Can there be a science of cities?

May be yes

Toward **scientific theory** of cities:

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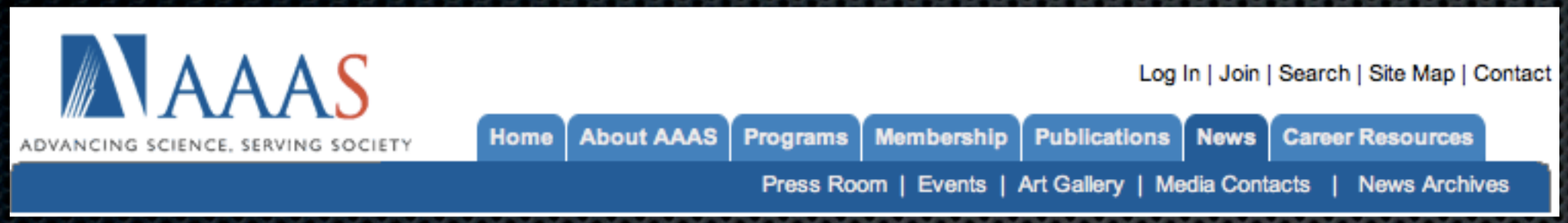
July 13 2012

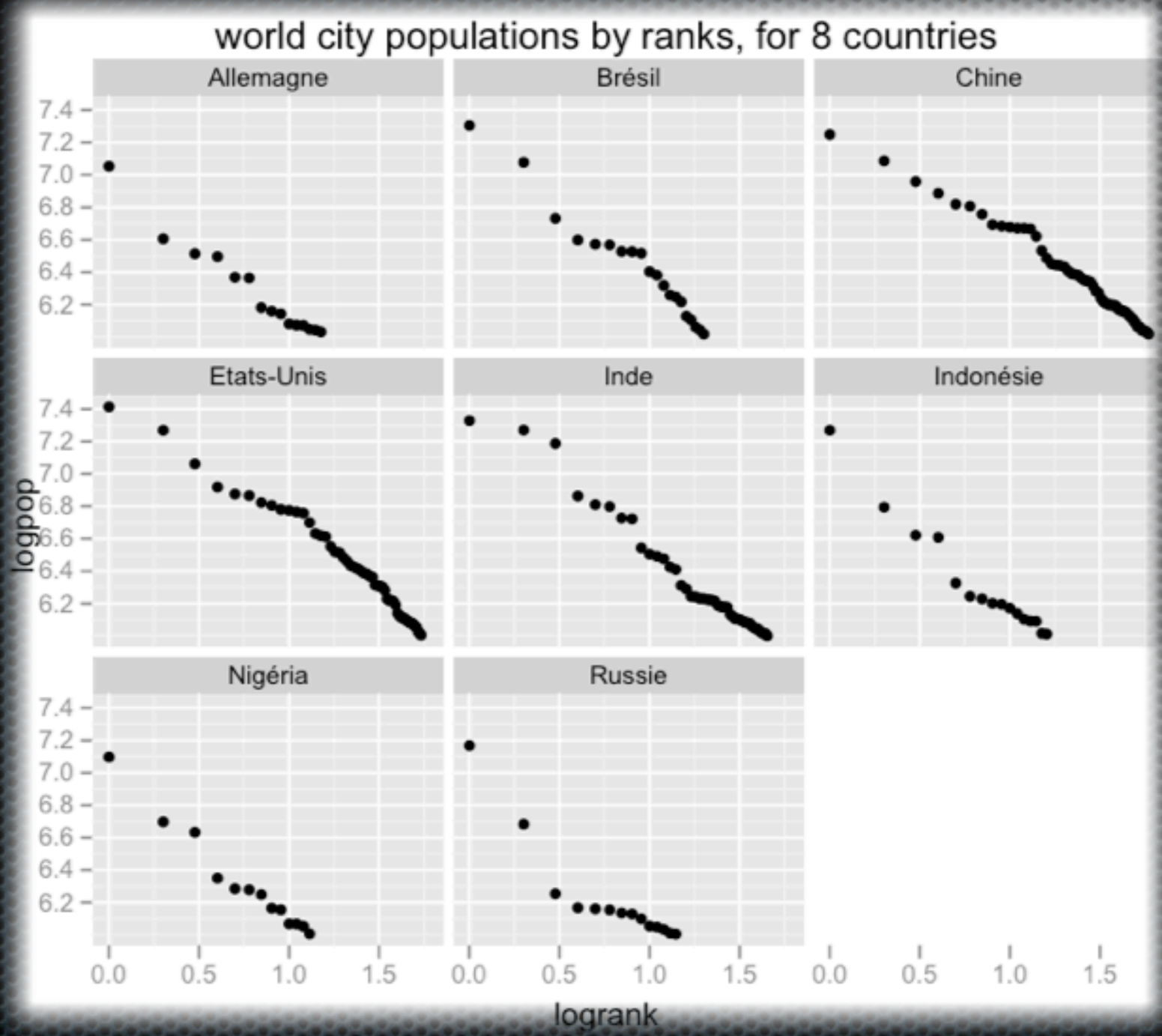


- In detective novels, a "theory" is little more than an educated guess, often based on a few circumstantial facts. In science, the word "theory" means much more. A scientific theory is a well-substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment.

Quantifiable, comparable regular patterns across cities, based on which "Mathematical" theory can be constructed.
(beyond just cherry pickings)

"What is a CITY?"
"What is a generic city"

Landmark: Zipf's law

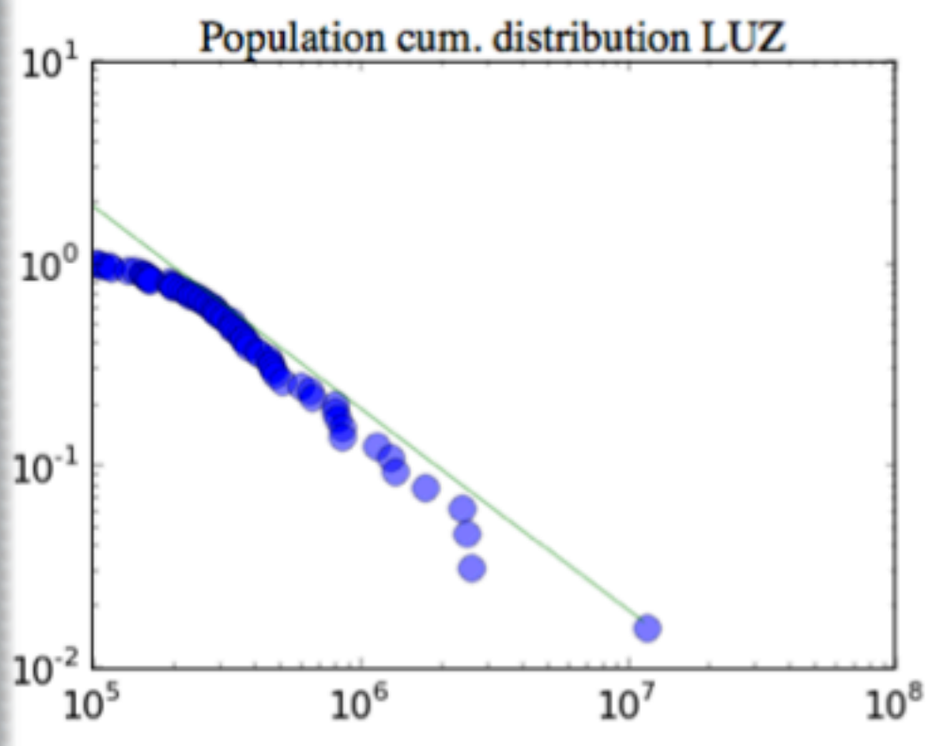


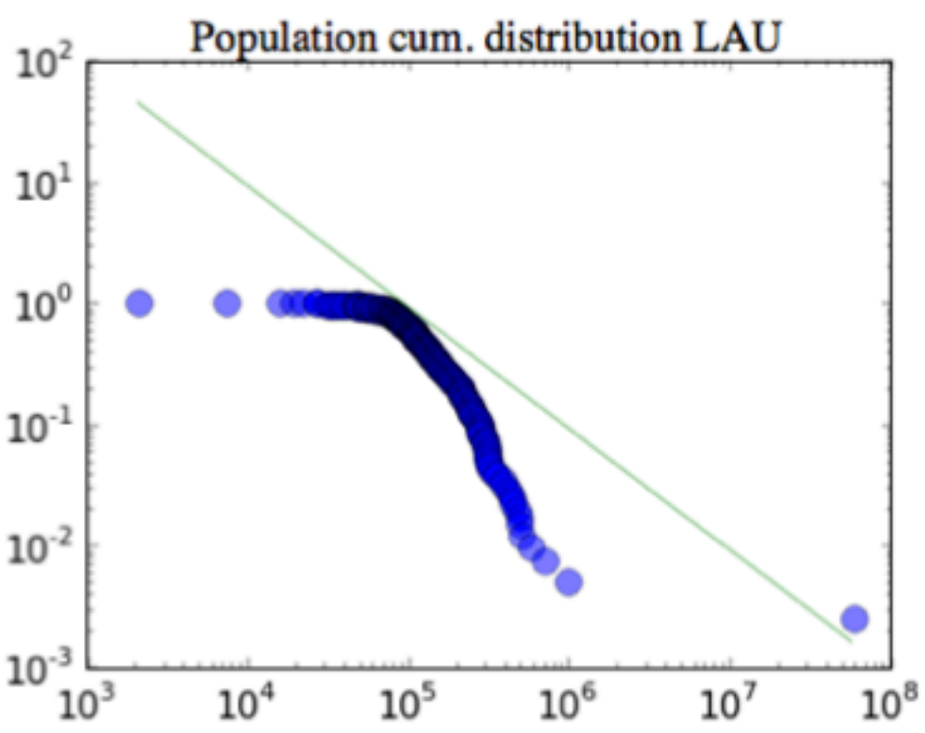
$p(r) \sim 1/r$

Models for Growth Dynamics

Landmark: Zipf's law

unit of analysis (UK)

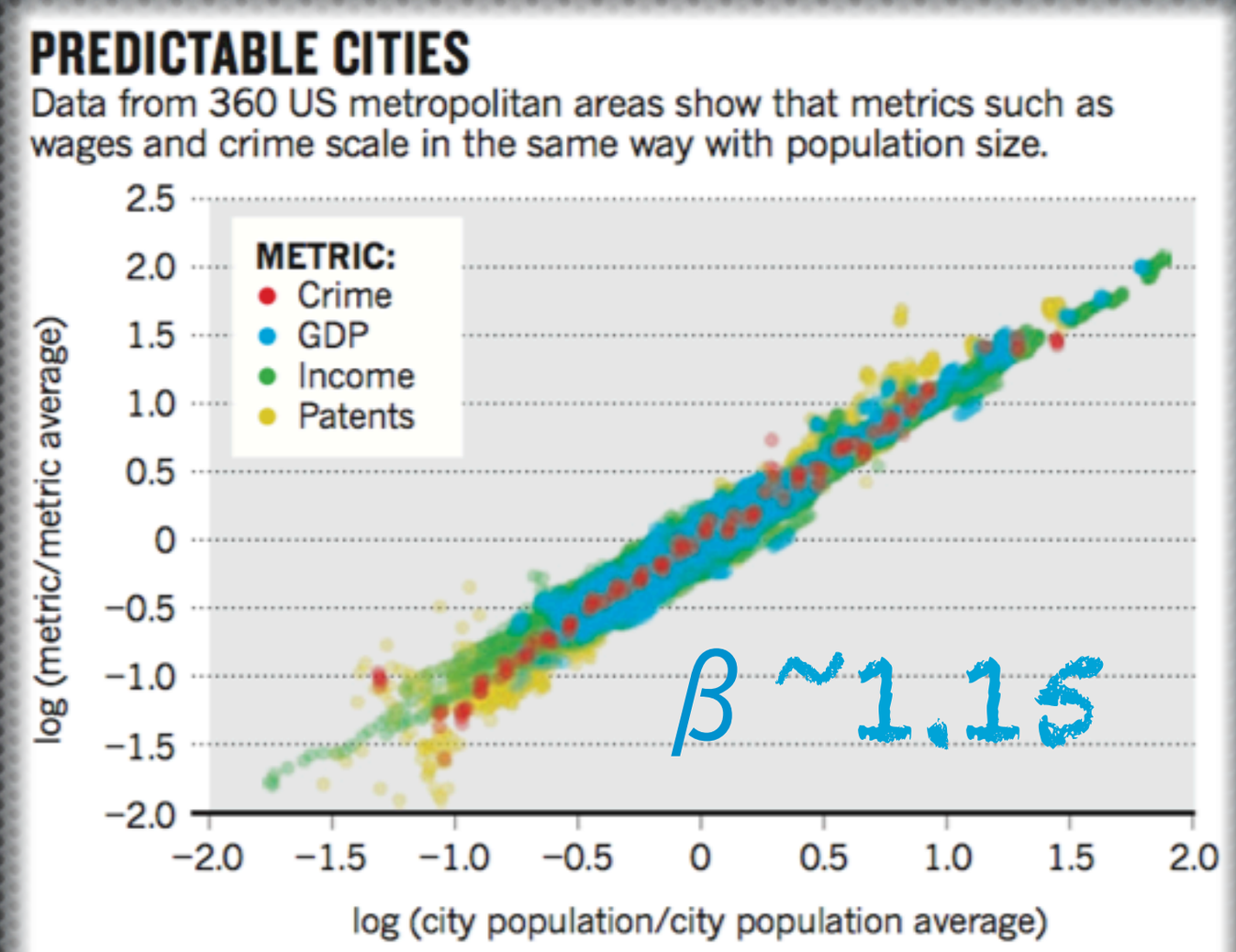




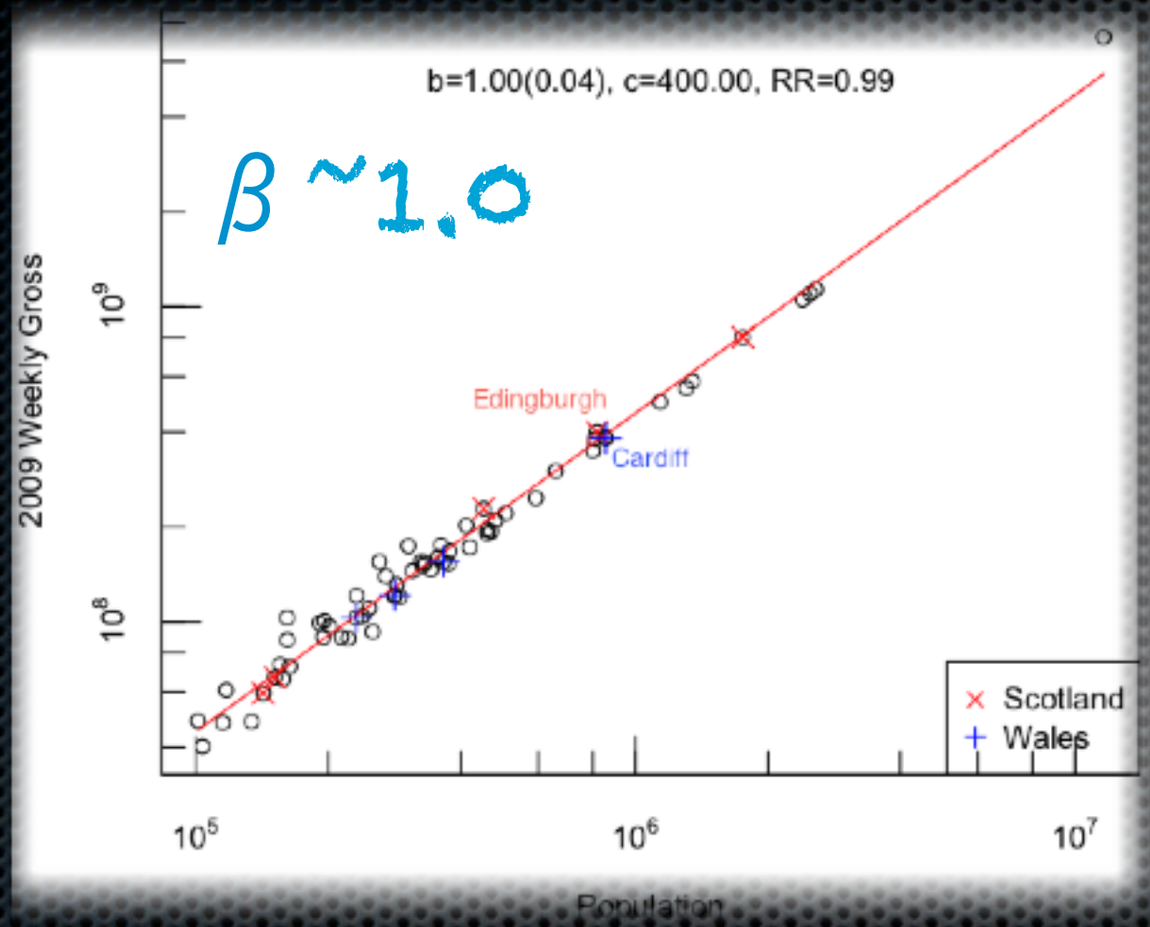
Landmark: Urban Scaling

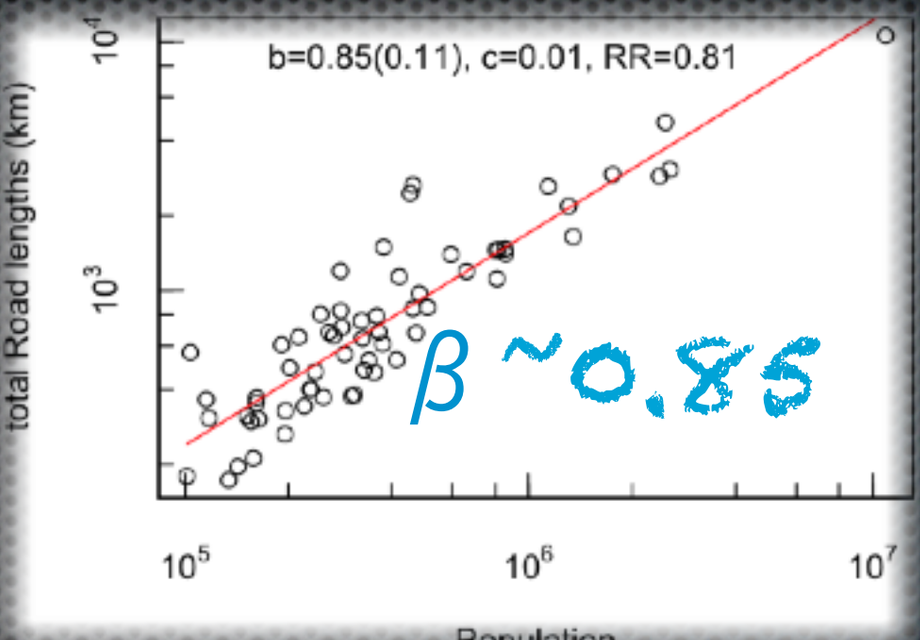
$$y \sim N^{\beta}$$

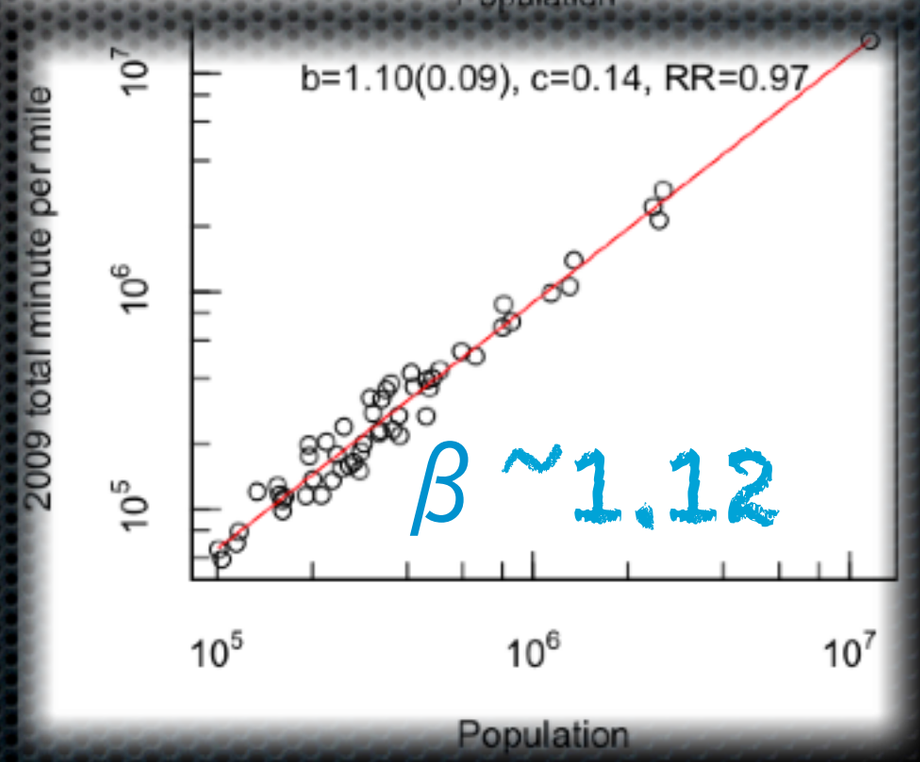
Bettencourt & West
Nature **467** (2010)



Landmark: UK Scaling



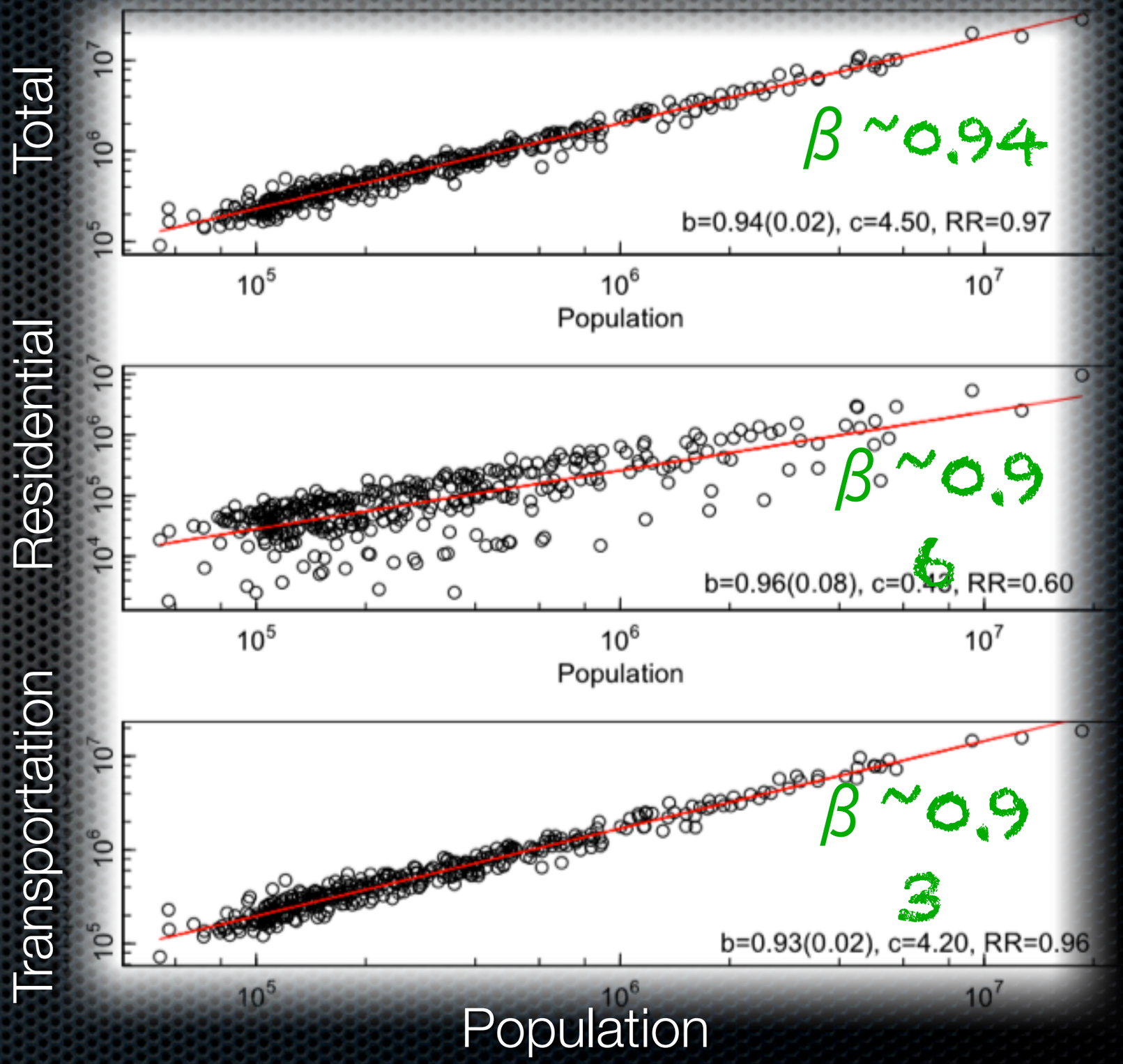




$$
\begin{aligned}
Nt &\sim N(N_v/L) \\
&\sim N^2/N^{0.85} \\
&\sim N^{1.15}
\end{aligned}
$$

Bigger, Greener?

$\gamma \sim N^{\beta}$



Commuting Choice of Mode of Transportation

↳ Depreciation, Insurance, Parking

(fixed cost) + (marginal cost) × (distance travelled)

↳ Gas, maintenance, TIME

Thermal Diffusion Model

$$E_{HC} = \int dt \kappa' S \Delta T(t) \longrightarrow E_{HC}/\Delta T = \kappa' S$$

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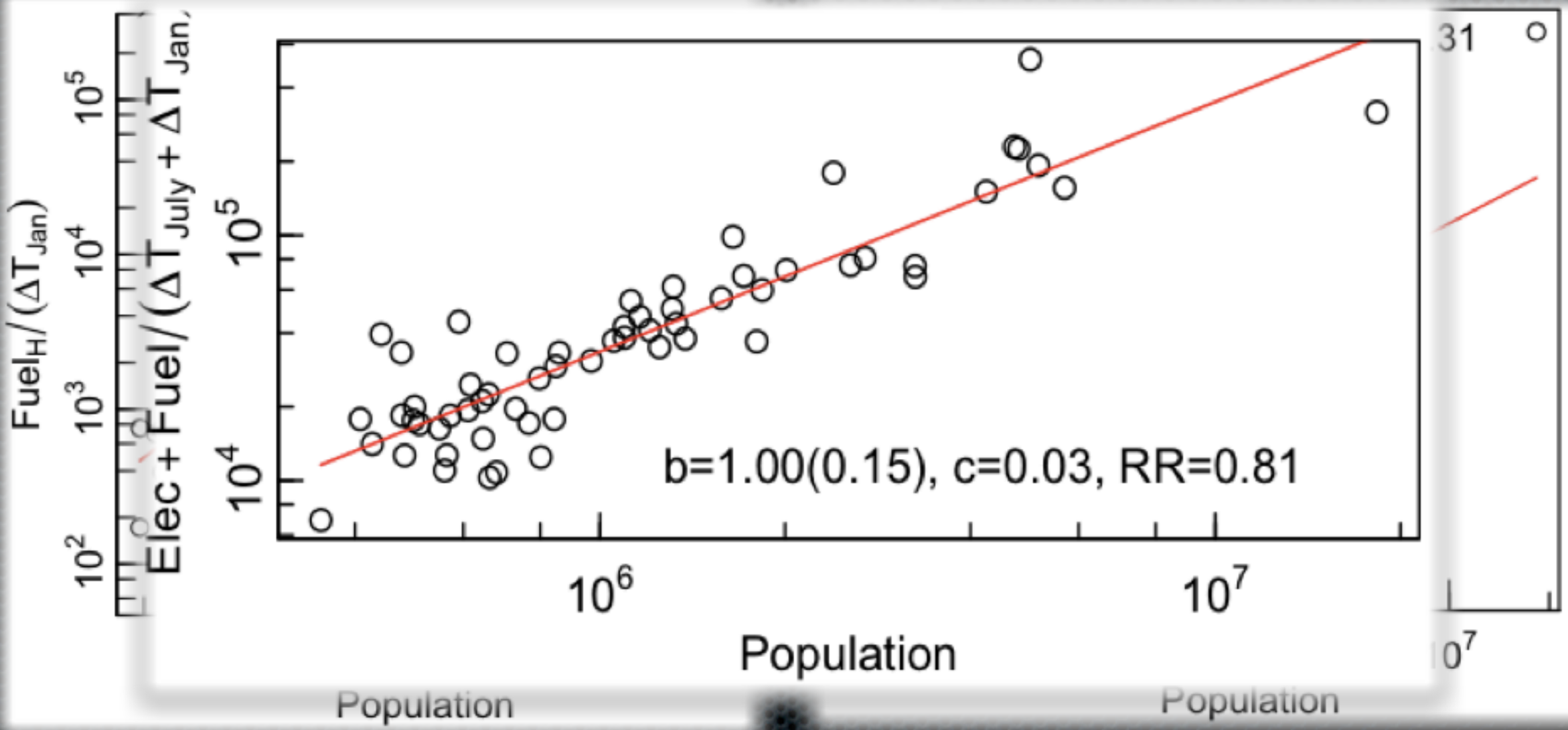
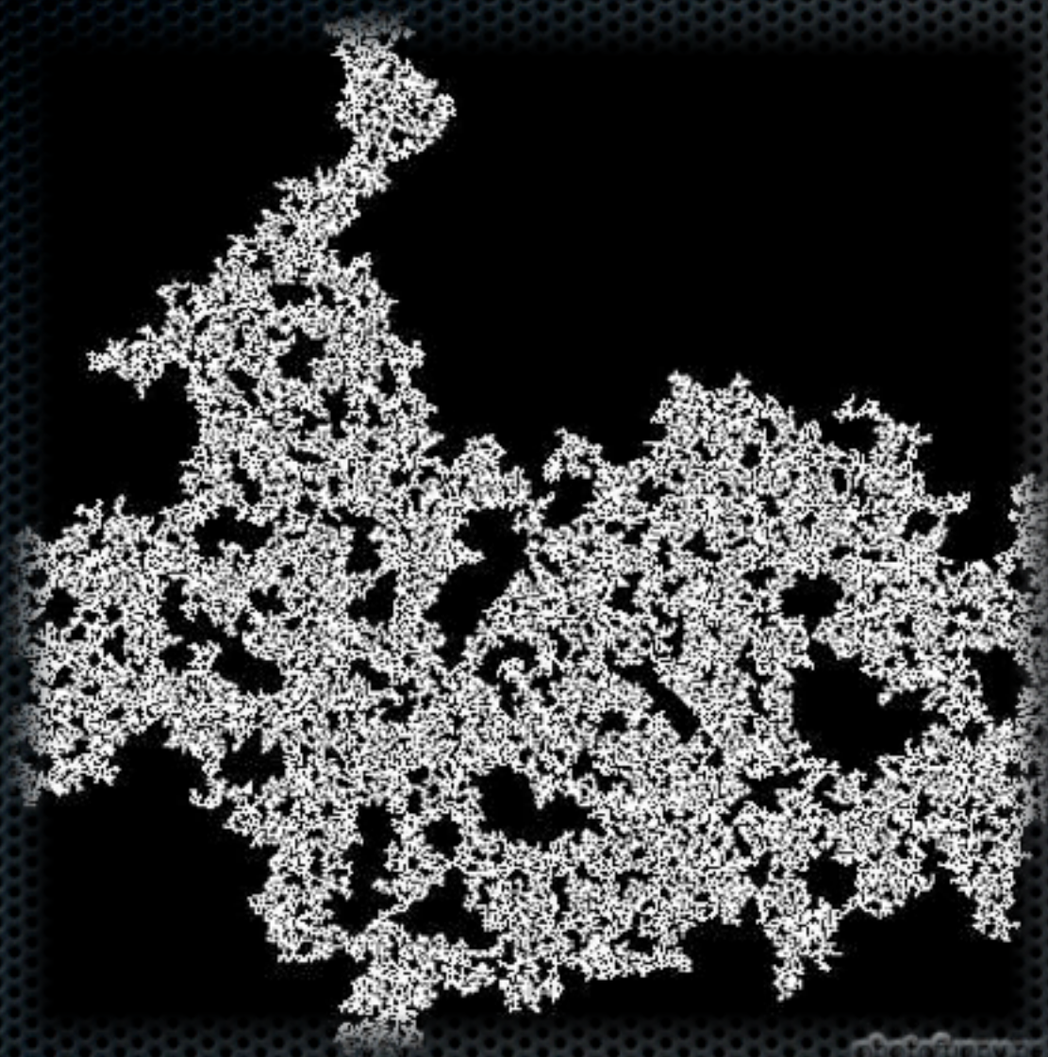
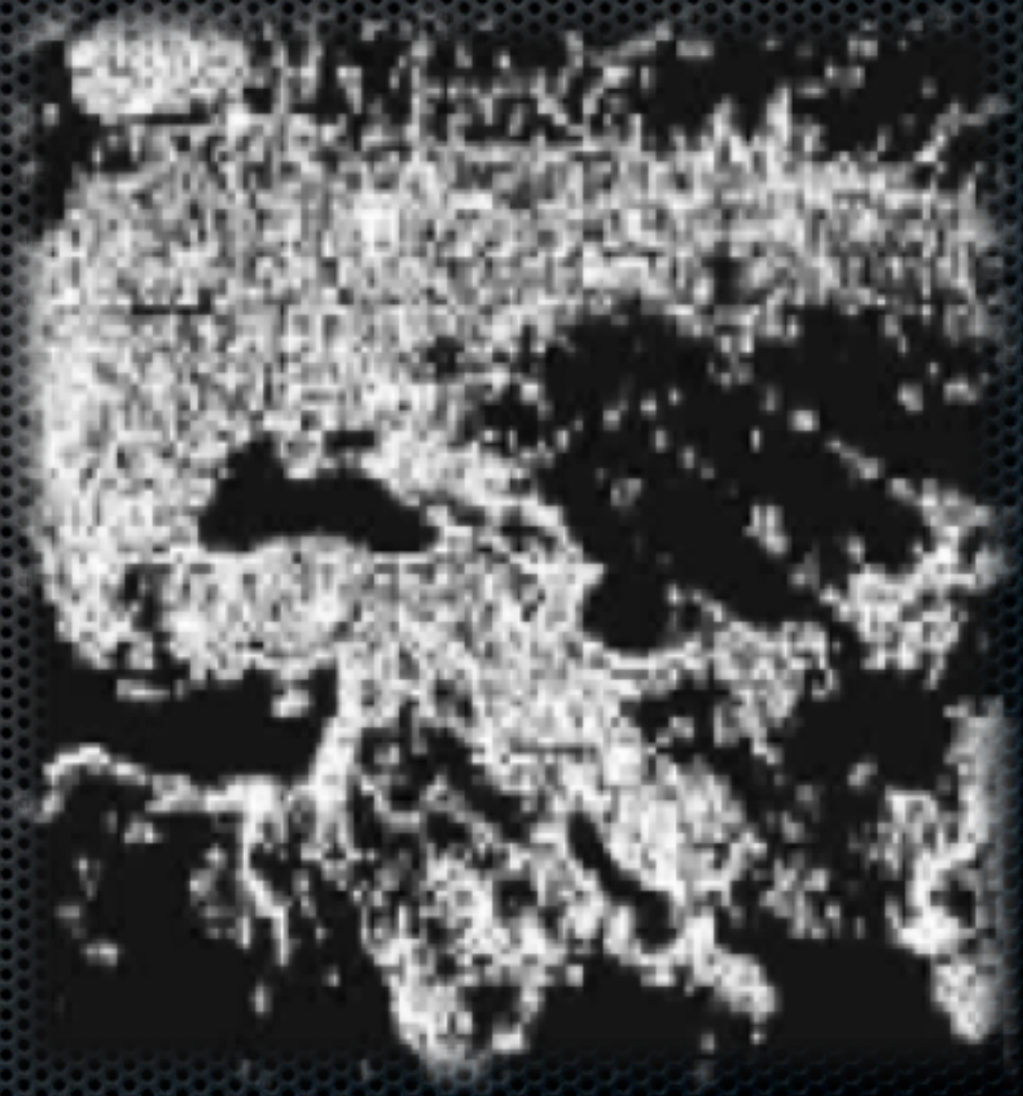


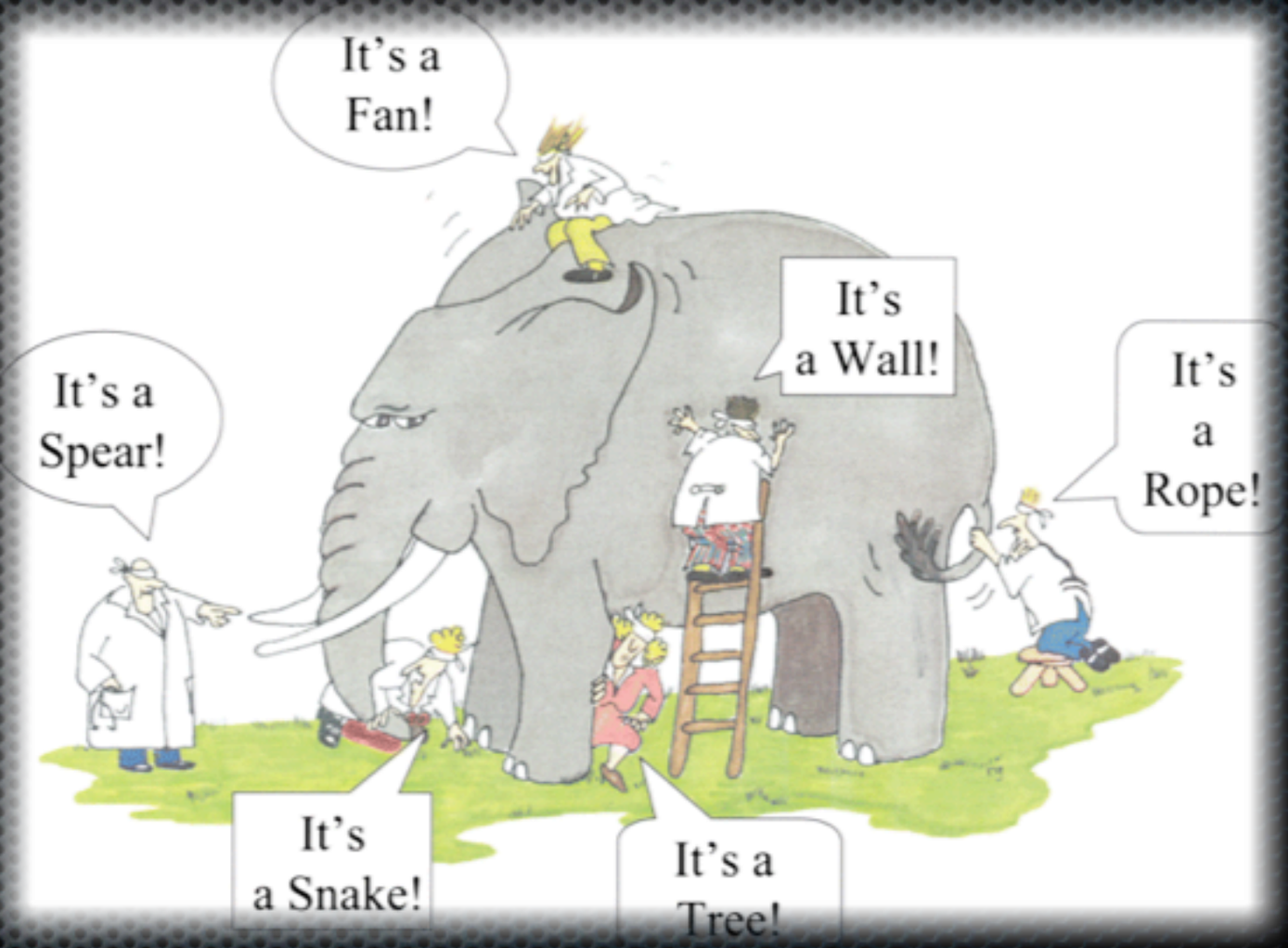
Population Distribution



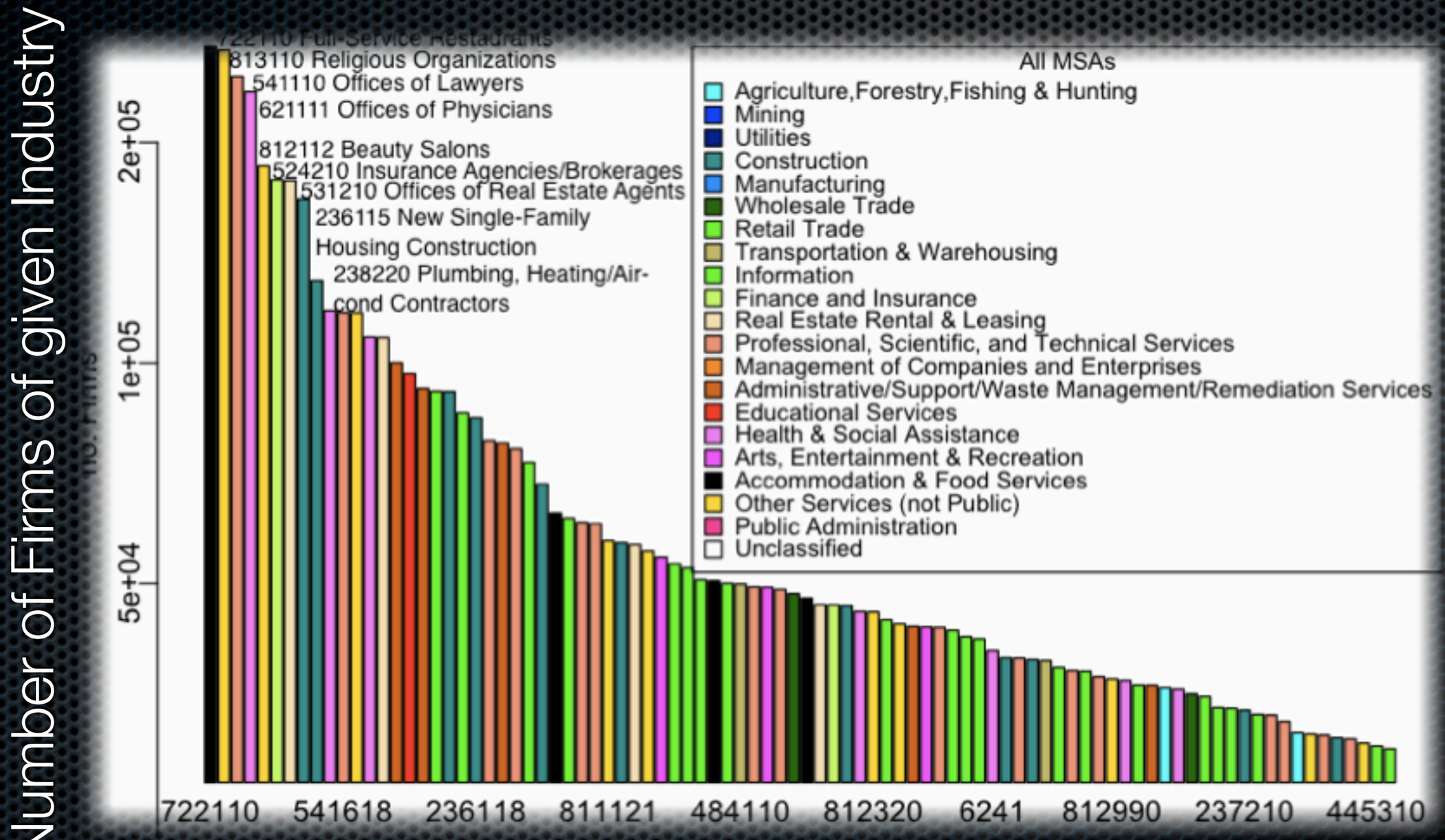


Urban Economic Diversity

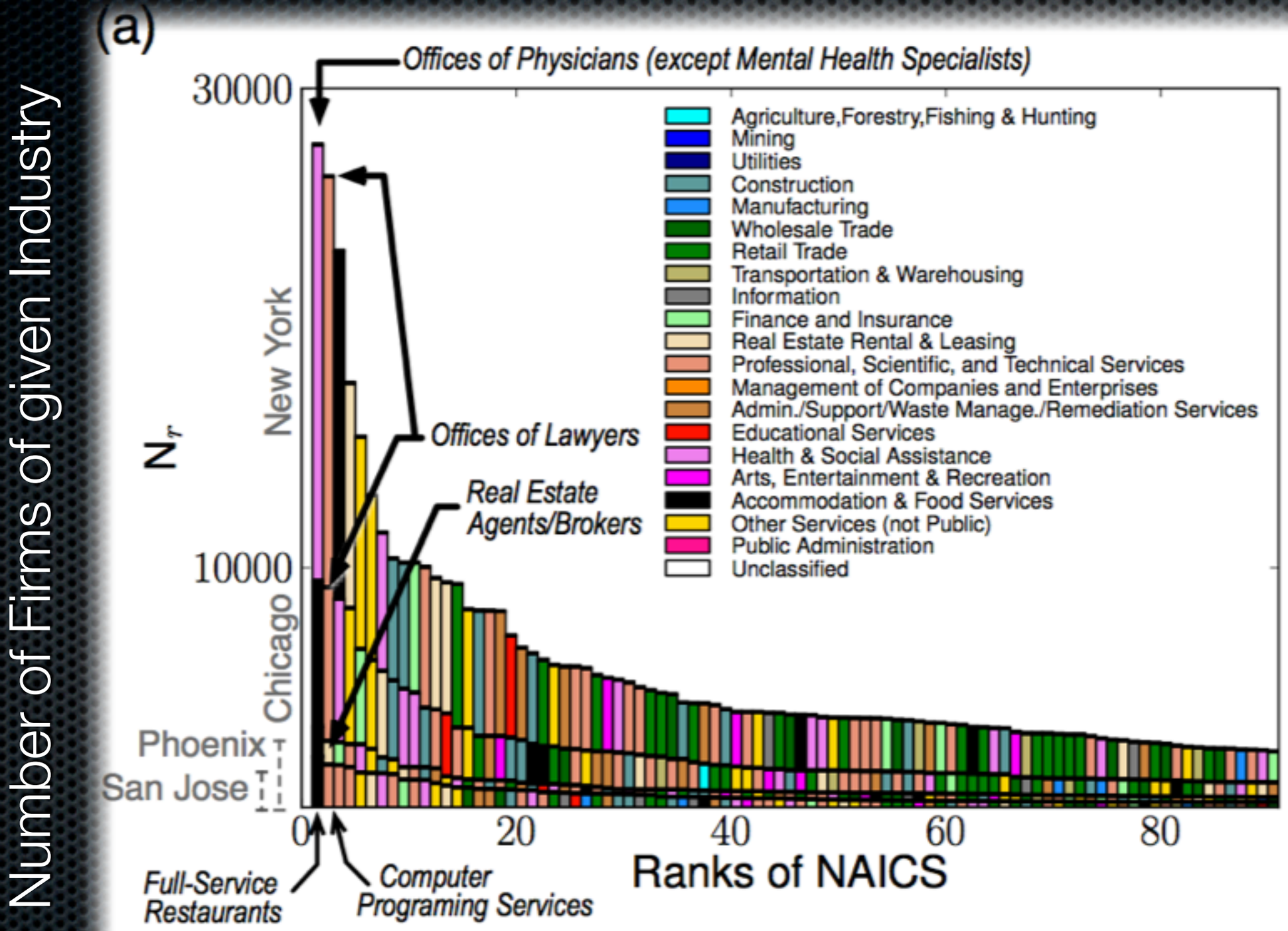
- Important urban feature
- Industrial Types (NAICS): Restaurants, Religious organizations, Lawyers, Physicians...
- Every city is special
  - Silicon Valley, Detroit, Phoenix, New York...



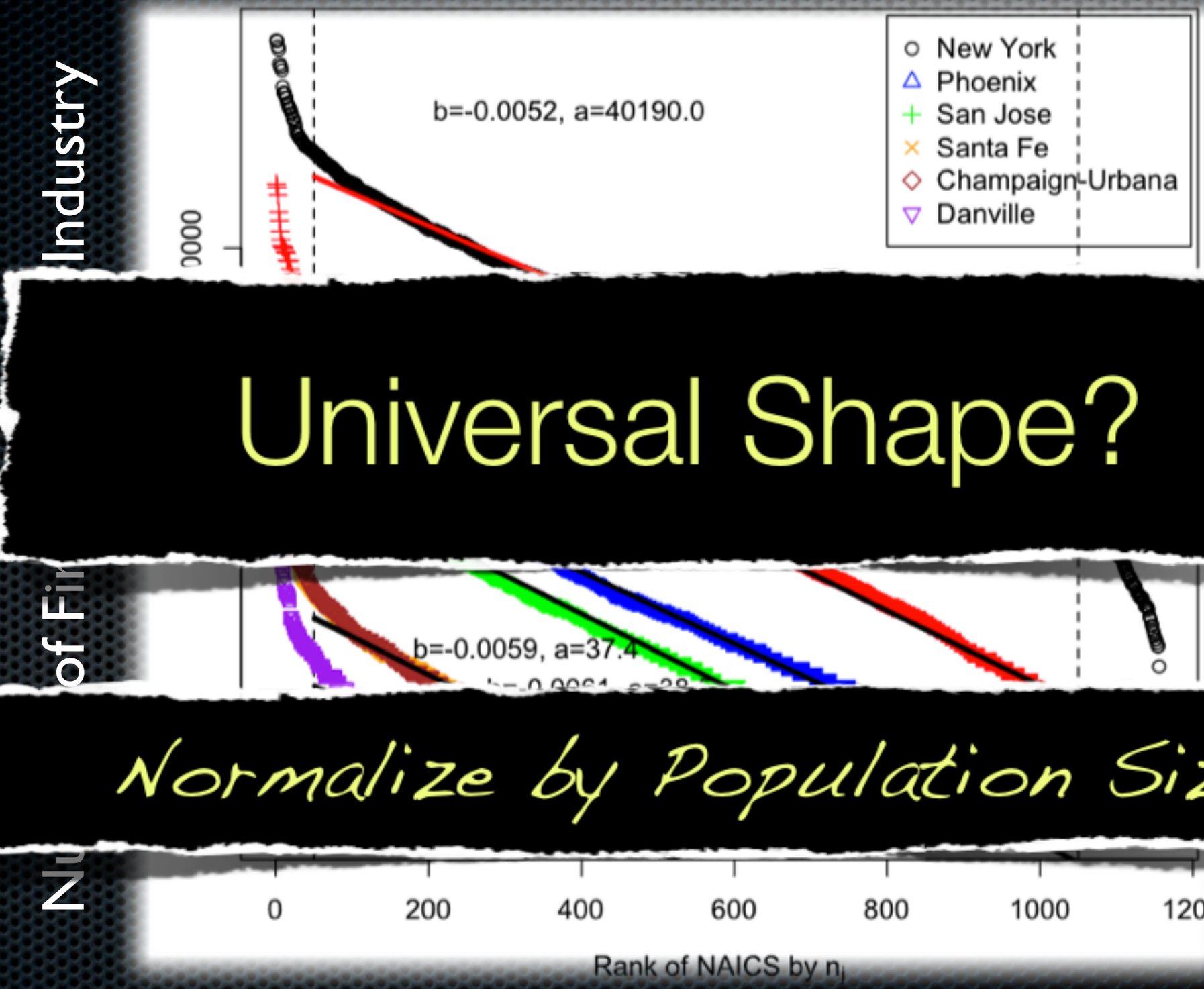
“Whole Picture” of All MSAs



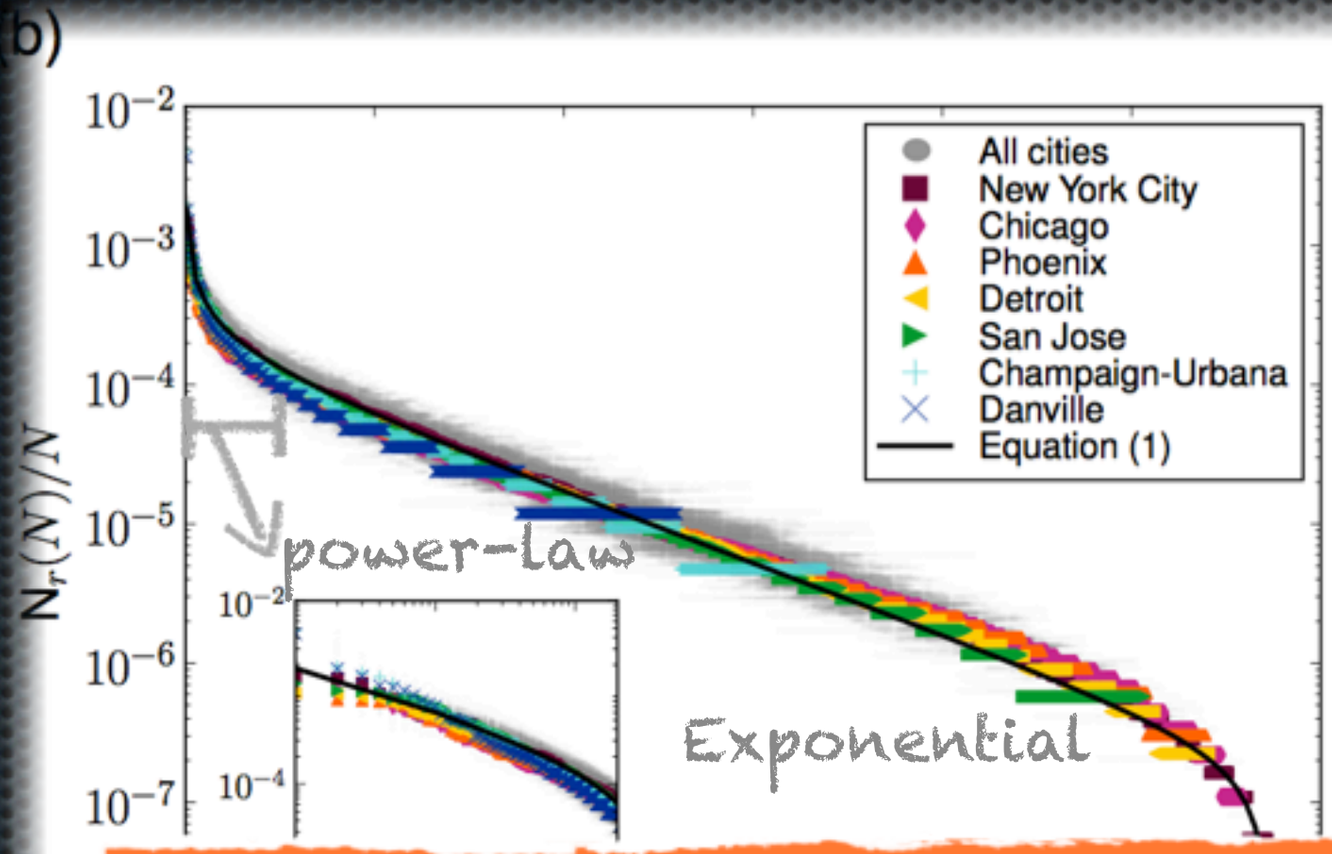
Individual Cities



Only Abundance Shape



Universal Distribution



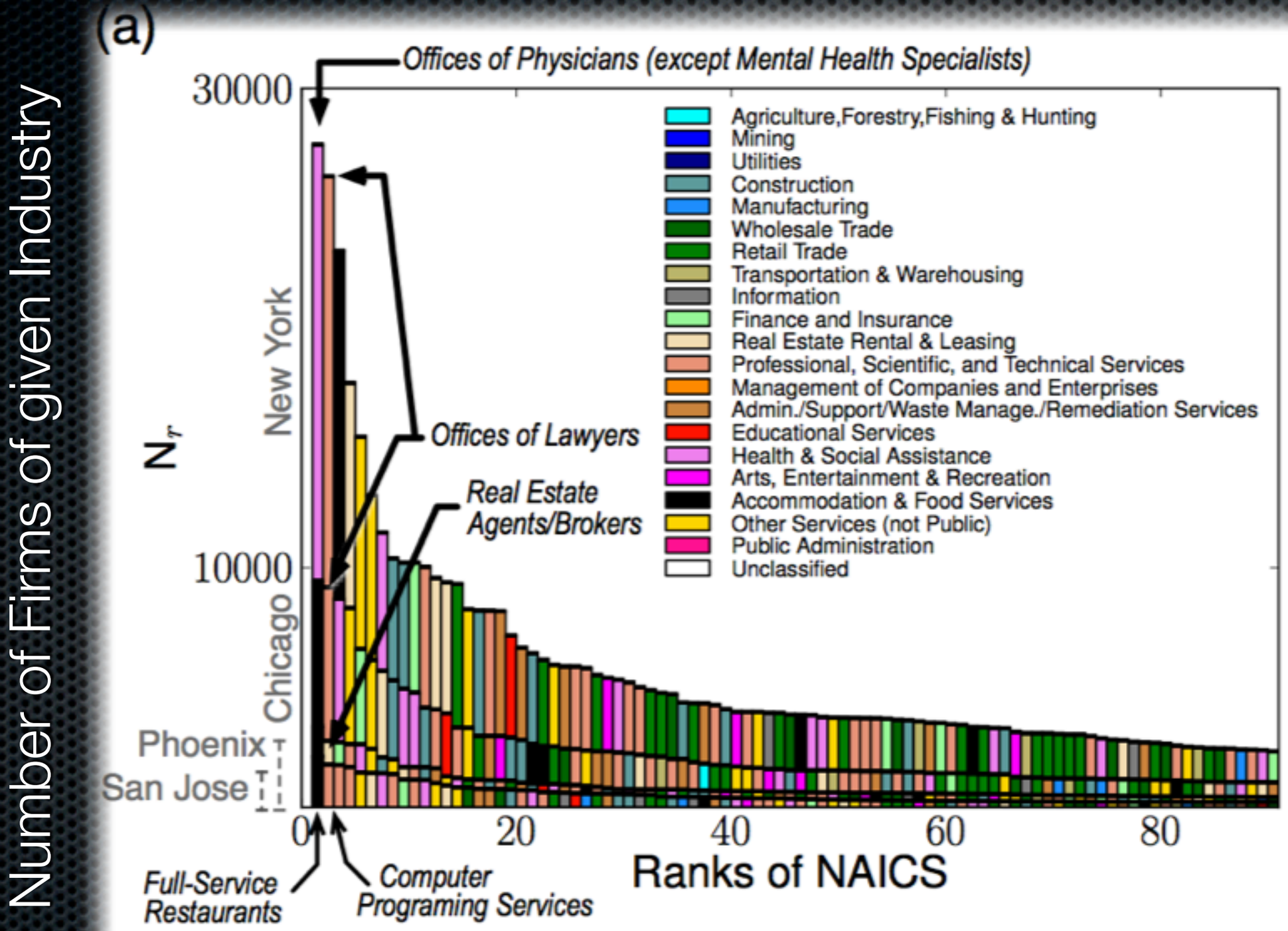
- Regardless of Density and Wealth
- Common Niche structures across all cities
- SAME underlying model for

However Special you are,
You cannot escape from this
universal distribution!

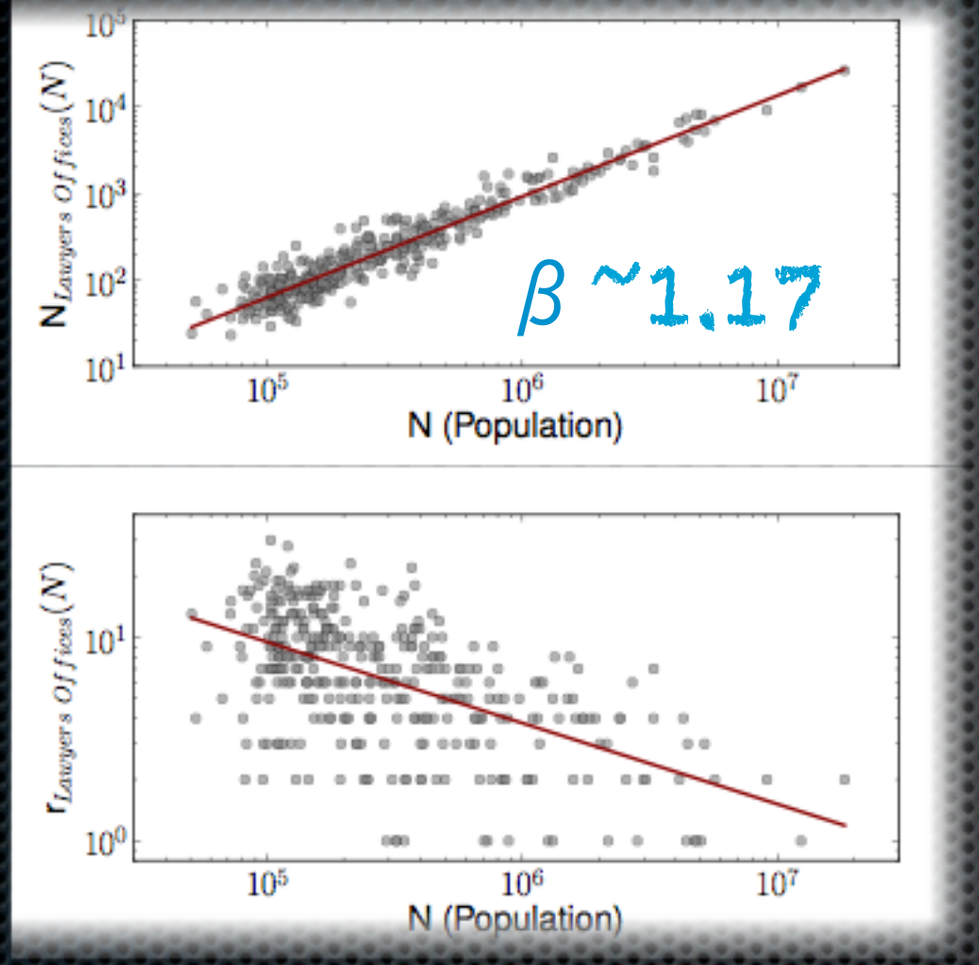
$p(r) \sim r^{\alpha} e^{\beta r}$

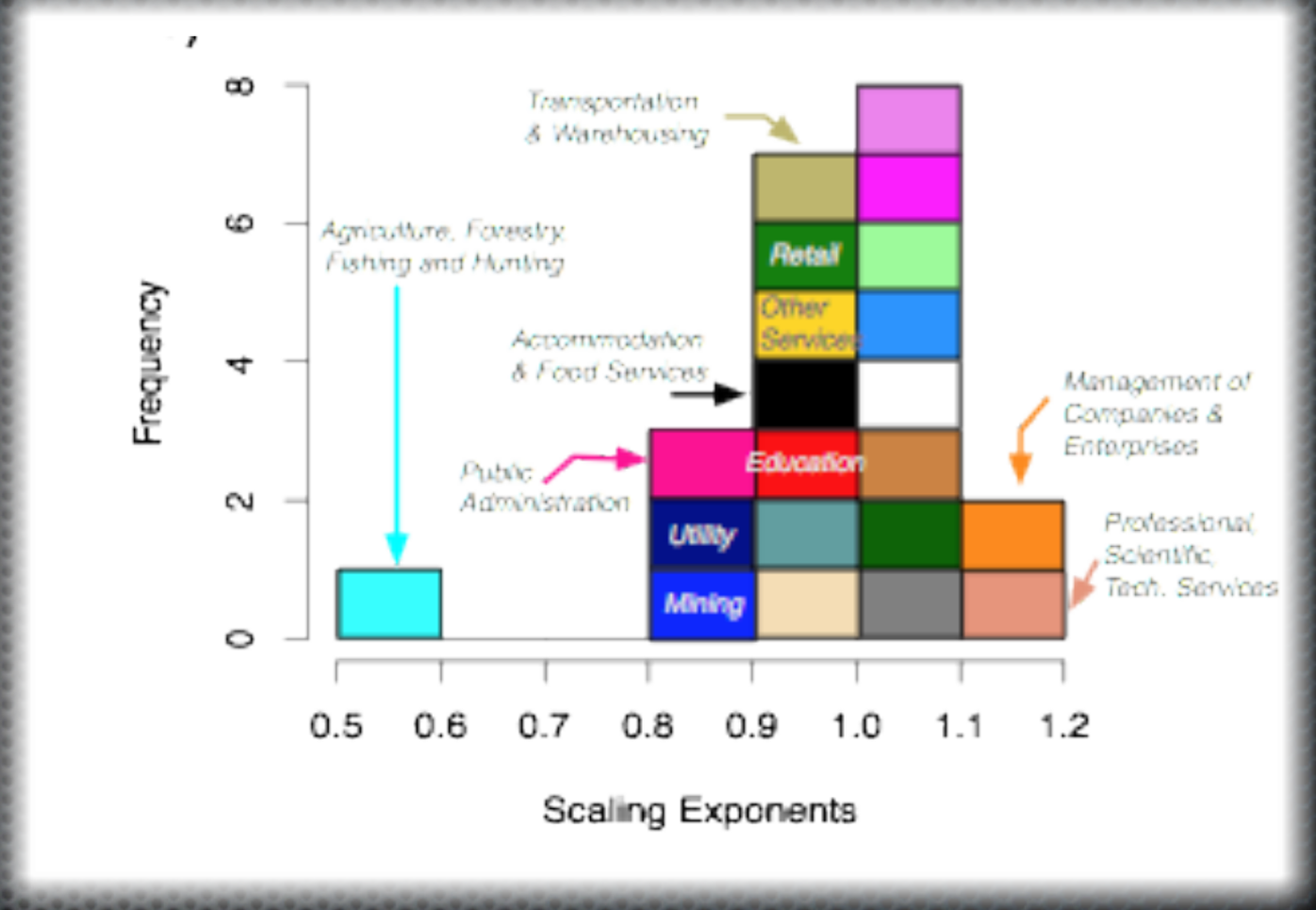
$$f(i, N_f) = \frac{1}{N_0} e^{\left(1 + A \frac{(1+i)^{\gamma}}{i - D_{\max}} + B \frac{(1+i)^{\gamma}}{(1+i)^{\gamma}}\right)}.$$

Individual Cities



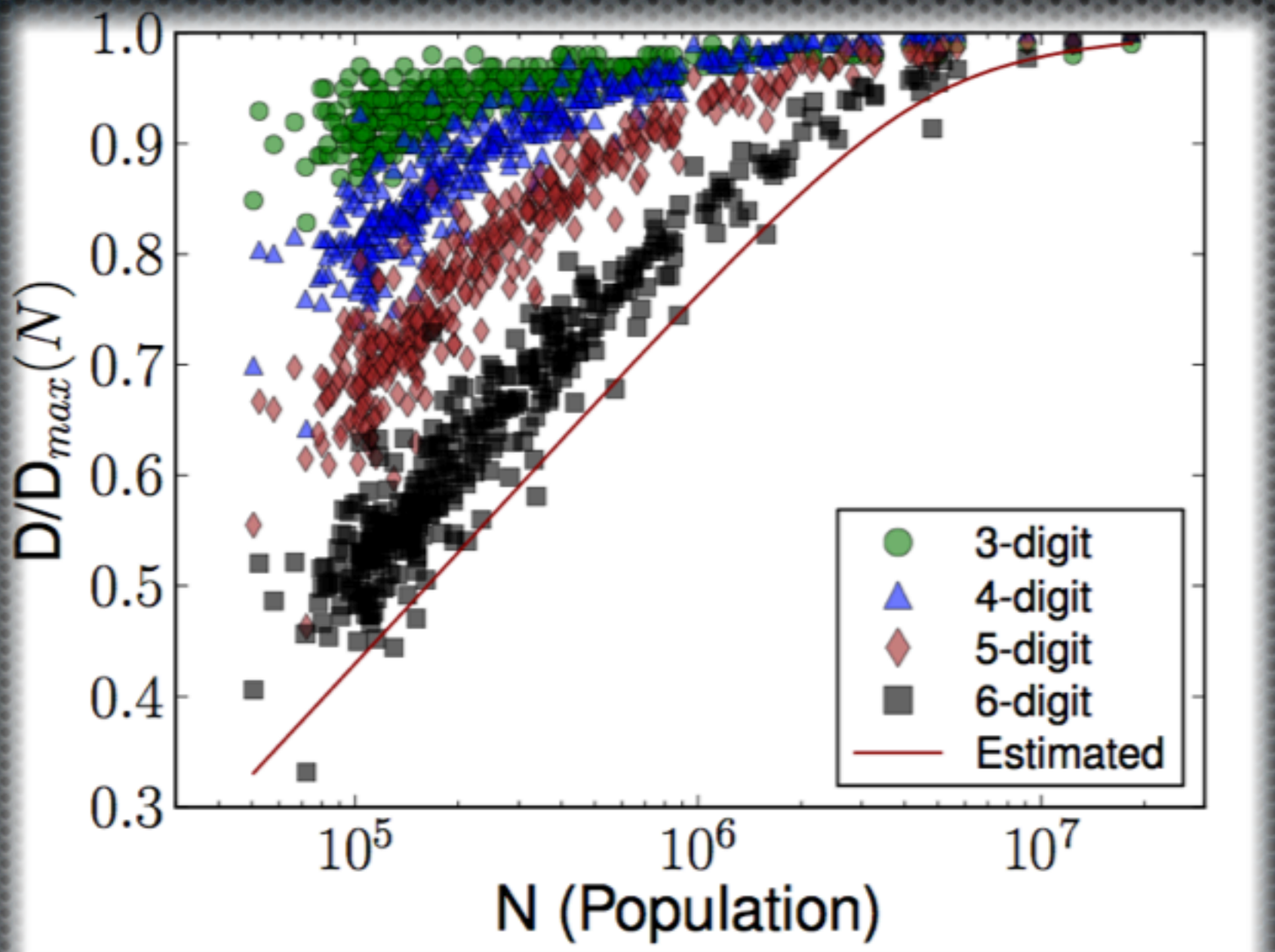
Systematic Shift of Sectors





- rank $i = \{ N^{(1-\alpha)/\gamma}$ for small $i < i_0$ $i_0 (1 - \alpha) \log (A$
- Increases in Productivity, Consumer demand

Total diversity of cities



- Genuine saturation, combination, not captured refinement

Conclusion

- Cities are unique in many particular aspects of their economic constitution, no city can deviate substantially from a universal pattern.
- Inherently self-similar not only in terms of their aggregated quantities (GDP, wages, homicides) but also of their internal economic fabric.
- a step forward towards developing a quantitative theory of cities.
- Collaborators: Luis, Jose, Debbie, Geoffrey