The City as a System for Innovation and Entrepreneurship

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Provided that some groups on earth continue either muddling or revolutionizing themselves into periods of economic development, we can be absolutely sure of a few things about future cities:

The cities will not be smaller, simpler or more specialized as cities of today.

Rather, they will be more intricate, comprehensive, diversified and larger than today's and will have even more complicated jumbles of old and new things as ours do.

Jane Jacobs
The Economy of Cities, 1980

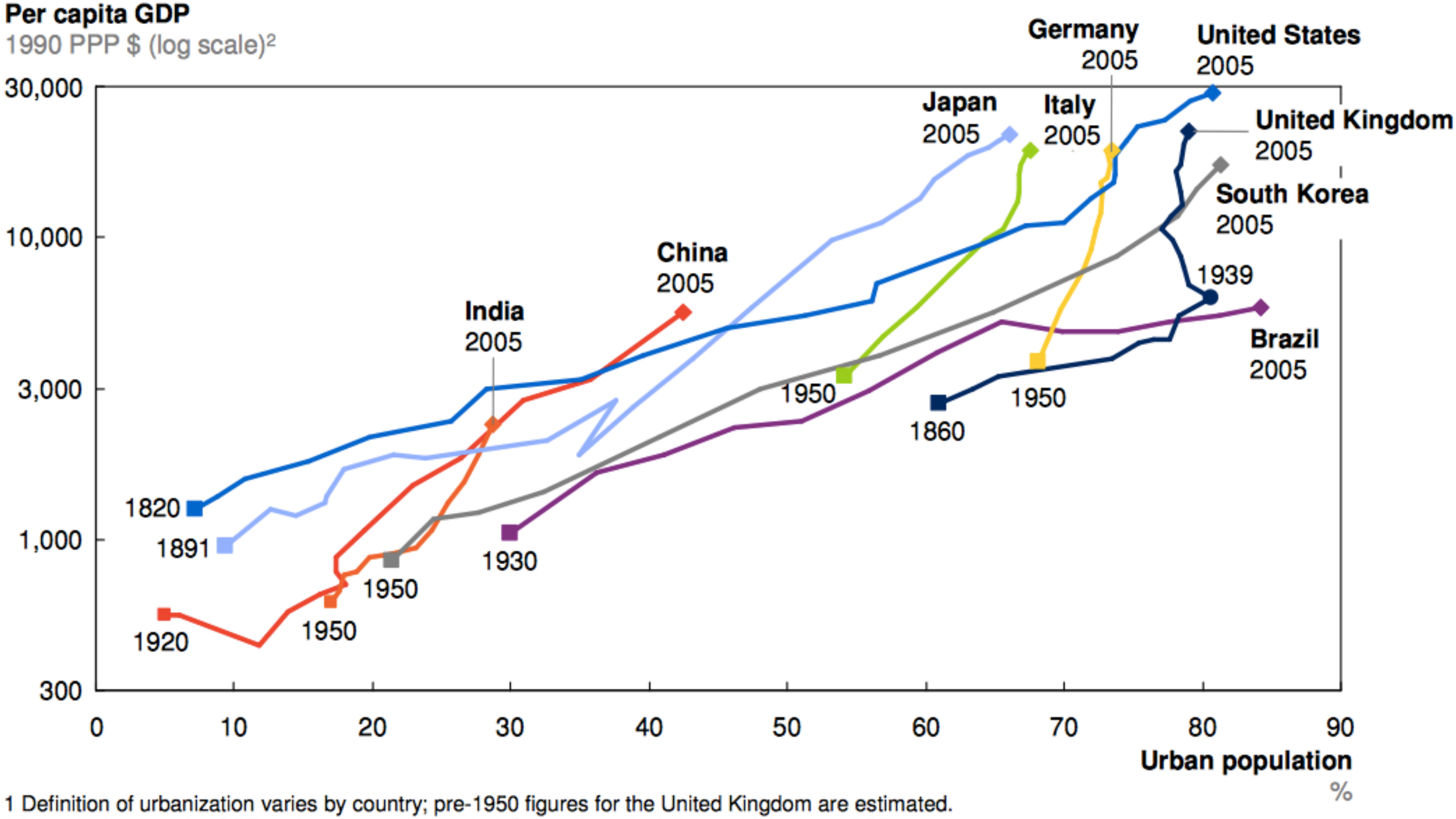
1876

1932

1988

2013

Per capita GDP and urbanization[1]



1 Definition of urbanization varies by country; pre-1950 figures for the United Kingdom are estimated.
2 Historical per capita GDP series expressed in 1990 Geary-Khamis dollars, which reflect PPP.

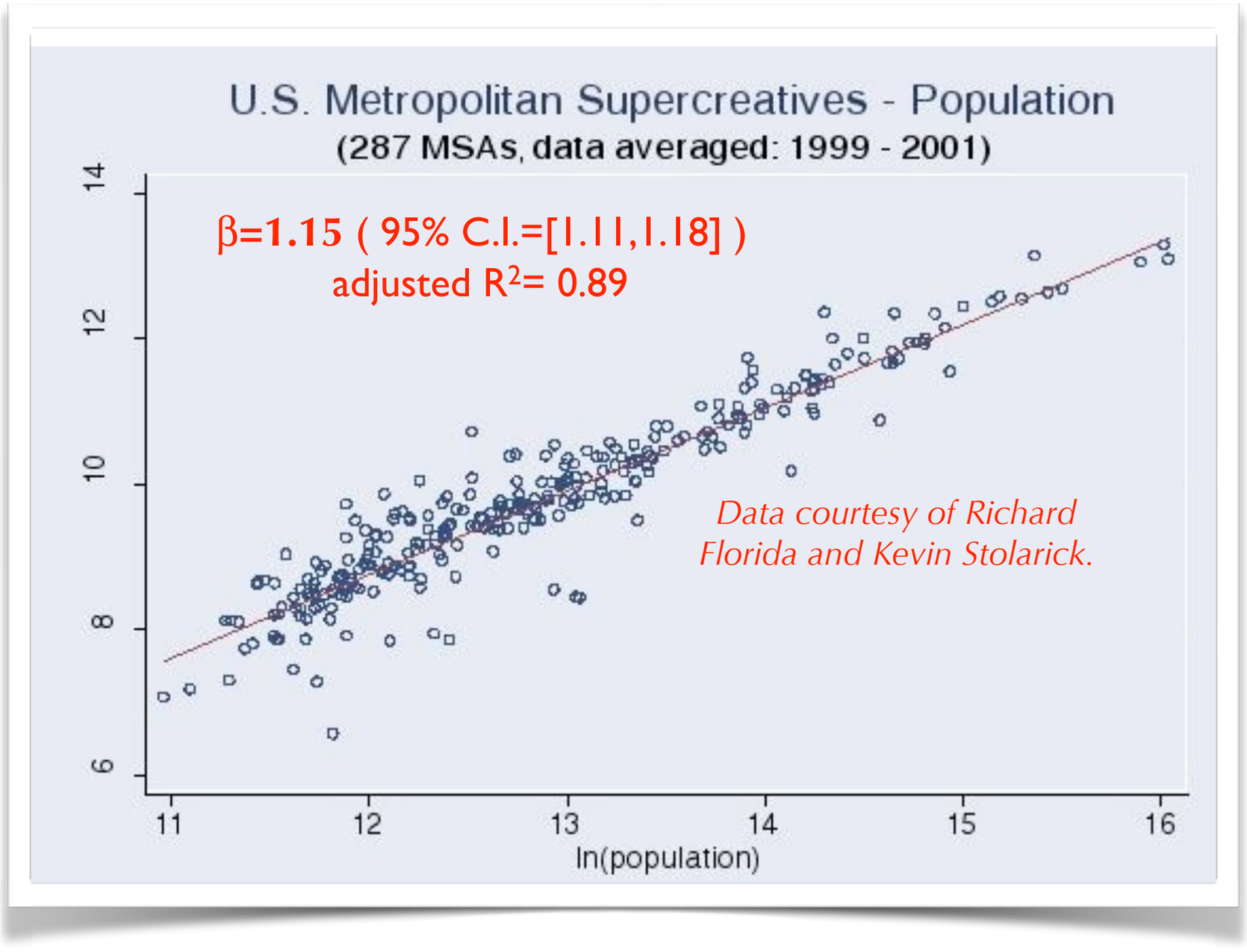
SOURCE: Population Division of the United Nations; Angus Maddison via Timetrics; Global Insight; Census reports of England and Wales; Honda in Steckel & Floud, 1997; Bairoch, 1975

[Real cities, present] situations in which several dozen quantities are all varying simultaneously and in subtly connected ways

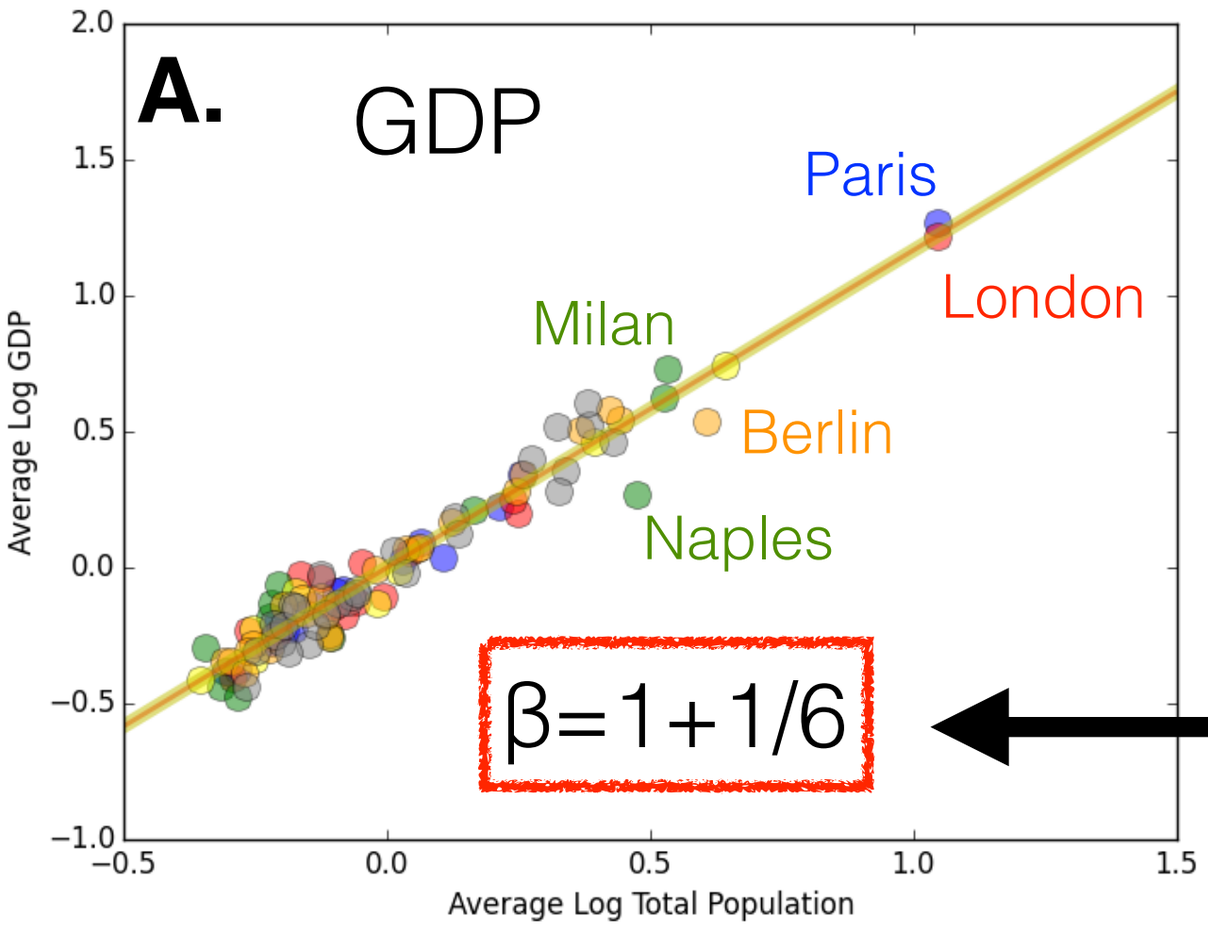
Jane Jacobs

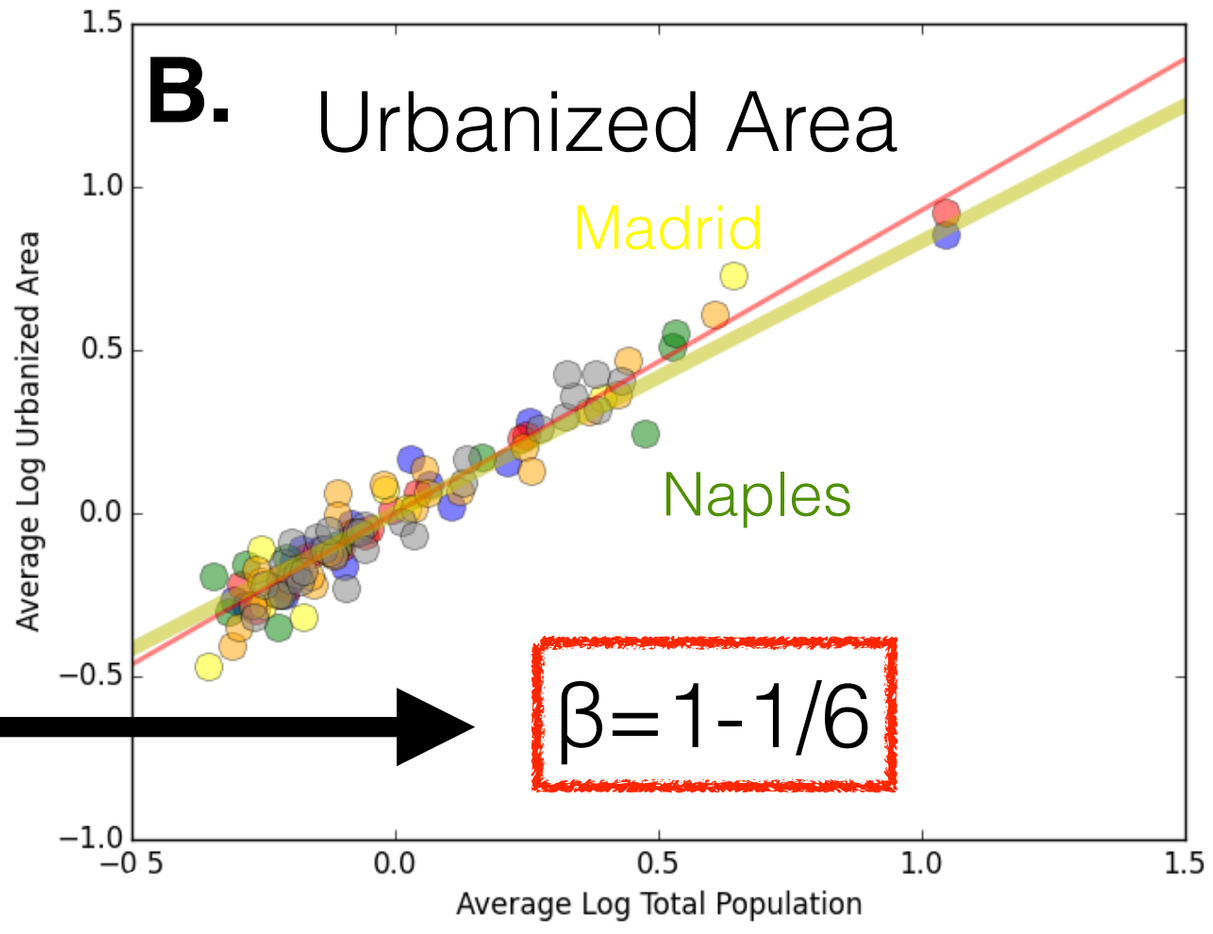
The death and life of great American cities 1961

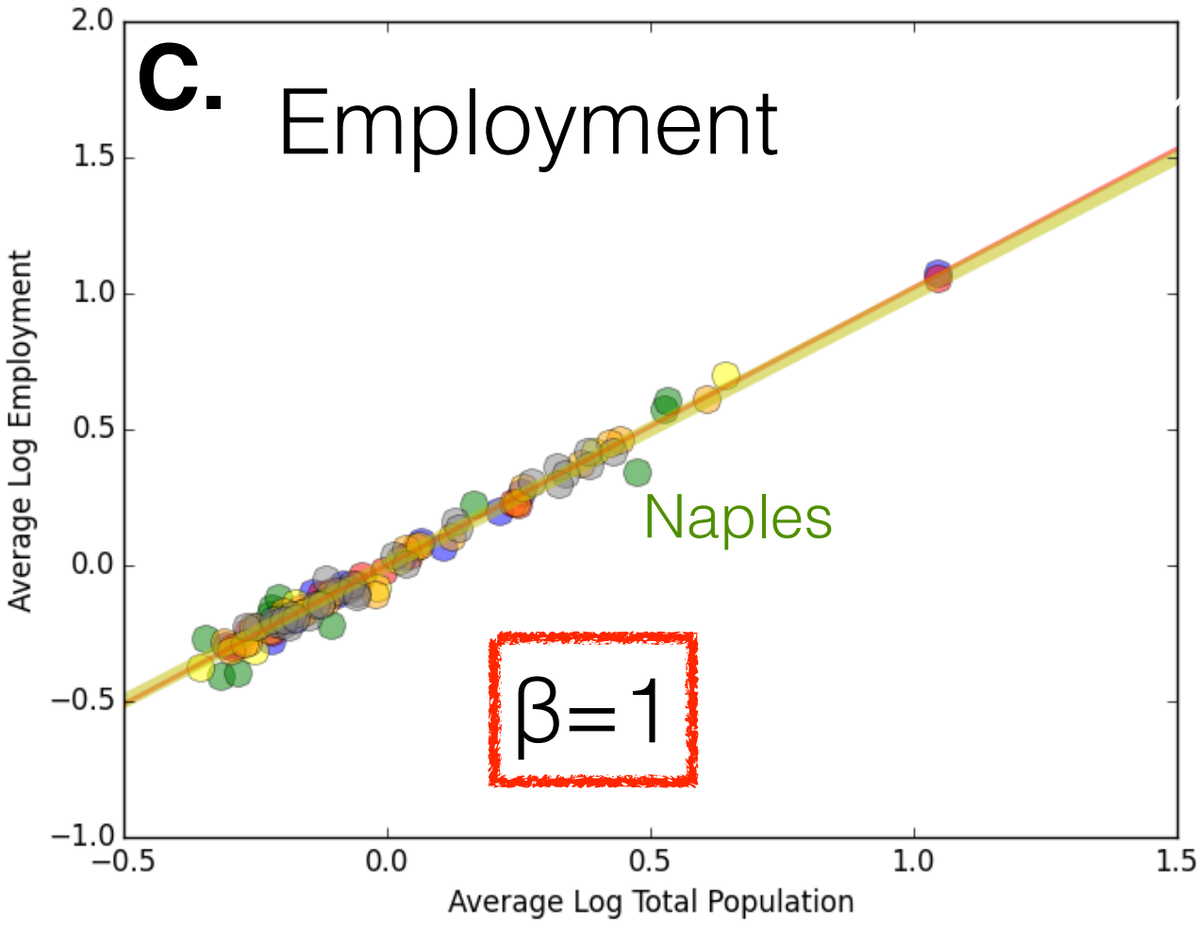
Wealth Creation is driven by Innovation

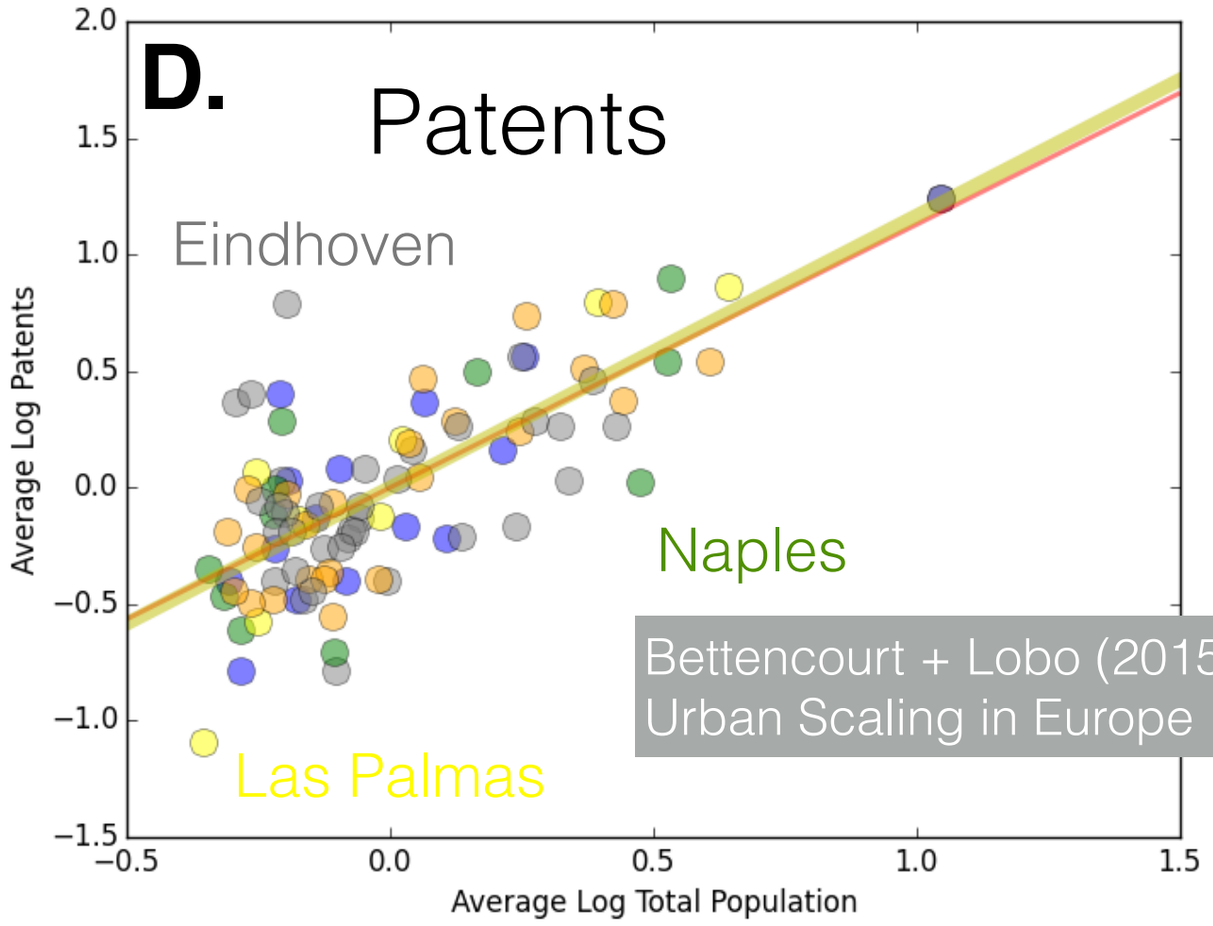


Supercreative professionals [Florida 2002, pages 327-329] are *"Computer and Mathematical, Architecture and Engineering, Life Physical and Social Sciences Occupations, Education training and Library, Arts, Design, Entertainment, Sports and Media Occupations".*

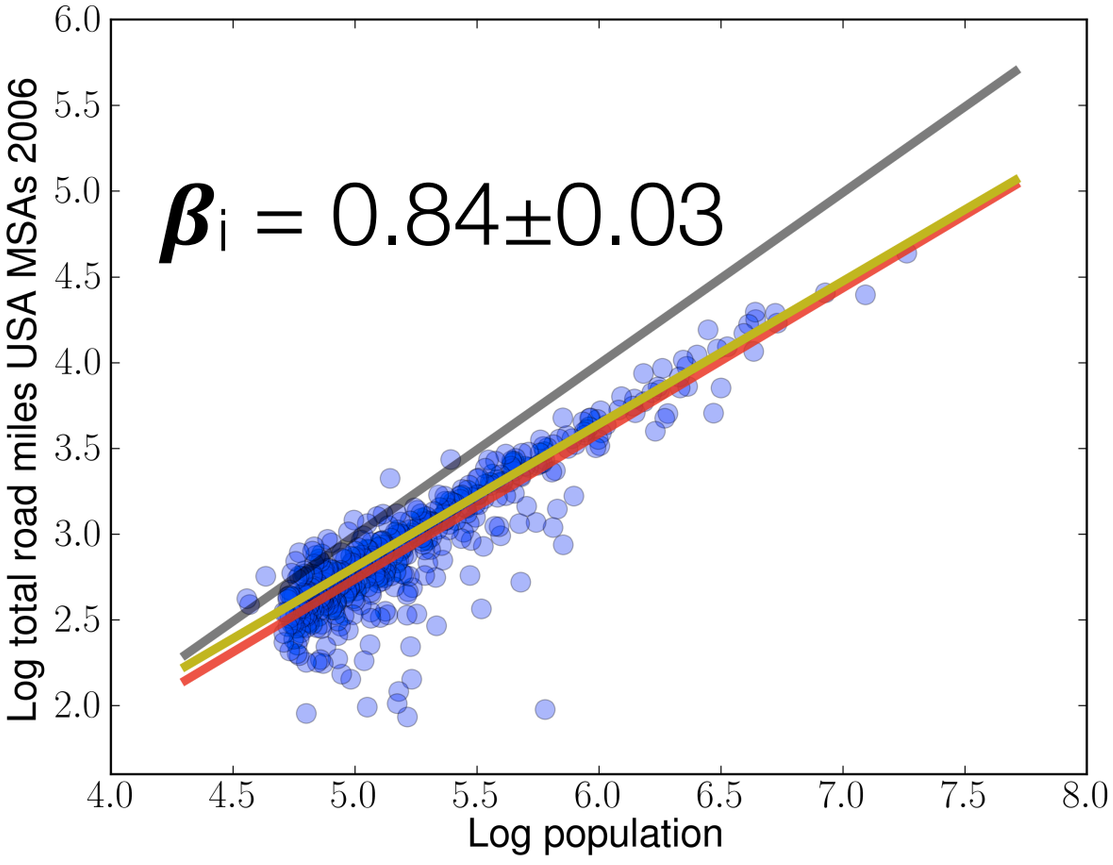

A.
GDP
Paris
London
Milan
Berlin
Naples
β=1+1/6
Average Log GDP
Average Log Total Population

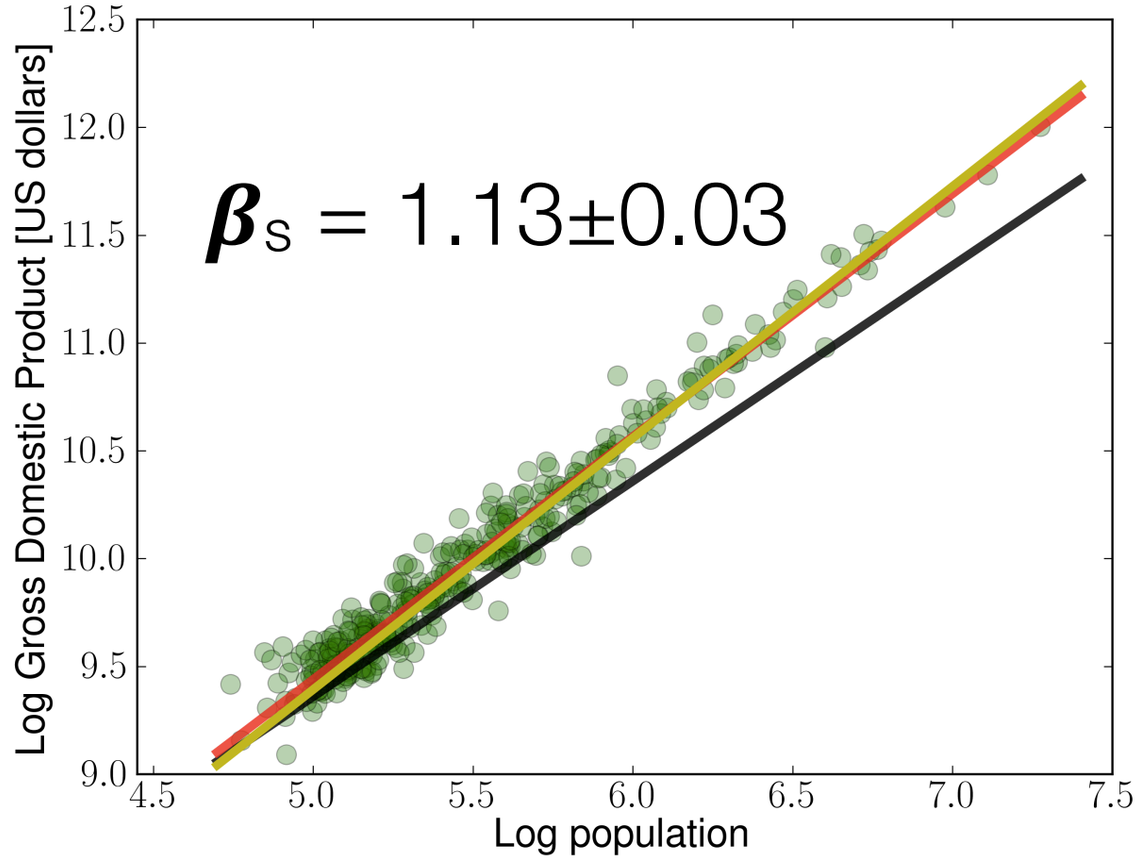

B.
Urbanized Area
Madrid
Naples
β=1-1/6
Average Log Urbanized Area
Average Log Total Population


C.
Employment
Naples
β=1
Average Log Employment
Average Log Total Population


D.
Patents
Eindhoven
Naples
Las Palmas
Bettencourt + Lobo (2015)
Urban Scaling in Europe
Average Log Patents
Average Log Total Population

Infrastructure & socioeconomic rates





Volume of Infrastructure

$$\sim N^{\beta_i}$$

$$\beta_i = 1 - \delta$$

$$\delta \simeq 0.15$$

Social Outputs

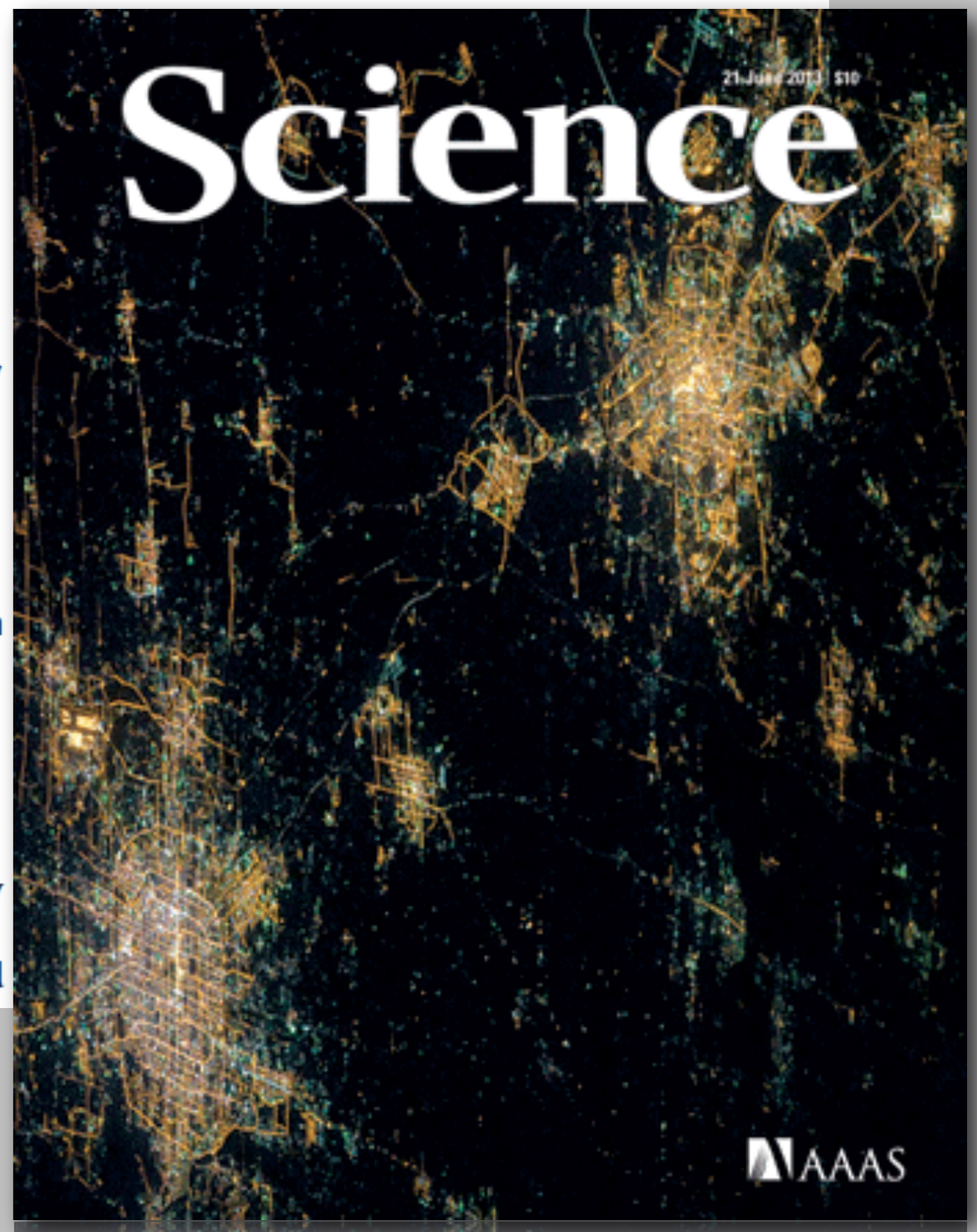
$$\sim N^{\beta_s}$$

$$\beta_s = 1 + \delta$$

The Origins of Scaling in Cities

Luís M. A. Bettencourt

Despite the increasing importance of cities in human societies, our ability to understand them scientifically and manage them in practice has remained limited. The greatest difficulties to any scientific approach to cities have resulted from their many interdependent facets, as social, economic, infrastructural, and spatial complex systems that exist in similar but changing forms over a huge range of scales. Here, I show how all cities may evolve according to a small set of basic principles that operate locally. A theoretical framework was developed to predict the average social, spatial, and infrastructural properties of cities as a set of scaling relations that apply to all urban systems. Confirmation of these predictions was observed for thousands of cities worldwide, from many urban systems at different levels of development. Measures of urban efficiency, capturing the balance between socioeconomic outputs and infrastructural costs, were shown to be independent of city size and might be a useful means to evaluate urban planning strategies.



Cities exist, in recognizable but changing forms, over an enormous range of scales (*1*), from small towns with just a few

form rather than function, which limit their ability to help us understand and plan cities.

Recently, our increasing ability to collect and

Photograph by Randy Olson

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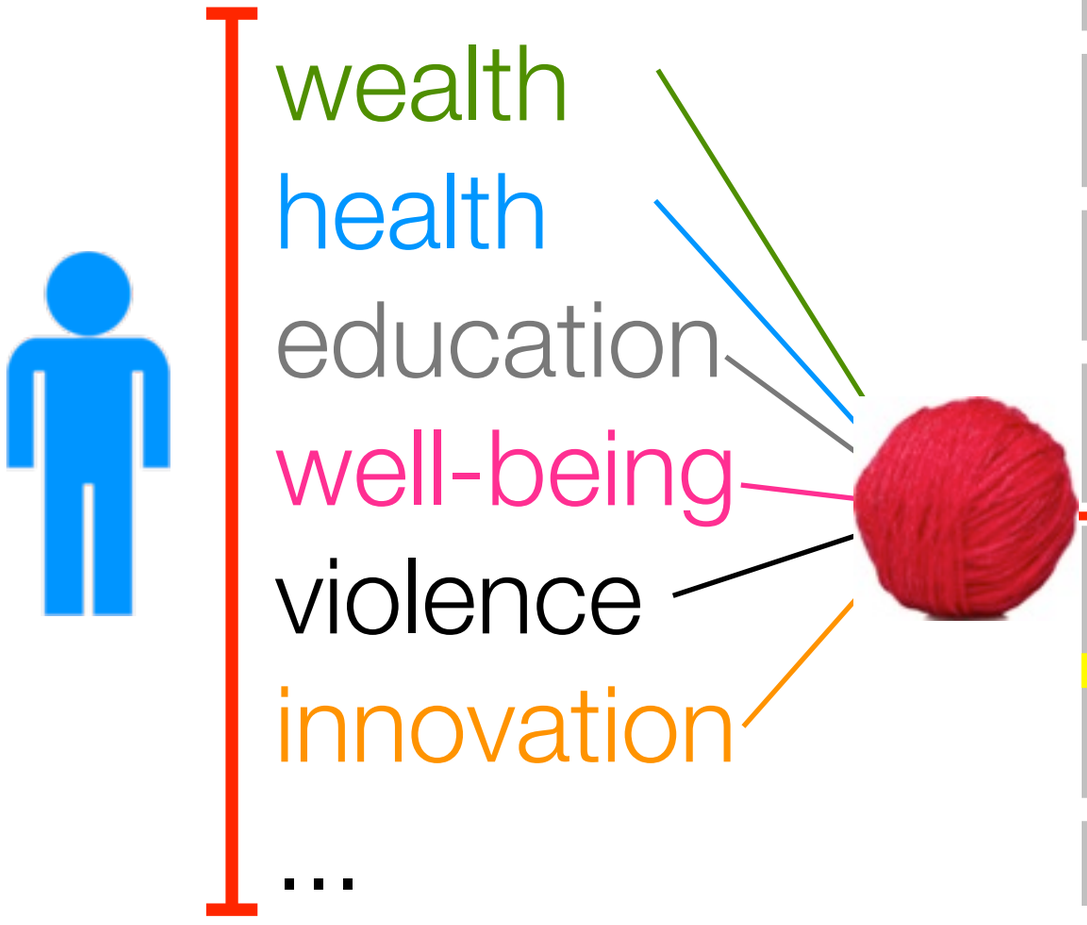
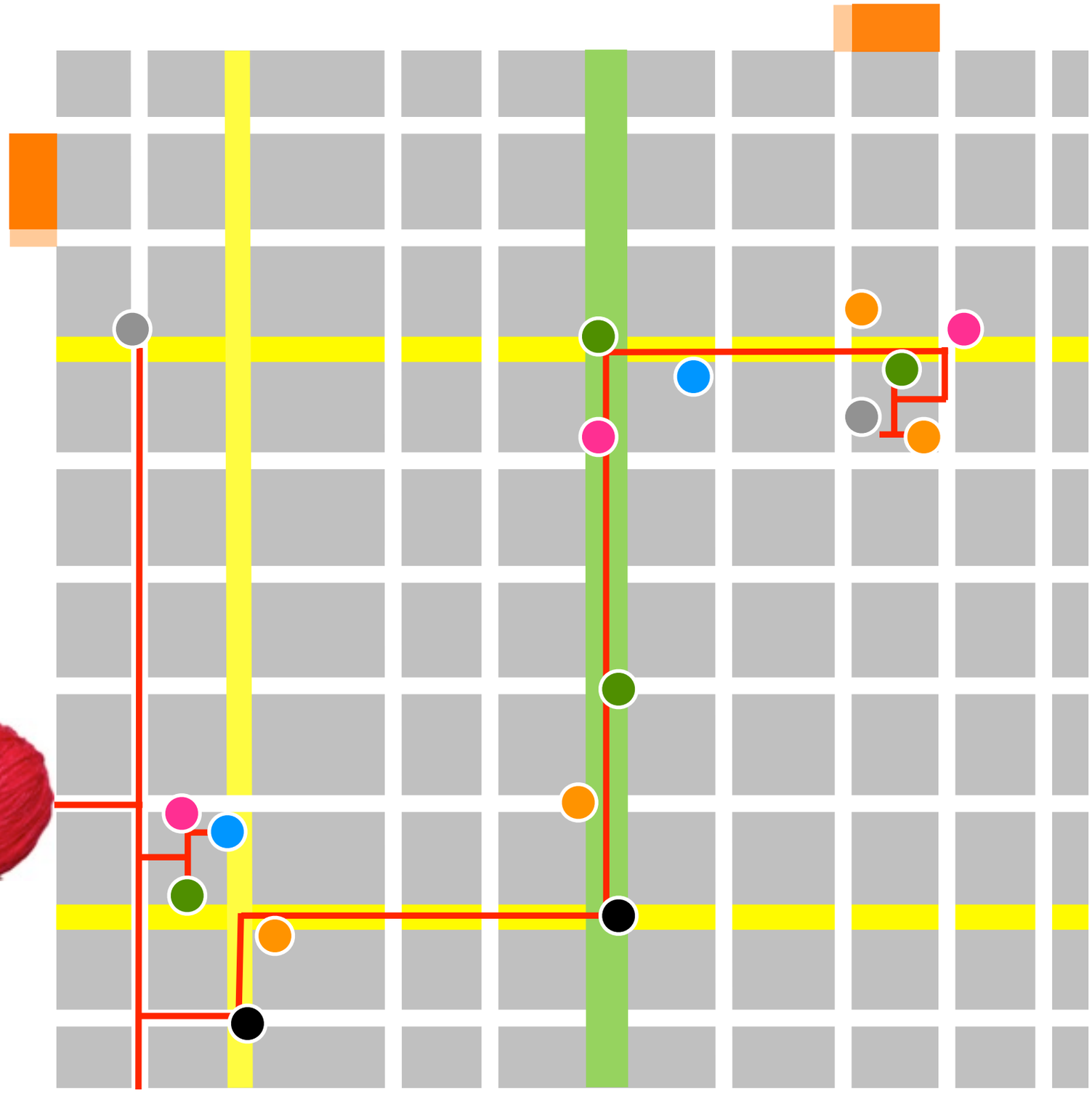
Cities are co-located social networks in space and time

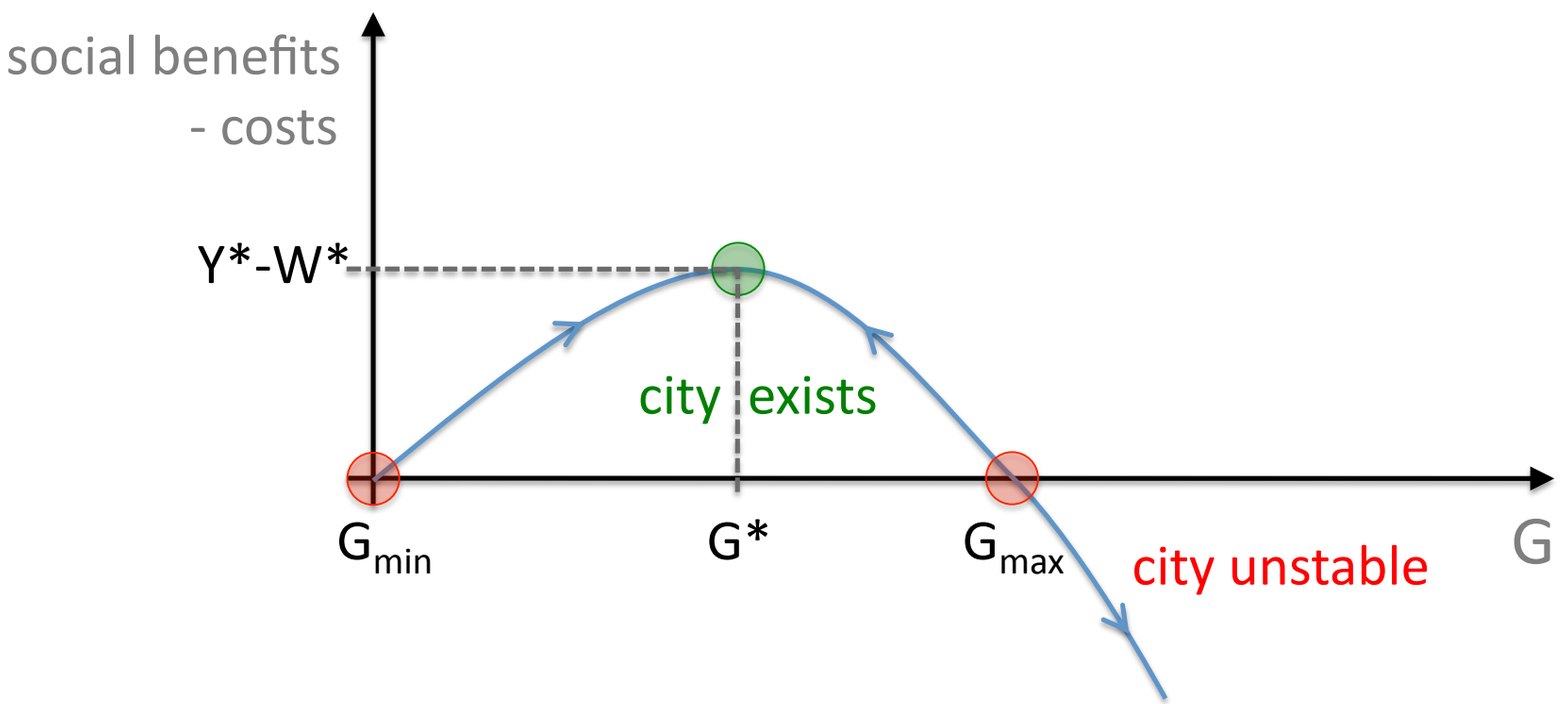
Individuals actively integrate possibilities of the urban environment





Predictions and Consequences

Urban Scaling Relations	Model (D=2,H=1)	Model (D, H)	Effect
Land area $A = aN^{\alpha}$	$\alpha = \frac{2}{3}$	$\alpha = \frac{D}{D+H}$	spatial densification
Network volume $A_n = A_{n0}N^{\nu}$	$\nu = \frac{5}{6}$	$\nu = 1 - \delta = \frac{D^2+DH-H}{D(D+H)}$	growth of infrastructure
Network length $L = L_0N^{\lambda}$	$\lambda = \frac{2}{3}$	$\lambda = \alpha$	area filling networks
Average network width $\bar{S} = \bar{S}_0N^{\bar{\sigma}}$	$\bar{\sigma} = \frac{5}{6}$	$\bar{\sigma} = 1 - \delta$	widening of roads
Interactions per capita $y = Y_0N^{\delta}$	$\delta = \frac{1}{6}$	$\delta = \frac{H}{D(D+H)}$	increased interactions
Socioeconomic rates $Y = Y_0N^{\beta}$	$\beta = \frac{7}{6}$	$\beta = 1 + \delta = \frac{D^2+DH+H}{D(D+H)}$	acceleration of social rates
Power dissipation $W = W_0N^{\omega}$	$\omega = \frac{7}{6}$	$\omega = 1 + \delta$	increased congestion
Land Value $P_L = P_0N^{\delta_L}$	$\delta_L = \frac{1}{2}$	$\delta_L = \alpha - \delta$	increased land rents

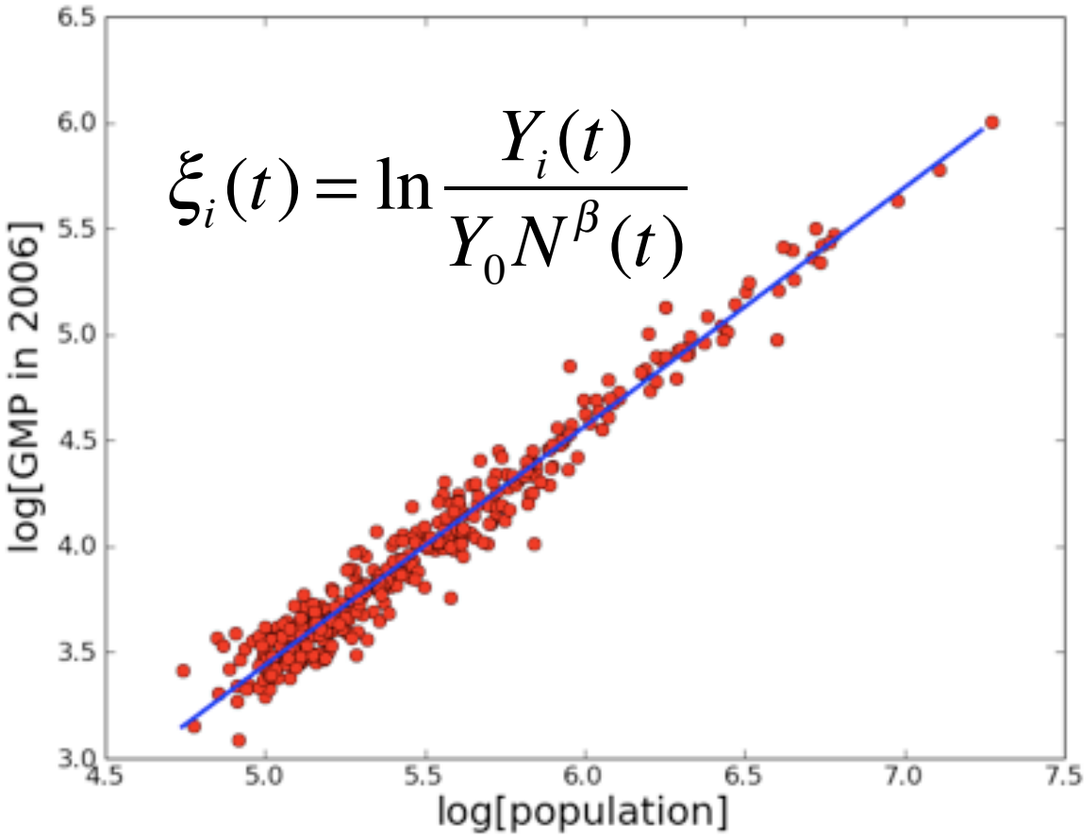


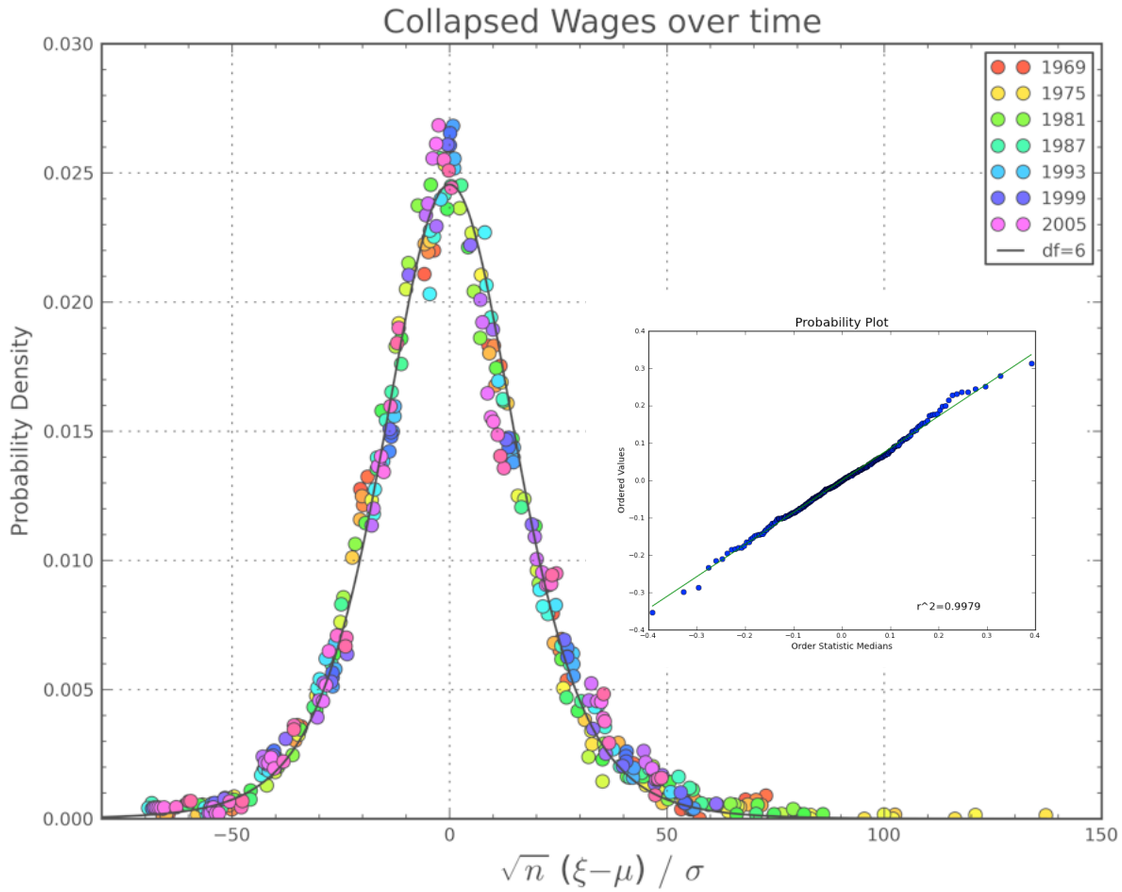
Scaling and Interdependence of Social, Economic, Infrastructural and Geographic factors

Deviations from Scaling

Scale **A**djusted **M**etropolitan **I**ndicator**s**: SAMIs

$$\xi_i(t) = \ln \frac{Y_i(t)}{Y_0 N^{\beta}(t)}$$



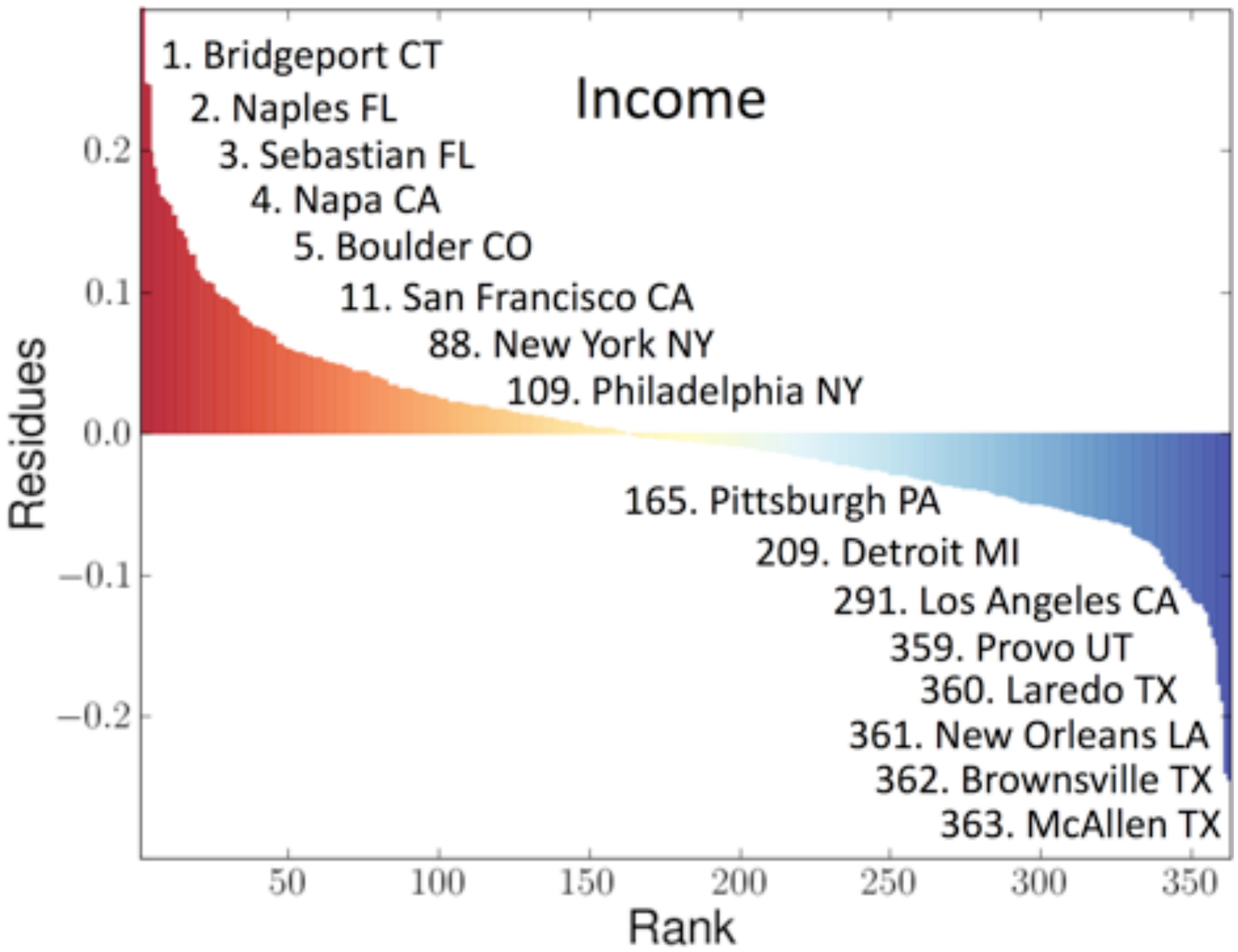


What is the structure of each city's deviation?

What is Its local flavor ...?

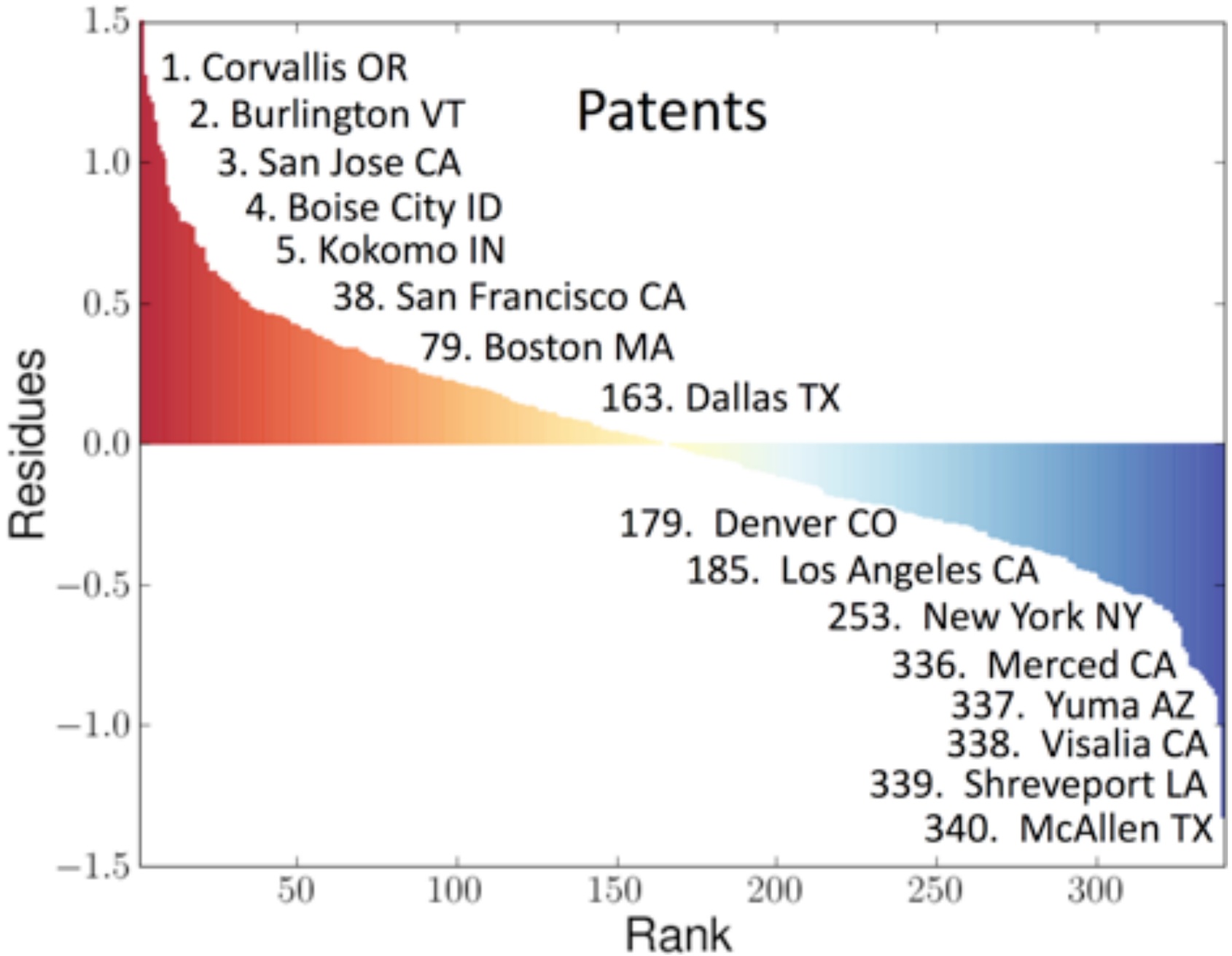
Ranking Cities

independently of their population size



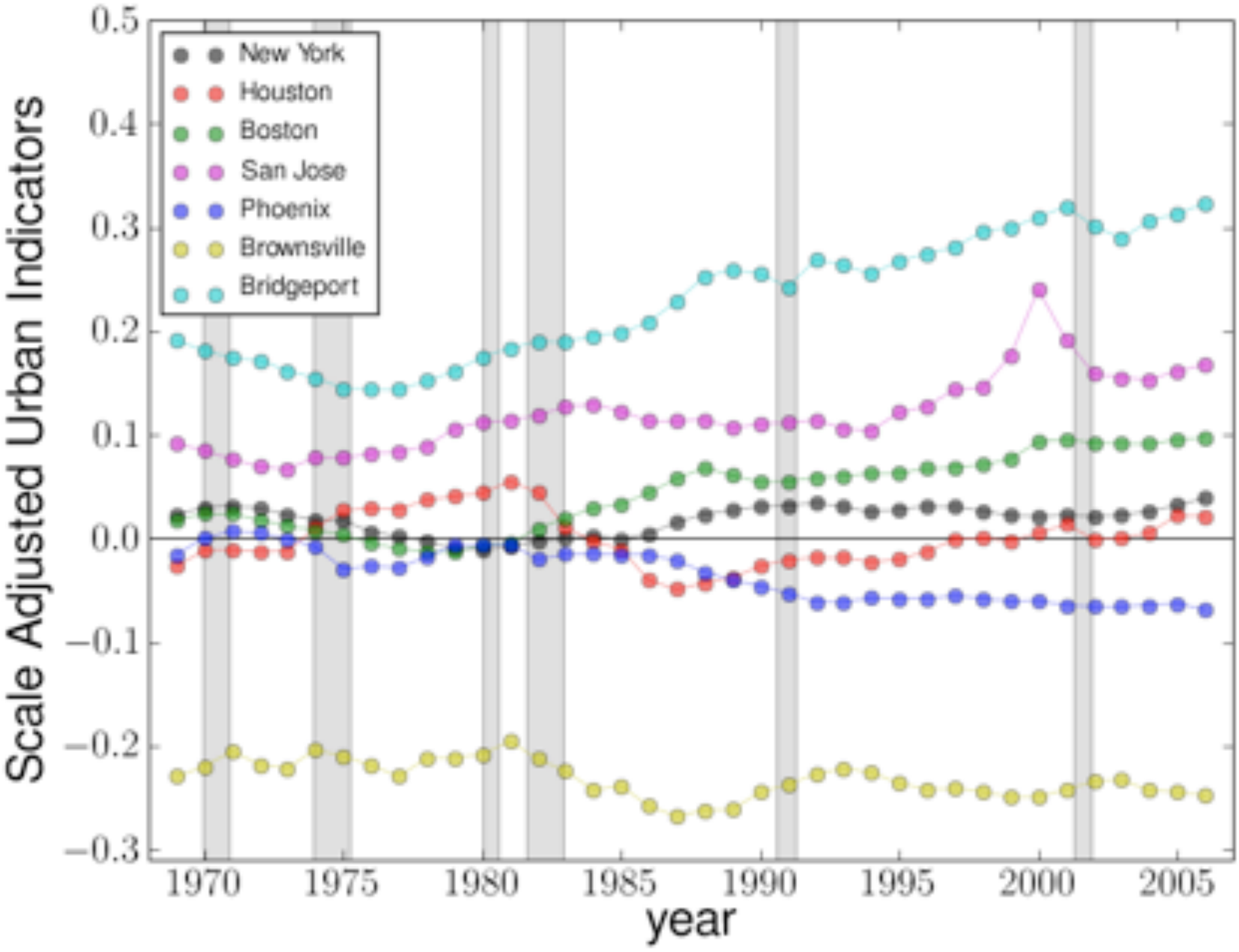
Ranking Cities

independently of their population size



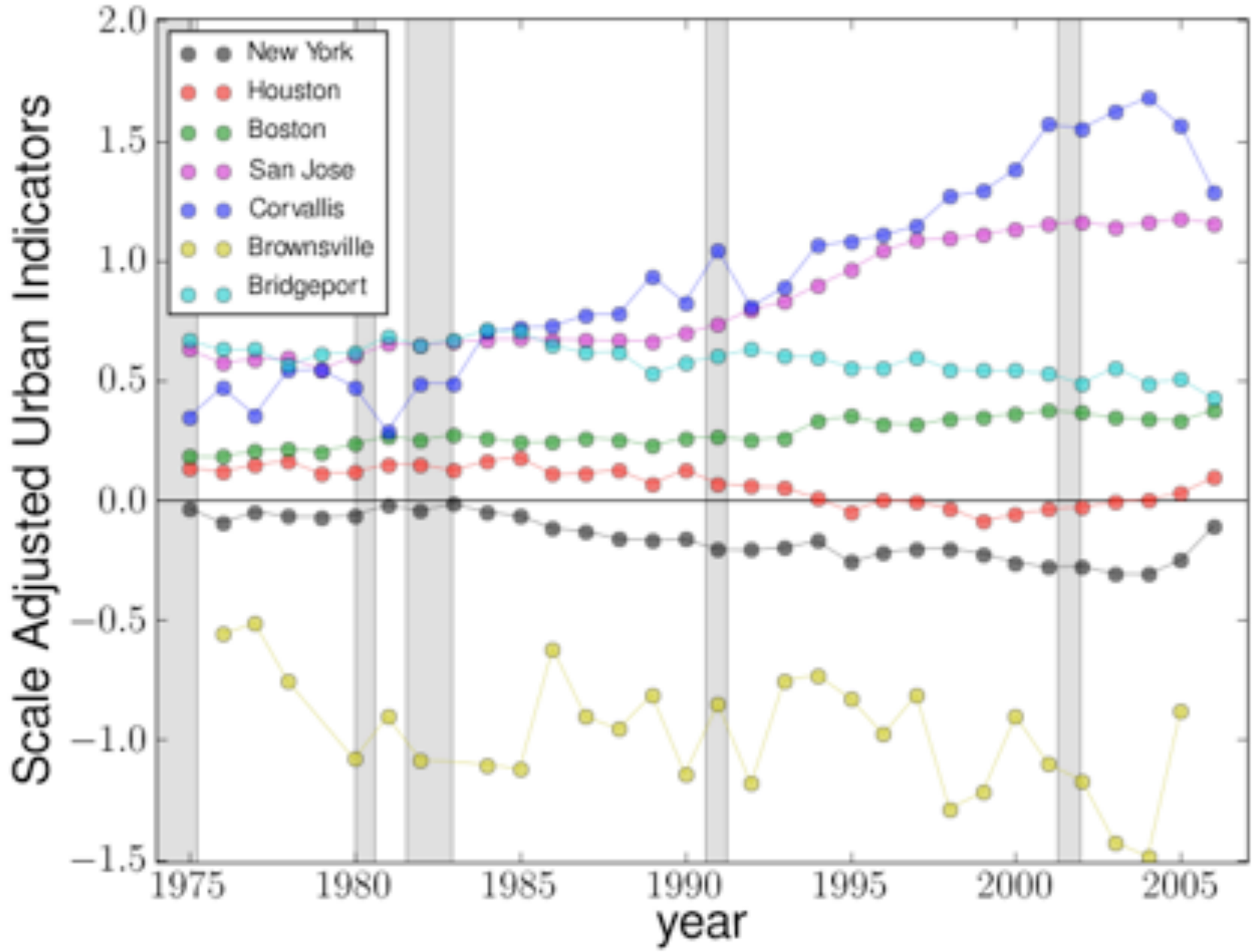
Temporal persistence

personal income



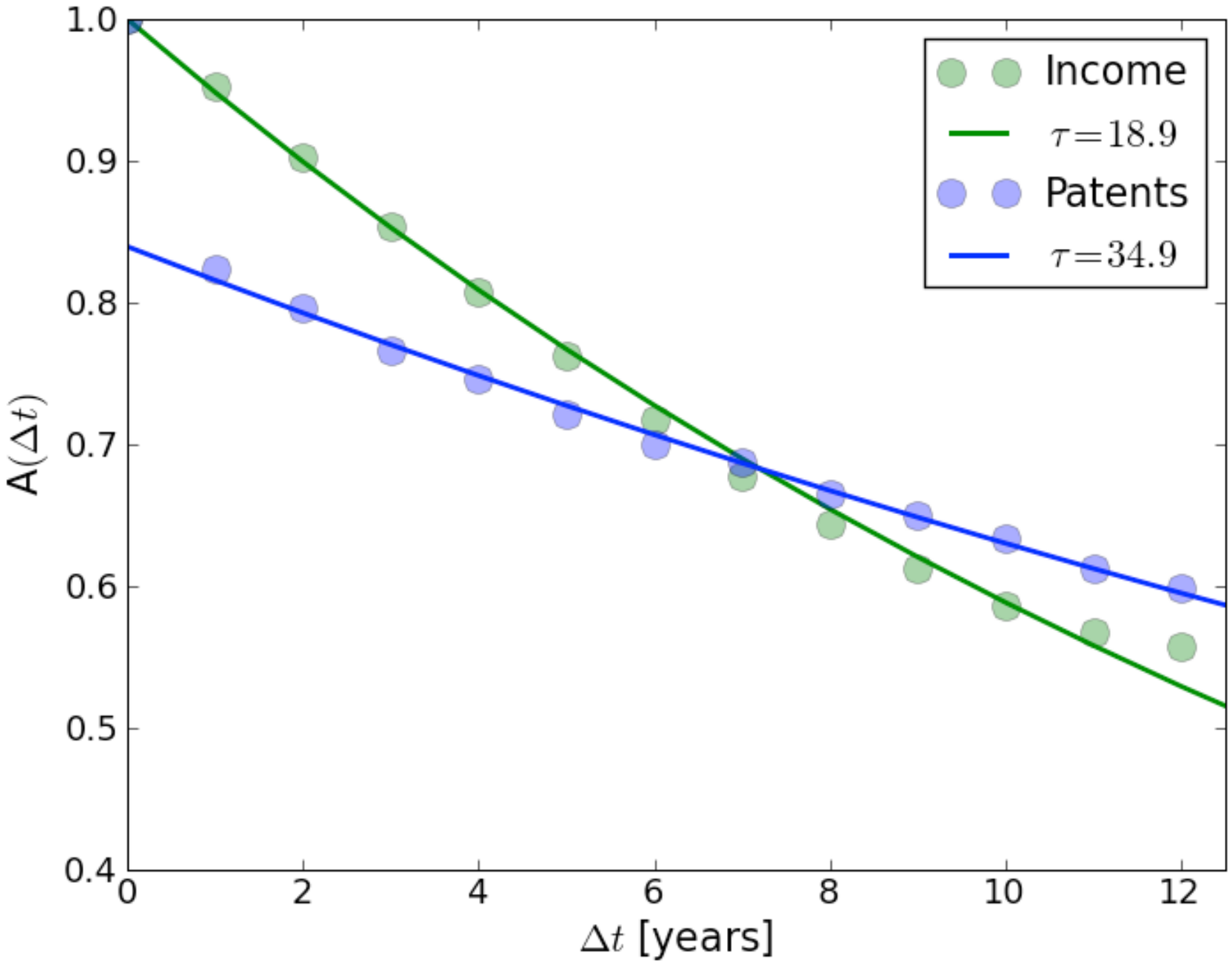
Temporal persistence

patents



Temporal persistence

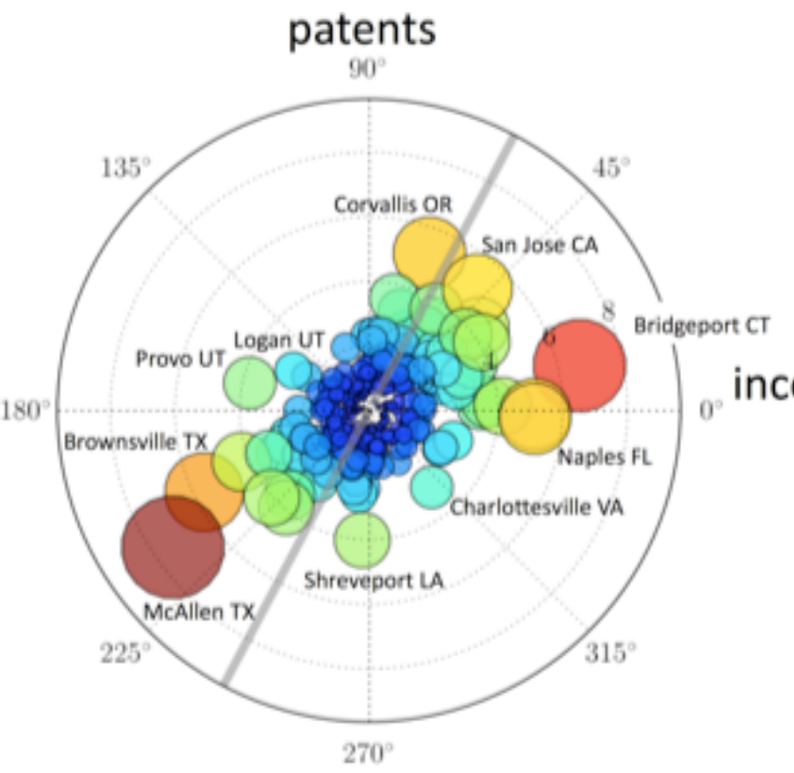
of scaling deviations

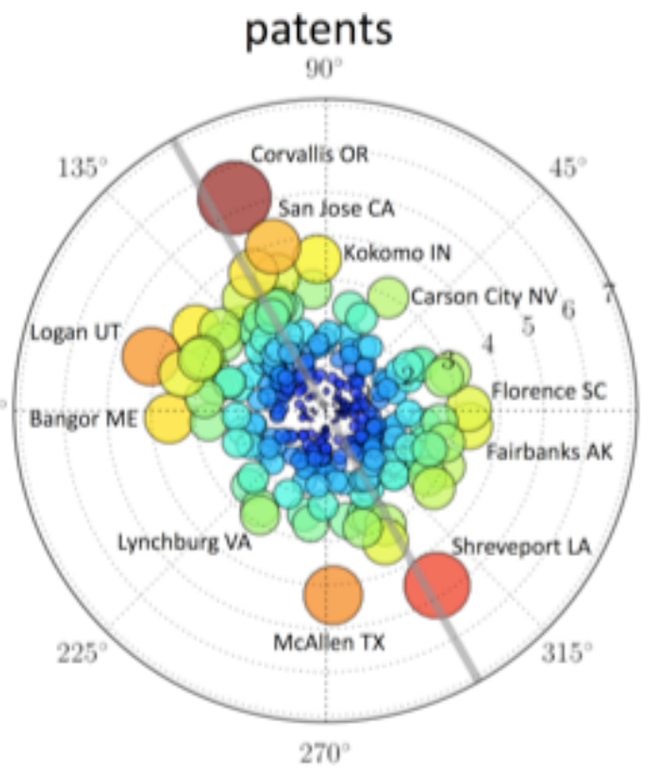


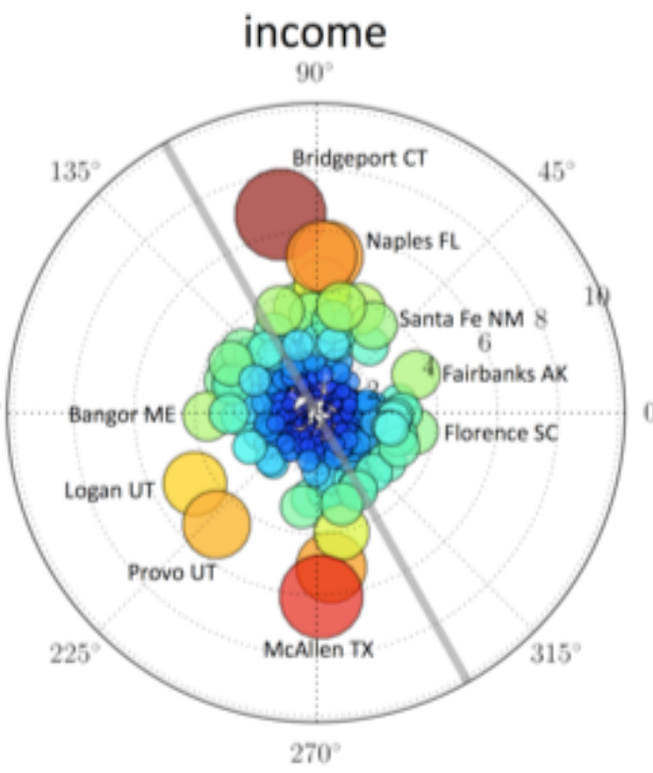
Persistence times are in the order of a few decades !

Beyond population size

are there correlations between







Population size accounts for most of the (co)-variation in these quantities.

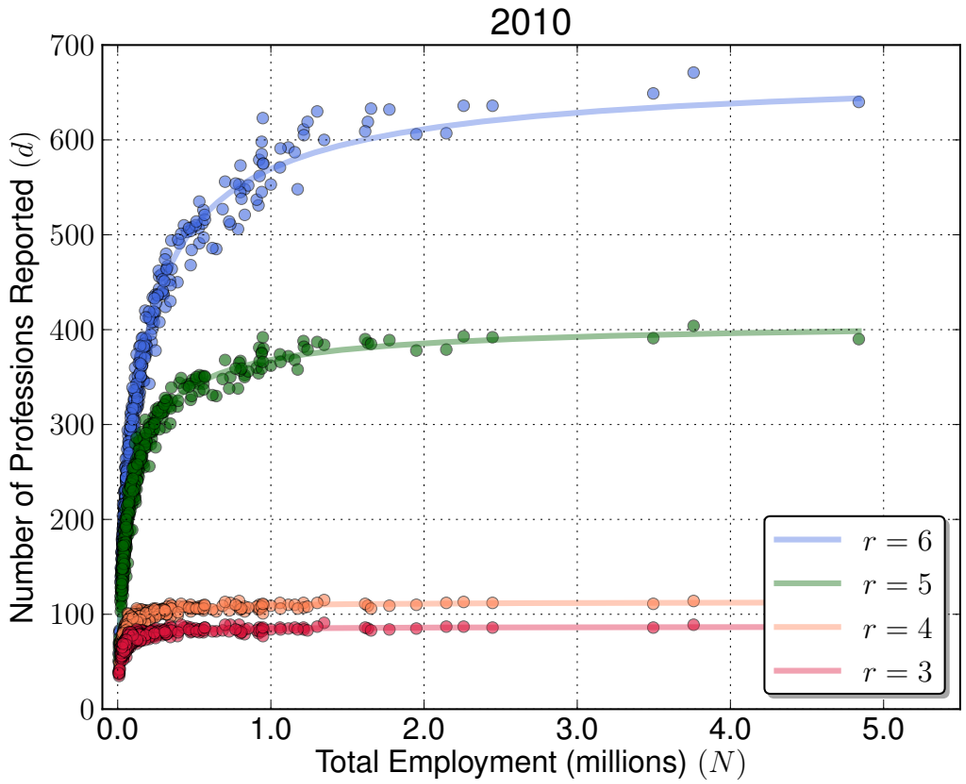
Cross correlations explain only 5-15% of the variation.

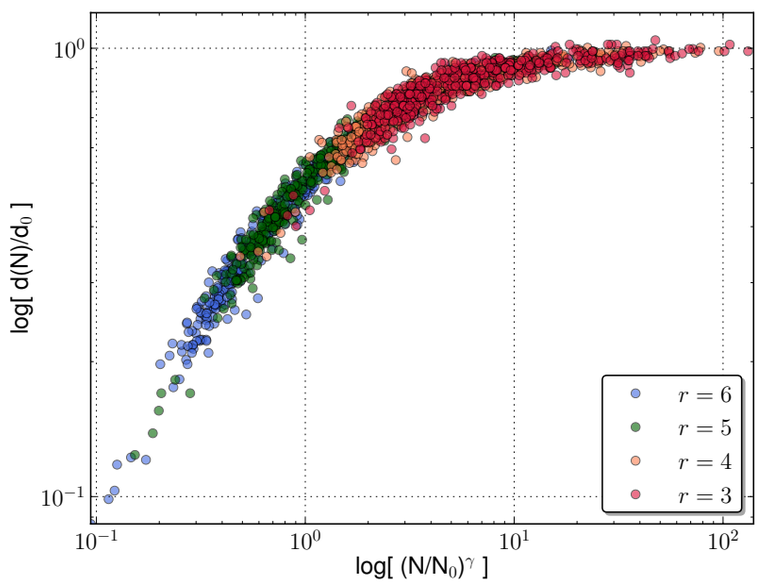
Professional Diversity and Classification Resolution

Occupations in US Metropolitan Statistical Areas

A good fit at all resolutions:

$$D(N_e) = d_0 \frac{\left(\frac{N_e}{N_0}\right)^{\gamma}}{1 + \left(\frac{N_e}{N_0}\right)^{\gamma}}.$$





The limit of infinite resolution

$$D(N) = d_0 h \left(\frac{N}{N_0}\right) \left(\frac{N}{N_0}\right)^{\gamma} \rightarrow \begin{cases} D_0 N^{\gamma}, & N << N_0, \\ d_0(r), & N >> N_0, \end{cases}$$

In the limit:

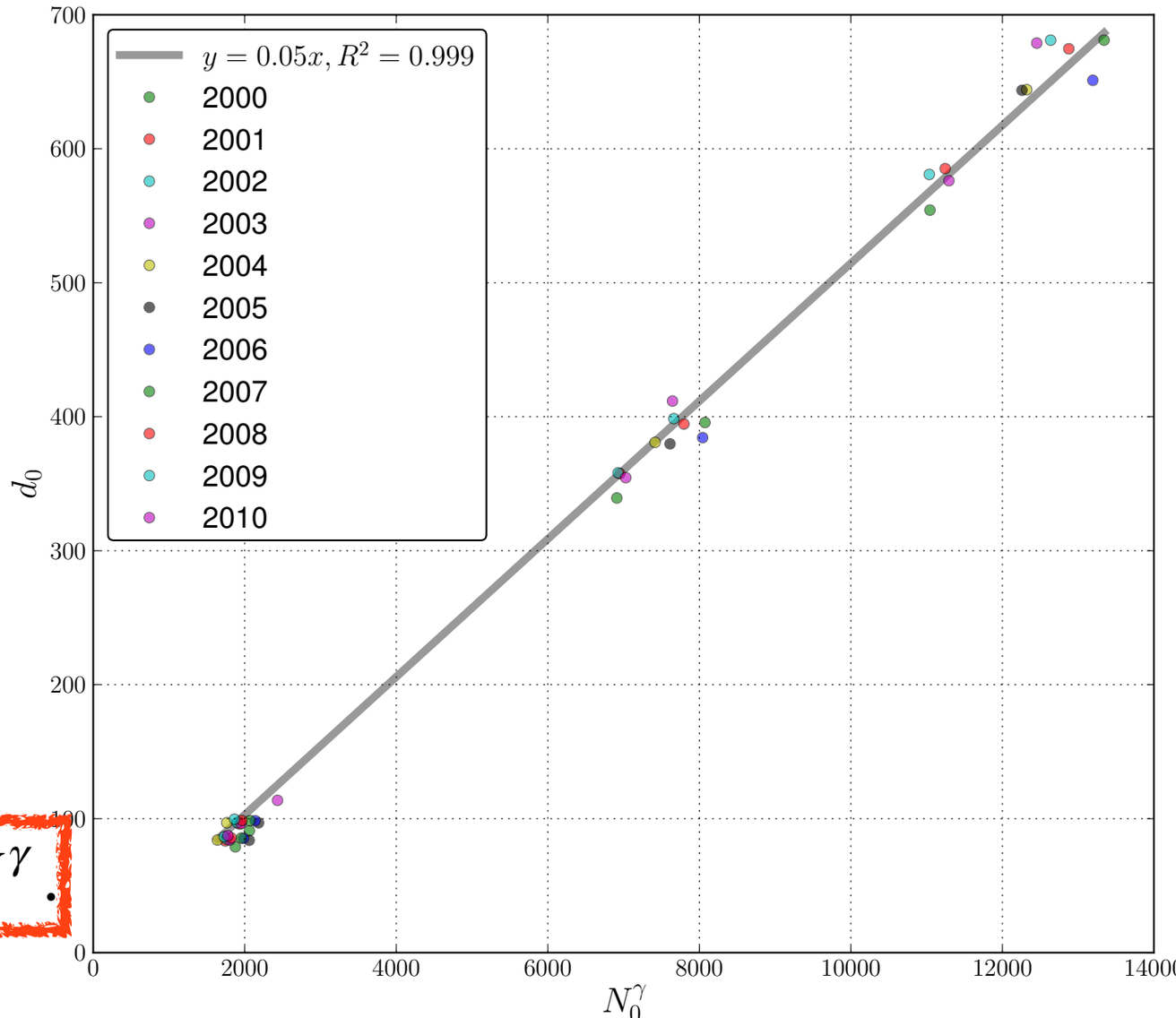
$$\frac{N}{N_0} \rightarrow 0; \qquad h \rightarrow 1, \qquad D_0 \rightarrow \frac{d_0}{N_0{}^{\gamma}}$$

In the limit:

$$\frac{N}{N_0} \rightarrow +\infty; \qquad h \rightarrow \left(\frac{N_0}{N}\right)^{\gamma},$$

A scaling limit exists iff:

$$D_0 \rightarrow \frac{d_0}{N_0{}^{\gamma}} = const. \quad \text{with} \quad \boxed{D(N) = D_0 N^{\gamma}}.$$



The rank size distribution of professions

From D(N), for all N, derive frequency distribution

$$f(i) = \frac{N_e}{N_0}\left(\frac{d_0 - i}{i}\right)^{1/\gamma}.$$

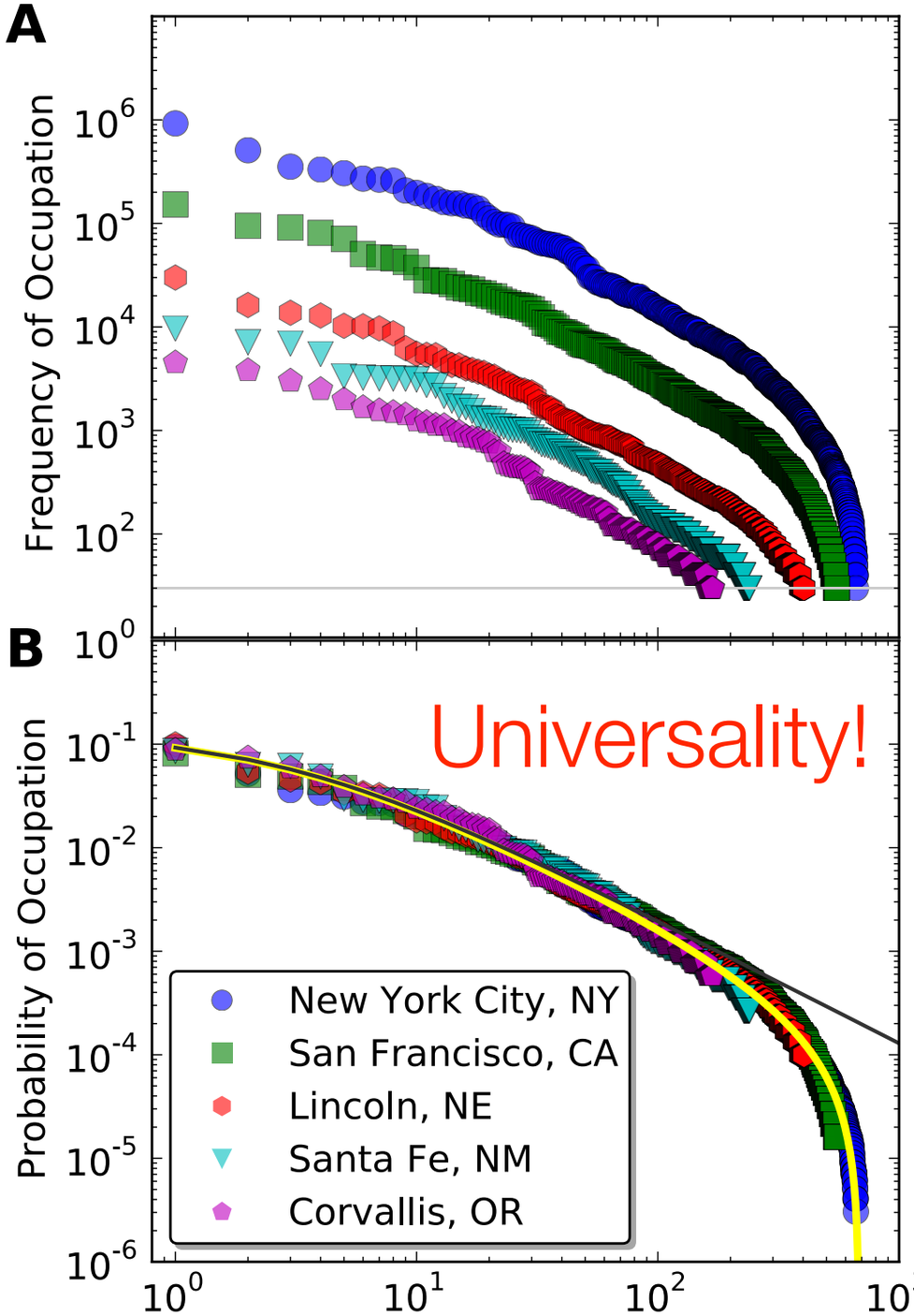
$$p(i) = \frac{f(i)}{\sum_{j=1}^{D(N)} f(j)} = \frac{1-\gamma}{\gamma}\frac{i^{-1/\gamma}}{1 - D(N)^{-\frac{1-\gamma}{\gamma}}};$$

Indices of Diversity:

$$HH(N) = \sum_{i=1}^{D(N)} p^2(i) = \frac{\delta^2}{1-\delta^2}\frac{1 - D_0^{-\frac{1+\delta}{1-\delta}} N^{-1-\delta}}{(1 - D_0^{\frac{\delta}{1-\delta}} N^{-\delta})^2}$$

$$\simeq \frac{\delta^2}{1-\delta^2}\left(1 + \frac{2}{D_0^{\frac{\delta}{1-\delta}} N^{\delta}}\right).$$

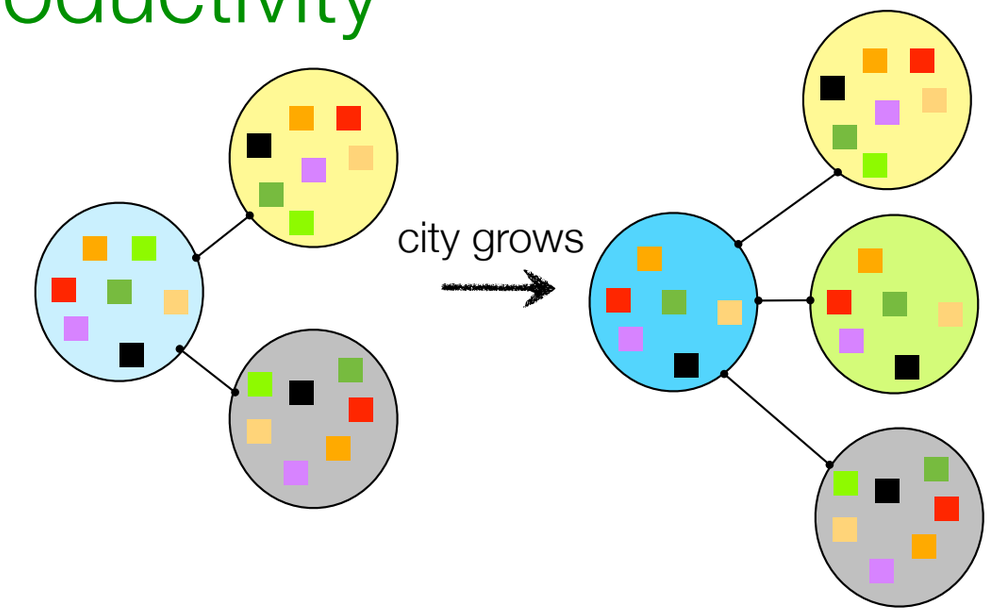
$$S = -\sum_{i=1}^{D(N)} p(i)\ln p(i) \simeq \frac{1}{\delta} - D_0^{-\delta/(1-\delta)} N^{-\delta} \ln(D_0^{1/\gamma} N)$$



Professional Diversity and Urban Productivity

Specialization and Division of Labor

as sources of increases in urban productivity



$$\mathcal{L}(d;\lambda) = \frac{g(kd)}{d} - \lambda\left(kd - A\right).$$

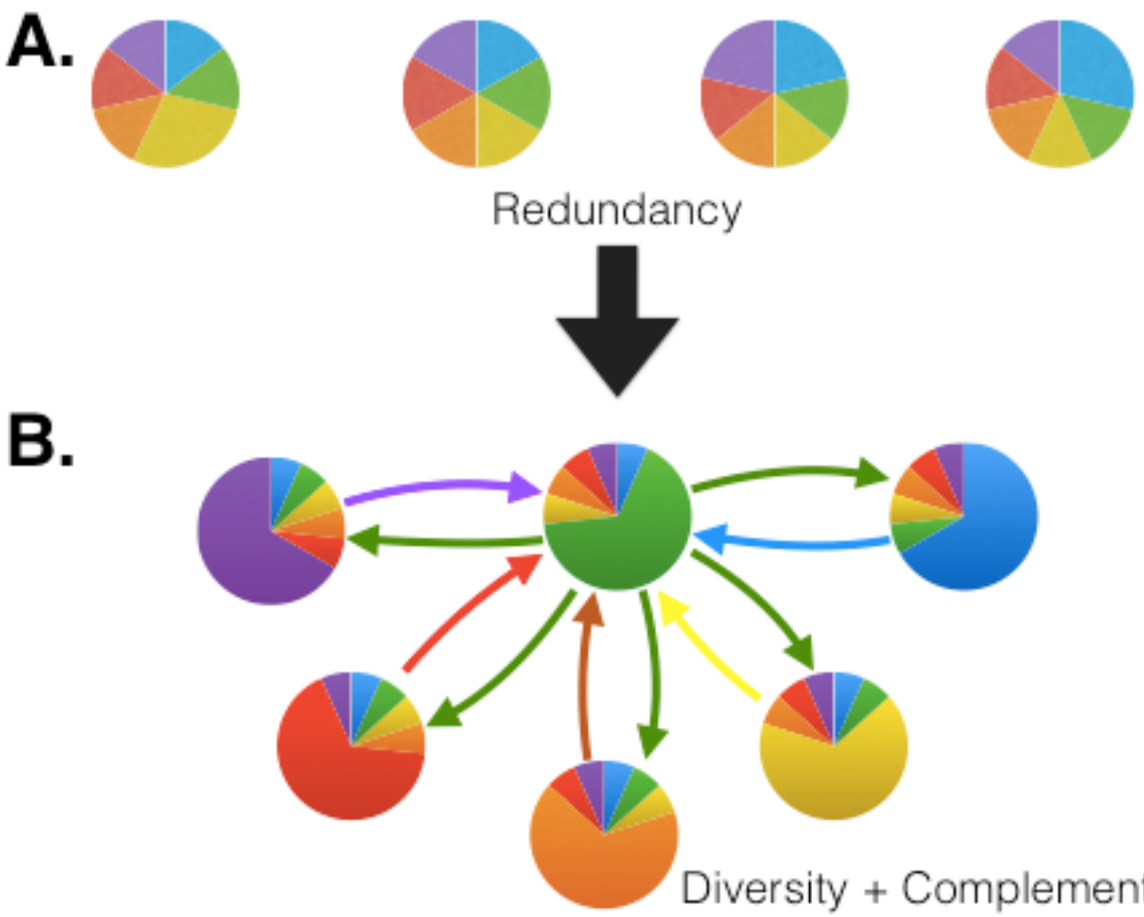
$$d = \frac{A}{k} = \frac{A}{k_0}\frac{1}{N^{\delta}}, \qquad w = \frac{g(A)}{A}k = \frac{g(A)}{A}k_0 N^{\delta},$$

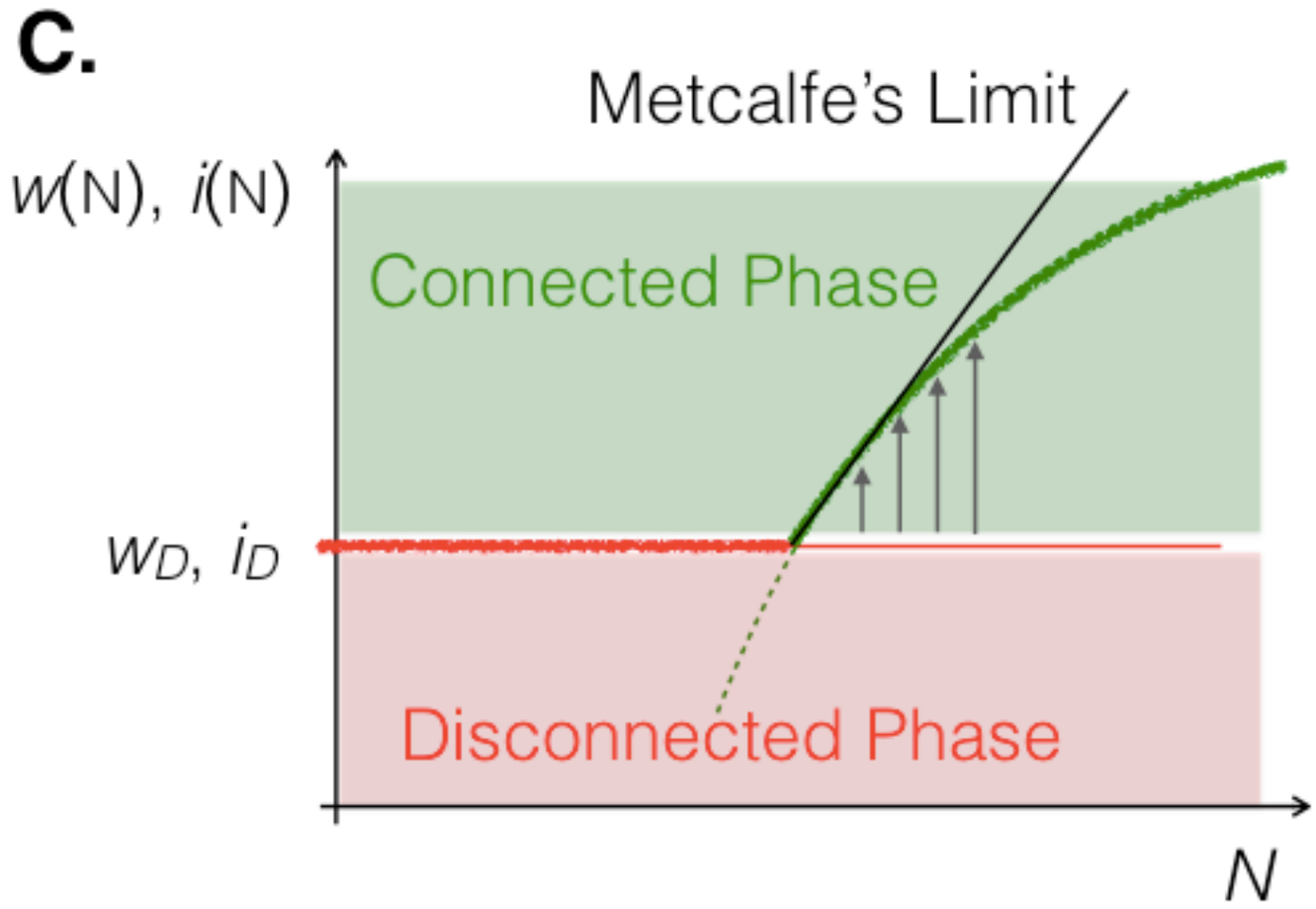
$$\frac{dg}{dA} - \frac{g}{A} - \lambda_1 A = 0 \rightarrow g(A) = \left[C + \int^{A} dA'\lambda_1(A')\right]A,$$

$D_0 = \frac{A}{k_0}$ =0.05

Bettencourt, Samaniego, Youn, 2013

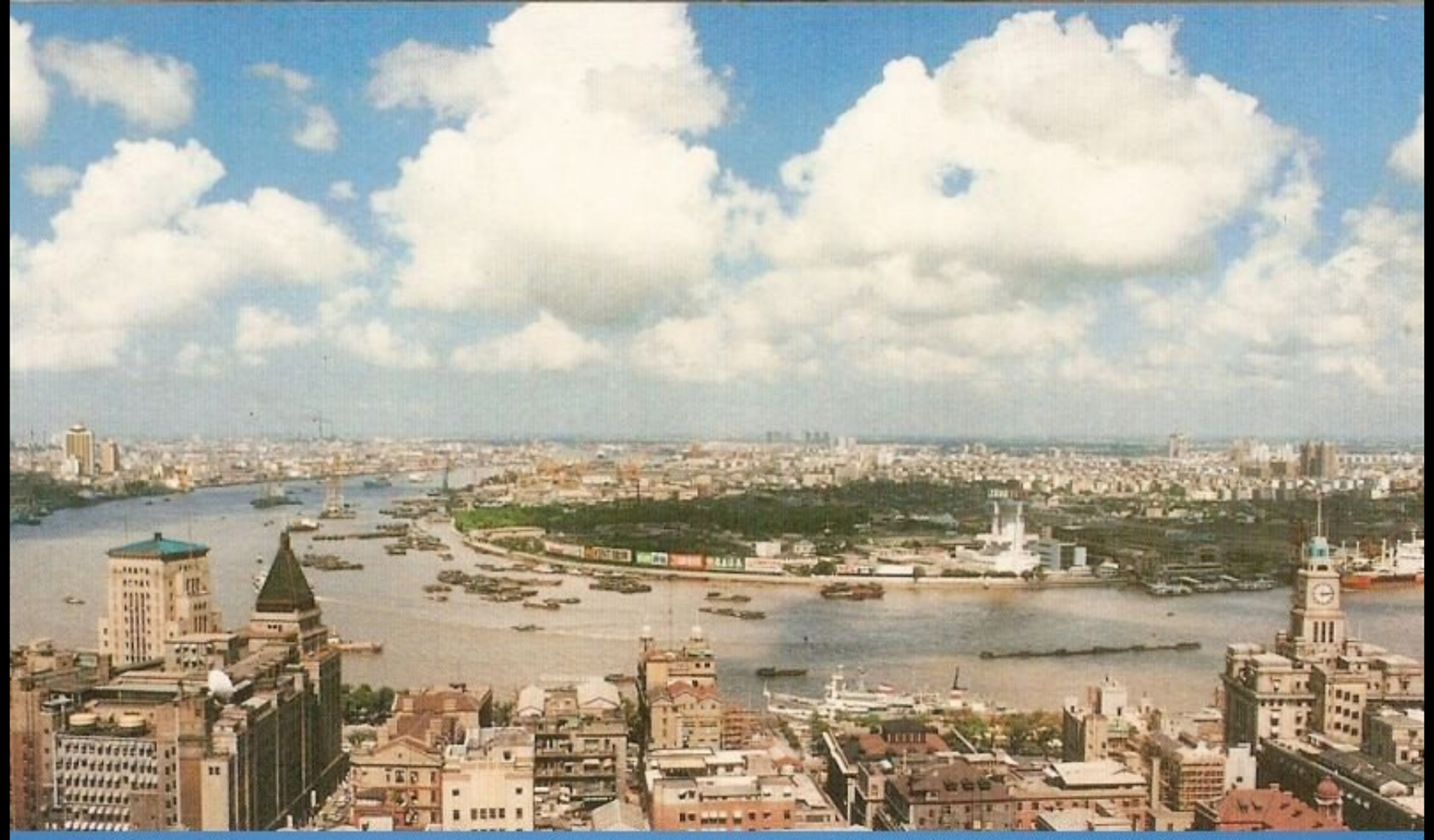
Information, Connectivity & Productivity Growth





Bettencourt 2014
The role of "technology" in social networks

1987



Shanghai

credit: telegraph/reuters/jesus diaz

2012