Lecture 14

The Structure of the Urban Systems and the Laws of Geography

14.1 The Laws of Geography

IUS 8.1

Empirical “Laws” in Urban Systems

https://blackmarble.gsfc.nasa.gov

credit: NASA

The Laws of (Urban) Geography

1. Central Place Theory & Urban Hierarchy

2. Tobler’s Two Laws

3. The Gravity Law for Flows

4. Gibrat’s Law of Proportional Growth

5. Zipf’s Law for the Size Distribution of Cities

The "Quantitative Revolution" in Geography

Quantitative revolution

From Wikipedia, the free encyclopedia

The **quantitative revolution** (**QR**)[n] was a paradigm shift that sought to develop a more rigorous and systematic methodology for the discipline of geography. It came as a response to the inadequacy of regional geography to explain general spatial dynamics. The main claim for the quantitative revolution is that it led to a shift from a descriptive (idiographic) geography to an empirical law-making (nomothetic) geography. The quantitative revolution occurred during the 1950s and 1960s and marked a rapid change in the method behind geographical research, from regional geography into a spatial science.[1][2]

In the history of geography, the quantitative revolution was one of the four major turning-points of modern geography – the other three being environmental determinism, regional geography and critical geography).

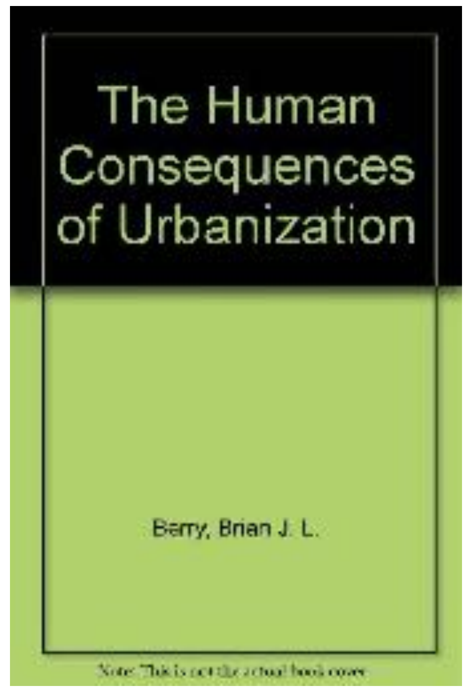
The quantitative revolution had occurred earlier in economics and psychology and contemporaneously in political science and other social sciences and to a lesser extent in history.

Brian J. L. Berry

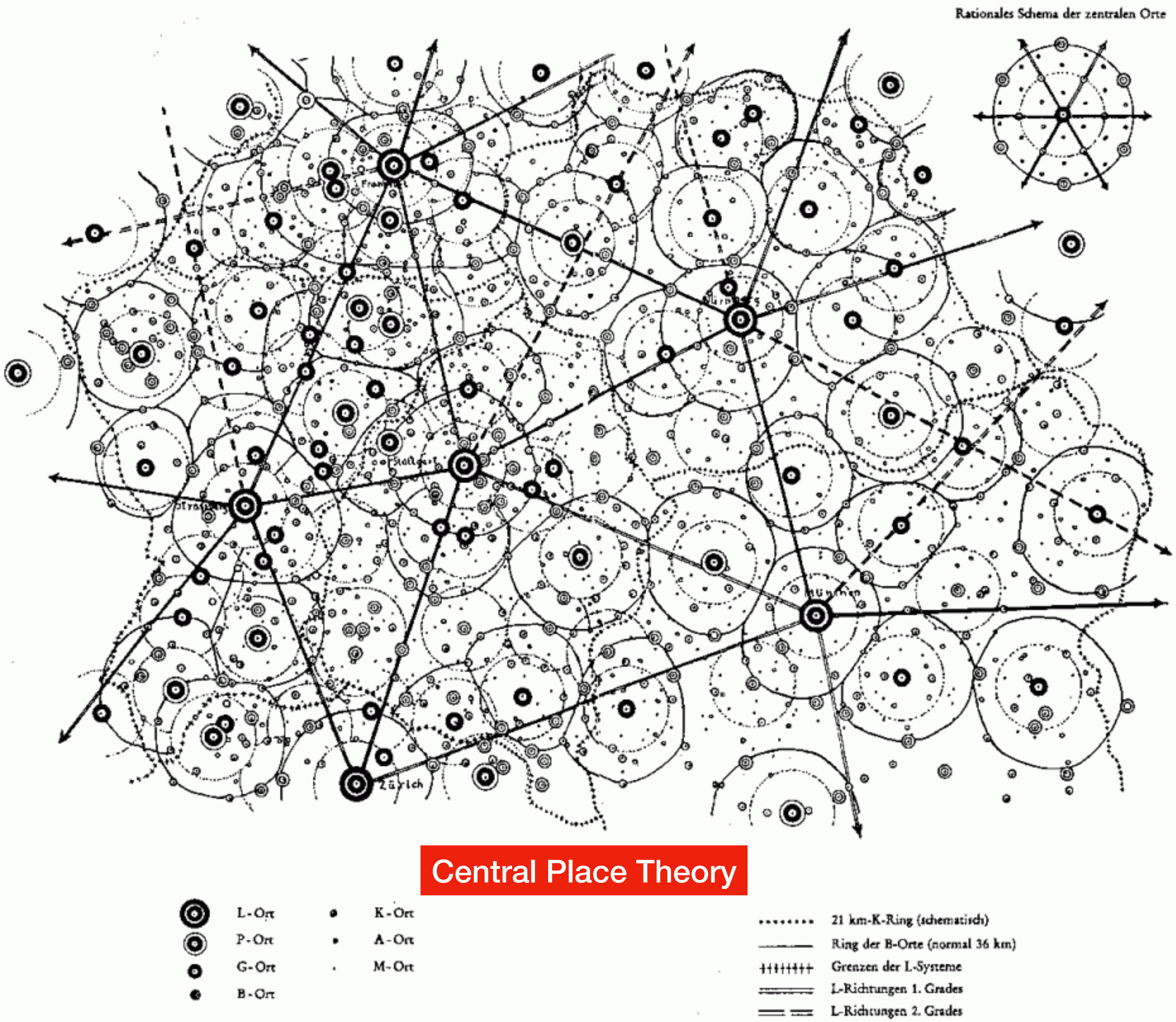
The changes introduced during the 1950s and 1960s under the banner of bringing 'scientific thinking' to geography led to an increased use of technique-based practices, including an array of mathematical techniques and computerized statistics that improved precision, and theory-based practices to conceptualize location and space in geographical research.[9]

Some of the techniques that epitomize the quantitative revolution include:[1]

- Descriptive statistics;
- Inferential statistics;
- Basic mathematical equations and models, such as gravity model of social physics, or the Coulomb equation;
- Stochastic models using concepts of probability, such as spatial diffusion processes;
- Deterministic models, e.g. Von Thünen's and Weber's location models.



This gave you GIS and all the spatial apps on your phone



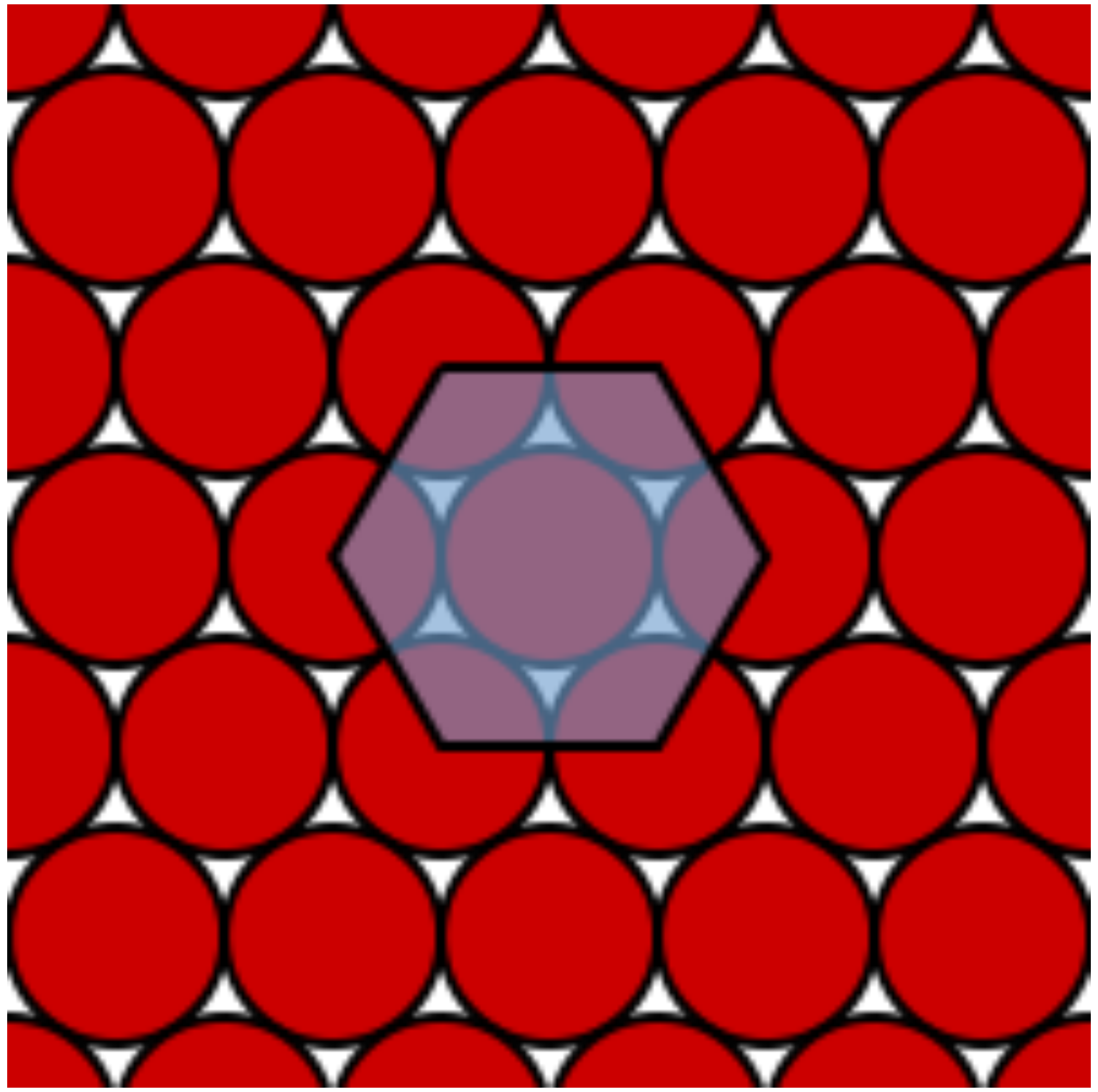
Central Place Theory

Karte 4
Das System der zentralen Orte in Süddeutschland

Walter Christaller 1933

Central Place Theory

an unbounded, homogeneous, limitless plane
an evenly distributed population
all settlements are equidistant



Kepler, Lagrange, Gauss…

Central Place Theory

hypotheses/principles

1. The larger the settlements are in size, the fewer in number they will be, i.e. there are many small villages, but few large cities.

   Zipf's law

2. The larger the settlements grow in size, the greater the distance between them, i.e. villages are usually found close together, while cities are spaced much further apart.

   Urban Hierarchy

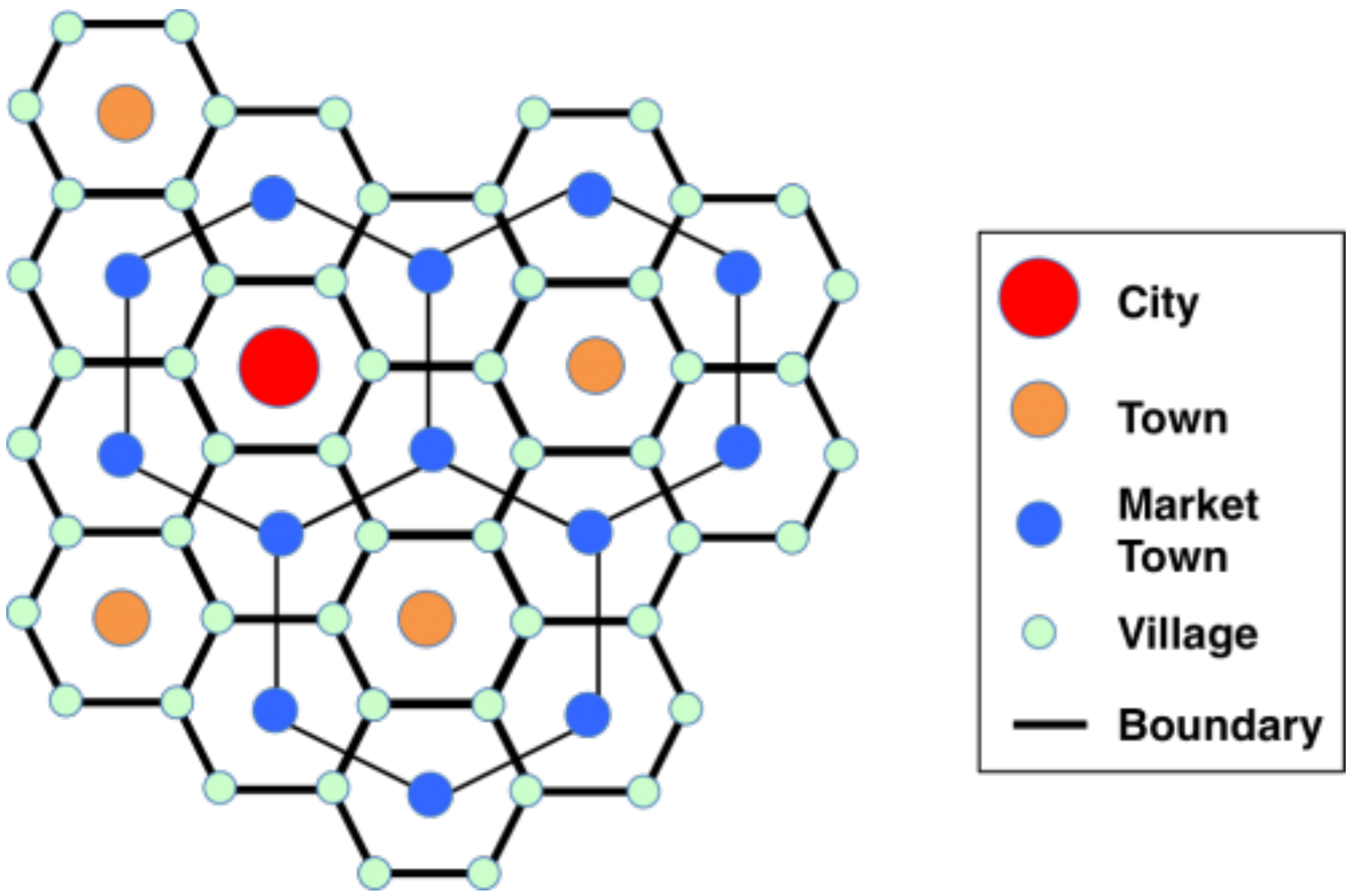
3. A settlement increases in size, the range and number of its functions will increase.

   Division of Labor

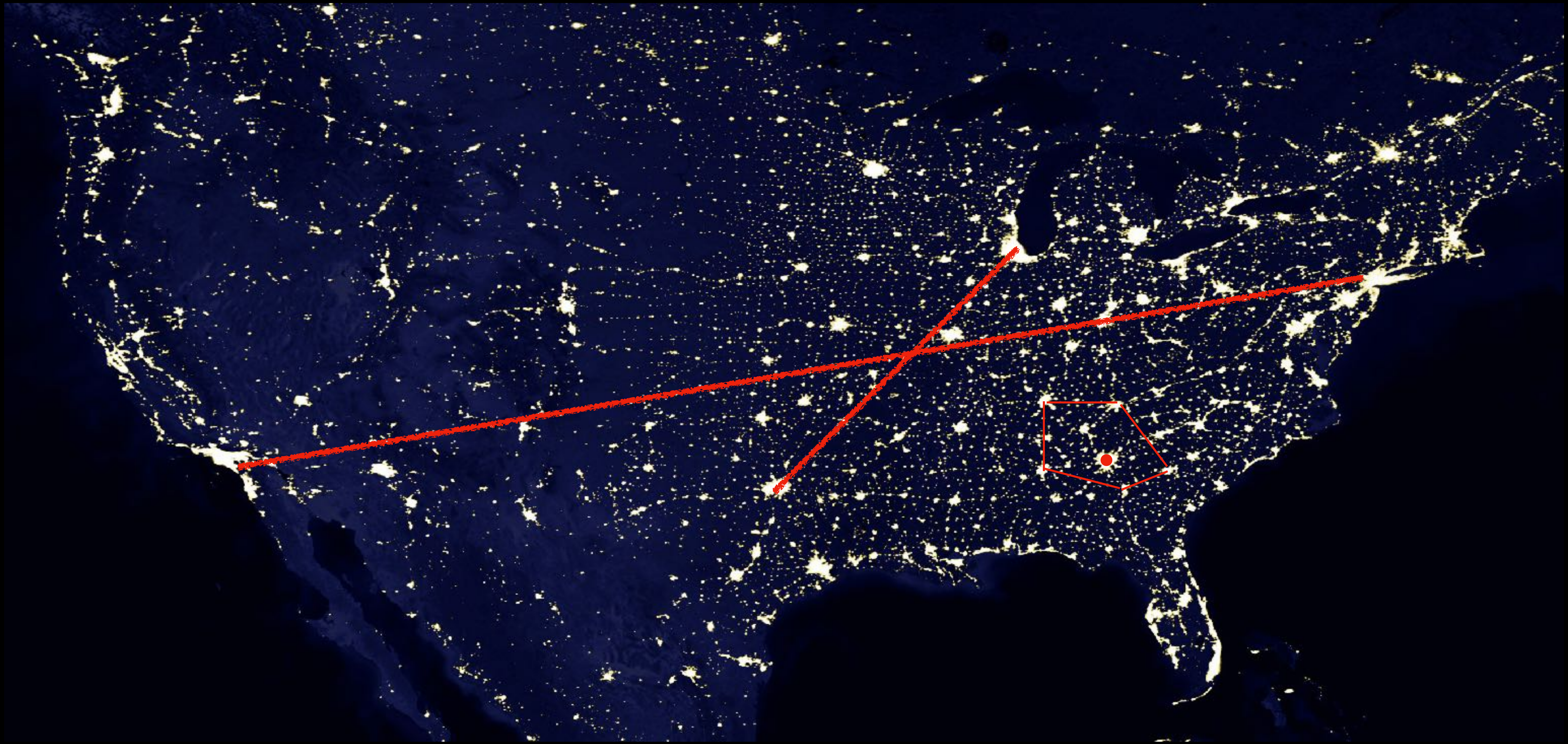
4. As a settlement increases in size, the number of higher-order services will also increase, i.e. a greater degree of specialization occurs in the services.

   Specialization, Innovation

Spatial Arrangement of Urban Hierarchy



Nested Hexagonal Lattices of Larger and Larger Cities.



credit: NASA

The Nature of Cities

By Chauncy D. Harris and Edward L. Ullman

university of chicago

CITIES are the focal points in the occupation and utilization of the earth by man. Both a product of and an influence on surrounding regions, they develop in definite patterns in response to economic and social needs.

Cities are also paradoxes. Their rapid growth and large size testify to their superiority as a technique for the exploitation of the earth, yet by their very success and consequent large size they often provide a poor local environment for man. The problem is to build the future city in such a manner that the advantages of urban concentration can be preserved for the benefit of man and the disadvantages minimized.

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Central Places

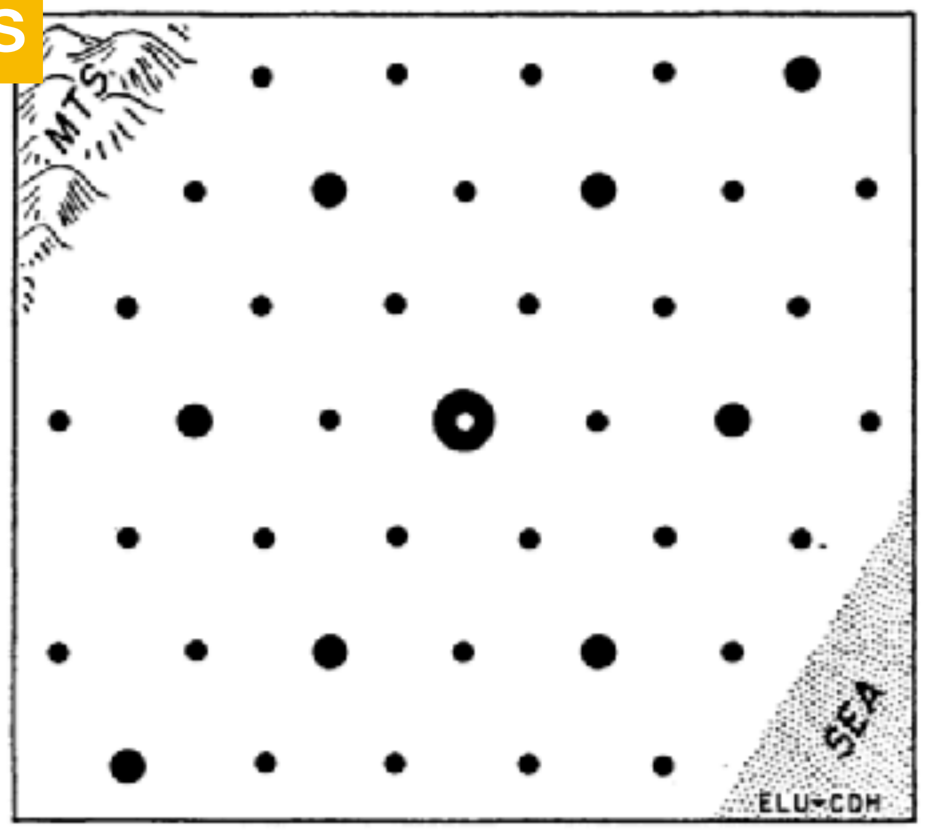

Fig. 1.—Theoretical distribution of central places. In a homogeneous land, settlements are evenly spaced; largest city in center surrounded by 6 medium-size centers which in turn are surrounded by 6 small centers. Tributary areas are hexagons, the closest geometrical shapes to circles which completely fill area with no unserved spaces.

Transport Centers+Routes

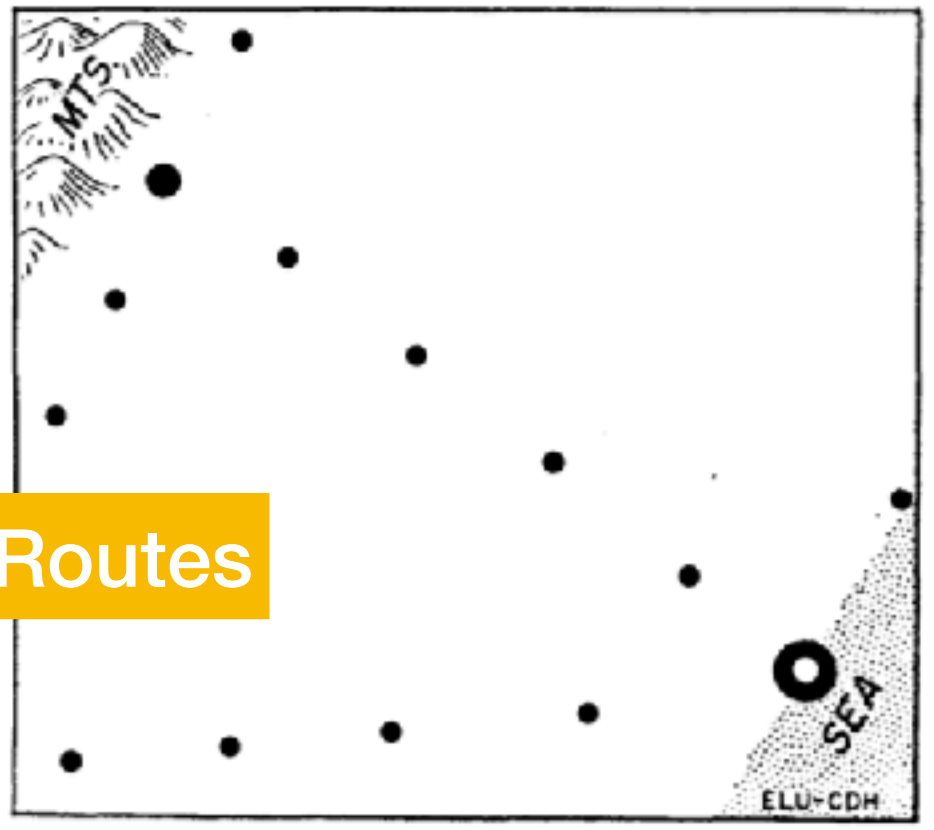

Fig. 2.—Transport centers, aligned along railroads or at coast. Large center is port; next largest is railroad junction and engine-changing point where mountain and plain meet. Small centers perform break of bulk principally between rail and roads.

Specialized-function Settlements

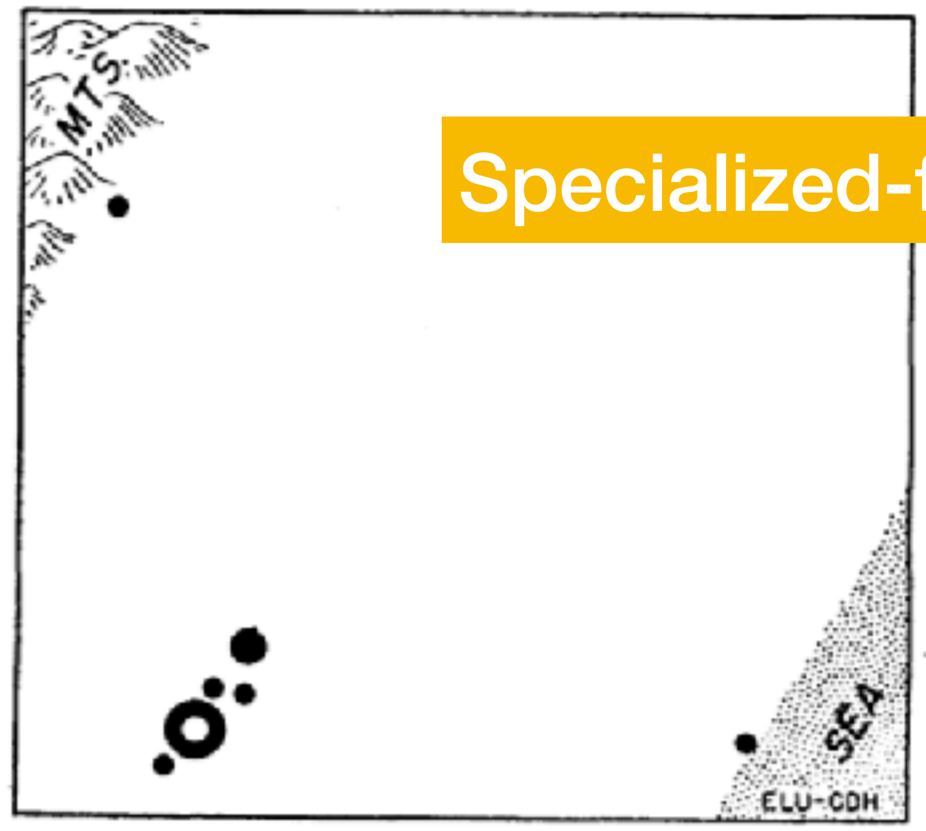

Fig. 3.—Specialized-function settlements. Large city is manufacturing and mining center surrounded by a cluster of smaller settlements located on a mineral deposit. Small centers on ocean and at edge of mountains are resorts.

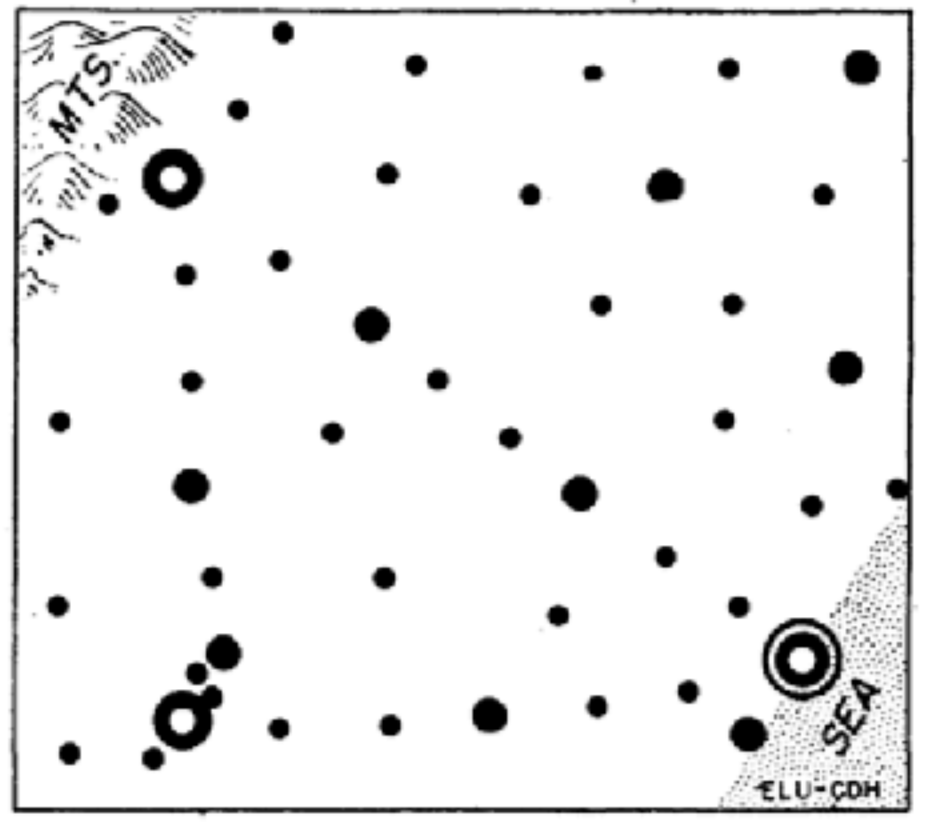

Fig. 4.—Theoretical composite grouping. Port becomes the metropolis and, although off center, serves as central place for whole area. Manufacturing-mining and junction centers are next largest. Railroad alignment of many towns evident. Railroad route in upper left of Fig. 2 has been diverted to pass through manufacturing and mining cluster. Distribution of settlements in upper right follows central-place arrangement.

THE FUNCTIONAL BASES OF THE CENTRAL PLACE HIERARCHY

Brian J. L. Berry and William L. Garrison

Mr. Berry is a Teaching Associate and Dr. Garrison is an Associate Professor in the Department of Geography, University of Washington. The present paper is one of several related to patterns of routes, urban sizes, and land uses stemming from recent research at that university.

Economic Geography 1958

https://www.jstor.org/stable/142299?seq=1#metadata_info_tab_contents

THE FUNCTIONAL BASES OF CLASSES OF CENTRAL PLACES IN SNOHOMISH COUNTY: VARIATES

Businesses / Services

Places

		Threshold Population	B - value	C				B									A																			
				Marysville	Snohomish	Arlington	Monroe	Edmonds	Stanwood	East Stanwood	Lynnwood	Sultan	Mukilteo	Darrington	Granite Falls	Alderwood Manor	Lake Stevens	Beverly Park	Lowell	Silvana	Gold Bar	Startup	Warm Beach	Index	Machias	Cathcart	Maltby	Oso	Cedarhome	Bryant	Robe	Getchell	Florence	Trafton	Silverton	Verlot
	Population			2460	3494	1915	1684	2996	720	390	500	850	900	974	600	600	2586	725	1600	300	325	300	314	220	200	175	700	200	100	150	50	25	300	25	15	20
	Number of Activities			64	62	59	56	42	42	38	36	34	28	25	25	22	16	13	12	10	9	8	6	6	5	5	4	4	4	3	3	3	2	2	2	1
1 1	Filling Stations	196	1.35	9	3	6	8	7	4	3	9	6	3	3	4	4	3	1	1	1	1	2	1		2	1	2	2	1	1	1	1	1		1	
	Food Stores	254	1.74	5	6	4	6	6	2	2	3	3	1	2	3	3	2	1	1	2	2	2								1						
	Churches	265	1.29	5	17	9	8	8	3	3	3	4	2	2	2	2	2		1	1		2	1		1		1		1							
	Restaurants	276	1.33	14	7	5	6	5	2	3	6	3	1	1	2	1	1		2		4	1		1							1					
	Taverns	282	1.65	2	5	3	5	5	2	5	3	3	1	3	2		2	1	1	1	1	2		1	1						1					
	Elementary Schools	322	1.67	6	6	4	2	1	3	1	1	1	2	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1		1		
2 1	Physicians	380	1.42	3	5	10	3	5	2	1	1	1			1																					
	Real Estate Agencies	384	1.40	6	7	3	2		2	2	6		1			2																				
	Appliance Stores	385	1.46	2	10	4	1	4	1	2	1	1		1	1	1																				
	Barber Shops	386	2.39	4	4	4	3	2	2	1	1	1	1	1	1	1	2	1	1		1					1										
	Auto Dealers	398	1.35	2	3	10	4	2	1	4	2																									
	Insurance Agencies	409	1.32		10	1	4		2	3	1	1			1																					
	Bulk Oil Distributors	419	1.56	6	5	5	2		3	1		2		1	1																					
	Dentists	426	1.57	1	5	4	3	4	1	1	5																									
	Motels	430	1.56	6			2	4			3	2		3			1				2															
	Hardware Stores	431	1.90	2	6	3	3	3		2	1	1		1	1	2	1																			
	Auto Repair Shops	435	1.72	4	6	1		1	2	1	1							1	1							1						1				
	Fuel Dealers (coal, etc.)	453	1.78	4	2	4	1	5	1		3			2		1																				
	Drug Stores	458	2.23	3	3	2	2	3	1	1	1	1	1	1	1	1	1	1																		
	Beauticians	480	1.89	5	1	1	3	4		1		1	1			2		1																		
	Auto Parts Dealers	488	1.94	3	3	4	1	2	2	2	2			1							1															
	Meeting Halls	525	2.01	1	3	1	4			1	1	1	1	1	1	1							1	1												
	Animal Feed Stores	526	1.79	4	2	2	4									1																				
	Lawyers	528	2.12	1	3	2	4	2	2	2	1	1																								
	Furniture Stores, etc.	546	1.85	2	1	1	2	2		1	4																									
	Variety Stores: 5 & 10	549	2.30	2	3	2	1	4	1	2	1					1	1																			
	Freight Lines & Storage	557	2.04	4	3	2	3		1	1				2																						
	Veterinaries	579	1.97	1	1	3	1		1	2						1													1							
	Apparel Stores	590	2.53	3	3	1	2	2	1	2		1	1	1																						
	Lumber Yards & Woodworking	598	2.49	1	3	1	1	1		1	3	1	1	1					1			1														
	Banks	610	2.05	1	1	2	1	2	2	1	1	1		1	1		1						1													
	Farm Implement Dealers	650	1.95		1		1		2		2																									
	Electric Repair Shops	693	2.62	1	1	2	3	1	1	1	1																									
	Florists	729	2.40	1	2	2	3																													
	High Schools	732	3.64	2	2	1	2	1	1	1		2	1	1	1		1																			
	Dry Cleaners	754	3.56	2	1	2	1	3			1			1	1			1																		
	Local Taxi Services	762	2.89	1	1	1	2	2	1	1	2																									
	Billiard Hall & Bowling Alleys	789	2.56	1	3	2							1																							
	Jewelry Stores	827	3.26	1	2	2	2	1		1	1	1																								
	Hotels	846	2.92	1	1	2			1				2																							

CENTRAL FUNCTIONS

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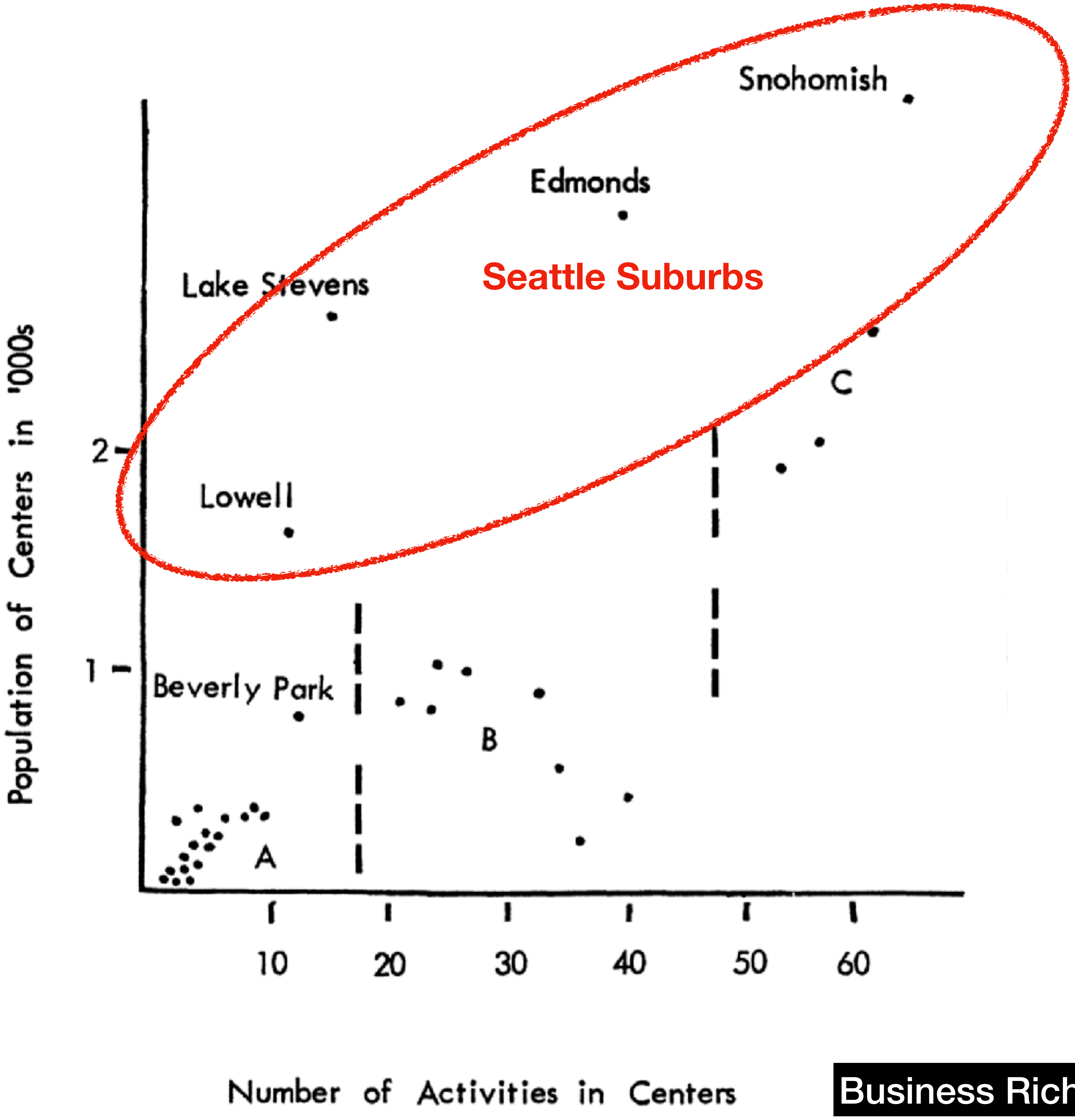

Business Richness= # unique types

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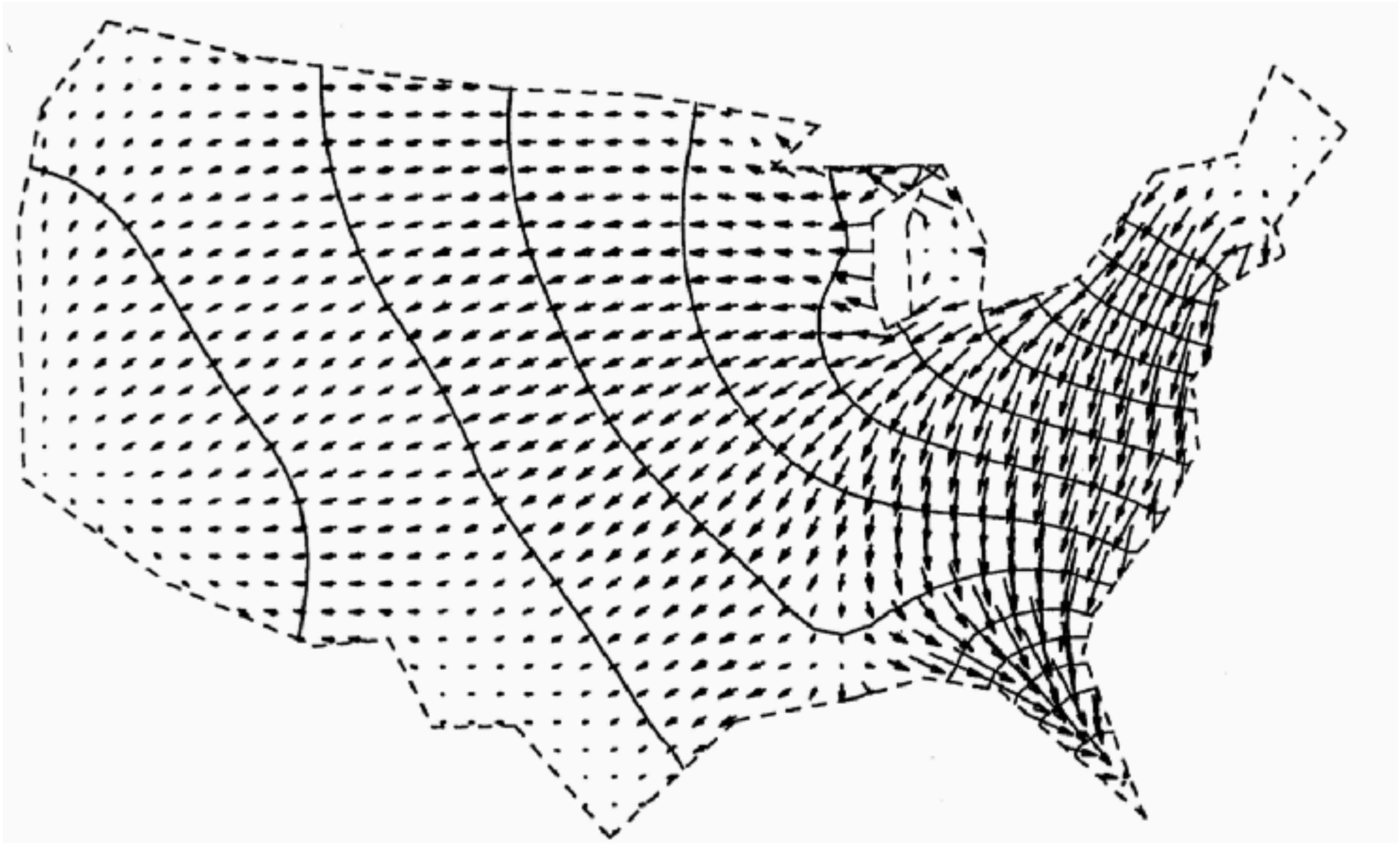
Tobler’s Laws of Geography

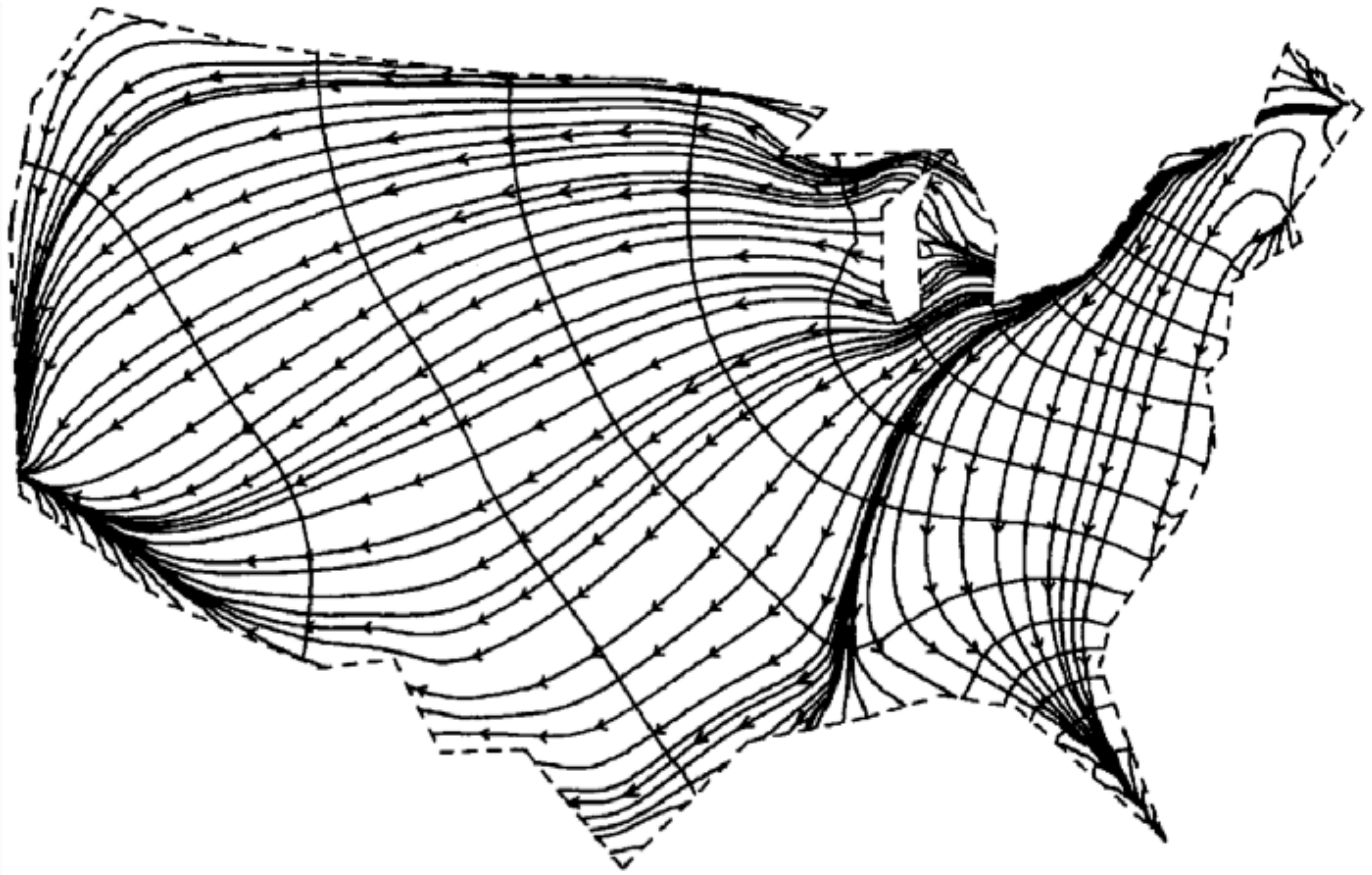
Waldo Tobler 1961

Tobler’s First Law:

"everything is related to everything else, but near things are more related than distant things.”

Tobler’s Second law: “The phenomenon external to an area of interest affects what goes on inside”





The Gravity Law of Geography

THE "GRAVITATION," OR GEOGRAPHICAL DRAWING POWER, OF A COLLEGE

https://www.jstor.org/stable/40219181?seq=1#metadata_info_tab_contents

By JOHN Q. STEWART

Princeton University

Many preparatory schools, colleges, and universities compile statistics of the places of residence of their students and alumni. The clustering of these residences around the alma mater is likely to be evident without benefit of heavy analysis. But although mathematics is not needed to define the matter, suitable mathematical treatment can refine it. I have examined the reported residences in recent alumni directories of Harvard, Princeton, Vassar and Yale, and in addition the distribution of residences of undergraduates of Harvard and Princeton.[1]

For the four colleges thus far examined, the rule is this: The number of alumni (or undergraduates) of a given college or university who reside in a given area tends to be directly proportional to the population of that area and inversely proportional to the distance from the college.

Flows between two Cities:

number of people per unit time

$$J_{ij} = G\frac{N_i N_j}{d_{ij}^a}$$

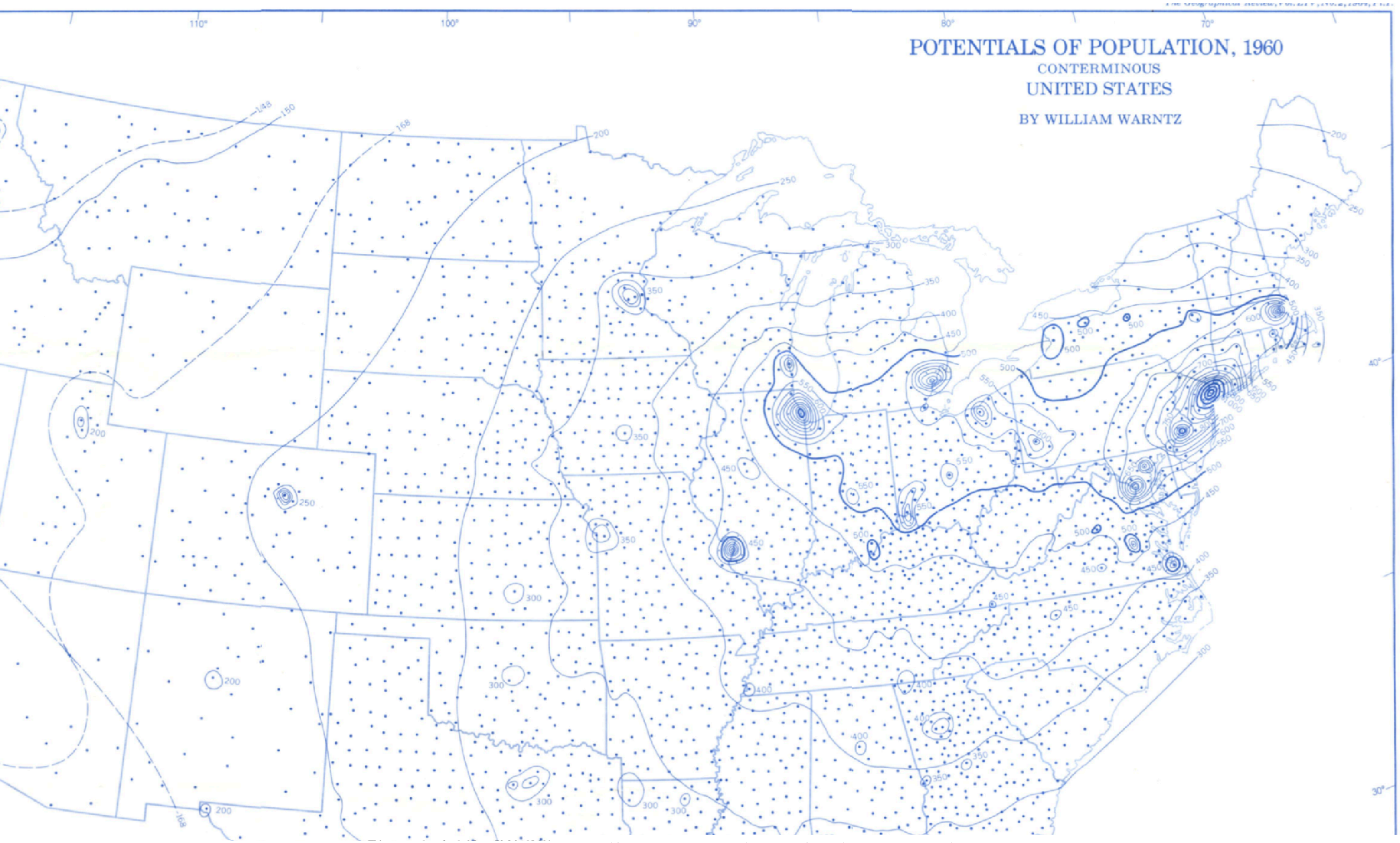
$$a \simeq 1 - 2$$

Applies to migration, trade flows, commuting, ….

“gravity” law

Population “Potential” or “Influence”

$$V_i = G\frac{N_i}{d_i^a}$$



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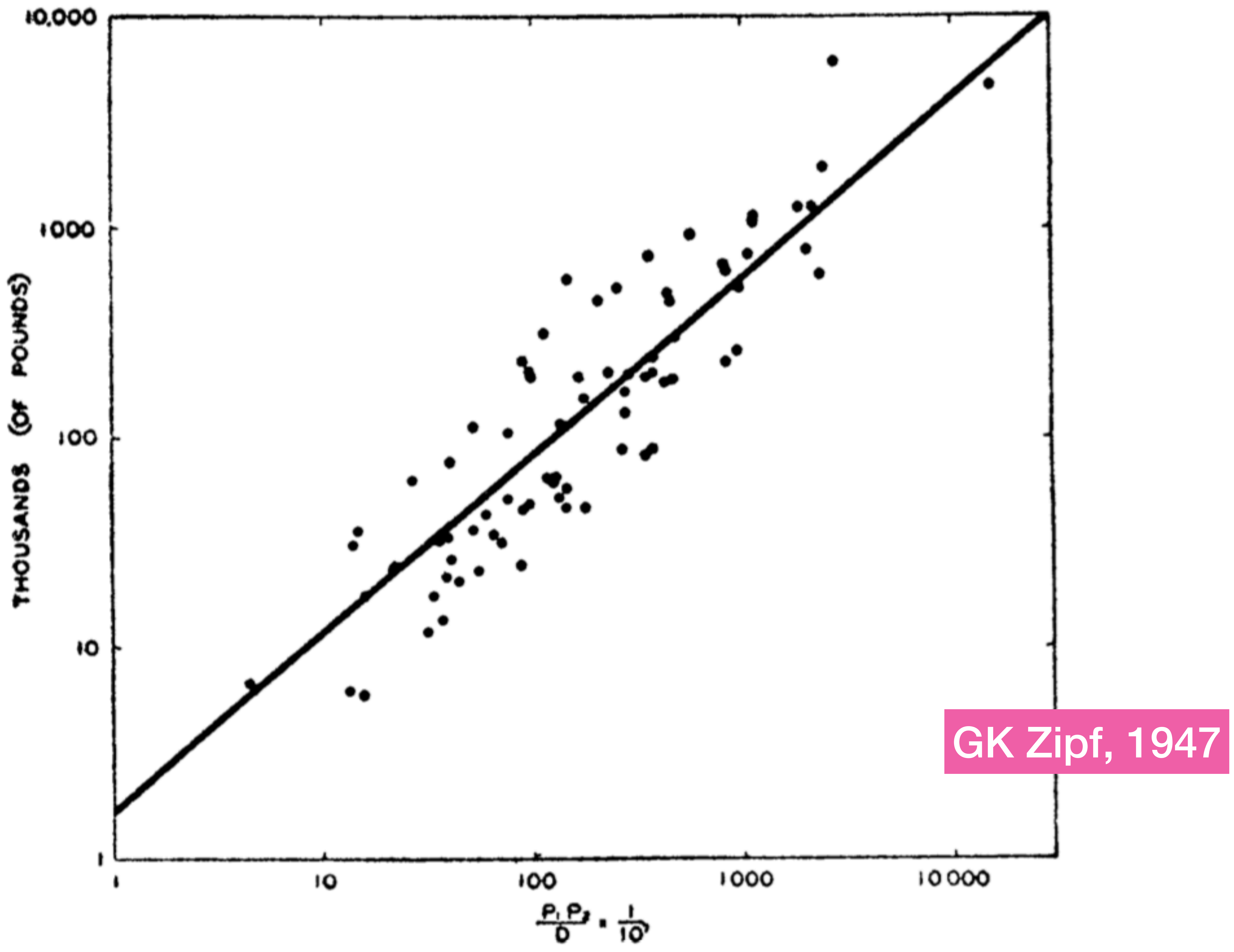


FIGURE 2. The movement of railway express (less carload lots) between 13 arbitrarily selected cities in the U.S.A. during May, 1939.

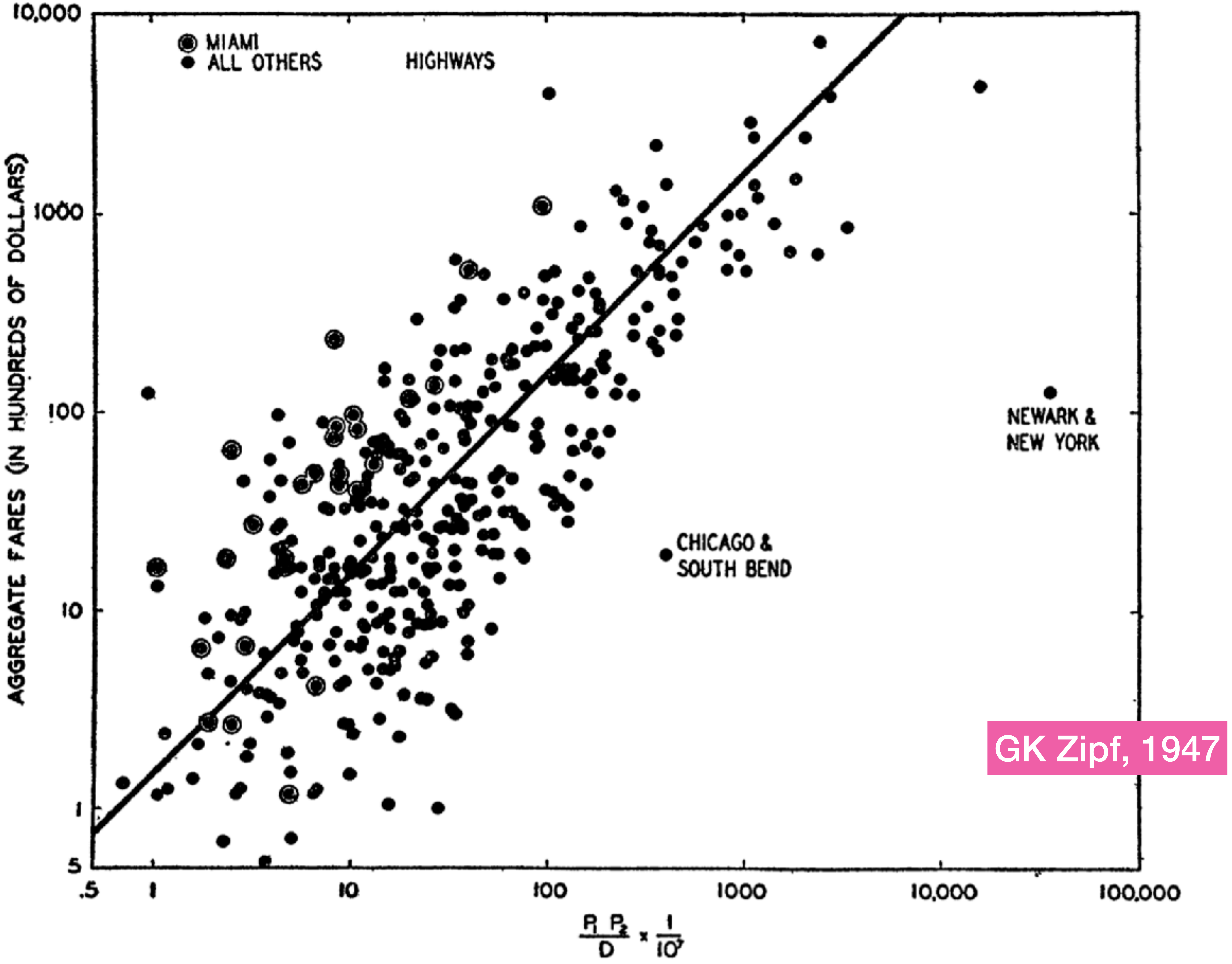


FIGURE 4. The aggregate fares (in hundreds of dollars) paid by the highway passengers reported in Figure 3. The ideal line has a slope of 1.

Many attempts at explanation !!

Not Physics !!

A simple picture

Social Outputs of Interactions ~ People moving per unit time

different cities

$$I_{ij} = G\frac{N_i N_j}{A_n} \longrightarrow J_{ij} = G'\frac{N_i N_j}{d_{ij}^a}$$

$$A_n \to d_{ij}^a$$

interaction area

a=1, line
a=2, area

fractal dimension

Problems with Gravity Law

works roughly, but…

1) never very precise

2) The exponent a varies a lot

3) Is symmetric : same number of people moving from city i-> j, as j->i !?

no growth from migration

So the gravity law cannot predict the growth of cities via migration !

Gibrat’s Law

law of proportional growth

“Les inegalites economiques; applications: aux inegalite's des richesses, a la concentration des entreprises, aux populations des villes, aux statistiques des familles, etc., d'une loi nouvelle, la loi de l'effet proportionnel.”

Paris: Librairie du Recueil Sirey, 1931.

$$r_t - r_{t-1} = \eta r_t$$

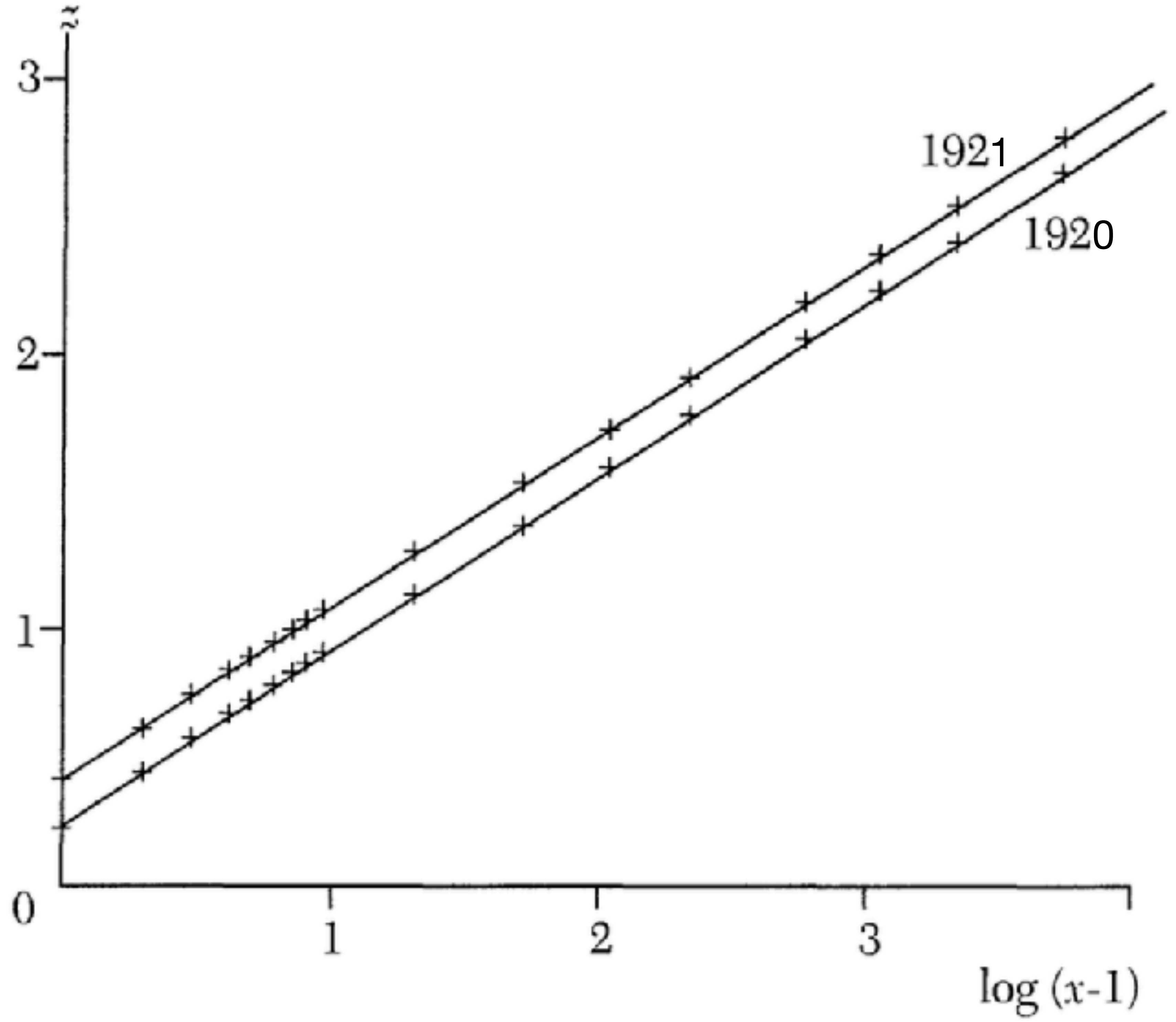
$$r_t = (1+\eta_t)r_{t-1} = (1+\eta_t)(1+\eta_{t-1})\ldots(1-\eta_0)r_0 \sim (1+\eta)^t\ r_0$$

exponential growth

http://pi.lib.uchicago.edu/1001/cat/bib/2014808

Growth is approximately independent of firm size

new size class of firm



previous size of firm

Figure 1. Gibrat's Data for French Manufacturing Establishments in 1920 and 1921

Gibrat’s law for cities

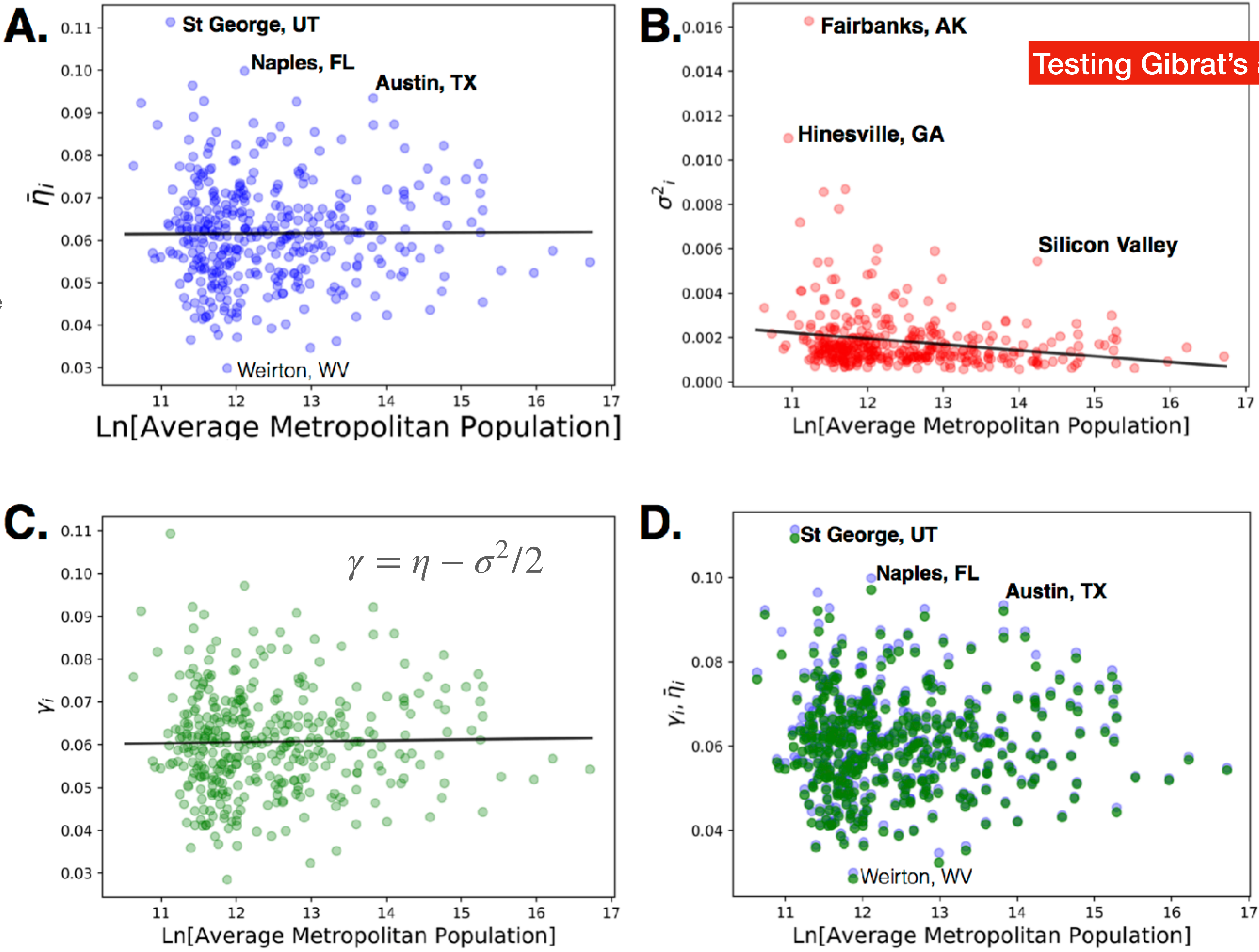
All cities grow with the same

average population growth rate $\bar{\eta}$

volatility σ

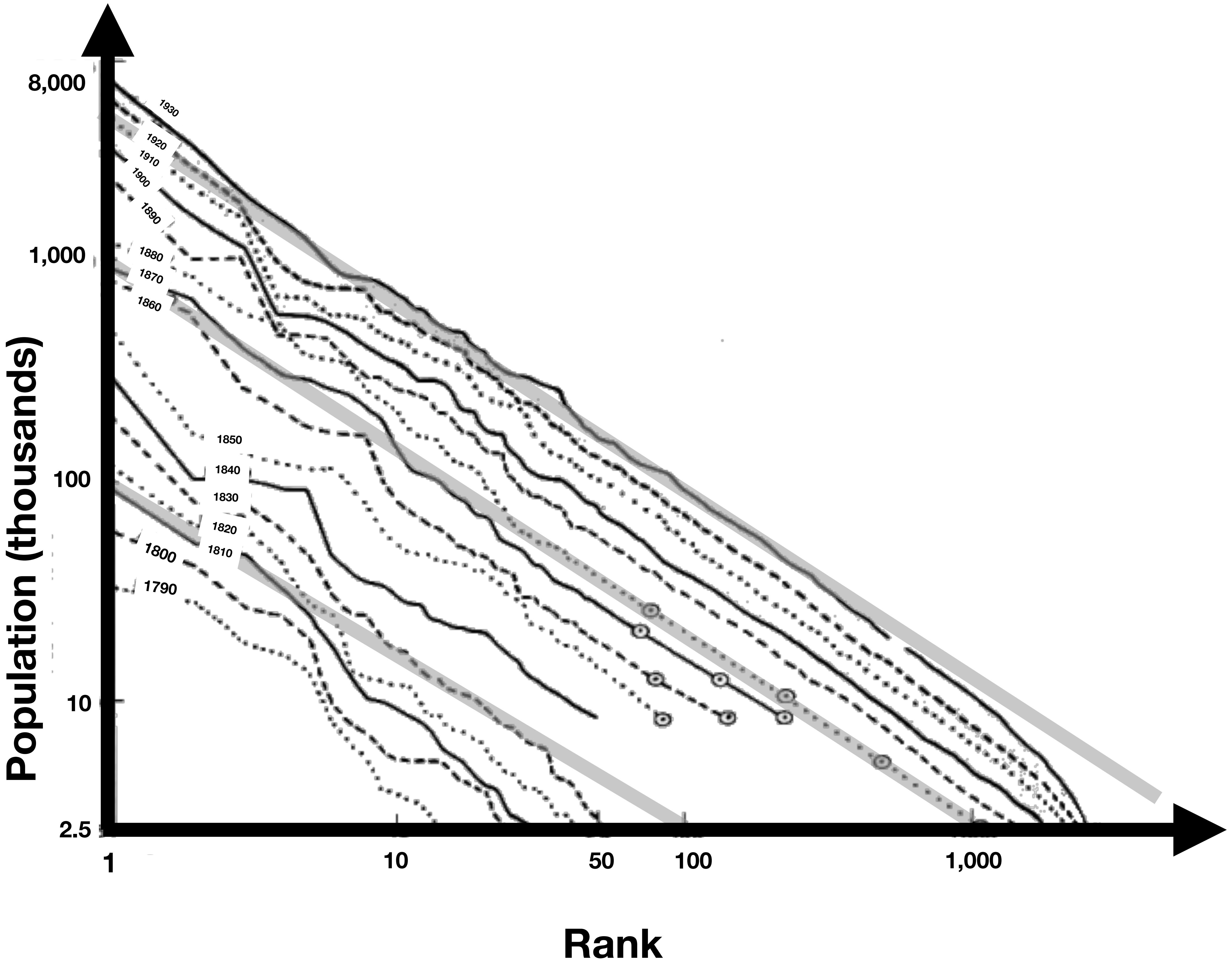
independent of population size !!

Population growth rare



Testing Gibrat’s assumption

Zipf's Law for the Size Distribution of Cities



G K Zipf (1949), Human behavior and the principle of least effort

https://openlibrary.org/books/OL6048217M/Human_behavior_and_the_principle_of_least_effort

The Meaning of Zipf's Law

$$N(rank) = \frac{N_{\max}}{rank}$$

population size of city

$$N(rank = 1) = N_{\max}$$

New York City: 20.3 million

$$N(rank = 2) = \frac{N_{\max}}{2}$$

Los Angeles: 13.13 million

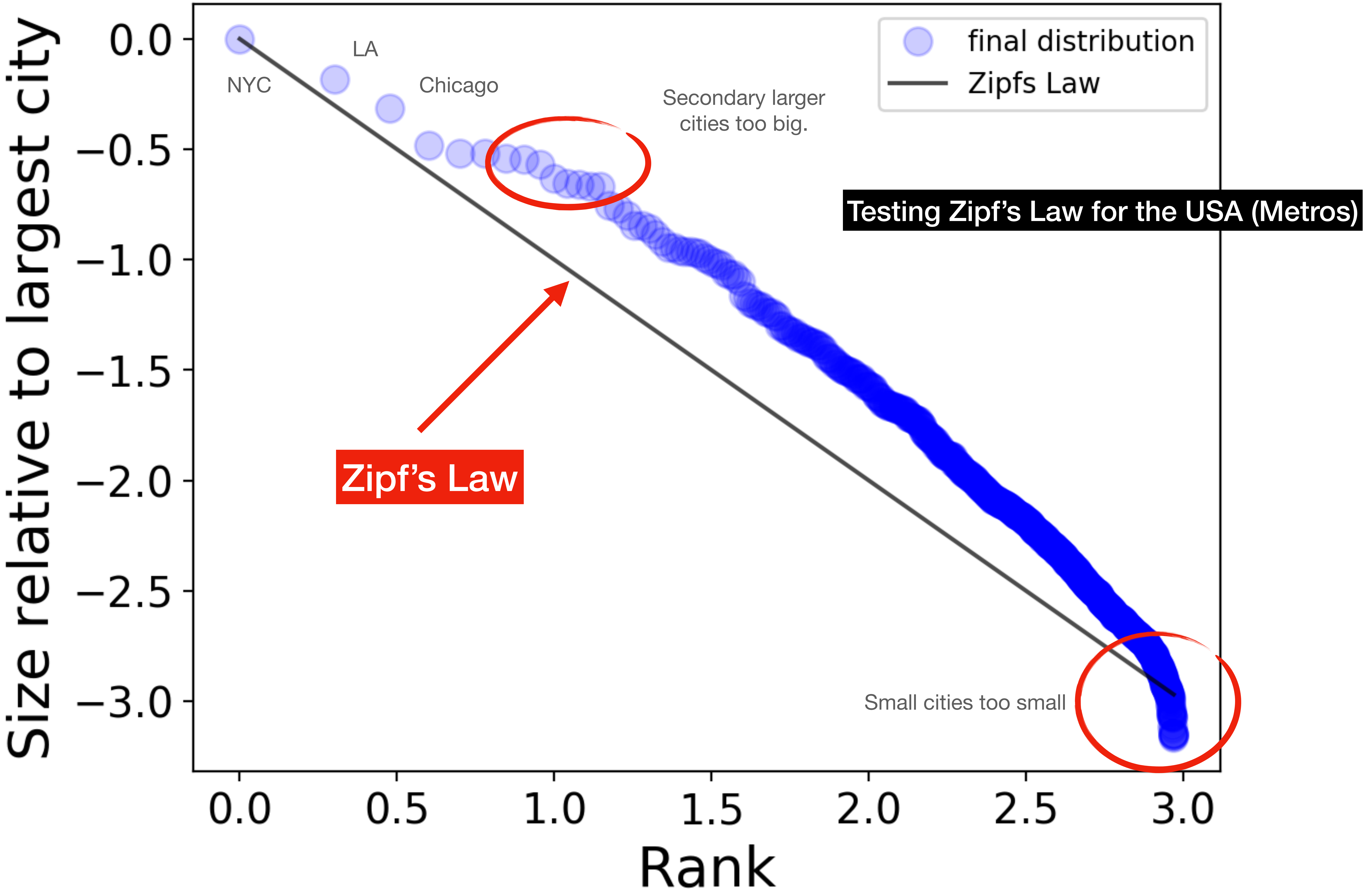
$$N(rank = 3) = \frac{N_{\max}}{3}$$

Chicago: 9.533 million

$$N(rank = 4) = \frac{N_{\max}}{4}$$

Dallas/Ft Worth: 7.233 million

Can be explained based on Gibrat's Law ++



Size relative to largest city
Rank
final distribution
Zipfs Law
NYC
LA
Chicago
Secondary larger cities too big.
Testing Zipf's Law for the USA (Metros)
Zipf's Law
Small cities too small
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

The Laws of Geography

Give us an **approximate**, quantitative description of the dynamics of systems of cities

Where do they come from? What do deviations “mean”?