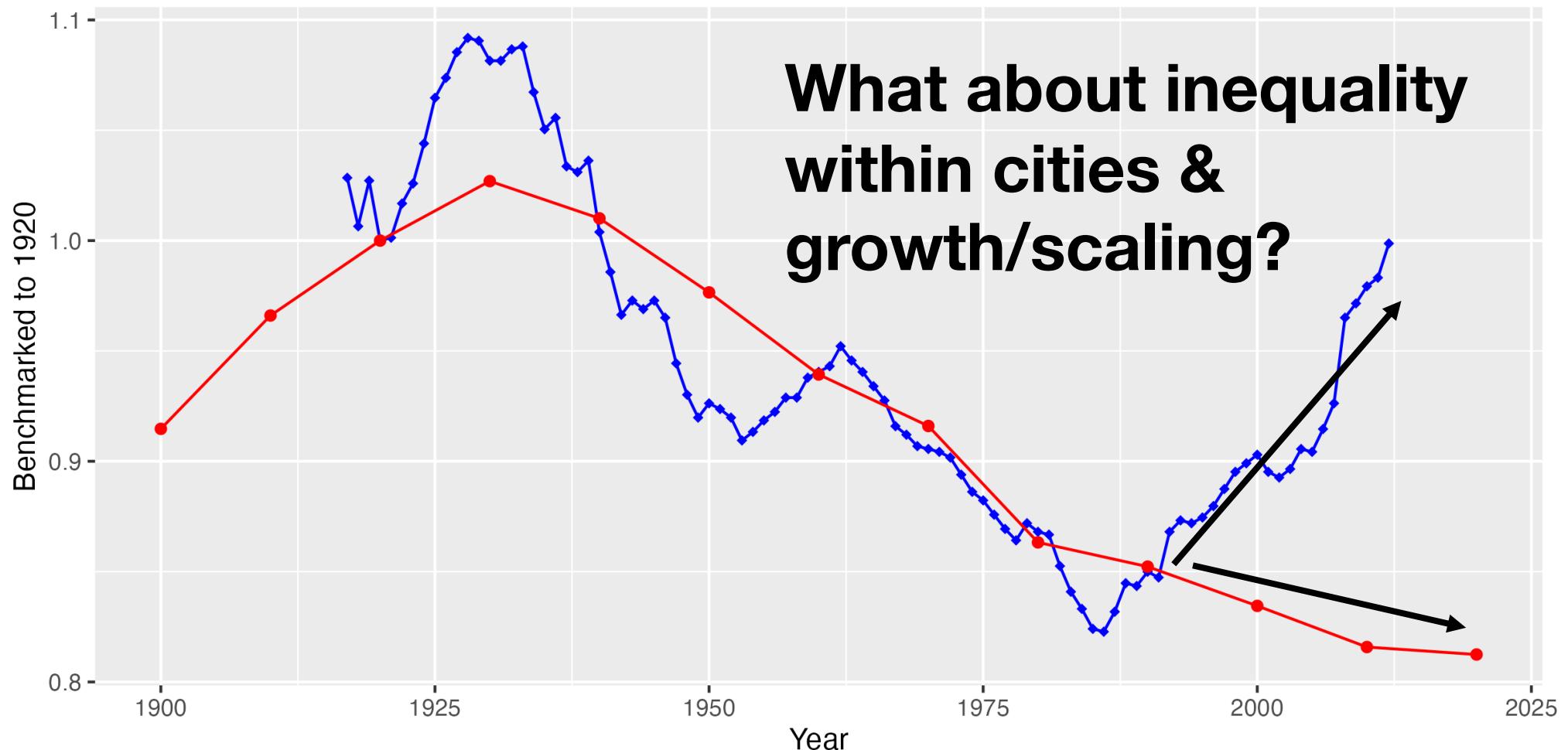




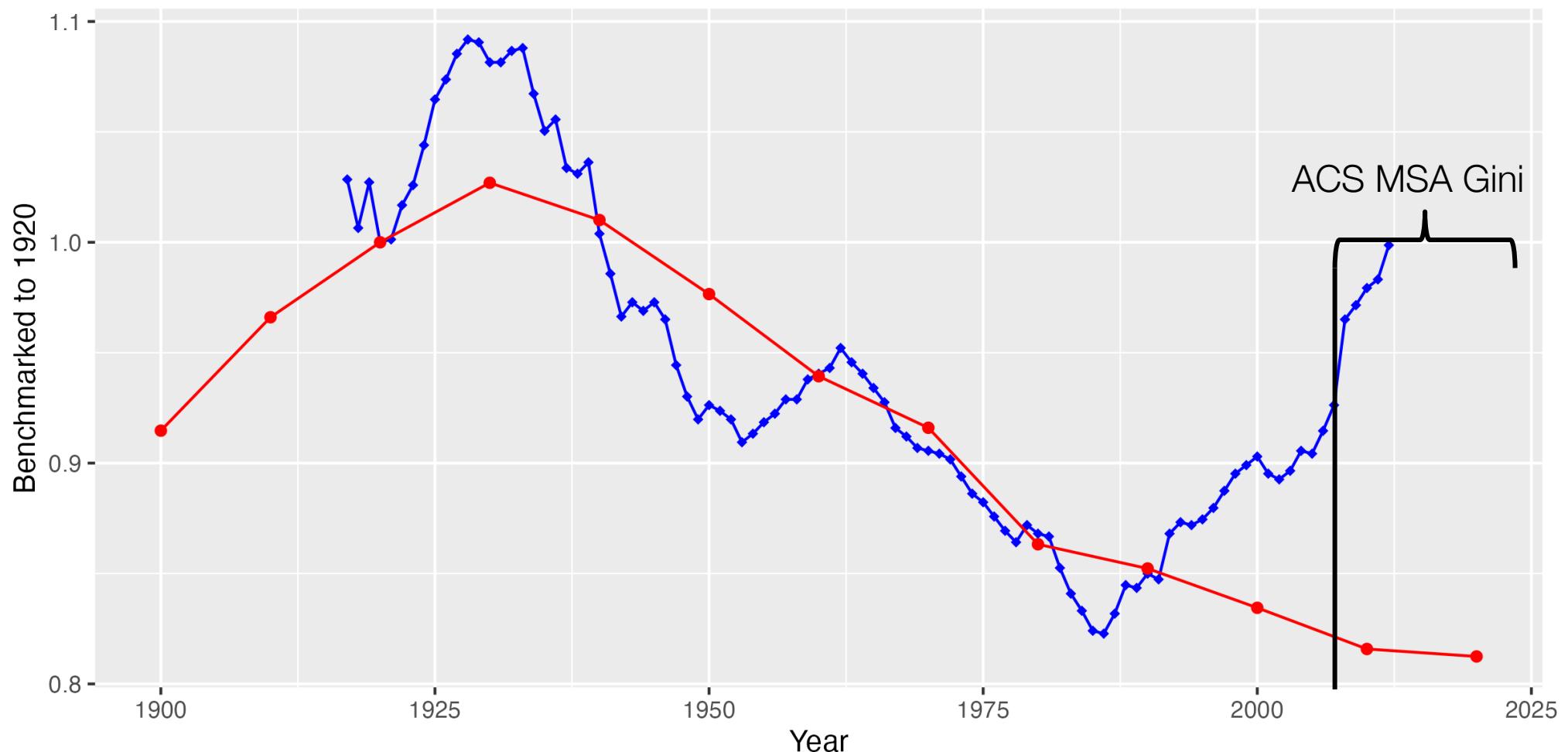
Between-city population inequality moved with macro-level income inequality



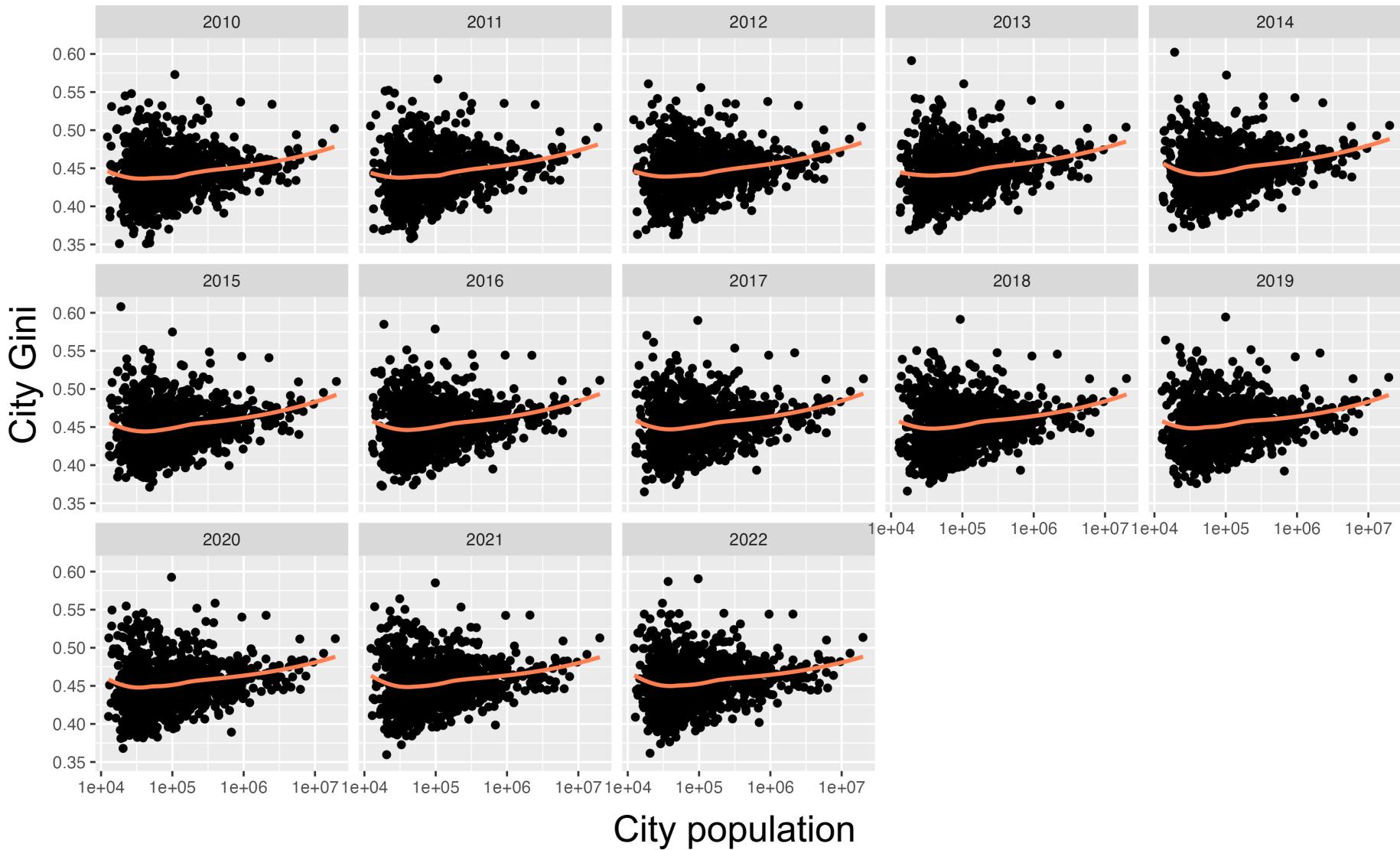
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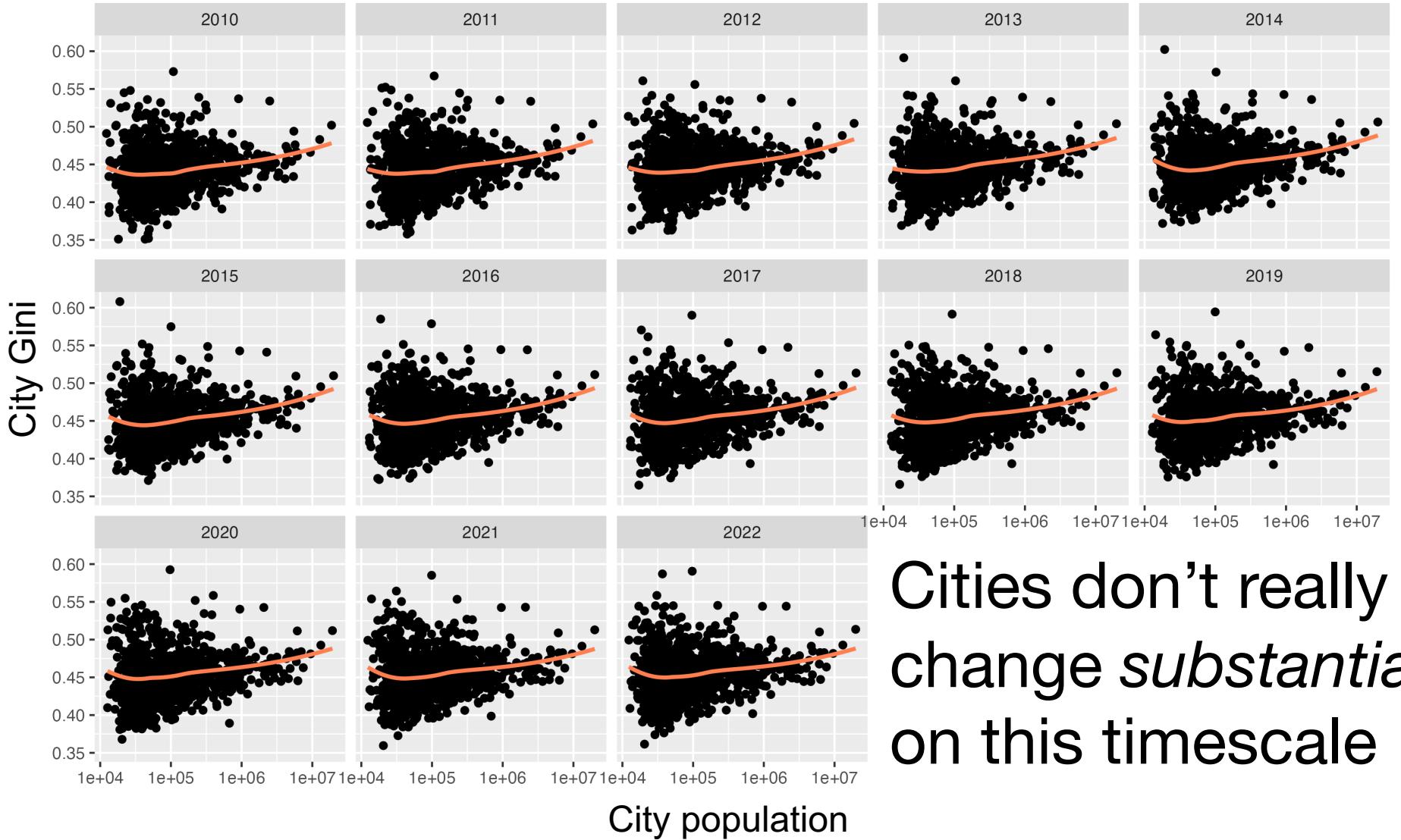


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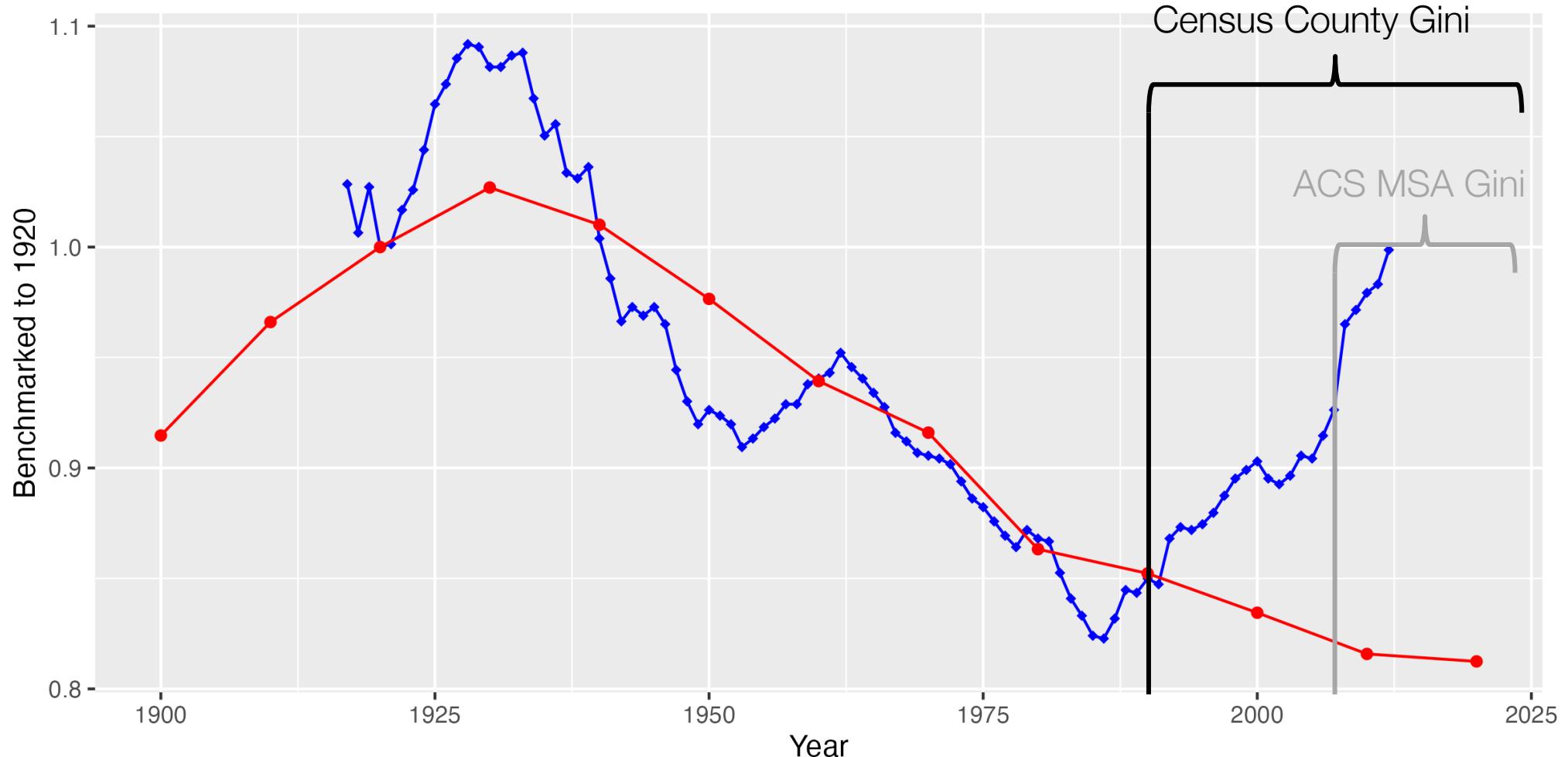


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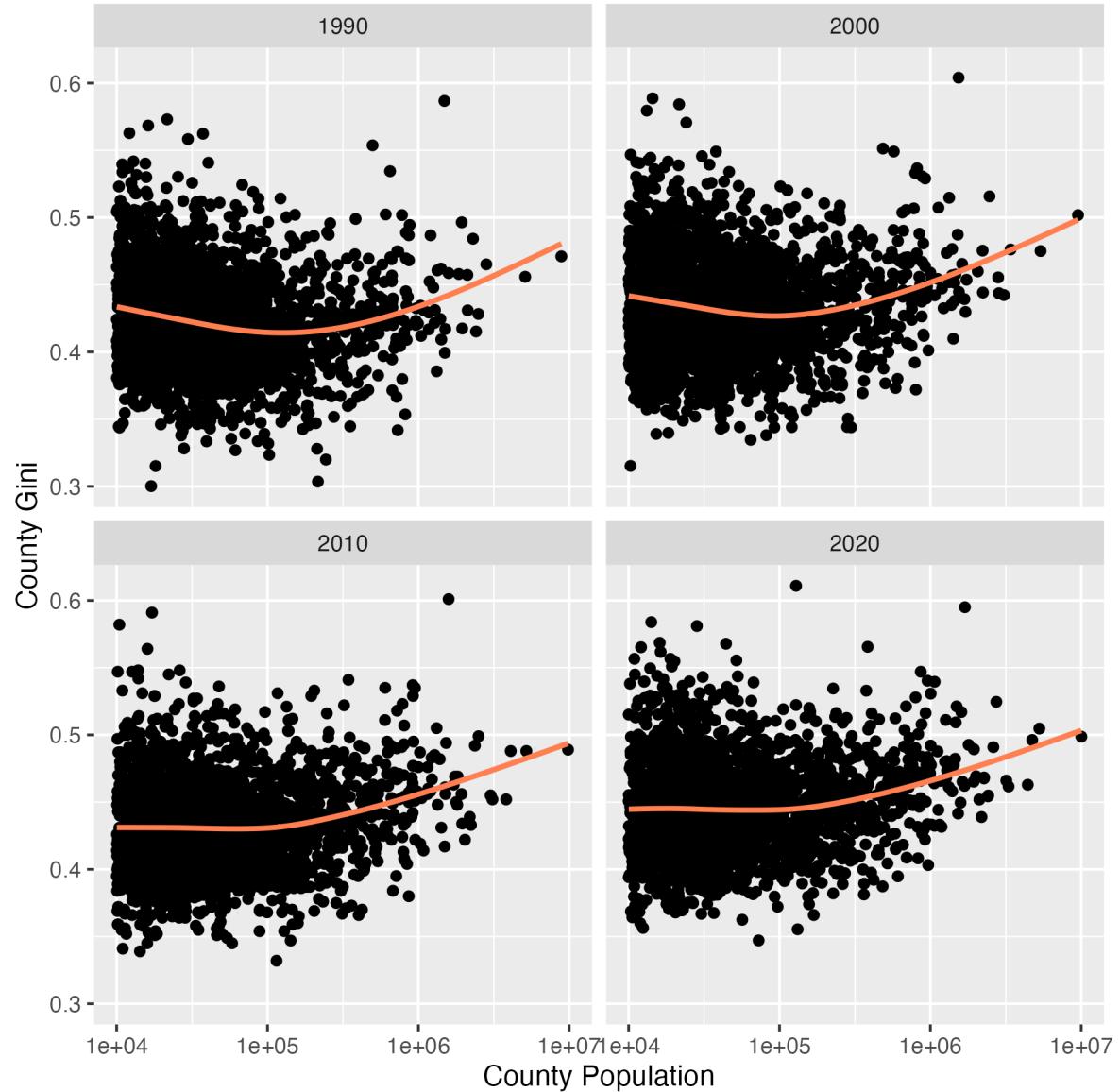


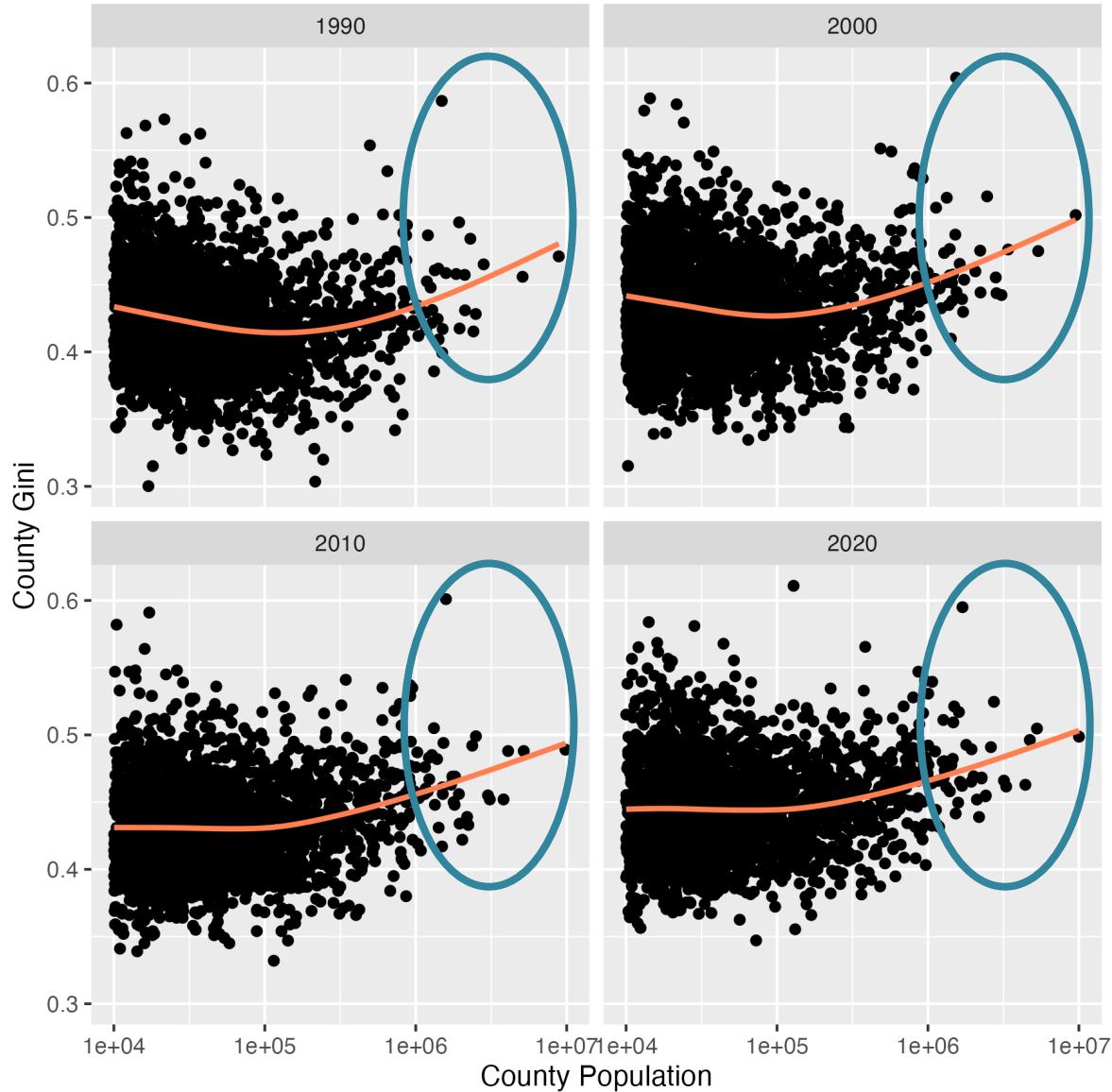


Cities don't really
change substantially
on this timescale

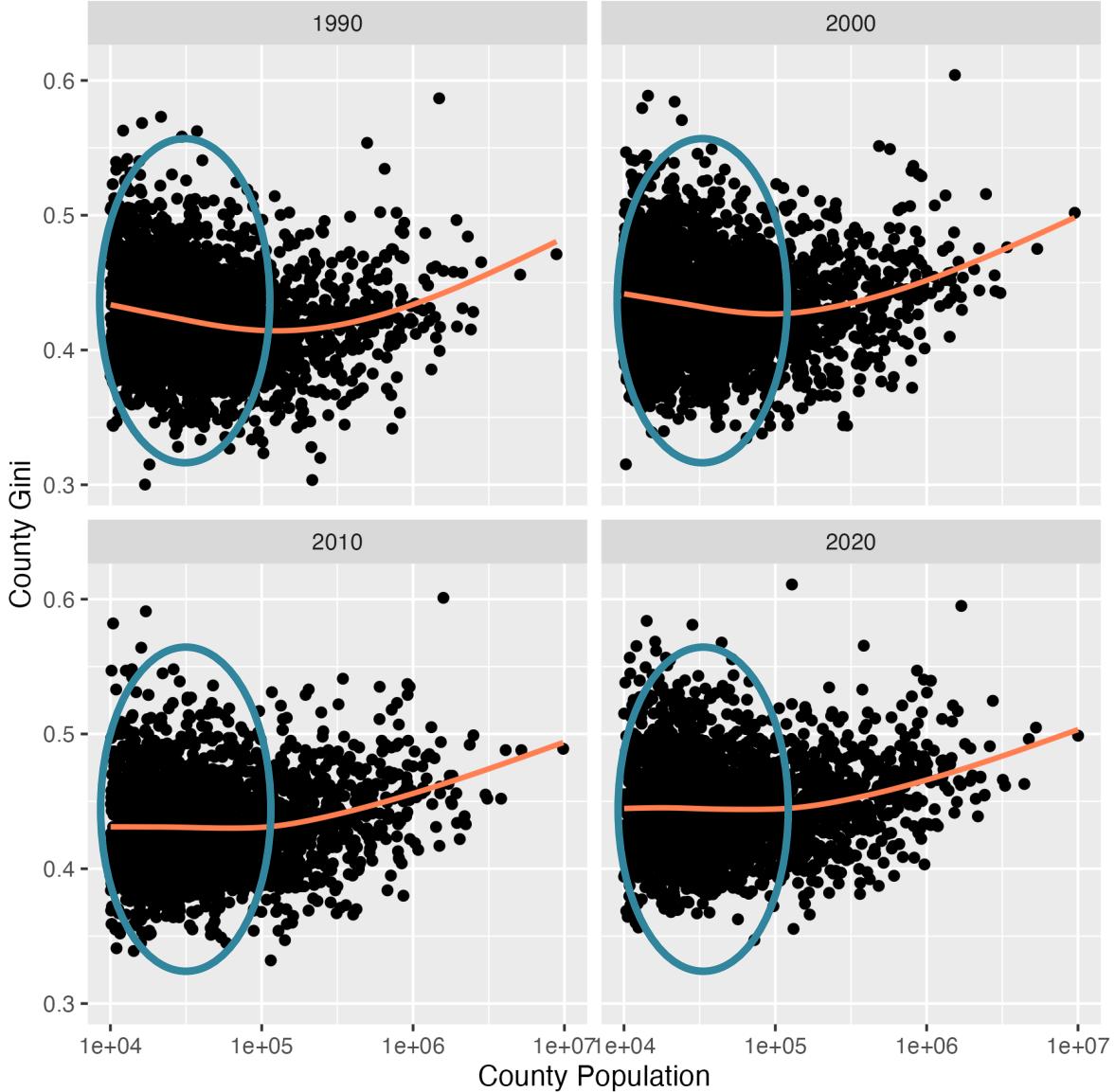


Between-city population inequality moved with macro-level income inequality until the 21st Century...

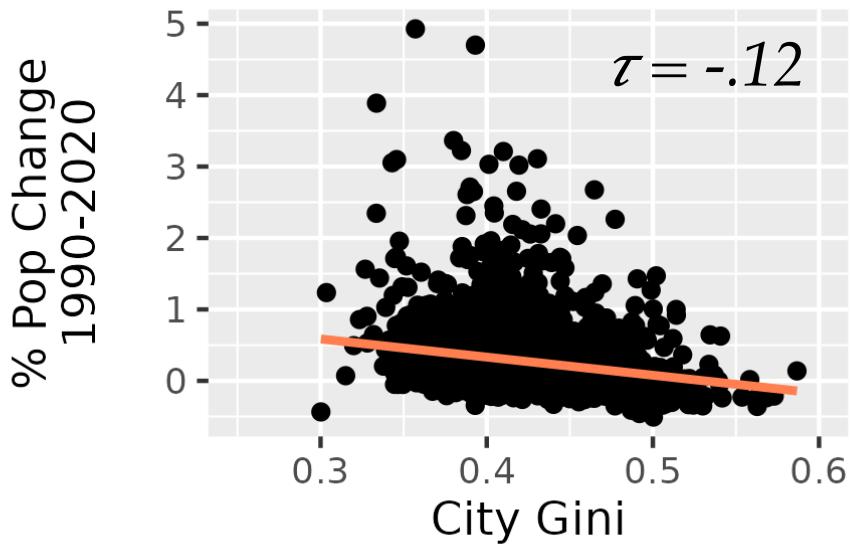
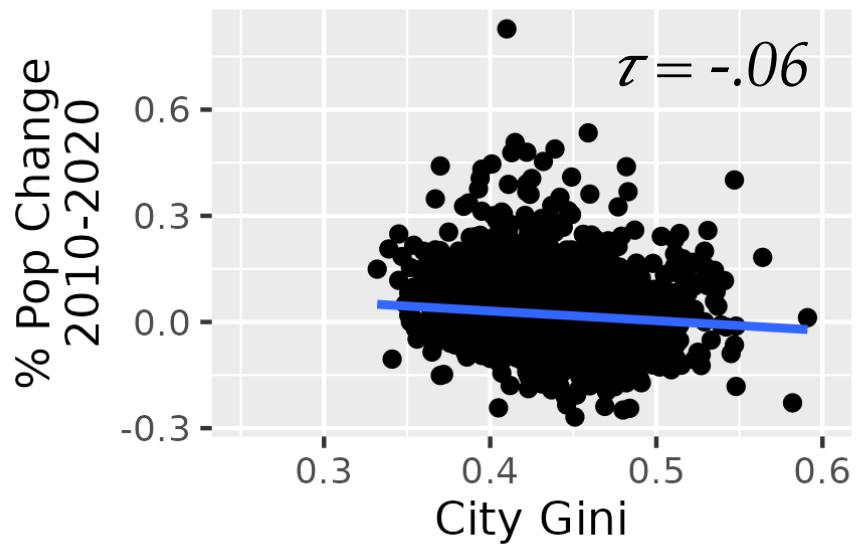
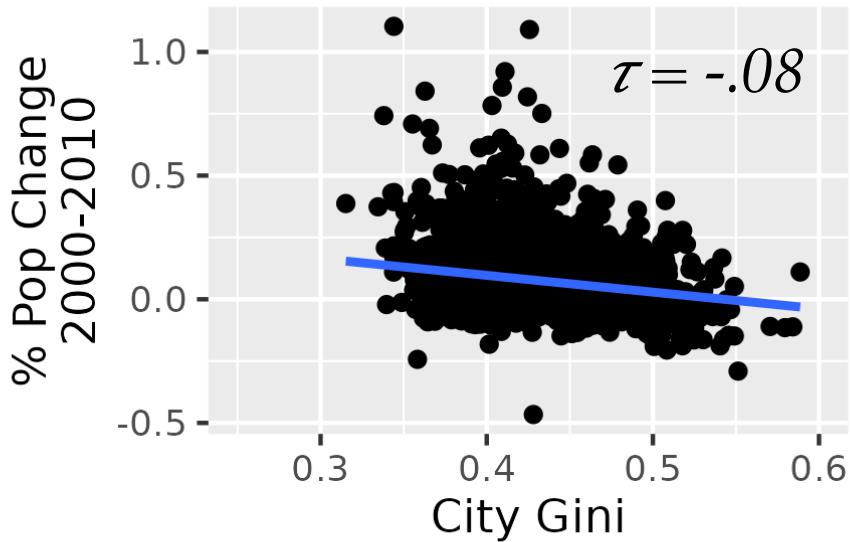
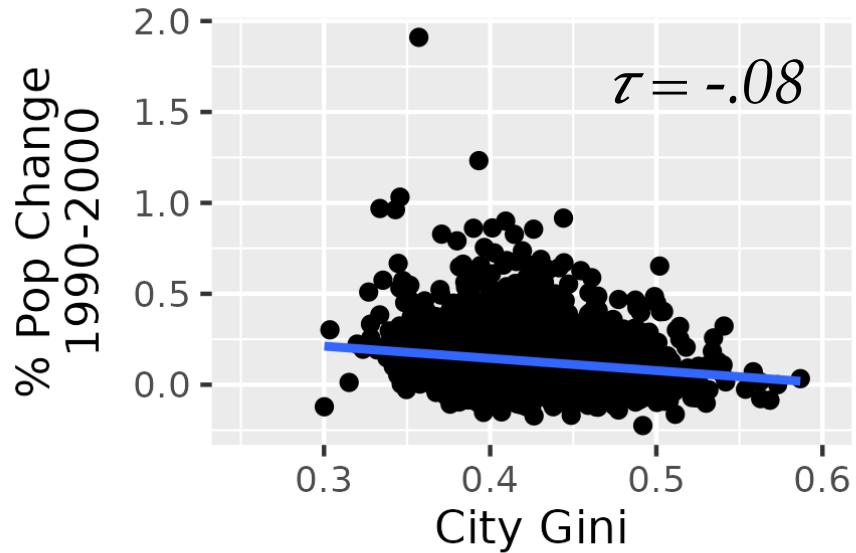




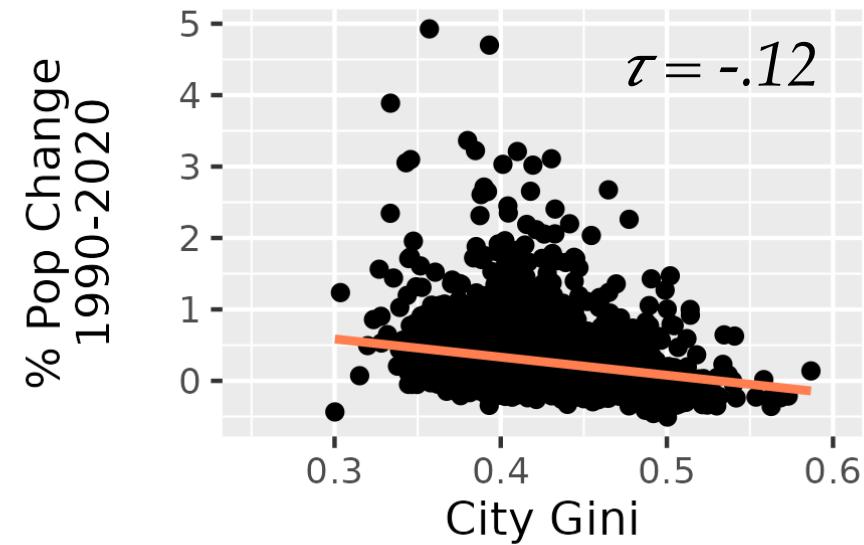
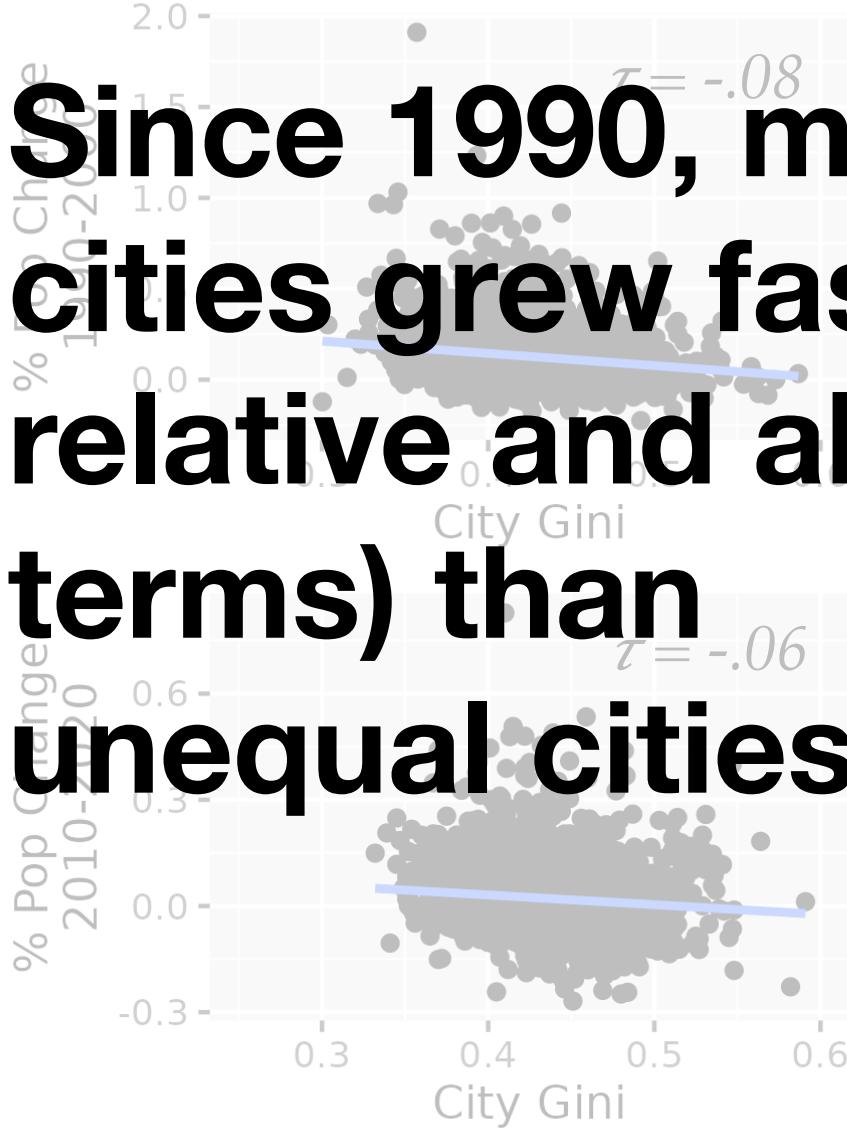
**Bigger cities
have tended to
have stronger
income
inequality**



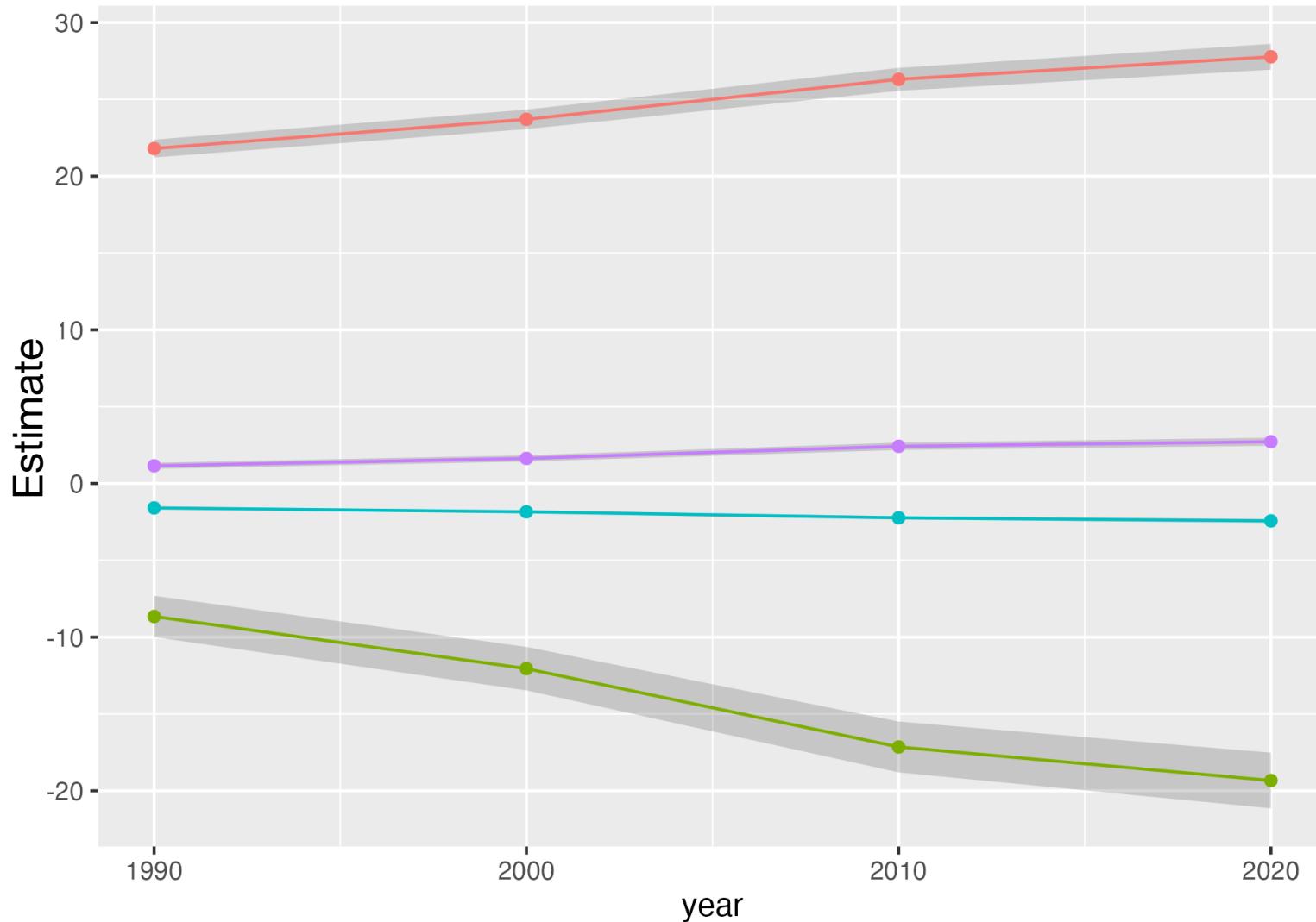
**But, mid-sized
cities have
become
marginally more
unequal**



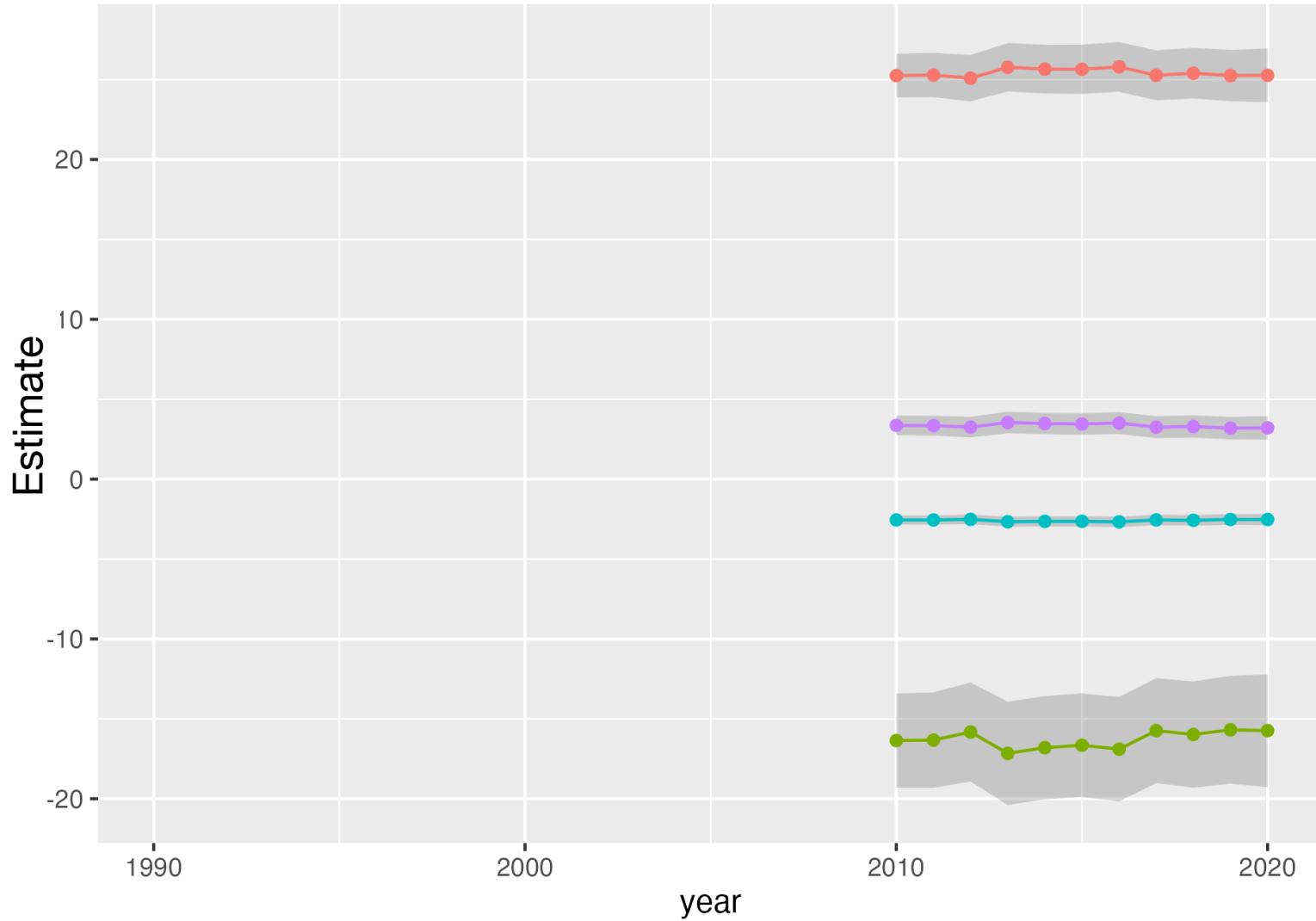
Since 1990, more equal cities grew faster (in both relative and absolute terms) than unequal cities



Decadal estimates by county since 1990

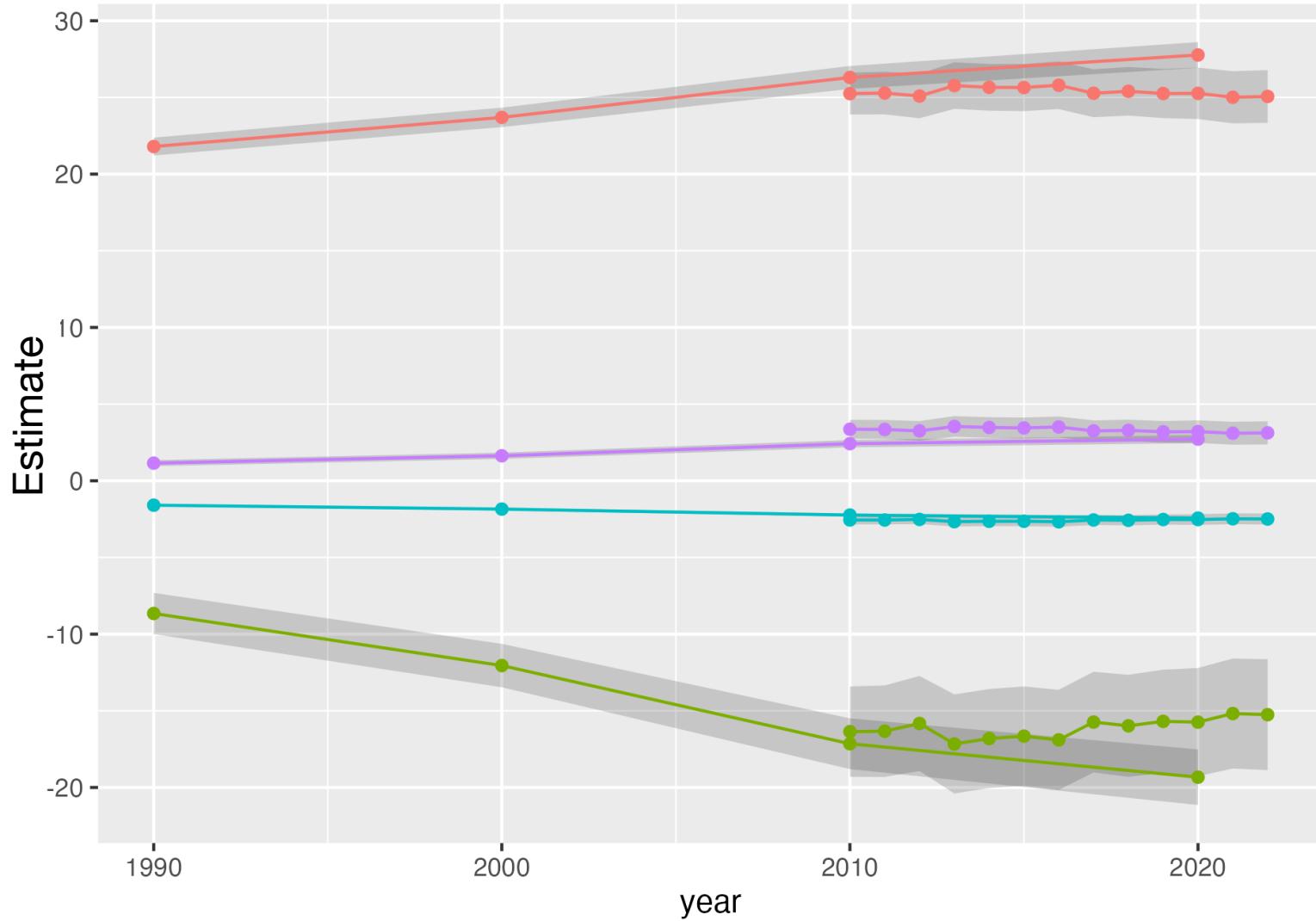


$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$



**Yearly
estimates
by city
since 2010**

$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$

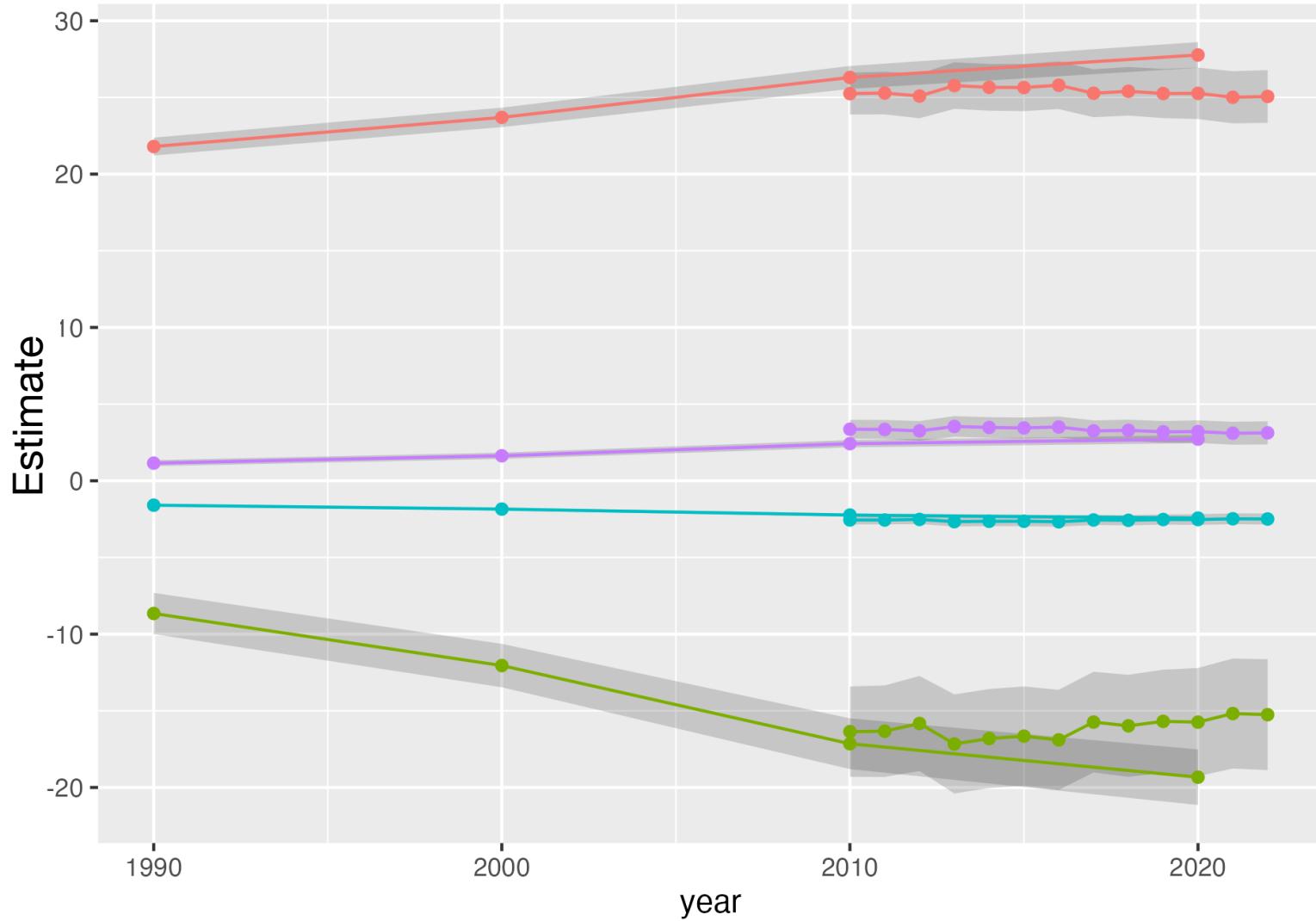


**Both
estimates**

Effect

- | | |
|------------|---------------|
| Intercept | Red circle |
| Gini | Green circle |
| Scaling | Cyan circle |
| Moderation | Purple circle |

$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$



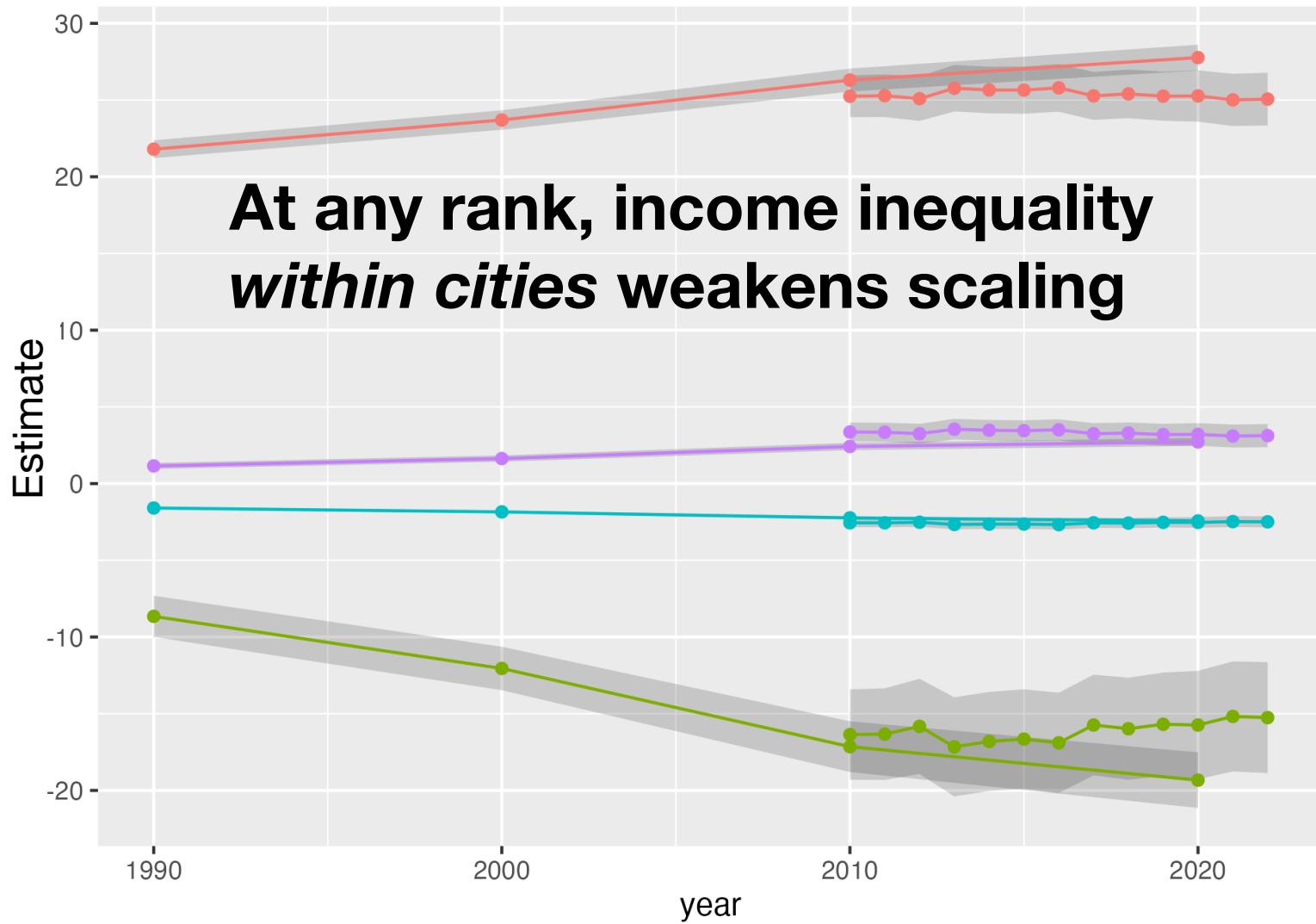
**Both
estimates**

Effect

- Intercept
- Gini
- Scaling
- Moderation

**Holding rank
constant,
increasing
inequality is
associated with
*decreasing size***

$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$



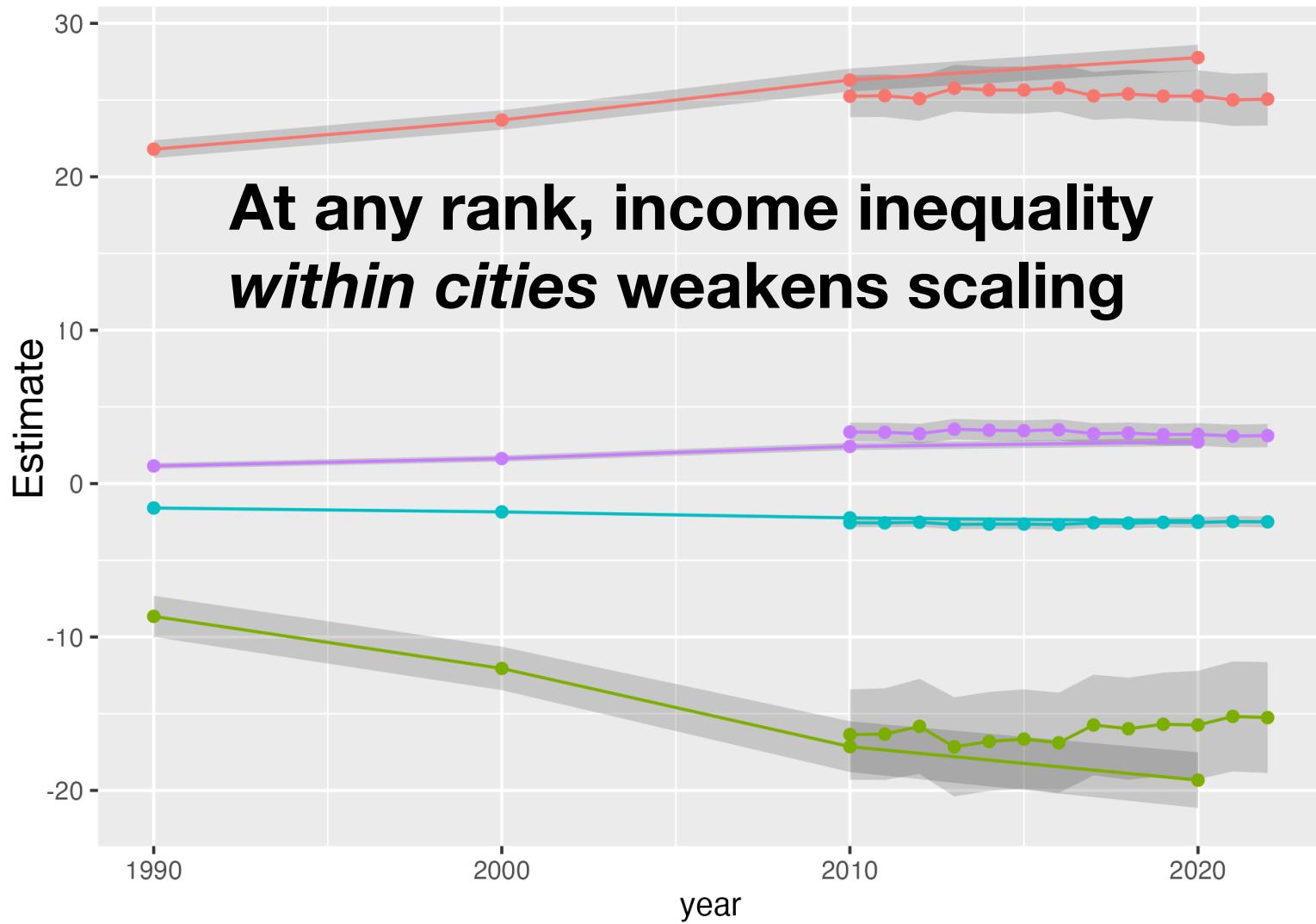
**Both
estimates**

Effect

- Intercept
- Gini
- Scaling
- Moderation

Holding rank constant,
increasing
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$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$



Both estimates

Effect

- Intercept
- Gini
- Scaling
- Moderation

Holding rank constant,
increasing inequality is
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decreasing size

$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$

[nature](#) > [scientific data](#) > [data descriptors](#) > [article](#)

Data Descriptor | [Open access](#) | [Published: 28 February 2024](#)

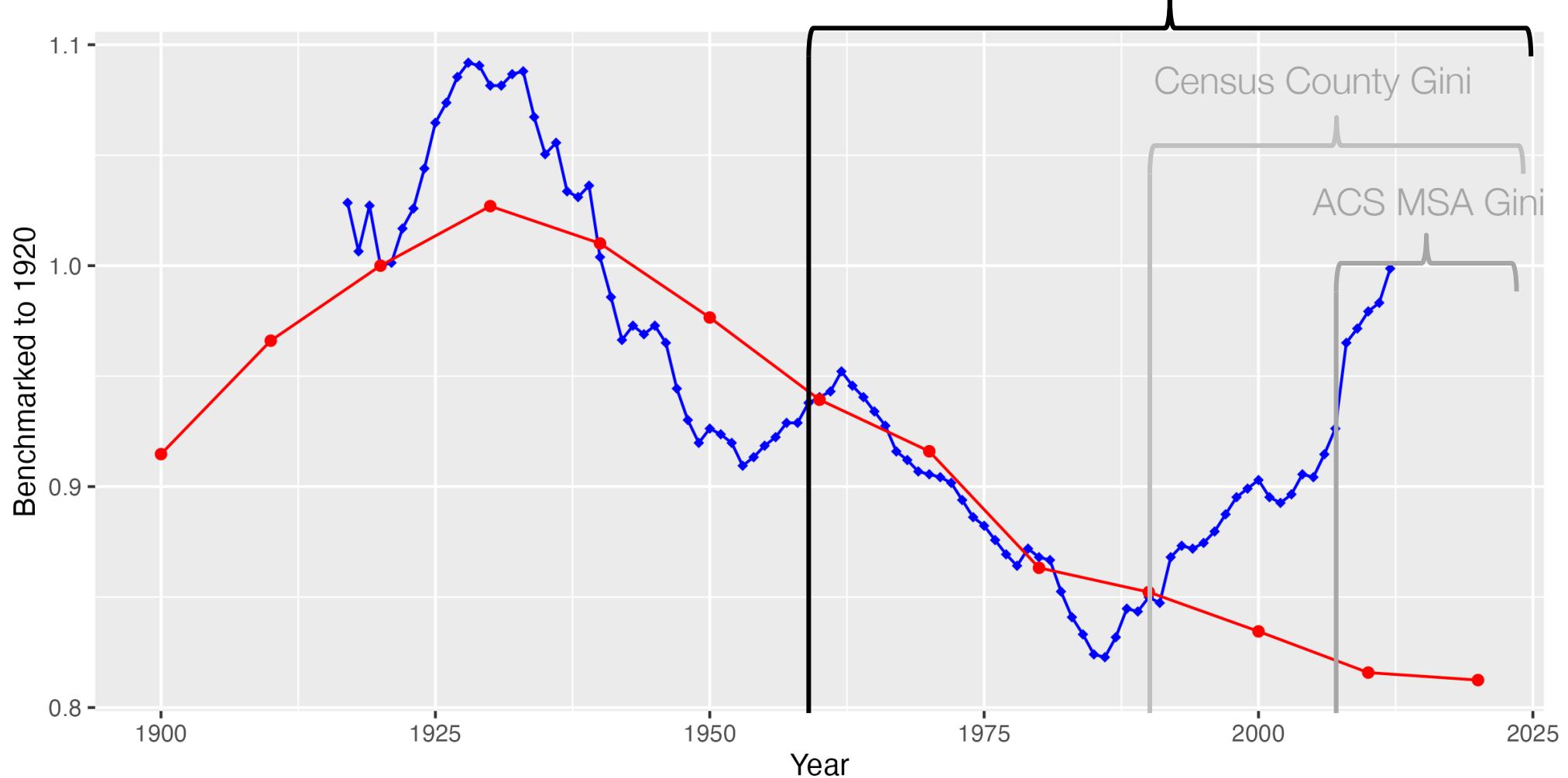
GEOWEALTH-US: Spatial wealth inequality data for the United States, 1960–2020

[Joel Suss](#), [Tom Kemeny](#)✉ & [Dylan S. Connor](#)

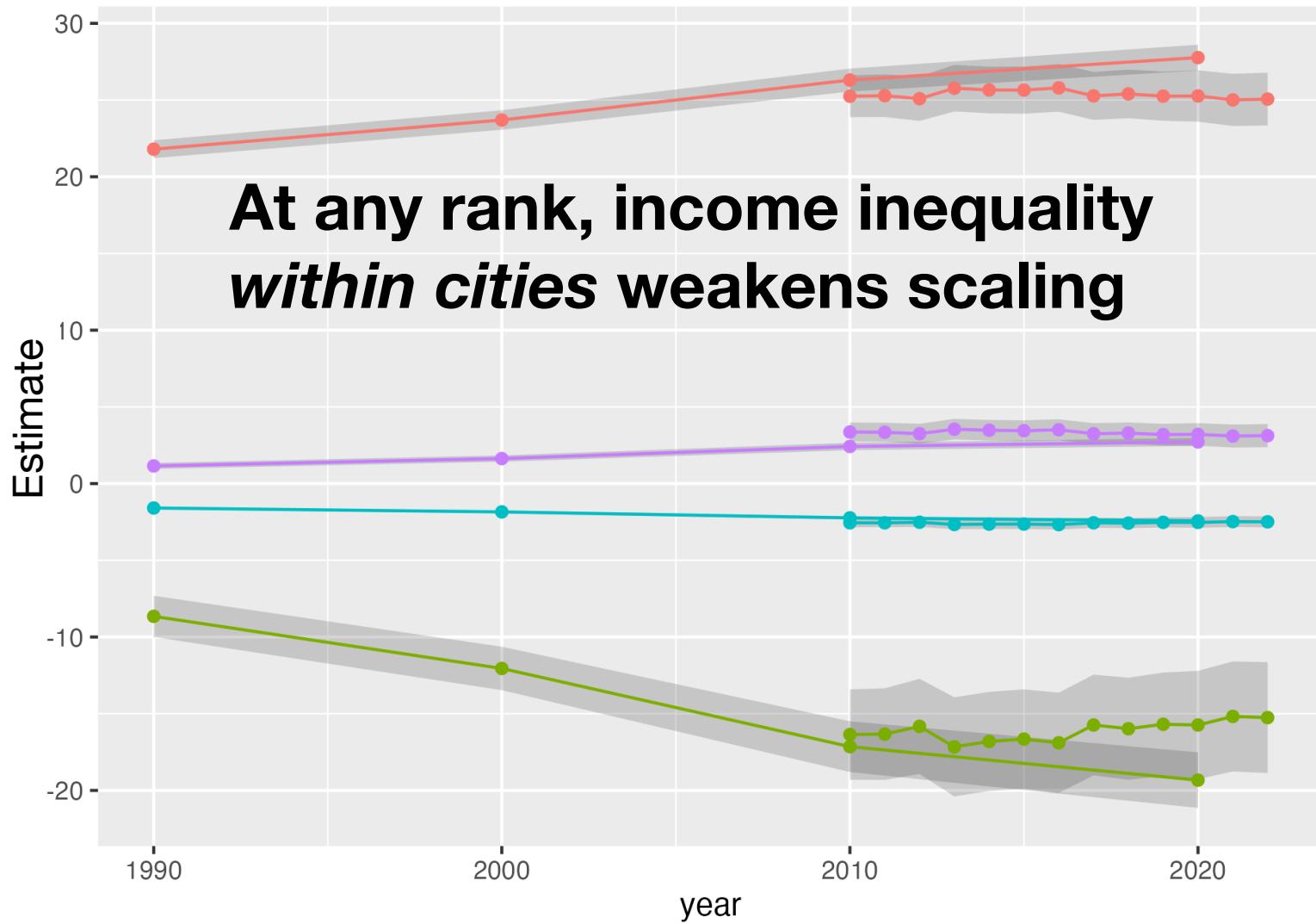
[Scientific Data](#) 11, Article number: 253 (2024) | [Cite this article](#)

481 Accesses | [Metrics](#)

GEOWEALTH County Gini



Between-city population inequality moved with macro-level income inequality until the 21st Century...



**Both
estimates**

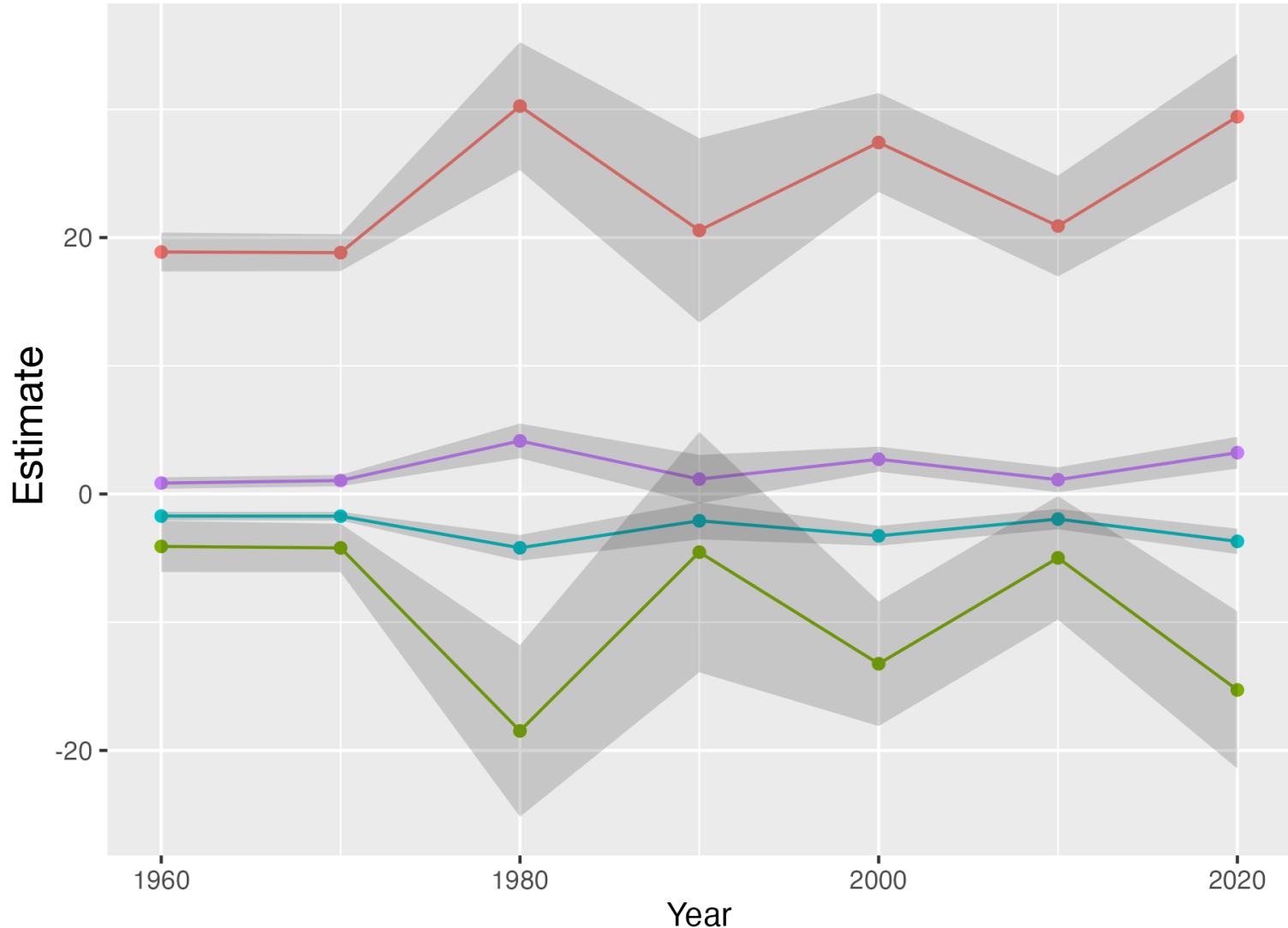
Effect

- Intercept
- Gini
- Scaling
- Moderation

Holding rank constant,
increasing
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decreasing size

$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$

Suss et al. estimates



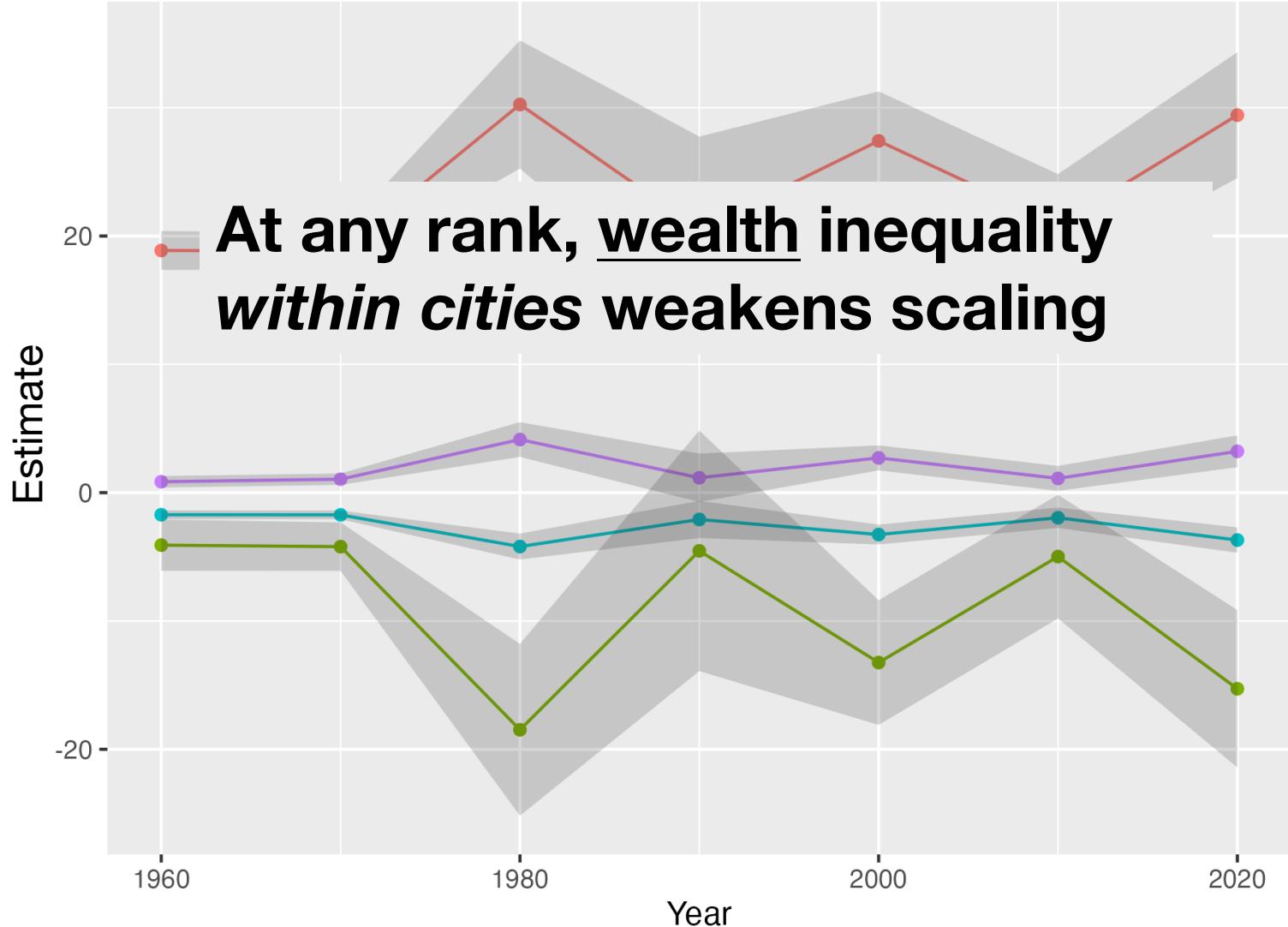
Effect

- Intercept
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$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$

**Suss et al.
estimates**



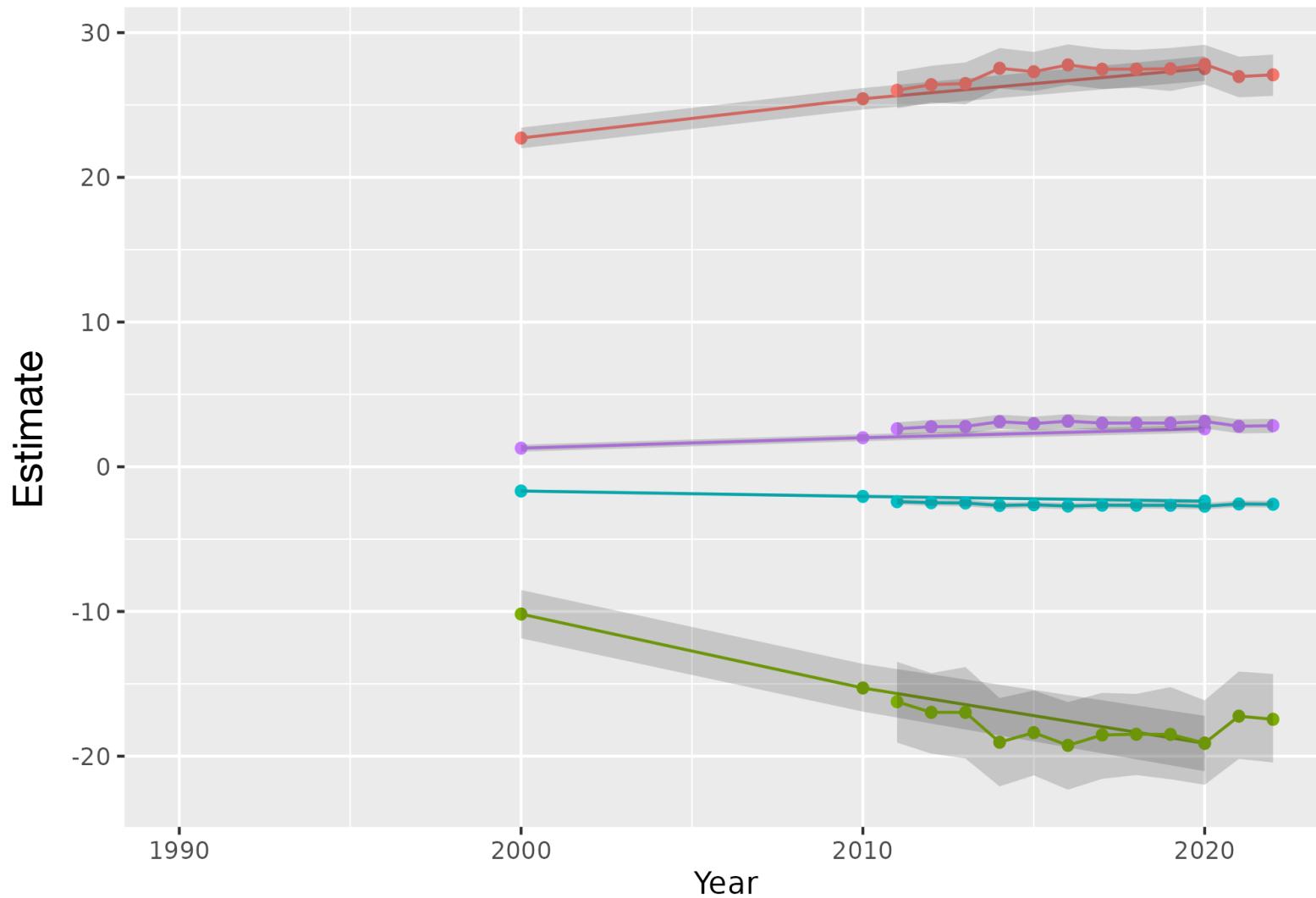
$$\log(\text{pop}) \sim 1 + \log(\text{rank}) + \text{gini} + \log(\text{rank}) * \text{gini}$$

Effect

- Intercept
- Gini
- Scaling
- Moderation

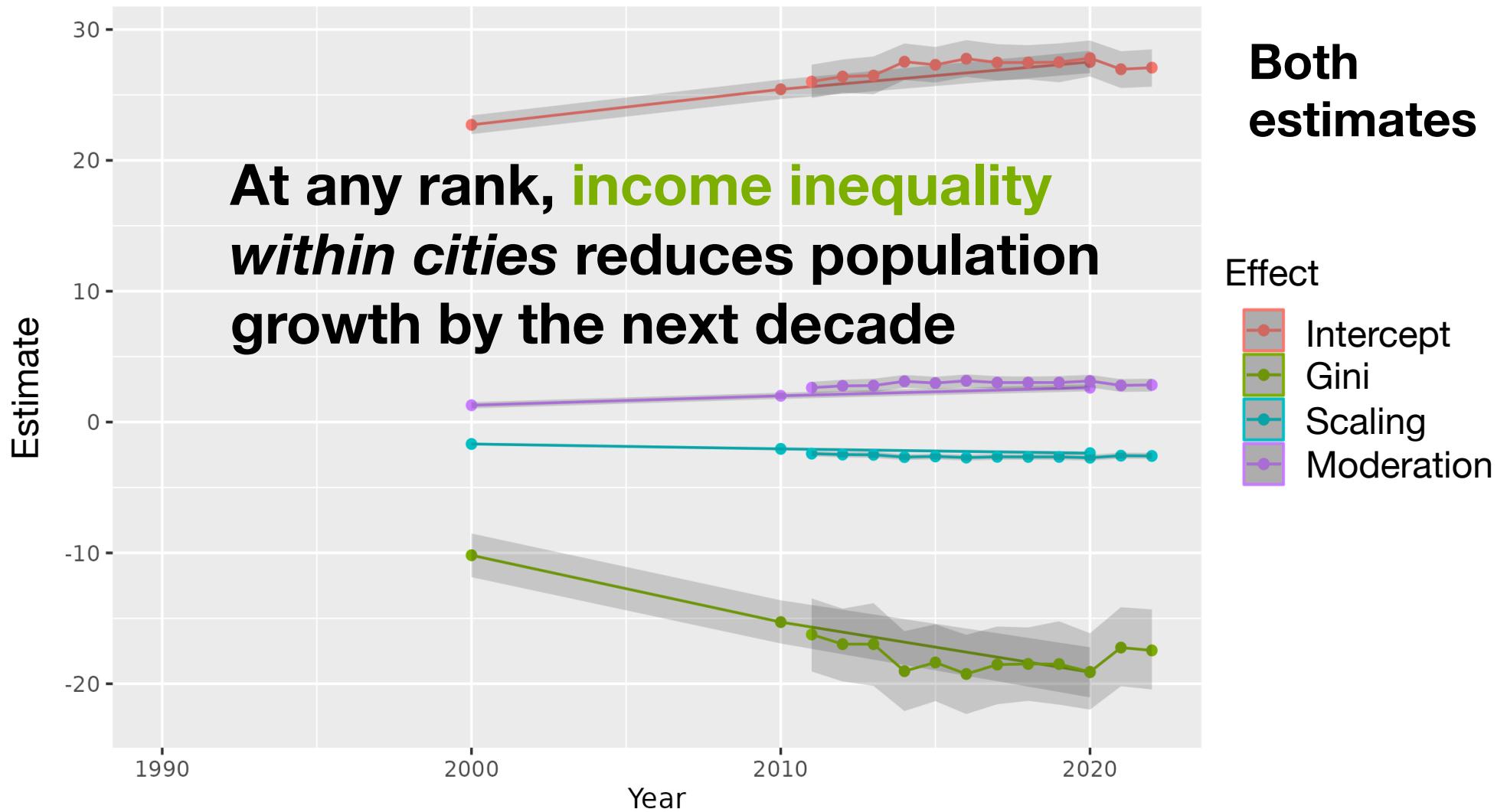
Holding rank constant,
increasing
inequality is
associated with
decreasing size

Both estimates



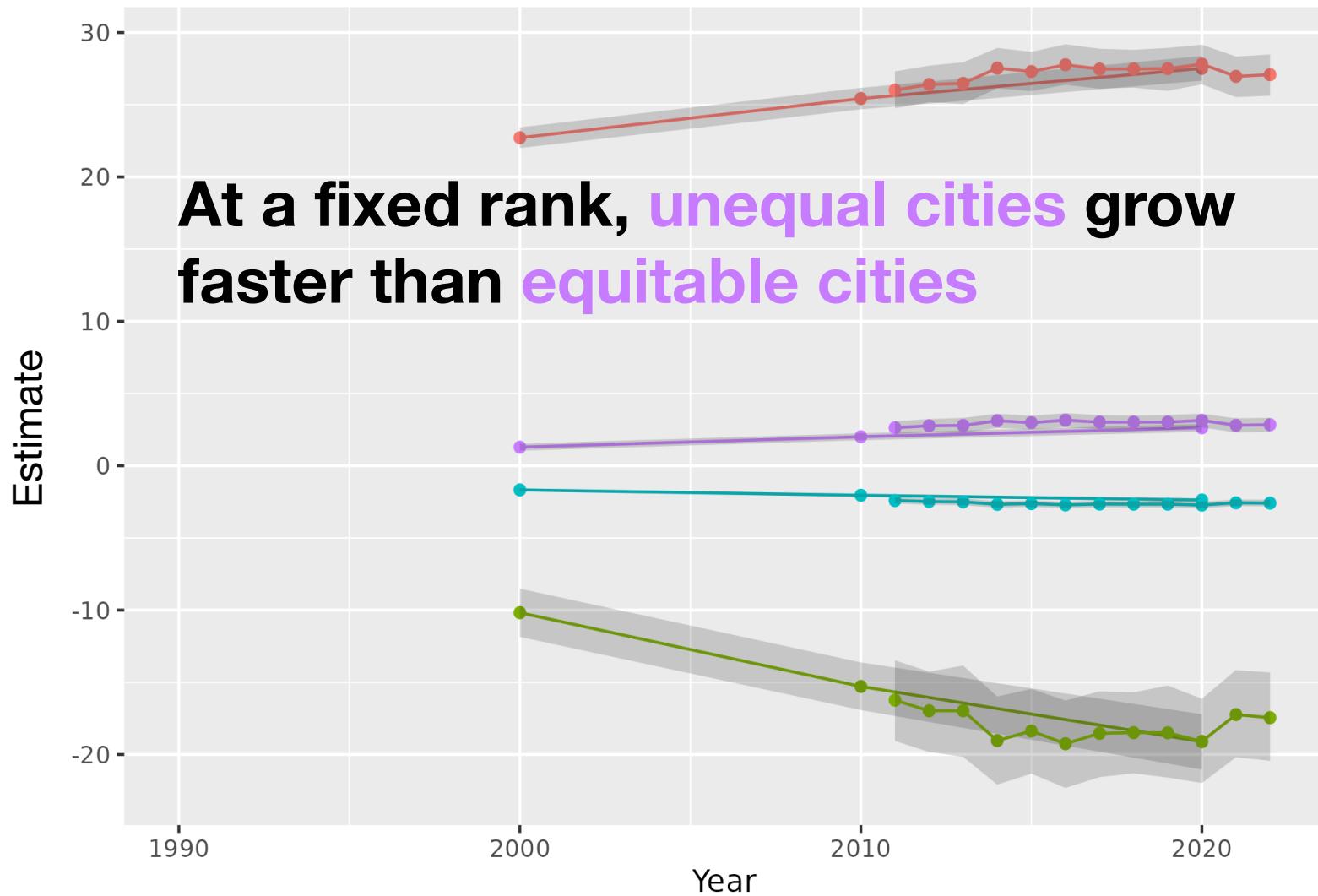
$$\log(\text{pop}_{t+1}) \sim 1 + \log(\text{rank}_t) + \text{gini}_t + \log(\text{rank}_t) * \text{gini}_t$$

**Both
estimates**



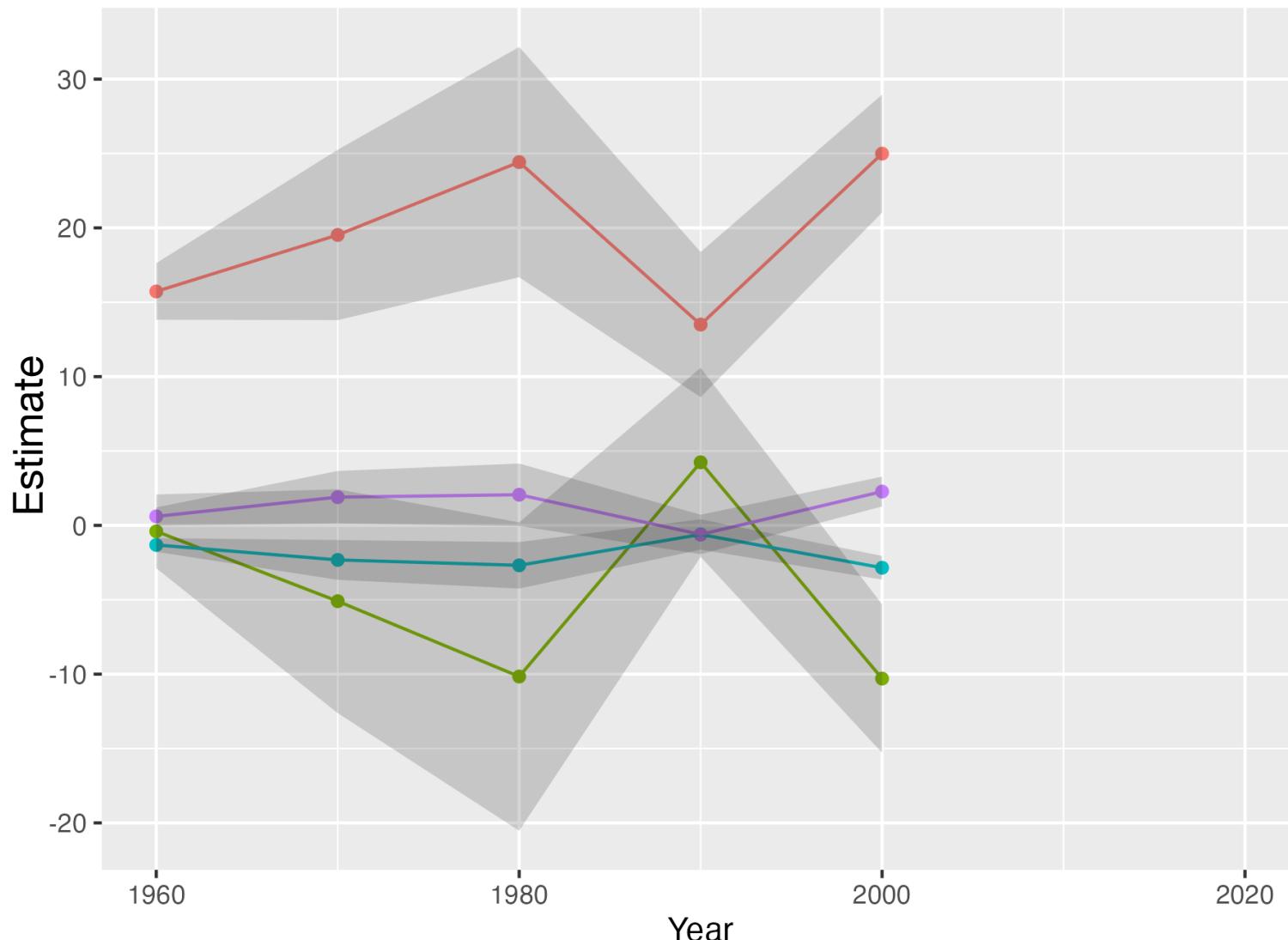
$$\log(\text{pop}_{t+1}) \sim 1 + \log(\text{rank}_t) + \text{gini}_t + \log(\text{rank}_t) * \text{gini}_t$$

Both estimates



$$\log(\text{pop}_{t+1}) \sim 1 + \log(\text{rank}_t) + \text{gini}_t + \log(\text{rank}_t) * \text{gini}_t$$

Suss et al.
estimates



Effect

- Intercept
- Gini
- Scaling
- Moderation

Reconstructed
wealth data is
a bit too noisy

$$\log(\text{pop}_{t+1}) \sim 1 + \log(\text{rank}_t) + \text{gini}_t + \log(\text{rank}_t) * \text{gini}_t$$

Urban scaling laws arise from within-city inequalities

Arvidsson et al. (2023)

City size-dependent cumulative advantage

- (1) Cities benefit their inhabitants
- (2) Benefits are unevenly distributed
- (3) In big cities, the top “gets” more from more people
- (4) Disparity compounds over time due to generational transfer and migration
- (5) This top causes scaling to emerge between cities

Within-city inequality should go hand-in-hand with pop growth

Between-city inequality should rise as income inequality rises

Scaling should get steeper as within-city inequality increases

Inequality *is not* opportunity!

generative value

regularity value

How often is this true?

contextual value

Where/when is this true?

generative value

How is this true?

City size distributions often
follow Zipf's Law...

... in “coherent” urban
systems ...

... because of within-city
inequality?

regularity value

How often is this true?

contextual value

Where/when is this true?

generative value

How is this true?

Lots of data about the present

Lots of data about the present, disaggregated by geography or time

Lots of data about, disaggregated by geography and time

Causal Values in GIScience

What do we mean by it?

Regularity and Contextuality

City scaling gives an example

Moving to generative value

Winner-take-all urbanity

Talk outline

WHAT WE TALK ABOUT WHEN WE TALK ABOUT CAUSE

CAUSAL VALUES IN GISCIENCE

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