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Density and Polycentrality: Impacts of Large Scale Built-Environment on Transportation

Jiawen Yang

School of City and Regional Planning
Georgia Institute of Technology

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Built-Environment and Obesity Research Team

- CDC/DACH

Analytic Methods Team

- James Holt
- Minho Kim
- Hua Lu
- Xingyou Zhang

Expertise

- Spatial epidemiology and statistics
- Bayesian statistical modeling
- GIS and spatial analysis
- Remote Sensing

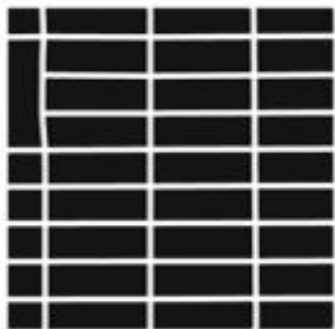
- GT /CRP

- Steven French
- Jiawen Yang
- Xuan Shi

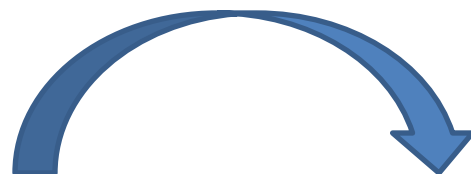
Expertise

- Urban/regional planning
- Transportation
- GIS and spatial analysis

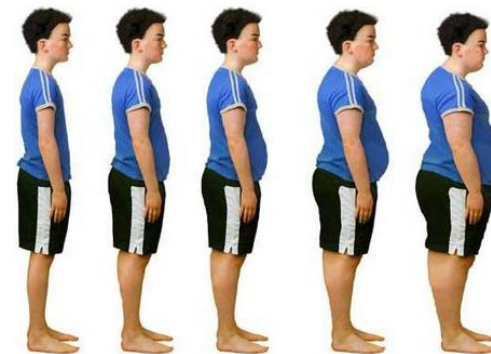
Streetcar Suburb Grid:
1880s-1900s



Rural Sprawl:
1980s-present



Active Life
Styles



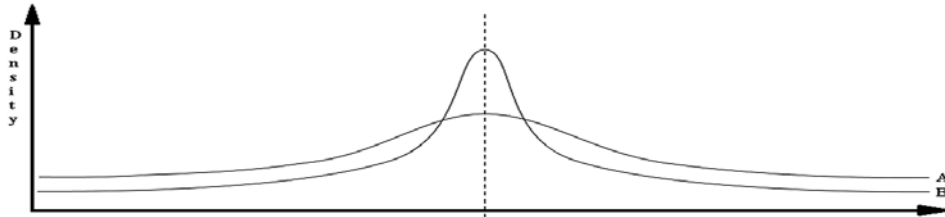
Research Background

- Built-environment impact on travel
 - Neighborhood level
 - Density, street connectivity, land use mix
- Large scale built-environment
 - Size of the metropolitan area
 - Regional density
 - Polycentric structure
- How and to what extent does the large scale urban built-environment impact urban transportation?
 - Duration
 - Mode

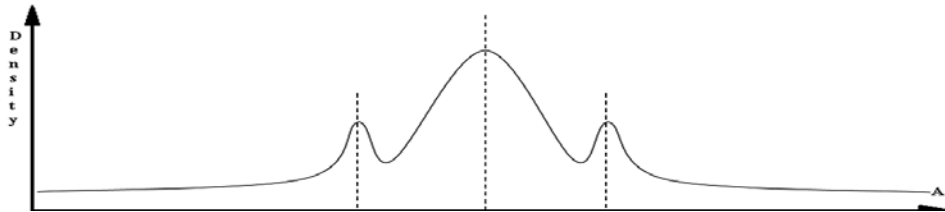
LBE Indicators

- Size of CBSA (core-based statistical area)
 - Population, land area
- Overall density
 - Population/land area
- Spatial variation of density
 - Degree of nodality (polycentrality)
 - Not an aggregation of the neighborhood level characterization to the regional level

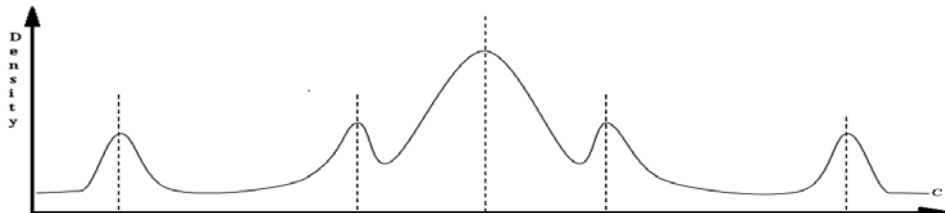
Variation of Density



“B” is more concentrated than “A”

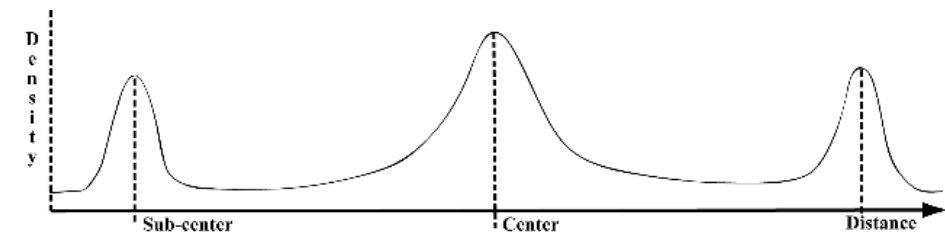
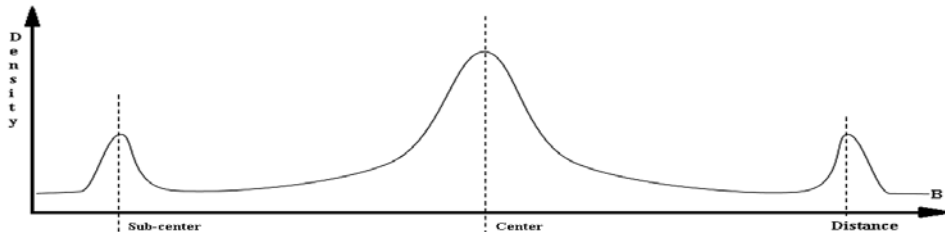


Concept of Polycentrality



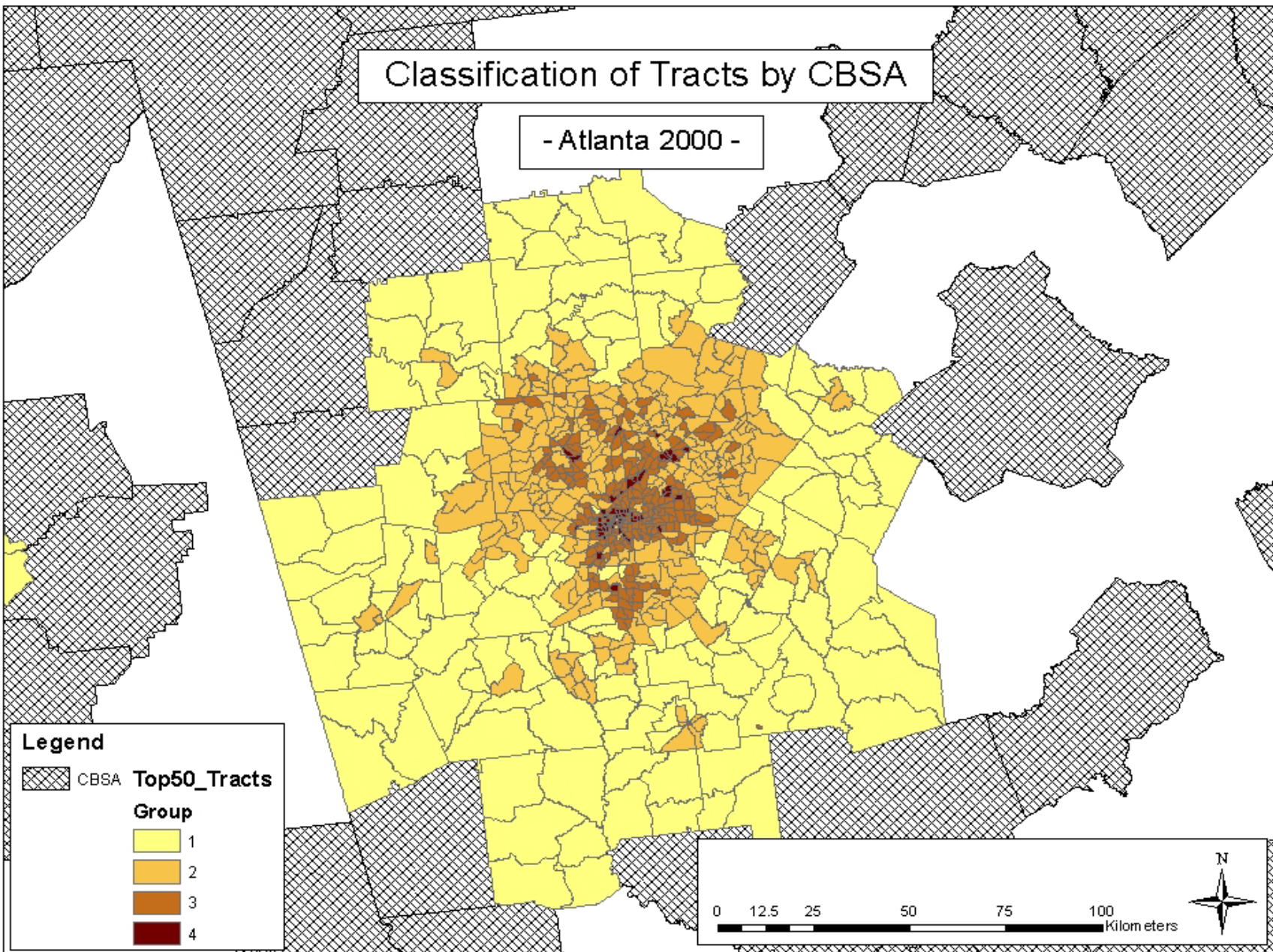
Higher Polycentrality can mean:

- 1) Stronger sub-centers
- 2) More sub-centers
- 3) More distanced sub-centers

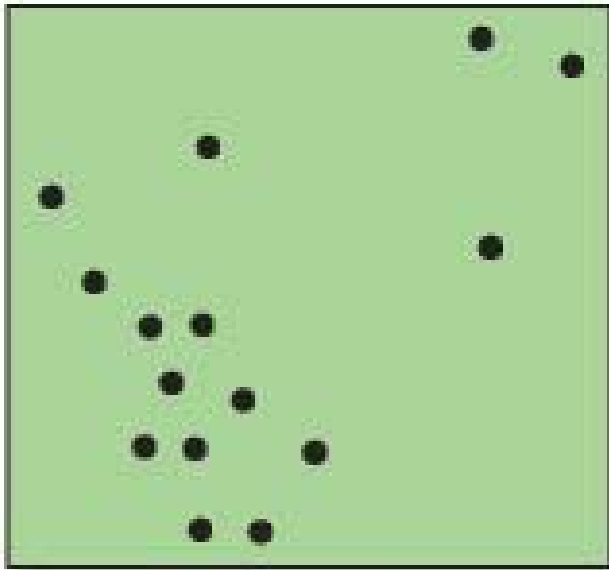


Classification of Tracts by CBSA

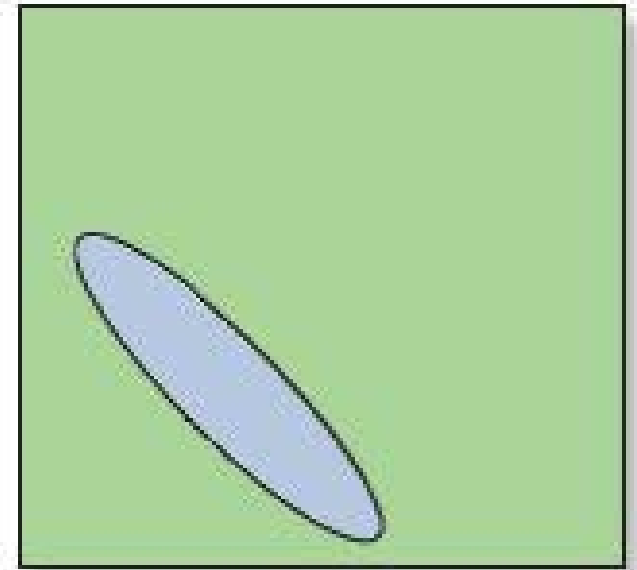
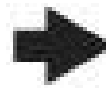
- Atlanta 2000 -



Measuring Spatial Distribution



INPUT



OUTPUT

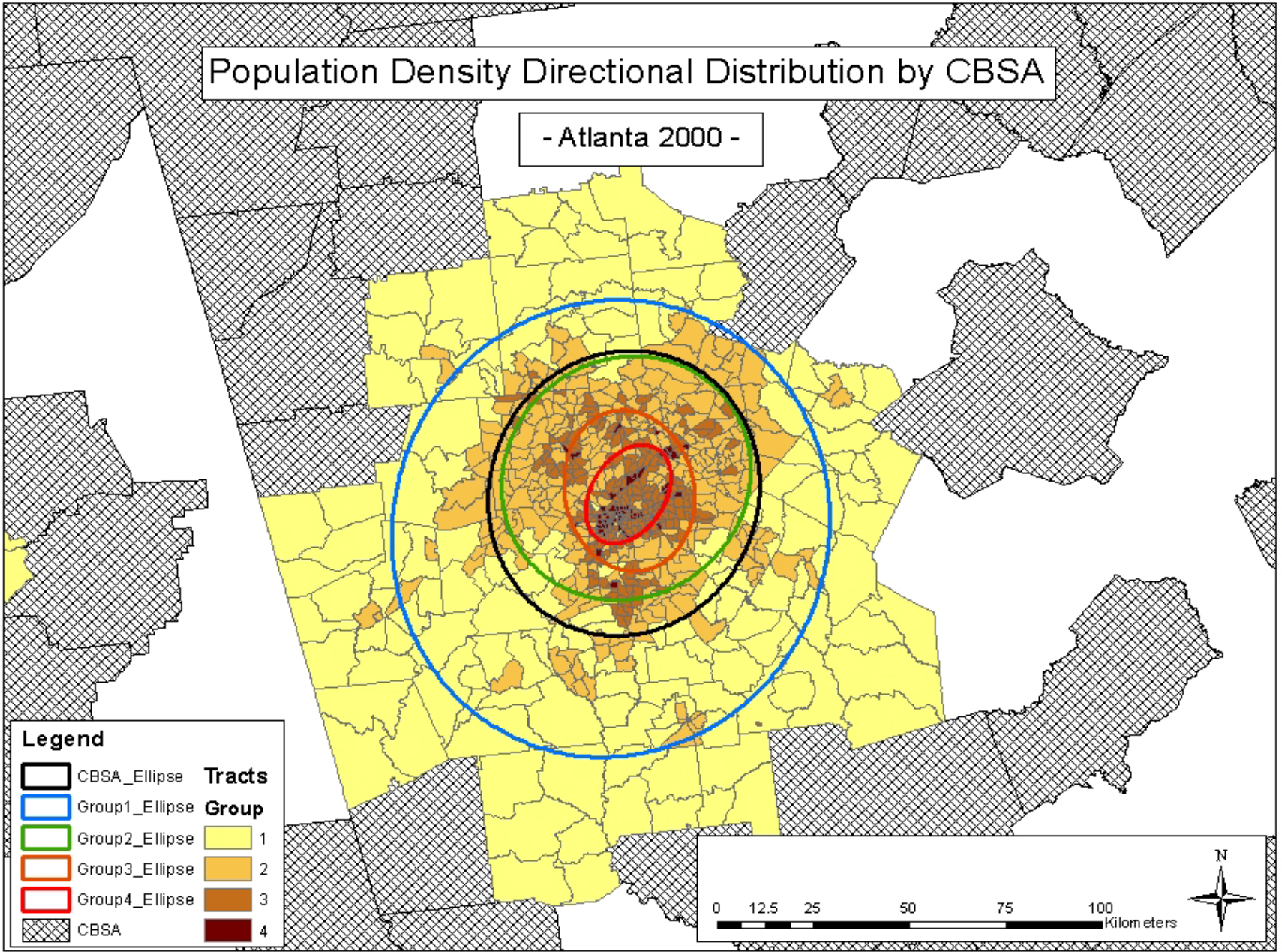
Spatial statistics based approach

Degree of dispersion:











Area of ellipse of all tracts of a CBSA (weighted by population count)
divided by Area of the CBSA

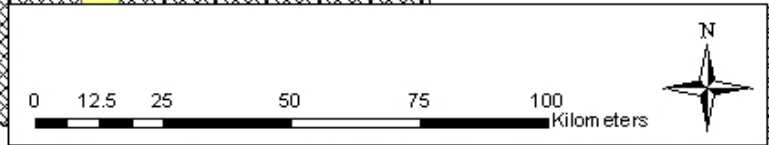
Population Density Directional Distribution by CBSA

- Atlanta 2000 -



Legend

- | | | |
|---|----------------|---|
|  | CBSA_Ellipse | Tracts |
|  | Group1_Ellipse | Group |
|  | Group2_Ellipse |  1 |
|  | Group3_Ellipse |  2 |
|  | Group4_Ellipse |  3 |
|  | CBSA |  4 |



Methodology

Directional Distribution & Indicators

Step 1.

For all CBSA, calculate directional distribution in ArcGIS for every tract weighted by population, and cased by CBSA

Step 2.

For each group, calculate directional distribution weighted by population and cased by CBSA

Step 3.

Calculate indicators:

Degree of polycentrality 1: $\text{Area of ellipse of group 4} / \text{Area of ellipse of all tracts}$

Degree of polycentrality 2: $\text{Area of ellipse of group 3} / \text{Area of ellipse of all tracts}$

Degree of dispersion: $\text{Area of ellipse of all tracts} / \text{Area of CBSA}$

Degree of low density sprawl: $\text{Area of ellipse of group 1} / \text{Area of ellipse of all tracts}$

Why this measure?

Relative density

- Filter out the baseline density

Normalized indicator

- Filter out the size effect

Focus on polycentric structure

- Spatial variation of density relative to the regional average

Policy sensitive

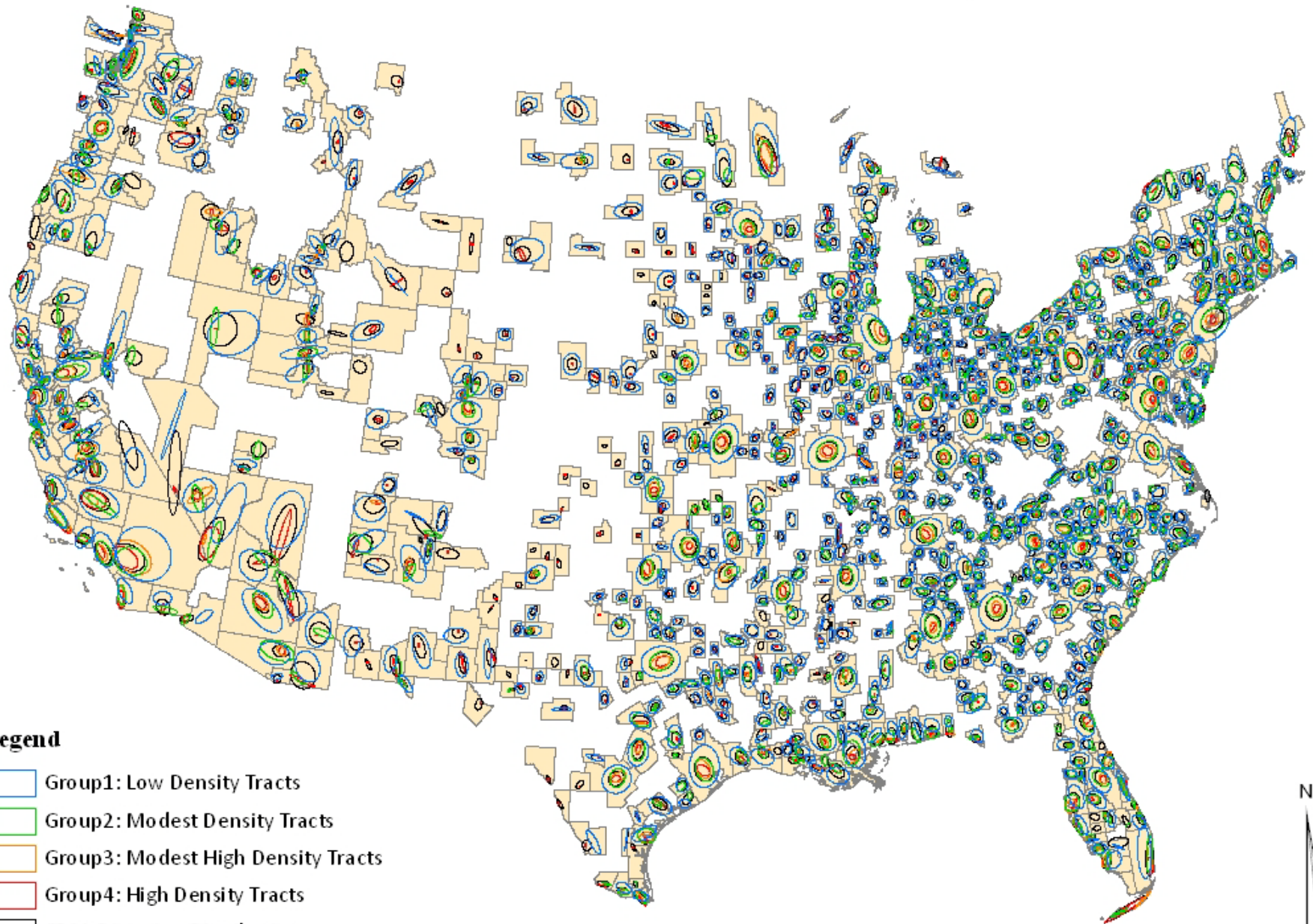
- Retrofitting suburbs

- livable centers/activity centers

- which location?

- how dense?

CBSA Direction Distribution Map

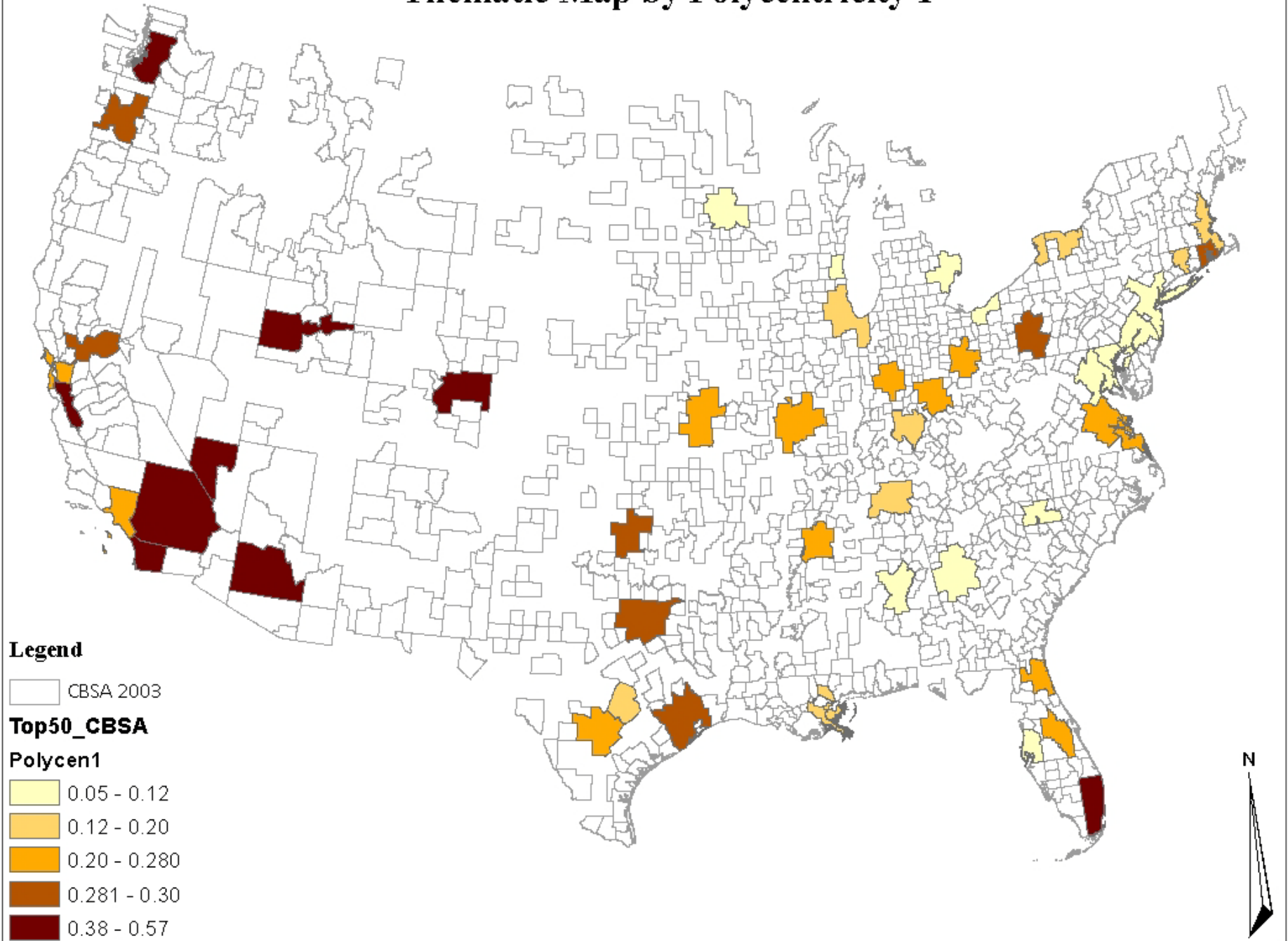


Legend

- Group1: Low Density Tracts
- Group2: Modest Density Tracts
- Group3: Modest High Density Tracts
- Group4: High Density Tracts
- CBSA Direction Distribution
- CBSA 2003

N

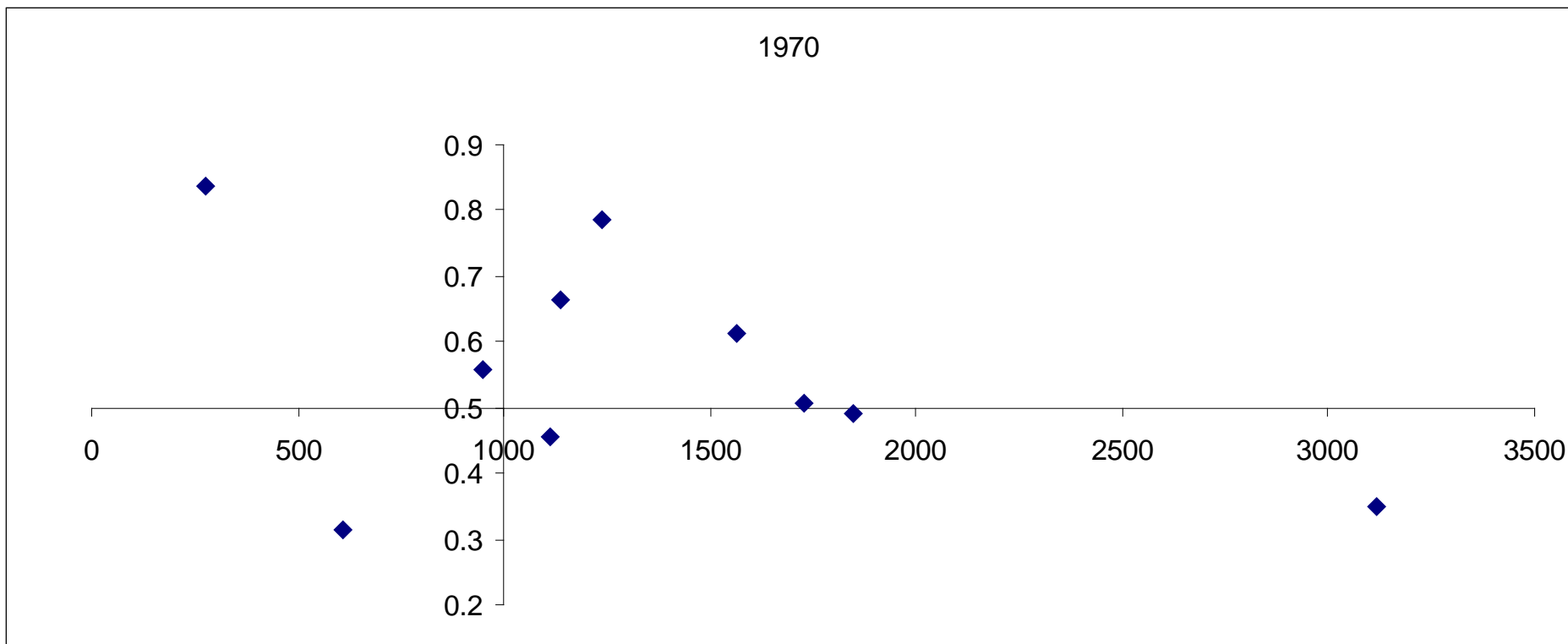
Thematic Map by Polycentricity 1



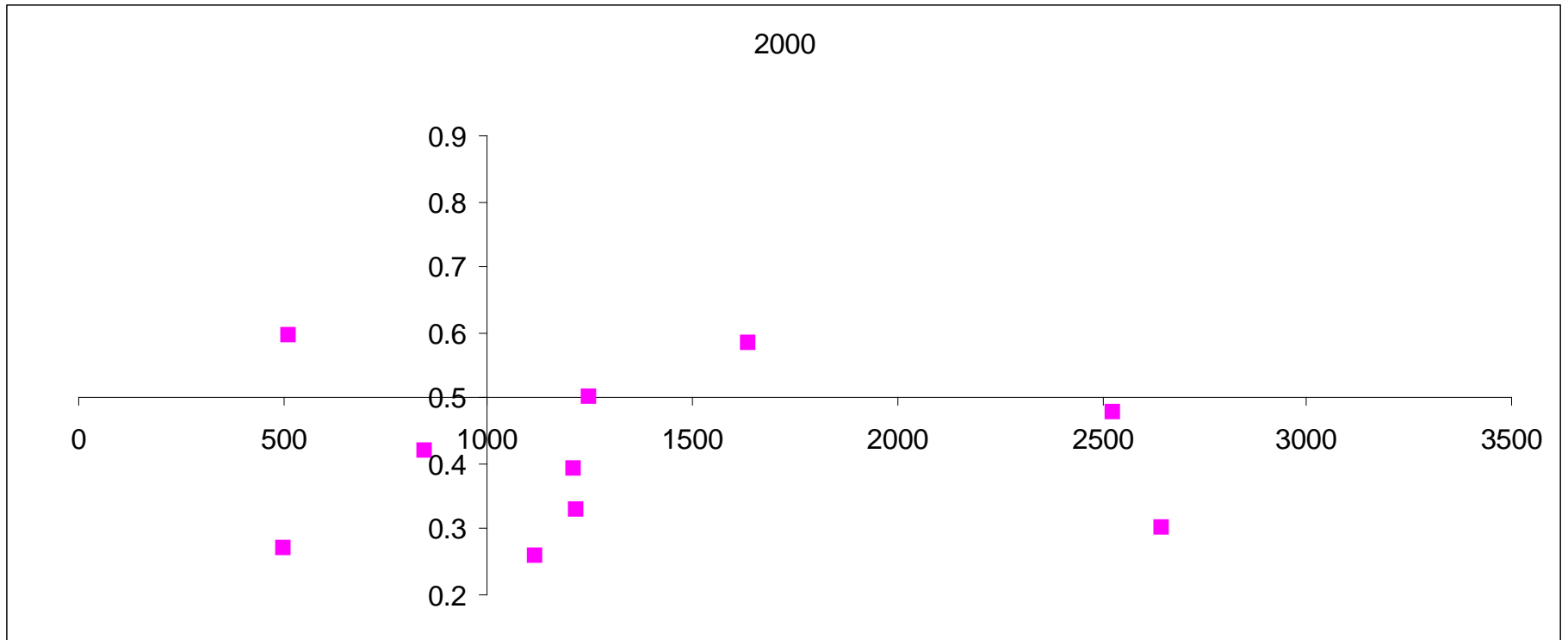
10 MSA

MSA Short Name	Population		Density (persons/sq km)		Polycentrality II	
	2000	1970	2000	1970	2000	1970
New York	18,323,002	16,781,381	2648	3114	0.30	0.35
Los Angeles	12,365,627	8,432,862	2530	1729	0.48	0.51
Chicago	9,098,316	7,729,961	1246	1563	0.50	0.61
Philadelphia	5,687,147	5,316,128	1209	1134	0.39	0.66
Washington	4,796,183	2,916,428	844	948	0.42	0.56
Houston	4,715,407	2,180,459	513	276	0.60	0.84
Detroit	4,452,557	4,430,927	1118	1112	0.26	0.46
Boston	4,391,344	3,499,776	1215	1848	0.33	0.49
Atlanta	4,247,981	1,460,699	501	612	0.27	0.31
San Francisco	4,123,740	3,100,411	1640	1235	0.58	0.79

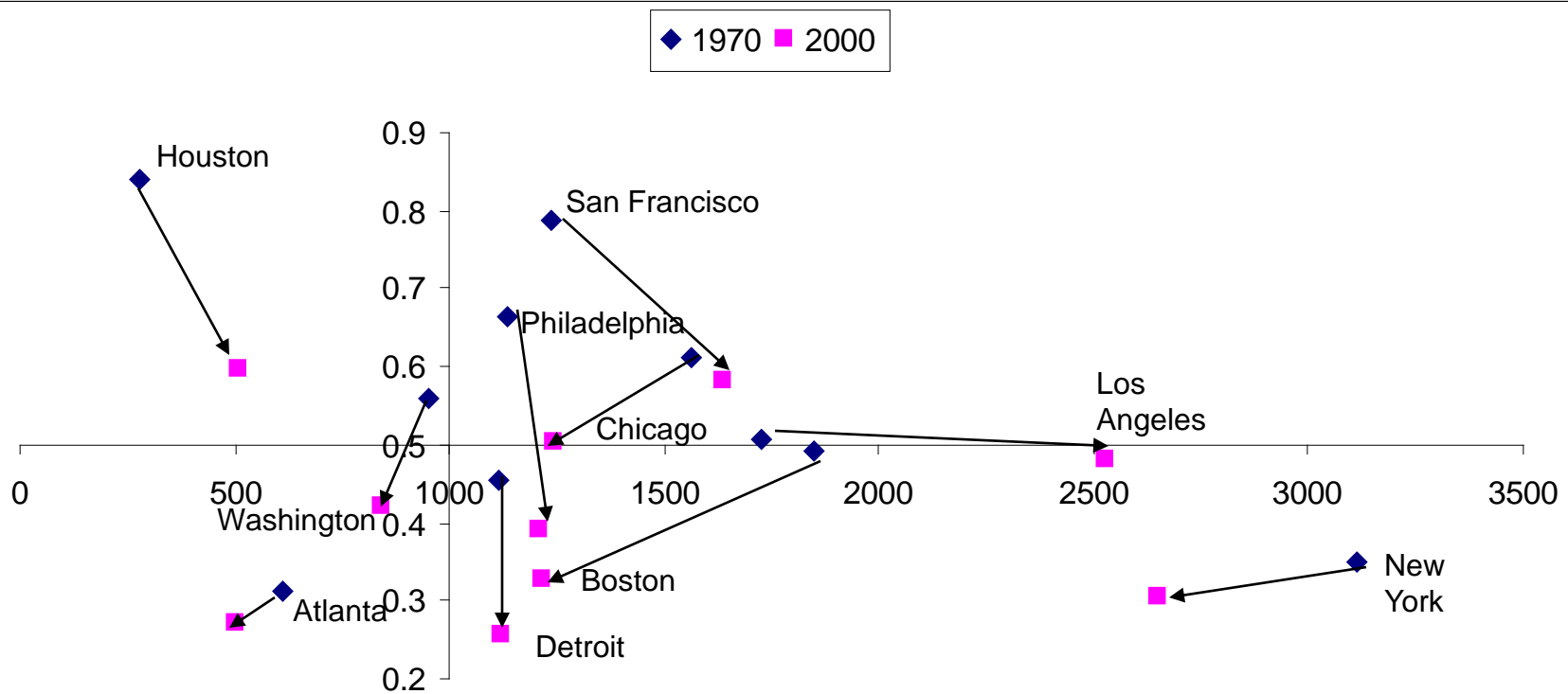
Polycentrality II: 1970



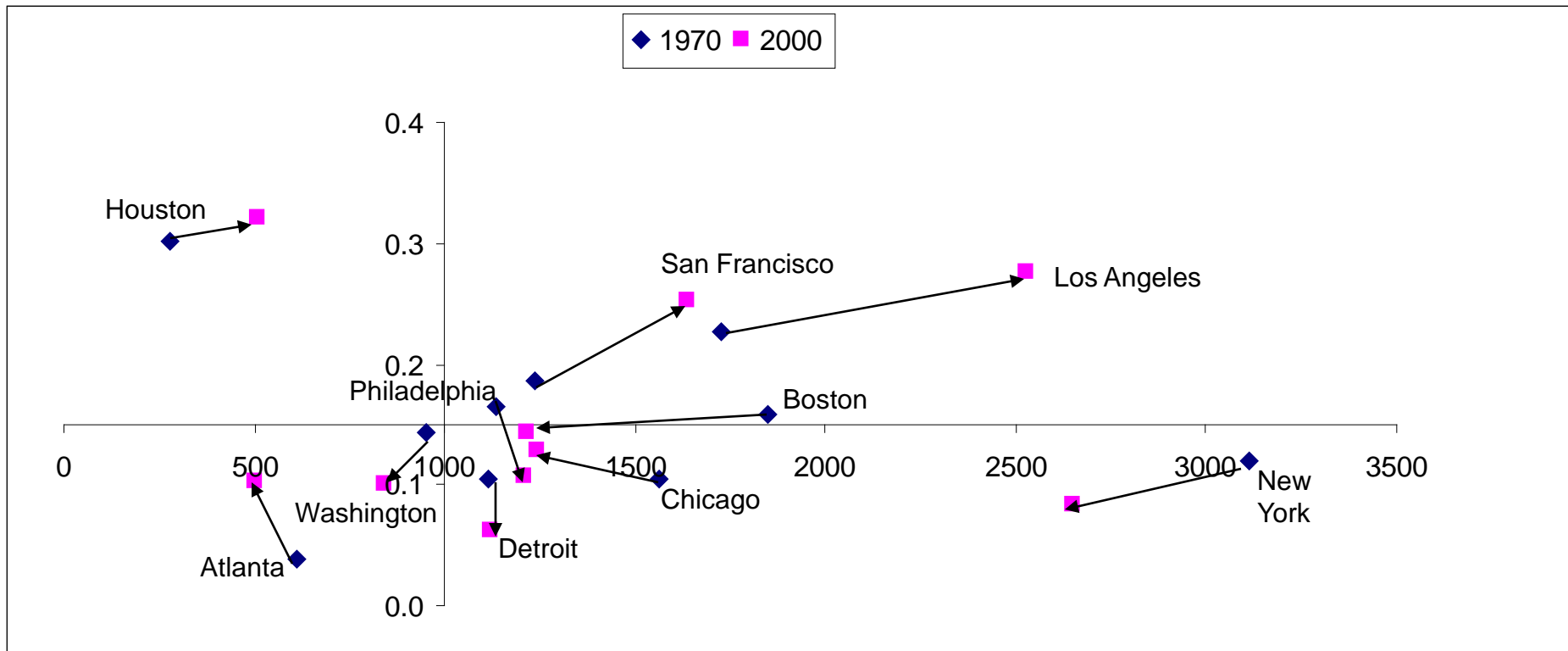
Polycentrality II: 2000



Polycentrality II: Change



Polycentrality I: Change



Variable Description

Average values	2000	1970
Population (million)	2.99	2.03
Density (person/sq km)	657	709
Polycentrality 1	0.24	0.23
Polycentrality 2	0.52	0.63
One way commuting time (minutes)*	25.7	24.1

Analysis units: top 50 MSA

Cross-sectional Regression

year 2000 data (Y variable: commuting time)

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-18.5977	8.849659	-2.10152	0.041226
Population size with log transformation	2.962402	0.639017	4.63587	3.06E-05
Population density	0.00042	0.000846	0.496008	0.622303
Polycentrality I	-8.8054	3.09836	-2.84195	0.006716
Polycentrality II	5.435916	1.91469	2.839058	0.006767

$R^2=0.56$

Analysis units: top 50 MSA

Interpreting Commuting Time Change

1970-2000 (Y variable: commuting time change)

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	1.357966725	0.207284437	6.551223743	1.357966725
Population size change (with log transformation)	0.640448326	0.310398873	2.06330751	0.640448326
Population density change	-0.00031299	0.000426401	-0.73402129	-0.00031299
Polycentrality I change	-3.15668145	1.065511588	-2.96259701	-3.15668145
Polycentrality II change	0.765839674	0.426207965	1.796868515	0.765839674

$R^2=0.23$

Analysis units: top 50 MSA

Combined Regression Model

Y variable: commuting time 2000

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-17.482	8.439038	-2.07157	0.044637
Population size change (with log transformation)	5.024898	0.992619	5.06226	9.18E-06
Population density change	-0.00078	0.001263	-0.61571	0.541487
Polycentrality I change	-8.18216	3.39779	-2.40808	0.020619
Polycentrality II change	6.090901	1.807857	3.369128	0.001652
Population size 1970 (with log transformation)	2.819413	0.624452	4.515019	5.26E-05
Population density 1970	0.001205	0.000936	1.287325	0.205201
Polycentrality I 1970	-8.42632	3.510166	-2.40055	0.020993
Polycentrality II 1970	4.200576	2.096128	2.003969	0.05171

$R^2=0.67$

Analysis units: top 50 MSA

Mode effects of Density

year 2000 data (Y variable: percentage of commuting by public transport)

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-22.1941	13.24679	-1.67543	0.100786
Population size with log transformation	1.561476	0.956526	1.632445	0.109565
Population density	0.004836	0.001266	3.818842	0.000408
Polycentrality I	-6.81388	4.637845	-1.46919	0.148738
Polycentrality II	4.184005	2.866043	1.459855	0.151277

$R^2=0.57$

Analysis units: top 50 MSA

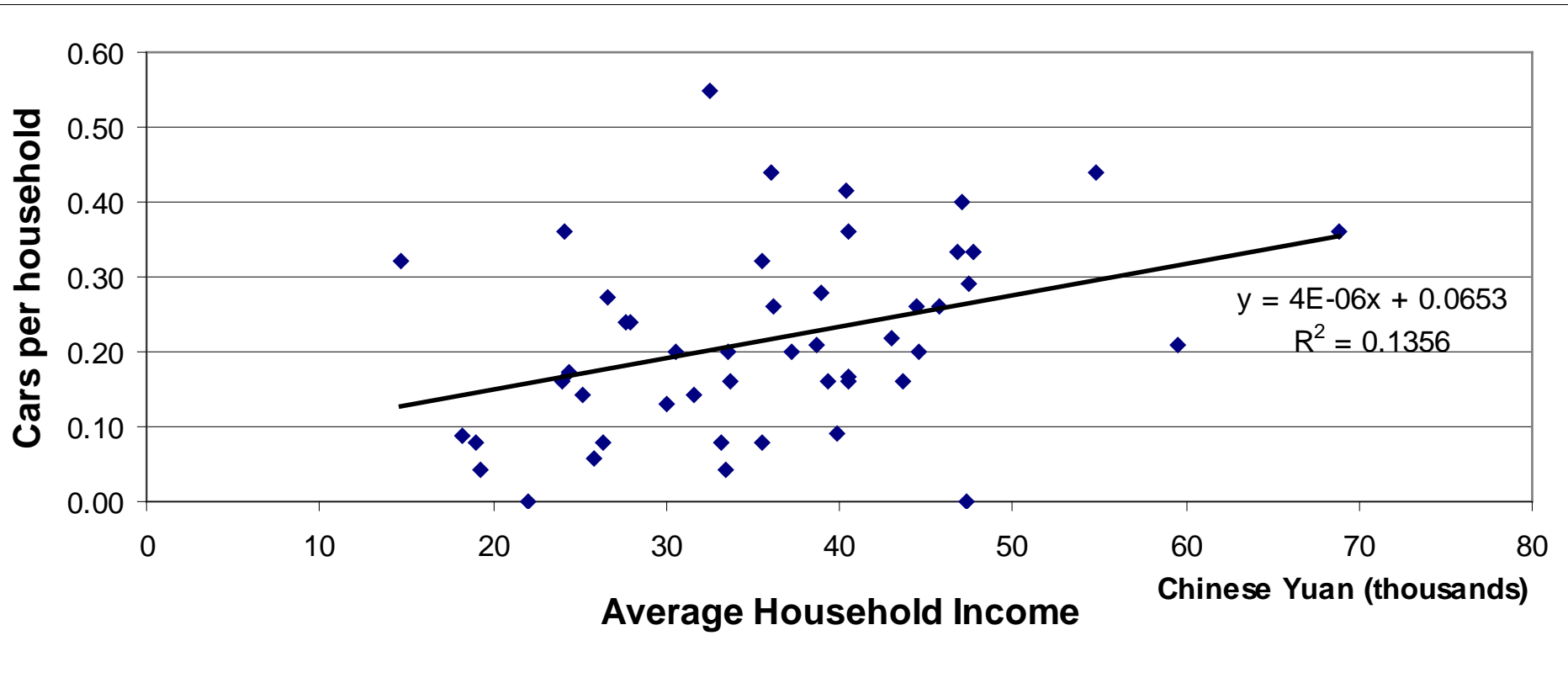
Summary

- Size of metropolitan area matters
 - It confirms the theoretical model
- Density has a positive mode impacts
- Density has a blurred time allocation impact
 - Distance effect and congestion effects comprise each other
- Polycentrality matters
 - High density suburban centers saves commuting
 - Policy sensitive variable

Implication for China's Transportation

- Size Control
 - Has been given up for other economic benefits
- Density
 - Very high density
 - Positive mode effects cannot be achieved without a matching mobility policy
- Polycentrality
 - Loss of polycentric structure

Car Ownership vs. Household Income



Cars/household =

$0.227 + 0.005 \cdot \text{income} - 0.0059 \cdot \text{population_density} - 0.154 \cdot \text{Balance_Percentage}$

(2.673) (3.439)

(-2.593)

(-1.967)

(R2=0.249)

Lack of spatial variation in mode split

Beijing, 2006

	Walking	Biking	Transit	Motorized mode	Commuting Time
Population density	-.008	-.295*	.415**	.104	.322*
Job density	.128	-.292*	.343*	.033	.199
Distance to job centers	.116	.130	-.278	-.049	-.145
Distance to geometric center	.218	.073	-.246	-.031	-.318*
Distance to subway station	-.091	.314*	-.332*	-.022	-.124
MRC	-.193	.337*	-.249	-.057	.030
PMC	.207	.028	-.167	-.030	-.252

1982
population
density



1990



2000

