The Spatial Structure of Cities in the United States

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Abstract

In recent years, the spatial structure of cities has become the subject of considerable interest, as travel behavior, greenhouse gas emissions, loss of habitat, public expenditures, and more are thought to be influenced by the spatial structure of cities. In this paper we examine the spatial structure of 35 metropolitan areas in the United States. Based on the 2010 Census data, we focus on the distributions of populations in metropolitan areas in 2010 and on changes between 1990 and 2010. Specifically, we examine population levels and population density at the metropolitan, urbanized area, principal city, and census block levels. We also examine how much growth has occurred since 1990 in previously urbanized areas, in newly urbanized areas, and in never urbanized areas. Finally, we examine the spatial distribution of populations within urban areas, exploring the extent to which population is concentrated within subareas and the extent to which population density declines with distance from the city center. We find that significant differences in recent growth patterns remain between the older and more densely developed cities of the Northeast and cities in the South and West. Most urban growth is now occurring in cities in the South and West, causing them to experience increases in density in their principal cities, urbanized area, and nonurbanized areas. We also find, however, that much of the population growth in the largest metropolitan areas of the United States continues to occur at the urban fringe, causing overall densities to decline, density gradients to flatten, and measures of concentration to fall.

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Introduction

The structure of urban areas has long been a subject of analysis, starting with the seminal work of von Thünen (1826), Chistaller (1933), and Lösch (1940) (Fischer, 2011). Ever since, it has been well understood that the size of urban areas is systematically related to the population of their hinterlands and that the density of urban population falls with distance from the central city. In more recent years, the spatial structure of cities has become the subject of more than academic interest, as travel behavior, greenhouse gas emissions, loss of habitat, public expenditures, and more are thought to be influenced by the spatial structure of cities. To minimize automobile travel, greenhouse gas emissions, habitat loss, and public expenditures, for example, many advocate building compact cities, with nodes of mixed use concentrations of activities, and infill development within the urban core (Smart Growth Network, n.d.). Further, in recent years a debate has raged about whether urban growth is beginning to exhibit these more "desirable" development patterns. Following the release of the 2010 Census data, for example, some analysts have proclaimed the beginnings of an urban revival in all or parts of metropolitan America. Cities like Washington, DC and Philadelphia, PA which lost population for many years, gained population between 2000 and 2010 (U.S. Census, 2011a). Other analysts, however, are skeptical, noting that the principal cities of Chicago, IL and Minneapolis, MN lost population between 2000 and 2010 despite a resurgence in population between 1990 and 2000 (U.S. Census, 2011b).

In this paper we extend earlier work by Lewis and Knaap (2009) and Knaap, Lewis, Carruthers and Lewis (2008) to examine the spatial structure of 35 metropolitan areas in the United States. Based on the 2010 Census data, we focus on the distributions of populations in metropolitan areas in 2010 and on changes between 1990 and 2010. Our examination focuses solely on measures of population. Specifically, we examine population levels and population density at the metropolitan, urbanized area, principal city, and census block levels. We also examine how much growth has occurred since 1990 in urbanized areas generally, in previously urbanized areas, and in newly urbanized areas. Finally we examine the spatial distribution of populations within urban areas, exploring the extent to which population is concentrated in subareas and the extent to which population density declines with distance from the city center. Our interests are twofold. First, we seek to extend the analysis of urban form in a way that focuses specifically at changes over the last two decades. Second, we seek to explore whether these trends are consistent with the proposition that U.S. cities are now experiencing, in some measure, more "desirable" spatial structure.

Previous Research

Careful examination of changes in the structure of metropolitan areas requires measurement of urban structure and an examination of changes in those measures over time. Urban analysts have taken a variety of approaches toward such measurement (Clifton et. al., 2008). Ecologists tend to focus on aggregate population density, or compactness, noting that more compact growth results

in less development on farmland and natural habitat. Economists tend to focus on population and employment density gradients. Gradients that show a more gradual decline in density are typically viewed as evidence of a weakening of the economic attraction to the central city. Transportation planners tend to view urban structure as a way of shaping distances between trip origins and destinations. Short distances between concentrations of activity facilitate carpooling, greater use of public transportation, biking and walking. All of these perspectives are valid, and the choice of measurement tends to reflect both the particular issue of concern and the data that are available for analysis.

In the analysis that follows, we use the recently released data from the census of population to re-examine urban structure and changes in structure over time. We are not the first to have done so. According to Nate Berg (2012), over 80 percent of the United States population resides in urban areas, and almost every urban area in the country expanded physically between 2000 and 2010. Only 50 of United States' approximately 3,500 urban areas declined in land area during this time. According to the Census Bureau, for example, only 24 of the 50 fastest growing metropolitan areas in 2000 were also among the 50 fastest growing in the 2010 Census. Nearly all of the fastest-growing metro areas from 2010 to 2011 (46 of 50) were located either entirely or partially in the South or West. The South and West accounted for 84 percent of the U.S. population increase from 2000 to 2010. All 10 of the most populous metropolitan areas in 2010 grew over the last decade. Approximately one out of every 10 people in the United States lived in either Los Angeles or New York, the nation's two most populous metro areas and almost two-thirds of the nation's counties gained population between 2000 and 2010 (U.S. Census Bureau, 2012).

Nine of the 10 most populous cities in 2010 gained population over the last decade. Chicago, which grew between 1990 and 2000, was the only one of these cities to decline in population between 2000 and 2010. William Frey of the Brookings Institution notes that growth in sun and snow belts tapered in the 2000s, especially in cities with "bubble economies." According to Frey, suburbs grew faster than cities in the 2000s but both had growth rates lower than the 1990s. Exurban and outer suburban counties experienced both a population boom and bust in the 2000s (Frey, 2012).

Several researchers focus on the question of whether the new century marks the end of urban sprawl. In an article titled "The End of Sprawl?", Richard Florida notes that only two of the 39 counties with 1 million-plus people—Michigan's Wayne (Detroit) and Ohio's Cuyahoga (Cleveland)—grew from 2006 to 2011. Of these, 28 grew faster than the nation, which as a whole grew at the slowest rate since the Great Depression (0.73 percent). Median growth rate for the 39 counties with 1 million-plus people was 1.3 percent and central metro counties accounted for 94 percent of U.S. growth, an increase from 85 percent before the recession. Eric Jaffe (2011) suggests that some places that experienced an overall decline, such as St. Louis, have downtown areas that showed some residential growth.

Wendell Cox (2012), on the other hand, strongly disputes the notion that the era of urban sprawl has ended. According to Cox, urban density in 2010 remained approximately 27 percent below that of 1950. Many core municipalities lost population while suburban and exurban populations expanded. Urban land area expanded along with this trend; Cox speculates that this may reflect

an American preference for low-density housing. Further, notes Cox, major metropolitan areas added 14 percent to their populations in the 2000s, down from 19 percent growth in the 1990s. The historic core municipalities grew four percent after 2000, compared to the 1990s rate of seven percent. Suburban areas grew 18 percent, compared to the 1990s rate of 26 percent. Kotkin (2011) concurs with Cox. According to Kotkin, the 2010 Census shows that just 8.6 percent of the population growth in metropolitan areas with more than 1 million people took place in the core cities while the rest took place in the suburbs. In the 1990s, the figure was 15.4 percent. Kotkin indicates that core city growth has declined over time. Regarding housing choices, single-family houses accounted for almost 80 percent of all the new households in the past decade, far exceeding multifamily or attached home growth.
In sum, the evidence that the structure of urban growth has changed in the most recent decade is mixed. While there is some evidence of renewed growth in central cities, there is also evidence of continued suburban expansion. In what follows we present a systematic evaluation of the distribution of population and population growth in the 35 largest metropolitan areas using simple and complex measures of urban form.

We find that significant differences remain between the older and more densely developed cities of the Northeast and cities in the South and West and significant differences in their recent growth patterns. Most urban growth is now occurring in cities in the South and West causing them to experience increases in density in their principal cities, urbanized area, and nonurbanized areas. We also find, however, that much of the population growth in the largest metropolitan areas of the United States continues to occur at the urban fringe, causing overall densities to decline, density gradients to flatten, and measures of concentration to fall.

Data and Methods

To reexamine and explore in some depth the distribution of population and population growth in US metropolitan areas we use data from the 1990, 2000, and 2010 Censuses for the 35 largest metropolitan areas in the United States and compute several measures of urban structure. Our measures include density gradients, concentration indices, density frequency distributions, and spatial distributions of growth. We used metropolitan area definitions from the U.S. Office of Management and Budget (OMB) released in 2002. Though census boundaries change, we use consistent metropolitan area boundaries for 1990, 2000 and 2010. Specifically we use "Core Based Statistical Areas[1]" and ignore Metropolitan Divisions and micropolitan areas in our analysis. Within metropolitan areas, we used normalized census block groups in 2000 boundaries. These data were derived from Geolytics, Inc. products which allocate selected 1990, 2000 and 2010 variables to 2000 block groups. Geolytics allows us to use consistent geographies to measure changes in urban form over time (GeoLytics n.d.) .

[1] Core Based Statistical Areas are defined by the U.S. Office of Management and Budget and "consist of the county or counties or equivalent entities associated with at least one core (urbanized area or urban cluster) of at least 10,000 population, plus adjacent counties having a high degree of social and economic integration with the core as measured through community ties with the counties associated with the core." (See: http://www.census.gov/geo/www/2010census/gtc/gtc_cbsa.html)

Our measures include both measures of population distributions in 2010 and measures of changes in those distributions from 1990 to 2010. Specifically, we measure:

Table 1: Static and Dynamic Indicators

Static and Dynamic Indicators	
Static (2010)	Dynamic (1990–2010)
Metropolitan Population	Change in Metropolitan Population
Metropolitan Density	Change in Metropolitan Density
Principal City Population	Change in Principal City Population
Principal City Density	Change in Principal City Density
Urbanized Area Population	Change in Urbanized Area Population
Number of Block Groups Meeting Critical Light Rail Transit Threshold*	Change in Block Groups Meeting Light Rail Threshold*
Number of Block Groups Meeting Critical Bus Transit Threshold*	Change in Block Groups Meeting Bus Threshold*
Number of Block Groups Declining in Population	Share of Block Groups Declining in Population
Density Gradient: Slope	Density Gradient: Change in Slope
Density Gradient: Intercept	Density Gradient: Change in Intercept
Gini Coefficient: Metropolitan Area	Change in Gini Coefficient: Metropolitan area
Gini Coefficient: Urbanized Area	Change in Gini Coefficient: Urbanized area
	Change in Population in 1990 Urbanized Area Boundary
	Change in Population in Areas that never met Urbanized Threshold
	Change in Urbanized Area
	Marginal Density**
	Density Gradient: Change in Slope & Intercept (Signs)
* The critical threshold for light rail is 15,000 Persons Per Square Mile The critical threshold for bus transit is 5,000 Persons Per Square Mile (Pushkarev & Zupan, 1977) ** Marginal Density is the Change in Urbanized Area divided by Change in Population	

In what follows, we present the measures listed above for each of the 35 metropolitan areas. To provide some context for these measures, we start by presenting national data on urban growth in the United States in 1990, 2000, and 2010. As shown in table 2, the population of the United States increased from 250 million in 1990 to nearly 310 million in 2010. Most of that growth

occurred in the South and West, a trend that continued in the 2000s. The 35 metro areas used in this study contained 46 percent of the population in 1990 and 47 percent in 2010.

Table 2: Population in the U.S. and Study Area—1990–2010

Table 2: Population in the U.S. and Study Area - 1990-2010			
	Population	1990-2000 % Change	Study Area: Population
1990 U.S. Population	248,709,873	13%	114,468,172 (46%)
Northeast	50,809,229	5%	
Midwest	59,668,632	8%	
South	85,445,930	17%	
West	52,786,082	20%	
		2000-2010 % Change	
2000 U.S. Population	281,421,906	10%	131,866,039 (47%)
Northeast	53,594,378	3%	
Midwest	64,392,776	4%	
South	100,236,820	14%	
West	63,197,932	14%	
		1990-2010 % Change	
2010 U.S. Population	308,745,538	24%	146,259,827 (47%)
Northeast	55,317,240	9%	
Midwest	66,927,001	12%	
South	114,555,744	34%	
West	71,945,553	36%	

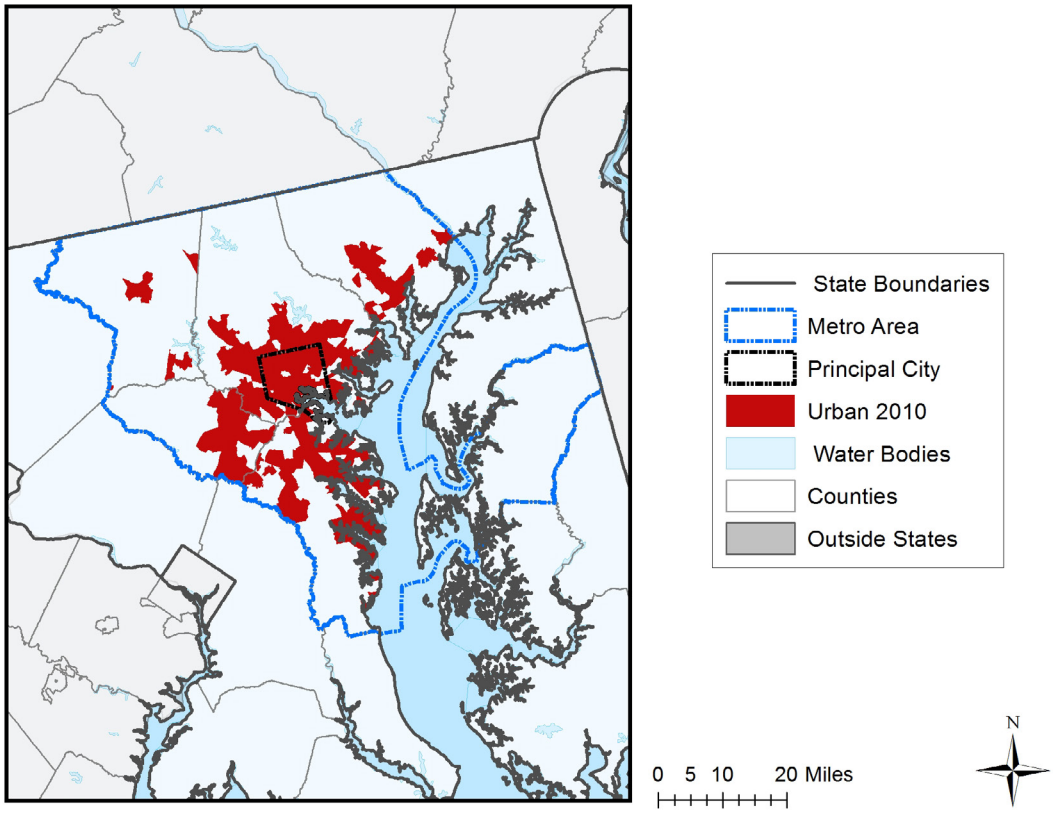
Population and Population Density

Population and population density are perhaps the simplest and most common measures of urban structure. By definition, urban areas are places with large populations and high relative population densities (McDonald, 1997). We measure population and population densities for three geographic areas: the metropolitan area, the urbanized area, and the principal city. Metropolitan areas are defined as the aggregate of counties that include an urban core with more than 50,000 residents and adjacent counties "that have a high degree of social and economic integration" with the urban core (U.S. Census, n.d.b). Metropolitan areas often include both urban and rural areas and, because some counties contain large, nonurbanized areas, measures of urban structure at the metropolitan scale often reflect how much of the metropolitan area is rural. In some metropolitan areas, for example, the nonurbanized, rural part of the metro area is relatively large, thus the overall density of the metropolitan area is relatively low.

Urbanized areas are defined as the aggregate of census tracts within a metropolitan area that meet urban density thresholds. An urban area is a place with (1) very high population densities compared to the surrounding area, and (2) a population greater than some minimum number (McDonald, 1997). Following the Census, we set the density threshold for urbanized areas at

1,000 persons per square mile. We do not, however, use the same contiguity rules as the Census. Instead we limit our definition of urbanized area to include any Census tract that meets the density threshold. As a result, our definition results in some non urban areas completely surrounded by urbanized areas and some urbanized census tracts that are not contiguous to any other urbanized area (Proposed Urban Area Criteria for the 2010 Census, 2010). The principal city is the central and often the largest and oldest jurisdiction in the metropolitan area. The Census defines the principal city as the "largest incorporated place or Census Designated Place of at least 10,000 population." (U.S. Census, 2011c). The geographic boundaries are political and not based on population density.[2] In every metropolitan area, the central city is contained within the urbanized areas. See figure 1.

Figure 1: Metropolitan Area, Principal City, and Urbanized Area Boundaries in Baltimore-Towson, MD (2010)



Measures of population and population density for the largest 35 metropolitan areas in the US from the 2010 Census are presented in tables 3 through 5. Tables 3 and 4 present population and density data for 2010 and table 5 shows changes in population from 1990 and 2010 for the entire metropolitan area, urbanized area, and principal city. The data for each geographic area are presented in descending order by population. As shown, the New York metropolitan area is the largest in the nation with a population of over 18 million people, followed by Los Angeles,

[2] Due to data limitations, we use 2000 Census principal city area. Thus, we do not consider expansion of principal cities. See: http://www.census.gov/statab/ccdb/cit1010r.txt

Chicago and Dallas. In general, but with exception, cities with large metropolitan-area populations have large populations in their urbanized areas and central cities.

Table 3: Population at Metropolitan, Principal City, and Urbanized Area Scale, Sorted in Rank Order

Metropolitan Area	Metropolitan Area Population (2010)	Metropolitan Area	Urbanized Area Population (2010)	Metropolitan Area	Principal City Population (2010)
New York	18,897,109	New York	17,685,468	New York	8,175,133
Los Angeles	12,828,837	Los Angeles	12,466,385	Los Angeles	3,792,621
Chicago	9,461,105	Chicago	8,429,648	Chicago	2,695,598
Dallas	6,371,773	Miami	5,302,551	Houston	2,099,451
Philadelphia	5,965,343	Dallas	5,206,669	Philadelphia	1,526,006
Houston	5,946,800	Philadelphia	4,998,187	Phoenix	1,445,632
Washington, DC	5,582,170	Houston	4,889,916	San Antonio	1,327,407
Miami	5,564,635	Washington, DC	4,655,904	San Diego	1,307,402
Atlanta	5,268,860	San Francisco	4,009,381	Dallas	1,197,816
Boston	4,552,402	Atlanta	3,678,746	San Jose	945,942
San Francisco	4,335,391	Detroit	3,675,546	Indianapolis	820,445
Detroit	4,296,250	Boston	3,549,238	San Francisco	805,235
Riverside	4,224,851	Phoenix	3,493,944	Austin	790,390
Phoenix	4,192,887	Riverside	3,457,162	Columbus	787,033
Seattle	3,439,809	Seattle	2,979,517	Charlotte	731,424
Minneapolis	3,279,833	San Diego	2,807,885	Detroit	713,777
San Diego	3,095,313	Minneapolis	2,480,342	Baltimore	620,961
St. Louis	2,812,896	Tampa	2,341,671	Boston	617,594
Tampa	2,783,243	Denver	2,237,312	Seattle	608,660
Baltimore	2,710,489	Baltimore	2,196,557	Washington, DC	601,723
Denver	2,543,482	St. Louis	2,039,944	Denver	600,158
Pittsburgh	2,356,285	Portland	1,846,200	Portland	583,776
Portland	2,226,009	Sacramento	1,782,172	Las Vegas	583,756
Sacramento	2,149,127	Las Vegas	1,744,814	Sacramento	466,488
San Antonio	2,142,508	San Jose	1,730,545	Kansas City	459,787
Orlando	2,134,411	Cleveland	1,694,537	Atlanta	420,003
Cincinnati	2,130,151	San Antonio	1,629,165	Miami	399,457
Cleveland	2,077,240	Orlando	1,601,566	Cleveland	396,815
Kansas City	2,035,334	Cincinnati	1,552,352	Minneapolis	382,578
Las Vegas	1,951,269	Pittsburgh	1,529,077	Tampa	335,709
San Jose	1,836,911	Kansas City	1,482,348	St. Louis	319,294
Columbus	1,836,536	Columbus	1,338,093	Pittsburgh	305,704
Charlotte	1,758,038	Indianapolis	1,255,099	Riverside	303,871
Indianapolis	1,756,241	Austin	1,203,173	Cincinnati	296,943
Austin	1,716,289	Charlotte	1,156,323	Orlando	238,300

Table 4: Population Density (in Persons per Square Mile) at Metropolitan, Principal City, and Urbanized Area Scale, Sorted in Rank Order

Metropolitan Area	Metropolitan Area Density (2010)	Metropolitan Area	Urbanized Area Density (2010)	Metropolitan Area	Principal City Density (2010)
New York	2,752	Los Angeles	7,418	New York	26,954
Los Angeles	2,625	New York	6,833	San Francisco	17,243
San Francisco	1,711	San Jose	6,415	Boston	12,760
Chicago	1,295	San Francisco	6,046	Chicago	11,870
Philadelphia	1,267	Las Vegas	4,717	Philadelphia	11,295
Boston	1,257	San Diego	4,678	Miami	11,189
Detroit	1,079	Miami	4,624	Washington, DC	9,800
Tampa	1,063	Chicago	4,200	Los Angeles	8,085
Cleveland	1,030	Denver	3,926	Baltimore	7,685
Baltimore	1,030	Washington, DC	3,915	Seattle	7,255
Miami	1,027	Sacramento	3,866	Minneapolis	6,969
Washington, DC	983	Portland	3,840	Tampa	5,633
San Diego	731	Baltimore	3,822	Pittsburgh	5,498
Dallas	686	Philadelphia	3,693	San Jose	5,408
San Jose	683	Boston	3,622	St. Louis	5,158
Houston	644	Seattle	3,551	Las Vegas	5,152
Atlanta	621	Phoenix	3,535	Detroit	5,142
Seattle	574	San Antonio	3,487	Cleveland	5,114
Charlotte	559	Riverside	3,387	Sacramento	4,799
Orlando	532	Houston	3,380	Portland	4,347
Minneapolis	515	Dallas	3,305	San Diego	4,031
Cincinnati	477	Detroit	3,258	Denver	3,912
Columbus	458	Cleveland	3,108	Riverside	3,891
Indianapolis	452	Columbus	3,105	Cincinnati	3,807
Pittsburgh	441	Minneapolis	2,904	Columbus	3,742
Sacramento	405	Austin	2,827	Houston	3,623
Austin	401	Tampa	2,819	Dallas	3,497
Portland	327	St. Louis	2,727	San Antonio	3,257
St. Louis	318	Pittsburgh	2,712	Atlanta	3,189
Denver	301	Kansas City	2,630	Austin	3,143
San Antonio	290	Orlando	2,576	Phoenix	3,044
Phoenix	287	Cincinnati	2,539	Charlotte	3,019
Kansas City	256	Indianapolis	2,492	Orlando	2,549
Las Vegas	241	Atlanta	2,189	Indianapolis	2,270
Riverside	154	Charlotte	2,095	Kansas City	1,467

Table 5: Change in Population Density at Metropolitan, Principal City, and Urbanized Area Scale (1990–2010), Sorted in Rank Order

Metropolitan Area	Change in Metropolitan Area Density (1990-2010)	Metropolitan Area	Change in Principal City Density (1990-2010)	Metropolitan Area	Change in Urbanized Area Population (1990-2010)
Las Vegas	163%	Las Vegas	126%	Las Vegas	159%
Austin	103%	Charlotte	85%	Austin	109%
Phoenix	87%	Austin	70%	Charlotte	103%
Orlando	74%	Phoenix	47%	Atlanta	87%
Atlanta	72%	Orlando	45%	Orlando	77%
Charlotte	72%	San Antonio	42%	Phoenix	77%
Riverside	63%	Riverside	34%	Riverside	70%
Dallas	60%	Portland	33%	Dallas	63%
Houston	58%	Houston	29%	Houston	62%
Denver	53%	Denver	28%	Portland	57%
San Antonio	52%	Sacramento	26%	Denver	51%
Portland	46%	Columbus	24%	Sacramento	46%
Sacramento	45%	San Jose	21%	San Antonio	46%
Miami	37%	Tampa	20%	Seattle	42%
Indianapolis	36%	Dallas	19%	Indianapolis	39%
Washington, DC	35%	Seattle	18%	Miami	39%
Tampa	35%	San Diego	18%	Tampa	37%
Seattle	34%	New York	12%	Washington, DC	36%
Columbus	31%	Miami	11%	Columbus	35%
Minneapolis	29%	San Francisco	11%	Minneapolis	27%
Kansas City	24%	Indianapolis	11%	San Diego	26%
San Diego	24%	Los Angeles	9%	Kansas City	22%
San Jose	20%	Boston	8%	San Jose	21%
San Francisco	18%	Atlanta	7%	Cincinnati	18%
Chicago	16%	Kansas City	6%	San Francisco	17%
Cincinnati	15%	Minneapolis	4%	Chicago	15%
Los Angeles	14%	Washington, DC	-1%	Baltimore	15%
Baltimore	14%	Chicago	-3%	Los Angeles	14%
New York	12%	Philadelphia	-4%	New York	13%
Boston	10%	Baltimore	-16%	Boston	10%
Philadelphia	10%	Pittsburgh	-17%	Philadelphia	9%
St. Louis	9%	Cincinnati	-18%	St. Louis	6%
Detroit	1%	St. Louis	-20%	Detroit	-1%
Cleveland	-1%	Cleveland	-22%	Cleveland	-3%
Pittsburgh	-5%	Detroit	-31%	Pittsburgh	-8%

Most of the differences in rank between these areas reflect differences in the extent to which the metropolitan area contains rural as well as urbanized areas. For this reason, for example, Miami ranks ninth in metropolitan population but third in the population of its urbanized area. New York, Los Angeles, and Chicago remain the three largest principal cities and only nine central cities have more than one million people. Because the central cities of Houston and Phoenix include a large share of their urbanized population, they rank relatively high in principal city population.

Population and population density are highly correlated at every level of geography; the largest metropolitan areas, urbanized areas and principal cities tend to be the most dense metropolitan areas, urbanized areas, and principal cities.[3] The metropolitan area of New York is the most dense, followed by Los Angeles, San Francisco, and Chicago. Los Angeles has the most densely populated urbanized area, followed by New York, San Jose, San Francisco, and Las Vegas. New York, San Francisco, Boston, and Chicago have the most densely populated principal cities, in that order. The relative ranking of the size of metropolitan area, urbanized area, and principal city populations have changed very little over the last two decades.

Growth Distribution and Infill

To gain further insights into the distribution of growth within metropolitan areas we examined the distribution of growth with respect to fixed urbanized-area boundaries. That is, for each metropolitan area we identified how much population growth from 1990 to 2010 occurred in: (i) the geographic area that was urbanized in 1990, (ii) the area that urbanized between 1990 and 2000, (iii) the areas that urbanized between 2000 and 2010, and (iv) the areas that have never been urbanized. How much growth occurred in each of these areas can be viewed as measures of infill and urban sprawl.

Metropolitan areas that had more growth within the area urbanized by 1990 can be said to have had more infill development. Table 7 presents the distribution of growth in areas urbanized in successive decades for each metropolitan area sorted by the share of growth that occurred in the area urbanized by 1990. As shown, Portland had the largest share of infill urban development, followed by Riverside, Las Vegas, and Austin. Las Vegas and Phoenix experienced the most growth in areas that still do not meet urban density thresholds. The urbanized areas of Las Vegas, Austin, and Charlotte more than doubled in population over the last two decades. Marginal urban density—that is, the percent change in urbanized areas divided by the percent change in urban population—was negative for Pittsburgh and Cleveland, because the population in their urbanized areas declined. Marginal densities were lowest for San Jose, Portland, and Los Angeles, meaning that these metropolitan areas accommodated the most urban population over the last 20 years with the smallest expansions of their urbanized areas. Many of these measures reflect overall population growth. Metropolitan areas that grew the most tended to have the highest rates of growth in their urbanized and nonurbanized areas; metropolitan areas that grew the least tended to have the lowest rates of growth in both their urbanized and non-urbanized areas. Proportions of growth, however, varied, as evidenced by differences in marginal densities.

[3] At the metropolitan level, the correlation between population and density equals 0.83; at the urbanized area, the correlation equals 0.67; at the principal city level, the correlation equals 0.69.

Table 6: Percent Change in Urbanized Area, Urbanized Land Area, and Marginal Density (1990–2010), Sorted in Rank Order

Metropolitan Area	Percent Change in Density in Urbanized Area (1990-2010)	Metropolitan Area	Percent Change in Urbanized Land Area (1990-2010)	Metropolitan Area	Marginal Density (Change in Area/Change in Population) (1990-2010)
Portland	7%	Pittsburgh	14%	San Jose	0.80
San Jose	5%	Los Angeles	14%	Portland	1.01
Los Angeles	0%	San Jose	16%	Los Angeles	1.04
Orlando	-1%	Boston	17%	San Antonio	1.06
San Francisco	-3%	New York	19%	Orlando	1.07
Seattle	-3%	San Francisco	20%	San Francisco	1.13
Miami	-3%	Cleveland	22%	Phoenix	1.15
Riverside	-4%	Detroit	25%	Miami	1.16
Houston	-5%	St. Louis	29%	Las Vegas	1.18
Atlanta	-5%	Philadelphia	32%	Riverside	1.22
New York	-6%	Baltimore	36%	Houston	1.22
Boston	-6%	San Diego	41%	Denver	1.27
San Antonio	-6%	Chicago	42%	Washington, DC	1.29
Washington, DC	-7%	Minneapolis	42%	Dallas	1.33
Dallas	-9%	Miami	43%	Seattle	1.34
Denver	-9%	Kansas City	43%	Atlanta	1.36
Charlotte	-10%	Washington, DC	46%	Sacramento	1.42
San Diego	-11%	Seattle	46%	Minneapolis	1.45
Minneapolis	-11%	Portland	46%	Austin	1.46
Sacramento	-11%	Cincinnati	48%	New York	1.59
Las Vegas	-11%	San Antonio	56%	Tampa	1.64
Phoenix	-12%	Tampa	57%	Boston	1.64
Tampa	-13%	Sacramento	64%	San Diego	1.71
Kansas City	-15%	Denver	67%	Charlotte	1.74
Baltimore	-16%	Columbus	69%	Kansas City	1.78
Austin	-16%	Indianapolis	70%	Indianapolis	1.95
Philadelphia	-17%	Houston	71%	Columbus	2.26
St. Louis	-17%	Riverside	77%	Baltimore	2.65
Indianapolis	-18%	Orlando	79%	Chicago	2.67
Chicago	-19%	Dallas	80%	Cincinnati	3.11
Pittsburgh	-19%	Atlanta	97%	St. Louis	3.22
Cincinnati	-21%	Phoenix	100%	Philadelphia	3.28
Columbus	-21%	Charlotte	125%	Detroit	22.77
Detroit	-21%	Austin	150%	Pittsburgh	-3.06
Cleveland	-21%	Las Vegas	192%	Cleveland	-18.59

Table 7: Change in Population in Urbanized and Never Urbanized Areas (1990–2010), Sorted in Rank Order

Metropolitan Area	Change in Population in 1990 Urbanized Areas (1990-2010)		Metropolitan Area	Change in Population in Never Urbanized Areas (1990-2010)
Portland	30%		Pittsburgh	10%
Riverside	25%		San Jose	25%
Las Vegas	25%		Boston	28%
Austin	23%		Baltimore	32%
Houston	22%		Cleveland	32%
Atlanta	21%		Cincinnati	35%
Orlando	20%		San Diego	36%
Phoenix	19%		St. Louis	38%
Seattle	18%		New York	41%
Miami	18%		Portland	42%
Denver	18%		Seattle	42%
Dallas	17%		Detroit	44%
San Jose	17%		Columbus	47%
Charlotte	13%		Philadelphia	48%
San Antonio	13%		Kansas City	56%
Washington, DC	12%		Los Angeles	56%
San Francisco	10%		San Francisco	68%
Tampa	9%		Chicago	68%
Los Angeles	8%		Sacramento	69%
Sacramento	8%		Minneapolis	71%
San Diego	8%		Washington, DC	72%
New York	8%		Indianapolis	73%
Minneapolis	5%		Charlotte	82%
Boston	5%		Tampa	84%
Chicago	1%		Riverside	101%
Indianapolis	0%		Houston	106%
Baltimore	0%		Dallas	110%
Columbus	0%		Atlanta	122%
Philadelphia	-1%		San Antonio	122%
Kansas City	-3%		Miami	123%
Cincinnati	-5%		Denver	151%
St. Louis	-7%		Austin	161%
Detroit	-11%		Orlando	165%
Cleveland	-11%		Phoenix	379%
Pittsburgh	-13%		Las Vegas	449%

Growth Distribution and Threshold Densities

To examine the distribution of population and growth in smaller geographic areas, we examine population and population growth by block groups. Densities in smaller geographic units are considered important because certain densities are viewed as thresholds for bus and rail transit service. According to Pushkarev and Zupan (1977), for example, a density of 15,000 persons per square mile is necessary to be viable for rail transit service and 5,000 persons per square mile is necessary for bus service to be viable. Cervero and Guerra (2011) utilize the same densities offered by Pusharev & Zupan to examine critical densities for transit investment. Farr (2008) illustrates that the work of Pushkarev & Zupan (1977) is still relevant today as he suggests using these coefficients to encourage sustainable urbanism.

Tables 8 and 9 presents the number and share of block groups that meet the rail and bus density thresholds in 2010 and the percent difference in the share block groups that met these critical thresholds from 1990 to 2010, as well as the new block groups meeting the thresholds. As shown, over 80 percent of block groups in Los Angeles, San Jose, San Francisco, Miami, New York, Las Vegas, and San Diego met the critical threshold for bus service in 2010. In Charlotte, less than 25 percent of block groups met this threshold. For light rail, nearly half of the block groups in New York met the transit density threshold in 2010. In San Francisco, Los Angeles, and Philadelphia more than 30 percent met this threshold. In Boston, Chicago, Baltimore, San Diego, San Jose and Washington more than 20 percent of block groups met this threshold. In all other metro areas, less than 10 percent of block groups met this threshold in 2010.

In Las Vegas, Phoenix, Portland, Denver and Austin, an additional 10 percent of block groups met the bus threshold between 1990 and 2010. In several cities, including Pittsburgh, Detroit, St. Louis, Cleveland, Indianapolis, Kansas City, and Cincinnati, the number and share of block groups meeting the critical threshold for bus service declined between 1990 and 2010. San Jose, Los Angeles and San Francisco showed the highest increases in the percentage of block groups at light rail density, while the number of block groups at light rail density declined in 15 metropolitan areas between 1990 and 2010.

Another critical dynamic threshold is zero. When block groups lose population it leaves housing units vacant and creates the potential for urban blight. As shown in table 10, for the period from 1990 to 2010, Las Vegas had the smallest share of block groups that lost population, followed by Riverside, Portland and Austin. Cleveland, Detroit, St. Louis and Cincinnati had the highest share of the block groups that lost population.

Table 8: Share and Count of Block Groups at Bus Density in 2010; Change in Share and Count of Block Groups at Bus Density (1990–2010), Sorted in Rank Order

Metropolitan Area	Share (Count) of Block Groups at Bus Density (>5,000 ppsm) (2010)
Los Angeles	90% (7,379)
San Jose	88% (915)
San Francisco	85% (2,304)
Miami	82% (2,070)
New York	82% (11,431)
Las Vegas	80% (668)
San Diego	80% (1,414)
Chicago	76% (5,002)
Denver	74% (1,240)
Phoenix	72% (1,610)
Philadelphia	69% (3,301)
Washington, DC	67% (1,969)
Portland	66% (833)
Seattle	65% (1,716)
Sacramento	65% (756)
San Antonio	65% (778)
Baltimore	64% (1,212)
Detroit	64% (2,522)
Dallas	63% (2,255)
Cleveland	62% (1,101)
Boston	60% (2,035)
Riverside	58% (1,111)
Houston	58% (1,596)
Columbus, OH	57% (719)
Tampa	57% (897)
Minneapolis	53% (1,193)
Austin	51% (393)
St. Louis	50% (1,025)
Cincinnati	45% (690)
Pittsburgh	43 (887)
Kansas City	43% (649)
Orlando	39% (272)
Indianapolis	39% (401)
Atlanta	28% (535)
Charlotte	22% (174)

Metropolitan Area	Change in Share (Count) of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)
Las Vegas	34% (287)
Phoenix	13% (289)
Portland	11% (137)
Denver	11% (180)
Austin	10% (74)
Riverside	9% (176)
Seattle	9% (227)
Miami	8%(202)
Washington, DC	8%(229)
Sacramento	8% (88)
Dallas	7% (258)
Houston	7% (191)
San Antonio	7% (78)
San Diego	6% (114)
Orlando	6% (41)
Atlanta	5% (92)
Tampa	4% (62)
Los Angeles	4% (295)
Columbus	3% (44)
San Jose	3% (33)
Baltimore	2% (45)
Chicago	2% (149)
San Francisco	2% (60)
Charlotte	2% (15)
New York	2% (247)
Minneapolis	1% (28)
Philadelphia	1% (46)
Boston	1% (28)
Cincinnati	-1% (-14)
Kansas City	-1% (-19)
Indianapolis	-2% (-22)
Cleveland	-3% (-51)
St. Louis	-3% (-61)
Detroit	-3% (-132)
Pittsburgh	-4% (-75)

Table 9: Share and Count of Block Groups at Light Rail Density in 2010; Change in Share and Count of Block Groups at Light Rail Density (1990–2010), Sorted in Rank Order

Metropolitan Area	Share (Count) of Block Groups at Light Rail Density (>15,000 ppsm) (2010)		**Metropolitan Area**	Change in Share (Count)of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)
New York	48% (6,723)		San Jose	5% (53)
San Francisco	34% (939)		Los Angeles	5% (406)
Los Angeles	32% (2,656)		San Francisco	4% (115)
Philadelphia	30% (1,442)		New York	3% (405)
Boston	25% (838)		Las Vegas	3% (22)
Chicago	24% (1,596)		Denver	1% (25)
Baltimore	19% (364)		Seattle	1% (38)
San Diego	18% (318)		Riverside	1% (27)
San Jose	16% (171)		San Diego	1% (24)
Washington	15% (437)		Washington, DC	1% (36)
Miami	9% (238)		Portland	1% (14)
Las Vegas	7% (61)		Phoenix	1% (20)
Seattle	5% (134)		Austin	1% (6)
Minneapolis	4% (94)		Minneapolis	1% (14)
Denver	4% (68)		Houston	1% (17)
Dallas	4%(128)		Boston	1% (20)
Columbus	3% (39)		Dallas	1% (21)
Riverside	3% (58)		Miami	<1% (10)
Pittsburgh	3% (62)		Orlando	<1% (1)
Houston	3% (82)		Atlanta	<1% (1)
Phoenix	3% (65)		Charlotte	-1% (-1)
Cleveland	2% (44)		Kansas City	-1% (-5)
Austin	2% (19)		Sacramento	-1% (-5)
Portland	2% (29)		San Antonio	-1% (-6)
Sacramento	2% (21)		Tampa	-1% (-8)
St. Louis	2% (34)		Philadelphia	-1% (-41)
Cincinnati	2% (25)		Indianapolis	-1% (-9)
Detroit	1% (49)		Chicago	-1% (-82)
Atlanta	1% (14)		Columbus	-2% (-25)
San Antonio	<1% (5)		Cincinnati	-3% (-42)
Indianapolis	<1% (4)		St. Louis	-3% (-61)
Tampa	<1% (5)		Detroit	-3% (-130)
Kansas City	<1% (3)		Pittsburgh	-4% (-77)
Orlando	<1% (1)		Baltimore	-5% (-91)
Charlotte	0% (0)		Cleveland	-8% (-147)

Table 10: Total Block Groups in 2010; Count & Share Declined (1990–2010), Sorted in Rank Order

Metropolitan Area	Total Number of Block Groups (2010)		**Metropolitan Area**	Count (Share) Block Groups Declined (1990-2010)
New York	14,009		Las Vegas	142 (17%)
Los Angeles	8,177		Riverside	379 (20%)
Chicago	6,590		Portland	271 (22%)
Philadelphia	4,793		Austin	166 (22%)
Detroit	3,942		Atlanta	483 (25%)
Dallas	3,552		Seattle	711 (27%)
Boston	3,378		Pittsburgh	576 (28%)
Washington, DC	2,949		San Jose	291 (28%)
Houston	2,739		Charlotte	225 (28%)
San Francisco	2,724		Denver	486 (29%)
Seattle	2,631		Houston	846 (31%)
Miami	2,516		Dallas	1110 (31%)
Minneapolis	2,241		Phoenix	715 (32%)
Phoenix	2,229		Los Angeles	2625 (32%)
Pittsburgh	2,053		Washington, DC	949 (32%)
St. Louis	2,050		Miami	823 (33%)
Atlanta	1,923		San Francisco	892 (33%)
Riverside	1,902		Orlando	231 (33%)
Baltimore	1,893		New York	4887 (35%)
Cleveland	1,766		San Diego	619 (35%)
San Diego	1,762		Tampa	569 (36%)
Denver	1,667		San Antonio	446 (37%)
Tampa	1,585		Sacramento	438 (38%)
Cincinnati	1,536		Boston	1288 (38%)
Kansas City	1,507		Minneapolis	956 (43%)
Columbus	1,259		Chicago	3107 (47%)
Portland	1,253		Baltimore	922 (49%)
San Antonio	1,199		Indianapolis	515 (50%)
Sacramento	1,162		Columbus	629 (50%)
San Jose	1,037		Philadelphia	2420 (50%)
Indianapolis	1,033		Kansas City	786 (52%)
Las Vegas	832		Cincinnati	859 (56%)
Charlotte	792		St. Louis	1237 (60%)
Austin	765		Detroit	2664 (68%)
Orlando	695		Cleveland	1234 (70%)

Concentration

Concentration is a measure of the extent to which populations are concentrated within subareas. Concentration can be measured using Gini coefficients and illustrated using Lorenz curves. The Gini index is commonly used to measure inequality. Gini coefficients that are close to 1 signal a high concentration of population in a few subareas implying that metropolitan populations are highly spatially concentrated. A Gini coefficient closer to zero and a flatter Lorenz curve signifies a more equal distribution of population across space. Lorenz curves can be used to illustrate distributions of population across space. In a two-region landscape that includes one urban region and one rural region, population concentration could be measured by how close the Gini coefficient was to one and how close to how close the Lorenz curve was to L-shaped (which indicates that all population was in the urban region and none in the rural region). A high Gini coefficient indicates an unequal distribution, meaning a large number of people are concentrated in a small area. The normative implications of concentrated populations are unclear, but some unevenness in the spatial distribution is necessary for the urban area to exhibit a polycentric pattern with high density mixed use nodes. An uneven distribution doesn't guarantee such a polycentric pattern, but an even distribution probably precludes it.

We calculate Gini coefficients for the entire metropolitan area and the urbanized area. In table 11, we present metropolitan level Gini coefficients for 2010 and changes in Gini coefficients for the period from 1990 to 2010. As shown, at the metropolitan scale, Riverside, Las Vegas, San Jose, Phoenix and Portland have are highly concentrated and have Gini coefficients greater than 0.90 in 2010. This is partially because these metropolitan areas have large rural areas within the metropolitan-area boundary. All of the 35 metropolitan areas became less concentrated between 1990 and 2010. Portland, San Jose, Riverside, and Indianapolis deconcentrated least, while Orlando, Atlanta, and Tampa Bay deconcentrated most. In Table 12, we present urbanized area Gini coefficients for 2010 and changes in Gini coefficients for the period from 1990 to 2010. When measured for their urbanized areas, New York, Boston, San Francisco, and Philadelphia are the most concentrated. Denver, Tampa, San Diego and San Francisco concentrated most between 1990 and 2010. The urbanized areas of Atlanta, Charlotte, Indianapolis, and Kansas City are the most deconcentrated while Atlanta, Cincinnati, and Baltimore deconcentrated the most between 1990 and 2010.

Table 11: Metropolitan Area Gini Coefficient (2010); Change in Metropolitan Area Gini Coefficient (1990–2010), Sorted in Rank Order

Metropolitan Area	Metroplitan Area Gini Coefficient (2010)		Metropolitan Area	Change in Metropolitan Area Gini Coefficient (1990-2010)
Riverside	0.95		Portland	-0.002
Las Vegas	0.95		San Jose	-0.006
Denver	0.92		Riverside	-0.010
San Jose	0.92		Indianapolis	-0.014
Phoenix	0.91		Seattle	-0.020
Portland	0.90		New York	-0.022
Sacramento	0.88		Los Angeles	-0.022
San Diego	0.88		San Diego	-0.022
Seattle	0.86		Kansas City	-0.024
San Antonio	0.86		Pittsburgh	-0.027
Miami	0.85		Denver	-0.028
Kansas City	0.84		St. Louis	-0.030
St. Louis	0.82		San Francisco	-0.030
San Francisco	0.82		Sacramento	-0.031
Houston	0.81		Columbus	-0.031
New York	0.80		Las Vegas	-0.031
Los Angeles	0.79		Boston	-0.035
Austin	0.78		Miami	-0.039
Dallas	0.78		San Antonio	-0.039
Chicago	0.78		Cincinnati	-0.042
Indianapolis	0.78		Phoenix	-0.042
Minneapolis	0.77		Baltimore	-0.044
Columbus	0.77		Charlotte	-0.044
Orlando	0.77		Minneapolis	-0.047
Washington, DC	0.76		Houston	-0.050
Cincinnati	0.74		Washington, DC	-0.051
Baltimore	0.73		Chicago	-0.055
Pittsburgh	0.72		Philadelphia	-0.056
Philadelphia	0.72		Cleveland	-0.059
Detroit	0.71		Austin	-0.061
Cleveland	0.69		Dallas	-0.062
Boston	0.67		Detroit	-0.064
Tampa	0.67		Atlanta	-0.074
Atlanta	0.67		Orlando	-0.076
Charlotte	0.66		Tampa	-0.086

Table 12: Urbanized Area Gini Coefficient (2010); Change in Urbanized Area Gini Coefficient (1990–2010), Sorted in Rank Order

Metropolitan Area	Urbanized Area Gini Coefficient (2010)		Metropolitan Area	Change in Urbanized Area Gini Coefficient (1990-2010)
New York	0.624		Denver	0.050
Boston	0.503		Tampa	0.016
San Francisco	0.480		San Diego	0.015
Philadelphia	0.473		San Francisco	0.011
Chicago	0.470		Phoenix	0.010
Los Angeles	0.434		Austin	0.010
San Diego	0.430		New York	0.009
Baltimore	0.421		San Jose	0.009
Washington, DC	0.419		Los Angeles	0.008
Riverside	0.390		Dallas	0.007
Miami	0.379		Miami	0.005
Seattle	0.376		Orlando	0.004
Las Vegas	0.374		Riverside	0.003
Cleveland	0.374		Portland	0.003
San Jose	0.369		Boston	0.002
Pittsburgh	0.367		Seattle	-0.002
Houston	0.363		Houston	-0.003
Denver	0.361		Sacramento	-0.009
Austin	0.360		Chicago	-0.014
Dallas	0.357		Las Vegas	-0.016
Minneapolis	0.355		Kansas City	-0.016
Phoenix	0.346		Minneapolis	-0.018
Portland	0.346		San Antonio	-0.020
Sacramento	0.344		Washington, DC	-0.020
Columbus	0.341		Charlotte	-0.022
Detroit	0.340		Philadelphia	-0.023
St. Louis	0.332		Pittsburgh	-0.029
Cincinnati	0.326		Cleveland	-0.040
Tampa	0.322		St. Louis	-0.042
San Antonio	0.321		Detroit	-0.043
Orlando	0.293		Indianapolis	-0.047
Kansas City	0.288		Columbus	-0.048
Indianapolis	0.286		Baltimore	-0.050
Charlotte	0.246		Cincinnati	-0.059
Atlanta	0.195		Atlanta	-0.089

Density Gradients

Population density gradients are classic measures of urban form at the metropolitan scale. Density gradients measure the degree to which population density declines with distance from the city center.[i] Density gradients can be expressed as a simple linear equation:

$$D(x) = \alpha + \beta\,(x)$$

where D(x) equals population density, x equals distance to the city center; α equals the estimated population at the city center, and β equals the rate at which density falls with distance to the city center. Dense and compact cities have relatively high values of alpha and beta.

The estimated slopes and intercepts of density gradients using 2010 block group data are presented in Table 13 for each of the 35 metropolitan areas. As shown, New York has the highest estimated intercept, by far, followed by San Jose, Chicago, Philadelphia and Los Angeles. Metropolitan areas with the lowest intercepts are Charlotte, Orlando, and Tampa. Portland has the steepest estimated density gradient, followed by Denver, Baltimore, and San Diego. Miami, Los Angeles, and Riverside have the flattest estimated density gradients.

In Table 14 we report changes in density gradients for each of the 35 metropolitan areas and group metropolitan areas into four categories. Metropolitan areas in which both the intercept and density gradients flattened from 2000 to 2010 we place in Group A. This group we characterize as having decentralized the most. Group B includes metropolitan areas in which the intercept rose and the gradient flattened. This group we characterize as having expanded. We place metropolitan areas in which the intercept rose and the density gradient steepened in Group C. We characterize this group as having centralized the most. Metropolitan areas in which the intercept fell and the density gradient steepened we place in Group D.

As shown in Table 14, most (22) metropolitan areas fall into group B; these metropolitan areas expanded from 1990 to 2010; that is, estimated densities are higher at every distance from the urban core. The eight metropolitan areas in Group A also have falling density gradients but also had declines in estimated density in the urban core. These metropolitan areas include Detroit, Cleveland and, surprisingly, Los Angeles. Five metropolitan areas fell into Group C, which experienced rising densities at the urban center and steeping density gradients. This group includes Charlotte, New York, Riverside, Sacramento and Tampa, metropolitan areas which would seem to have little else in common. There were no metropolitan areas that fell into Group D.

Table 13: Density Gradient Slope and Intercept (2010), Sorted in Rank Order

Metropolitan Area	Density Gradient - Slope (2010)	Metropolitan Area	Density Gradient - Intercept (2010)
Portland	-0.139	New York	43,245
Denver	-0.132	San Jose	20,977
Baltimore	-0.119	Chicago	17,378
San Diego	-0.109	Philadelphia	16,190
Minneapolis	-0.104	Los Angeles	14,394
Indianapolis	-0.103	Denver	12,958
Columbus	-0.099	Boston	12,666
Austin	-0.089	Baltimore	12,457
Cincinnati	-0.086	Portland	11,890
Philadelphia	-0.085	Seattle	11,414
Kansas City	-0.082	San Francisco	11,049
Cleveland	-0.081	Washington, DC	10,661
Pittsburgh	-0.080	St. Louis	9,108
San Antonio	-0.080	Minneapolis	9,094
Charlotte	-0.080	Phoenix	8,619
New York	-0.075	Cleveland	8,463
Seattle	-0.074	Detroit	8,385
Orlando	-0.072	Miami	7,753
Boston	-0.070	Houston	7,743
Atlanta	-0.069	Las Vegas	7,642
Phoenix	-0.068	San Diego	7,601
Washington, DC	-0.068	Dallas	7,593
San Jose	-0.067	Columbus	7,101
Houston	-0.062	San Antonio	6,539
Las Vegas	-0.061	Pittsburgh	6,018
Chicago	-0.061	Cincinnati	5,857
St. Louis	-0.061	Riverside	5,829
Detroit	-0.059	Austin	5,696
San Francisco	-0.049	Atlanta	5,429
Dallas	-0.048	Sacramento	5,289
Sacramento	-0.044	Indianapolis	4,946
Tampa	-0.040	Kansas City	4,882
Riverside	-0.039	Tampa	4,757
Los Angeles	-0.031	Orlando	4,365
Miami	-0.016	Charlotte	3,822

Table 14: Change in Density Gradient—Category, Slope, Intercept (1990–2010), Sorted in Rank Order

Metropolitan Area	Density Gradient Category (Sign of Slope and Intercept) (1990-2010)	Metropolitan Area	Change in Density Gradient Slope (1990-2010)	Metropolitan Area	Change in Density Gradient Intercept (1990-2010)
Charlotte	C	Tampa	-0.004	Las Vegas	9.04
New York	C	Sacramento	-0.004	Riverside	1.79
Riverside	C	Riverside	-0.003	Austin	1.75
Sacramento	C	New York	-0.003	Sacramento	1.74
Tampa	C	Charlotte	-0.001	Phoenix	1.56
Atlanta	B	Chicago	0.001	Tampa	1.52
Austin	B	Pittsburgh	0.001	Charlotte	1.47
Boston	B	Boston	0.002	Houston	1.33
Chicago	B	Seattle	0.003	Portland	1.32
Columbus	B	Cleveland	0.003	Dallas	1.29
Dallas	B	Miami	0.003	Washington, DC	1.27
Denver	B	Houston	0.004	Miami	1.27
Houston	B	San Jose	0.005	Orlando	1.26
Indianapolis	B	Portland	0.005	New York	1.26
Kansas City	B	Dallas	0.006	San Francisco	1.24
Las Vegas	B	Columbus	0.007	St. Louis	1.22
Miami	B	Austin	0.008	Columbus	1.15
Minneapolis	B	San Antonio	0.008	Chicago	1.15
Orlando	B	Philadelphia	0.008	Denver	1.14
Phoenix	B	Kansas City	0.008	Seattle	1.13
Portland	B	Washington, DC	0.008	Atlanta	1.11
San Diego	B	Indianapolis	0.008	San Jose	1.10
San Francisco	B	St. Louis	0.009	Kansas City	1.09
San Jose	B	San Francisco	0.009	San Diego	1.09
Seattle	B	Orlando	0.010	Indianapolis	1.07
St. Louis	B	Cincinnati	0.011	Boston	1.04
Washington, DC	B	Minneapolis	0.013	Minneapolis	1.04
Baltimore	A	Detroit	0.014	Philadelphia	0.97
Cincinnati	A	Atlanta	0.014	Cleveland	0.93
Cleveland	A	San Diego	0.017	Cincinnati	0.93
Detroit	A	Phoenix	0.021	San Antonio	0.89
Los Angeles	A	Baltimore	0.024	Pittsburgh	0.88
Philadelphia	A	Los Angeles	0.029	Baltimore	0.87
Pittsburgh	A	Las Vegas	0.043	Los Angeles	0.81
San Antonio	A	Denver	0.047	Detroit	0.77

Legend: A=decentralization; B=expansion; C=centralization

Combined Indicator Analysis

To analyze how metropolitan areas compare across indicators we compute a combined indicator rank for each metropolitan area. We compute the combined rank by assigning each metropolitan area a quintile-rank for each urban form indicator (as described above) and computing the sum of the quintile-rank across the 13 static and 16 dynamic indicators. Recognizing the well-known limitations of combined rankings, we compute this ranking not to offer an overall normative assessment of urban form, but to serve as a basis for comparing metropolitan areas across indicators. Specifically we color code every metropolitan area for every indicator, and the combined ranking, on a continuum from green (the lowest value) to red (the highest value) then sort the metropolitan areas by the average rank. We present the results for the static and dynamic indicators in tables 15 and 16 respectively.

As shown in Table 15, and not surprisingly, the larger older cities received the highest combined rank among the static measures. The largest Northeastern cities—New York, Chicago, and Philadelphia—have the highest combined rank, followed by the large Western cities of Los Angeles and San Francisco. Also not surprisingly, the smaller Southern cities of Charlotte and Orlando have the lowest combined rank but the next lowest combined rank belongs to the smaller Midwestern cities of Kansas City, Indianapolis and Cincinnati. Perhaps also not surprising, but more interestingly, the rankings of almost all the indicators are highly correlated with the exception of two: metro area Gini coefficient and slope of the density gradient.[4] Both the exceptions and the rule are easy to explain. As evident by the color coding in Table 17, the indexes are highly correlated because metropolitan areas with large populations tend to have high densities and large populations in urban areas and individual block groups. The exception is explained by the rather unsystematic geographic delineation of metropolitan areas. Metropolitan areas with large rural areas within the metropolitan area have relatively flat population density gradients and relatively high concentration indexes. These are not necessarily the largest metropolitan areas.

[4] All of the other indicators have a correlation >0.60. The correlation with Metropolitan Area Gini and Density Gradient Slope have correlation coefficients with other static indicators ranging from -0.31 to 0.39.

Table 15: Static Index and Rank

Metropolitan Area	Index	Rank of Index
New York	58	1
Los Angeles	56	2
Chicago	55	3
Philadelphia	55	4
San Francisco	52	5
San Diego	51	6
Miami	50	7
Washington, DC	49	8
Boston	48	9
Seattle	47	10
Baltimore	45	11
Denver	45	12
Dallas	44	13
Houston	44	14
Phoenix	44	15
San Jose	43	16
Portland	42	17
Las Vegas	39	18
Detroit	38	19
Minneapolis	38	20
Riverside	37	21
San Antonio	35	22
Cleveland	34	23
Sacramento	32	24
Austin	31	25
St. Louis	31	26
Columbus, OH	30	27
Atlanta	28	28
Tampa	28	29
Pittsburgh	27	30
Cincinnati	23	31
Indianapolis	23	32
Orlando	22	33
Kansas City	21	34
Charlotte	20	35

Patterns in the variation of dynamic measures are less obvious or systematic. Table 16 presents the dynamic index and rank for metropolitan areas. As shown, the growing Western cities of Riverside, Portland, San Jose, Seattle, and Las Vegas have the highest average ranks, followed by New York. The only reason New York didn't have a higher average rank is because its substantial population growth was small relative to its current population, causing the percent change in metropolitan, urbanized area, and principal city growth to be relatively low. The next 12 highest metropolitan areas are also located in the South and West.

As evident by the color coding in Table 18, the various dynamic measures are also highly correlated but less so than the static measures.[5] In general, the metropolitan areas that grew most had the greatest increases in population and population densities in their urbanized area and principal cities, the fewest number of block groups that lost population, and the greatest number of block groups that met density thresholds. Four dynamic measures did not, however, vary consistently with the others: change in density gradient, change in concentration, growth of population in nonurbanized areas, and growth of the urbanized area. This is because population growth in metropolitan areas that grew tended to grow throughout the metropolitan area—but especially in peripheral areas. Thus the fastest growing metropolitan areas had growth in the urban core but also had growth in the urban periphery, causing the slopes of density gradients to fall, concentration indexes to fall, urbanized areas to expand, and growth to occur in nonurban areas. Portland was the only metropolitan area that ranked highly in every dynamic measure.

[5] The mostly highly correlated indicators are: change in metropolitan/urbanized/principal city area density with urbanization indicators and change in density gradient intercept; change in population in never urbanized areas with percent change in urbanized land area and change in density gradient intercept. All of these correlations are greater than 0.60.

Table 16: Dynamic Index and Rank

Metropolitan Area	Dynamic Index	Dynamic Rank
Riverside	66	1
Portland	64	2
San Jose	63	3
Seattle	58	4
Las Vegas	57	5
New York	56	6
San Francisco	56	7
Austin	54	8
Miami	54	9
Orlando	54	10
Phoenix	54	11
Sacramento	54	12
Charlotte	53	13
Denver	53	14
Houston	53	15
Los Angeles	50	16
San Diego	50	17
Tampa	48	18
Washington, DC	48	19
Dallas	47	20
San Antonio	46	21
Boston	45	22
Atlanta	43	23
Minneapolis	43	24
Chicago	40	25
Columbus, OH	40	26
Kansas City	38	27
Indianapolis	37	28
Pittsburgh	37	29
Baltimore	34	30
Philadelphia	33	31
St. Louis	31	32
Cleveland	30	33
Cincinnati	29	34
Detroit	24	35

Table 17: Static Measures Sorted by Metropolitan Area, Color Coded by Quintile

Metropolitan Area	Metropolitan Area Population (2010)	Metropolitan Area Density (2010)	Principal City Population (2010)	Principal City Density (2010)	Urbanized Area Population (2010)	Urbanized Area Density (2010)	Total Number of Block Groups (2010)	Share (Count) of Block Groups at Bus Density (>5,000 ppsm) (2010)	Share (Count) of Block Groups at Light Rail Density (>15,000 ppsm) (2010)	Metroplitan Area Gini Coefficient (2010)	Urbanized Area Gini Coefficient (2010)	Density Gradient - Slope (2010)	Density Gradient - Intercept (2010)
Atlanta	5,268,860	621	420,003	3,189	3,678,746	2,189	1,923	28% (535)	1% (14)	0.666	0.195	-0.069	5,429
Austin	1,716,289	401	790,390	3,143	1,203,173	2,827	765	51% (393)	2% (19)	0.785	0.360	-0.089	5,696
Baltimore	2,710,489	1,030	620,961	7,685	2,196,557	3,822	1,893	64% (1,212)	19% (364)	0.734	0.421	-0.119	12,457
Boston	4,552,402	1,257	617,594	12,760	3,549,238	3,622	3,378	60% (2,035)	25% (838)	0.673	0.503	-0.070	12,666
Charlotte	1,758,038	559	731,424	3,019	1,156,323	2,095	792	22% (174)	0% (0)	0.661	0.246	-0.080	3,822
Chicago	9,461,105	1,295	2,695,598	11,870	8,429,648	4,200	6,590	76% (5,002)	24% (1,596)	0.781	0.470	-0.061	17,378
Cincinnati	2,130,151	477	296,943	3,807	1,552,352	2,539	1,536	45% (690)	2% (25)	0.745	0.326	-0.086	5,857
Cleveland	2,077,240	1,030	396,815	5,114	1,694,537	3,108	1,766	62% (1,101)	2% (44)	0.686	0.374	-0.081	8,463
Columbus	1,836,536	458	787,033	3,742	1,338,093	3,105	1,259	57% (719)	3% (39)	0.771	0.341	-0.099	7,101
Dallas	6,371,773	686	1,197,816	3,497	5,206,669	3,305	3,552	63% (2,255)	4%(128)	0.785	0.357	-0.048	7,593
Denver	2,543,482	301	600,158	3,912	2,237,312	3,926	1,667	74% (1,240)	4% (68)	0.923	0.361	-0.132	12,958
Detroit	4,296,250	1,079	713,777	5,142	3,675,546	3,258	3,942	64% (2,522)	1% (49)	0.706	0.340	-0.059	8,385
Houston	5,946,800	644	2,099,451	3,623	4,889,916	3,380	2,739	58% (1,596)	3% (82)	0.807	0.363	-0.062	7,743
Indianapolis	1,756,241	452	820,445	2,270	1,255,099	2,492	1,033	39% (401)	<1% (4)	0.775	0.286	-0.103	4,946
Kansas City	2,035,334	256	459,787	1,467	1,482,348	2,630	1,507	43% (649)	<1% (3)	0.844	0.288	-0.082	4,882
Las Vegas	1,951,269	241	583,756	5,152	1,744,814	4,717	832	80% (668)	7% (61)	0.948	0.374	-0.061	7,642
Los Angeles	12,828,837	2,625	3,792,621	8,085	12,466,385	7,418	8,177	90% (7,379)	32% (2,656)	0.789	0.434	-0.031	14,394
Miami	5,564,635	1,027	399,457	11,189	5,302,551	4,624	2,516	82% (2,070)	9% (238)	0.852	0.379	-0.016	7,753
Minneapolis	3,279,833	515	382,578	6,969	2,480,342	2,904	2,241	53% (1,193)	4% (94)	0.773	0.355	-0.104	9,094
New York	18,897,109	2,752	8,175,133	26,954	17,685,468	6,833	14,009	82% (11,431)	48% (6,723)	0.800	0.624	-0.075	43,245
Orlando	2,134,411	532	238,300	2,549	1,601,566	2,576	695	39% (272)	<1% (1)	0.765	0.293	-0.072	4,365
Philadelphia	5,965,343	1,267	1,526,006	11,295	4,998,187	3,693	4,793	69% (3,301)	30% (1,442)	0.719	0.473	-0.085	16,190
Phoenix	4,192,887	287	1,445,632	3,044	3,493,944	3,535	2,229	72% (1,610)	3% (65)	0.915	0.346	-0.068	8,619
Pittsburgh	2,356,285	441	305,704	5,498	1,529,077	2,712	2,053	43 (887)	3% (62)	0.723	0.367	-0.080	6,018
Portland	2,226,009	327	583,776	4,347	1,846,200	3,840	1,253	66% (833)	2% (29)	0.900	0.346	-0.139	11,890
Riverside	4,224,851	154	303,871	3,891	3,457,162	3,387	1,902	58% (1,111)	3% (58)	0.949	0.390	-0.039	5,829
Sacramento	2,149,127	405	466,488	4,799	1,782,172	3,866	1,162	65% (756)	2% (21)	0.884	0.344	-0.044	5,289
San Antonio	2,142,508	290	1,327,407	3,257	1,629,165	3,487	1,199	65% (778)	<1% (5)	0.862	0.321	-0.080	6,539
San Diego	3,095,313	731	1,307,402	4,031	2,807,885	4,678	1,762	80% (1,414)	18% (318)	0.880	0.430	-0.109	7,601
San Francisco	4,335,391	1,711	805,235	17,243	4,009,381	6,046	2,724	85% (2,304)	34% (939)	0.816	0.480	-0.049	11,049
San Jose	1,836,911	683	945,942	5,408	1,730,545	6,415	1,037	88% (915)	16% (171)	0.922	0.369	-0.067	20,977
Seattle	3,439,809	574	608,660	7,255	2,979,517	3,551	2,631	65% (1,716)	5% (134)	0.863	0.376	-0.074	11,414
St. Louis	2,812,896	318	319,294	5,158	2,039,944	2,727	2,050	50% (1,025)	2% (34)	0.817	0.332	-0.061	9,108
Tampa	2,783,243	1,063	335,709	5,633	2,341,671	2,819	1,585	57% (897)	<1% (5)	0.670	0.322	-0.040	4,757
Washington, DC	5,582,170	983	601,723	9,800	4,655,904	3,915	2,949	67% (1,969)	15% (437)	0.764	0.419	-0.068	10,661

Table 18: Dynamic Measures Sorted by Metropolitan Area, Color Coded by Quintile

Metropolitan Area	Change in Metropolitan Area Density (1990-2010)	Change in Principal Density (1990-2010)	Change in Urbanized Area Population (1990-2010)	Change in Density in Urbanized Area (1990-2010)	Change in Population in 1990 Urbanized Areas (1990-2010)	Change in Population in Never Urbanized Areas (1990-2010)	Percent Change in Urbanized Land Area (1990-2010)	Marginal Density (Change in Area/Change in Population) (1990-2010)	Number (Share) of Block Groups Declining in Population (1990-2010)	Change in Count(Share) of Block Groups at Bus Density (>5,000 ppsm) (1990-2010)	Change in Count(Share) of Block Groups at Light Rail Density (>15,000 ppsm) (1990-2010)	Change in Metropolitan Area Gini Coefficient (1990-2010)	Change in Urbanized Area Gini Coefficient (1990-2010)	Density Gradient Category (Sign of Slope and Intercept) (1990-2010)	Change in Density Gradient Slope (1990-2010)	Change in Density Gradient Intercept (1990-2010)
Atlanta	72%	7%	87%	-5%	21%	122%	97%	1.36	483 (25%)	5% (92)	<1% (1)	-0.074	-0.089	B	0.014	1.106
Austin	103%	70%	109%	-16%	23%	161%	150%	1.46	166 (22%)	10% (74)	1% (6)	-0.061	0.010	B	0.008	1.746
Baltimore	14%	-16%	15%	-16%	0%	32%	36%	2.65	922 (49%)	2% (45)	-5% (-91)	-0.044	-0.050	A	0.024	0.873
Boston	10%	8%	10%	-6%	5%	28%	17%	1.64	1288 (38%)	1% (28)	1% (20)	-0.035	0.002	B	0.002	1.039
Charlotte	72%	85%	103%	-10%	13%	82%	125%	1.74	225 (28%)	2% (15)	-1% (-1)	-0.044	-0.022	C	-0.001	1.474
Chicago	16%	-3%	15%	-19%	1%	68%	42%	2.67	3107 (47%)	2% (149)	-1% (-82)	-0.055	-0.014	B	0.001	1.149
Cincinnati	15%	-18%	18%	-21%	-5%	35%	48%	3.11	859 (56%)	-1% (-14)	-3% (-42)	-0.042	-0.059	A	0.011	0.926
Cleveland	-1%	-22%	-3%	-21%	-11%	32%	22%	-18.59	1234 (70%)	-3% (-51)	-8% (-147)	-0.059	-0.040	A	0.003	0.931
Columbus	31%	24%	35%	-21%	0%	47%	69%	2.26	629 (50%)	3% (44)	-2% (-25)	-0.031	-0.048	B	0.007	1.152
Dallas	60%	19%	63%	-9%	17%	110%	80%	1.33	1110 (31%)	7% (258)	1% (21)	-0.062	0.007	B	0.006	1.292
Denver	53%	28%	51%	-9%	18%	151%	67%	1.27	486 (29%)	11% (180)	1% (25)	-0.028	0.050	B	0.047	1.137
Detroit	1%	-31%	-1%	-21%	-11%	44%	25%	22.77	2664 (68%)	-3% (-132)	-3% (-130)	-0.064	-0.043	A	0.014	0.774
Houston	58%	29%	62%	-5%	22%	106%	71%	1.22	846 (31%)	7% (191)	1% (17)	-0.050	-0.003	B	0.004	1.325
Indianapolis	36%	11%	39%	-18%	0%	73%	70%	1.95	515 (50%)	-2% (-22)	-1% (-9)	-0.014	-0.047	B	0.008	1.072
Kansas City	24%	6%	22%	-15%	-3%	56%	43%	1.78	786 (52%)	-1% (-19)	-1% (-5)	-0.024	-0.016	B	0.008	1.094
Las Vegas	163%	126%	159%	-11%	25%	449%	192%	1.18	142 (32%)	34% (287)	3% (22)	-0.031	-0.016	B	0.043	9.042
Los Angeles	14%	9%	14%	0%	8%	56%	14%	1.04	2625 (32%)	4% (295)	5% (406)	-0.022	0.008	A	0.029	0.814
Miami	37%	11%	39%	-3%	18%	123%	43%	1.16	823 (33%)	8%(202)	<1% (10)	-0.039	0.005	B	0.003	1.268
Minneapolis	29%	4%	27%	-11%	5%	71%	42%	1.45	956 (43%)	1% (28)	1% (14)	-0.047	-0.018	B	0.013	1.035
New York	12%	12%	13%	-6%	8%	41%	19%	1.59	4887 (35%)	2% (247)	3% (405)	-0.022	0.009	C	-0.003	1.262
Orlando	74%	45%	77%	-1%	20%	165%	79%	1.07	231 (33%)	6% (41)	<1% (1)	-0.076	0.004	B	0.010	1.262
Philadelphia	10%	-4%	9%	-17%	-1%	48%	32%	3.28	2420 (50%)	1% (46)	-1% (-41)	-0.056	-0.023	A	0.008	0.971
Phoenix	87%	47%	77%	-12%	19%	379%	100%	1.15	715 (32%)	13% (289)	1% (20)	-0.042	0.010	B	0.021	1.563
Pittsburgh	-5%	-17%	-8%	-19%	-13%	10%	14%	-3.06	576 (28%)	-4% (-75)	-4% (-77)	-0.027	-0.029	A	0.001	0.881
Portland	46%	33%	57%	7%	30%	42%	46%	1.01	271 (22%)	11% (137)	1% (14)	-0.002	0.003	B	0.005	1.317
Riverside	63%	34%	70%	-4%	25%	101%	77%	1.22	379 (20%)	9% (176)	1% (27)	-0.010	0.003	C	-0.003	1.786
Sacramento	45%	26%	46%	-11%	8%	69%	64%	1.42	438 (38%)	8% (88)	-1% (-5)	-0.031	-0.009	C	-0.004	1.735
San Antonio	52%	42%	46%	-6%	13%	122%	56%	1.06	446 (37%)	7% (78)	-1% (-6)	-0.039	-0.020	A	0.008	0.888
San Diego	24%	18%	26%	-11%	8%	36%	41%	1.71	619 (35%)	6% (114)	1% (24)	-0.022	0.015	B	0.017	1.094
San Francisco	18%	11%	17%	-3%	10%	68%	20%	1.13	892 (33%)	2% (60)	4% (115)	-0.030	0.011	B	0.009	1.239
San Jose	20%	21%	21%	5%	17%	25%	16%	0.80	291 (28%)	3% (33)	5% (53)	-0.006	0.009	B	0.005	1.099
Seattle	34%	18%	42%	-3%	18%	42%	46%	1.34	711 (27%)	9% (227)	1% (38)	-0.020	-0.002	B	0.003	1.129
St. Louis	9%	-20%	6%	-17%	-7%	38%	29%	3.22	1237 (60%)	-3% (-61)	-3% (-61)	-0.030	-0.042	B	0.009	1.215
Tampa	35%	20%	37%	-13%	9%	84%	57%	1.64	569 (36%)	4% (62)	-1% (-8)	-0.086	0.016	3	-0.004	1.517
Washington, DC	35%	-1%	36%	-7%	12%	72%	46%	1.29	949 (32%)	8%(229)	1% (36)	-0.051	-0.020	B	0.008	1.272

Legend:

- Top Quintile (5)
- (4)
- (3)
- (2)
- Bottom Quintile (1)

Summary and Conclusions

Every metropolitan area in the US is unique. Its urban form and changes in its urban form reflect unique natural features, economic forces, and political and social dynamics. Still, our analysis of static and dynamic urban form measures reveals some clear and systemic patterns.

First, the urbanization process in the United States continues. With a few Rust Belt exceptions, most metropolitan areas have grown in population and, hence, density. Further, though with largely the same exceptions, the populations of urbanized areas have grown; and in about three fourths of the 35 largest metropolitan areas the population of principal cities have grown. Three thousand net new block groups met transit density thresholds; and over 500 net new block groups met bus density thresholds. These results suggest that when metropolitan areas grow, growth is distributed across the metropolitan area causing existing cities and urbanized areas to grow and densities to rise.

On the other hand, most metropolitan areas continue to grow at the fringe. While some growth has gone to existing urban areas, the urbanized areas of all metro areas have expanded, in some places by quite a lot. In some Southern and Western metropolitan areas, urbanized areas nearly doubled over the last 20 years. On average, the size of urbanized areas have increased by 57 percent more than population, although the marginal densities in some metropolitan areas are close to one, meaning that population and urbanized area are growing at roughly the same rate. The extent of growth within the 1990 urbanized area boundaries varies widely, from minus 13 to nearly 30 percent; but most growth over the last twenty years occurred in newly urbanized areas and with considerable growth in exurban areas. 35,000 block groups actually lost population. Every metropolitan area became less concentrated; two-thirds of their urbanized areas became less concentrated. Finally, in aggregate, the intercepts of density gradients rose and the slopes flattened. Few had steepening slopes and few had falling intercepts. The bottom line is this: while fast growing cities grew throughout their metropolitan areas, most growth in the 35 largest cities over the last 20 years has taken place at the urban fringe, at relatively low population densities by historical standards.

The policy implications of these results are difficult to identify given the small sample size and relatively coarse level of analysis. But if population density, concentration, and urban infill are taken as normatively favorable, then the most crucially important factor appears to be population growth. Growing metropolitan areas scored "well" on most dynamic urban indicators. Declining cities scored poorly. But if sprawl is defined as population growth at the urban fringe at relatively low urban densities, sprawl has continued unabated over the last two decades.[6]

While every metropolitan area has its story, there are two metropolitan areas we consider most noteworthy. First, like many of its Northeastern neighbors, the New York metropolitan area ranks high if not highest in population, population density, and population concentration at multiple levels of scale. Unlike its Northeastern neighbors, however, the New York metropolitan area did not experience population or population density loss over the last two decades. New York thus stands out as a metropolitan area that remains attractive to new residents despite its

[6] It is important to note that we do not test for whether patterns in urban growth changed after 2000 or after 2006, when the housing market collapsed. We leave this for future work.

stature as an old Northeastern city and dense place to live. Perhaps this is partially the result of policy decisions at the multiple levels, but more likely it is the result of economic forces that continue to sustain the growth of the nation's primate urban area. Second, like many of its Western Neighbors, the Portland metropolitan area was not particularly large or dense by national standards; but as a result of strong demographic trends that favor Southern and Western cities, most of its dynamic measures moved in a "favorable" direction. Also, like many other Western and Southern metropolitan areas, the Portland metropolitan is still not large or dense, but with one exception (percent change in urbanized land area) it ranked no lower than the second quintile on all of the individual measures and in most measures ranked above much faster growing metropolitan areas. It is perhaps possible that Portland experienced more favorable demographic and economic trends than its Southern and Western counterparts, but there is growing evidence that Portland's strong and long-held growth management policies have begun to have measureable effects.

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Appendix

In this appendix we present figures and maps that illustrate urban spatial structure and changes in spatial structure over time for selected metropolitan areas. In most cases we present figure and maps for metropolitan areas at the extremes of the distribution. We show maps and figures, for example, for metropolitan areas that are the most and the least concentrated and the metropolitan areas that concentrated most and least. Similar figures are available from the authors for all of the 35 metropolitan areas in the study sample.

Figure 1: Total Population in 2010

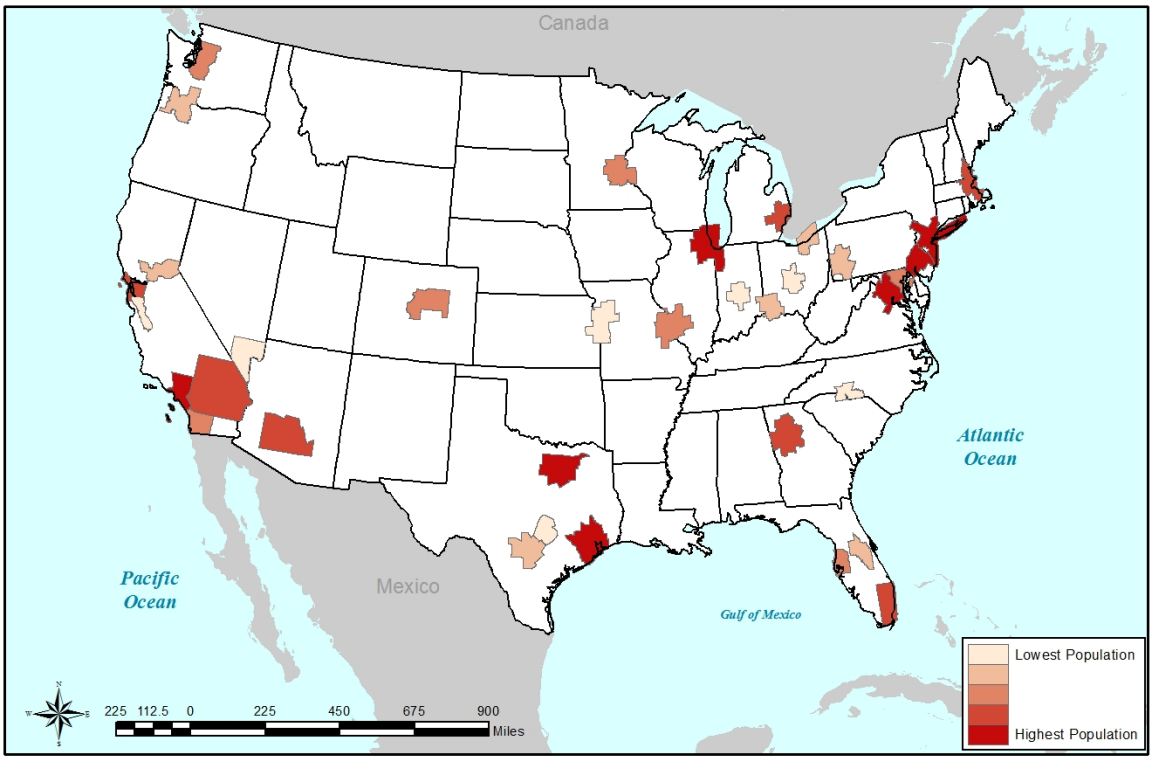
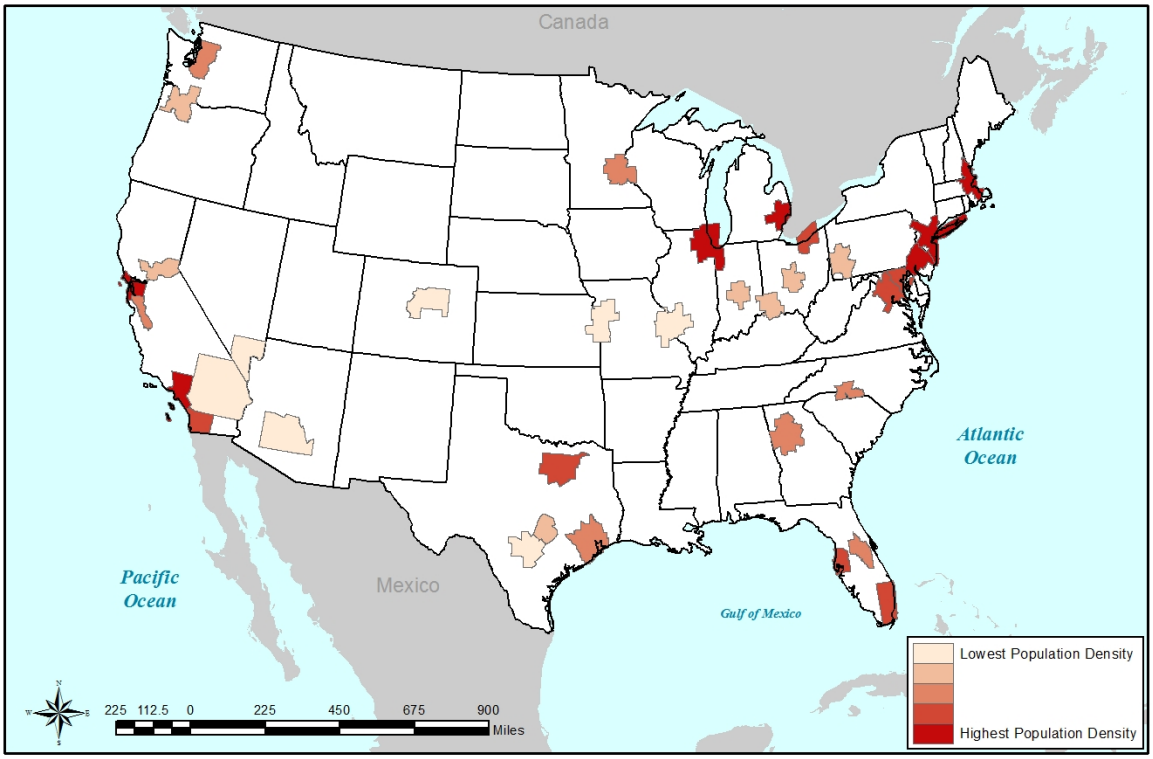


Figure 2: Average Population Density: 2010



Figures 1 and 2 above illustrate the location of the 35 largest metropolitan areas and their total population and population densities in 2010. As shown, the largest metropolitan areas are distributed across with nation with a concentration of large metropolitan areas in the Northeast, only one large metropolitan area in the intermountain west, only two in the Northwest. The pattern reflects a central place hierarchy and illustrates a high degree of correlation between total population and population density at the metropolitan scale. That is, big cities tend to be dense cities.

Figure 3: Percent Change in Population Density (1990–2010)

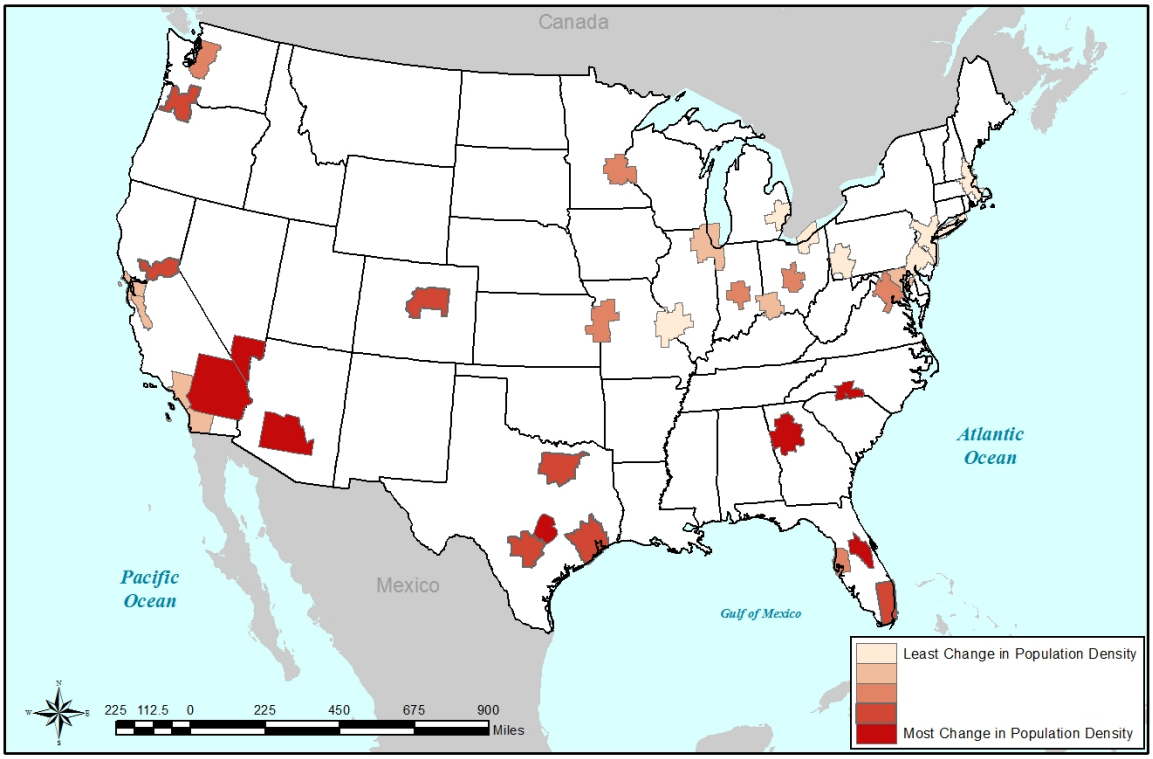
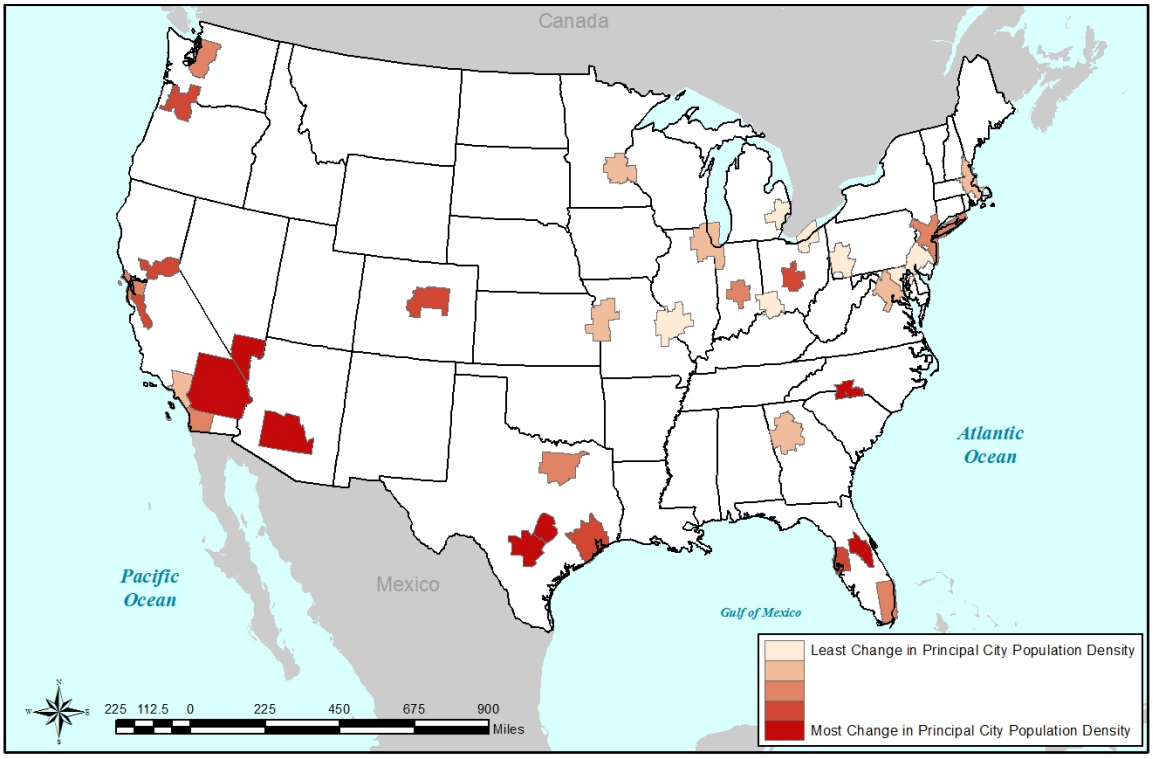
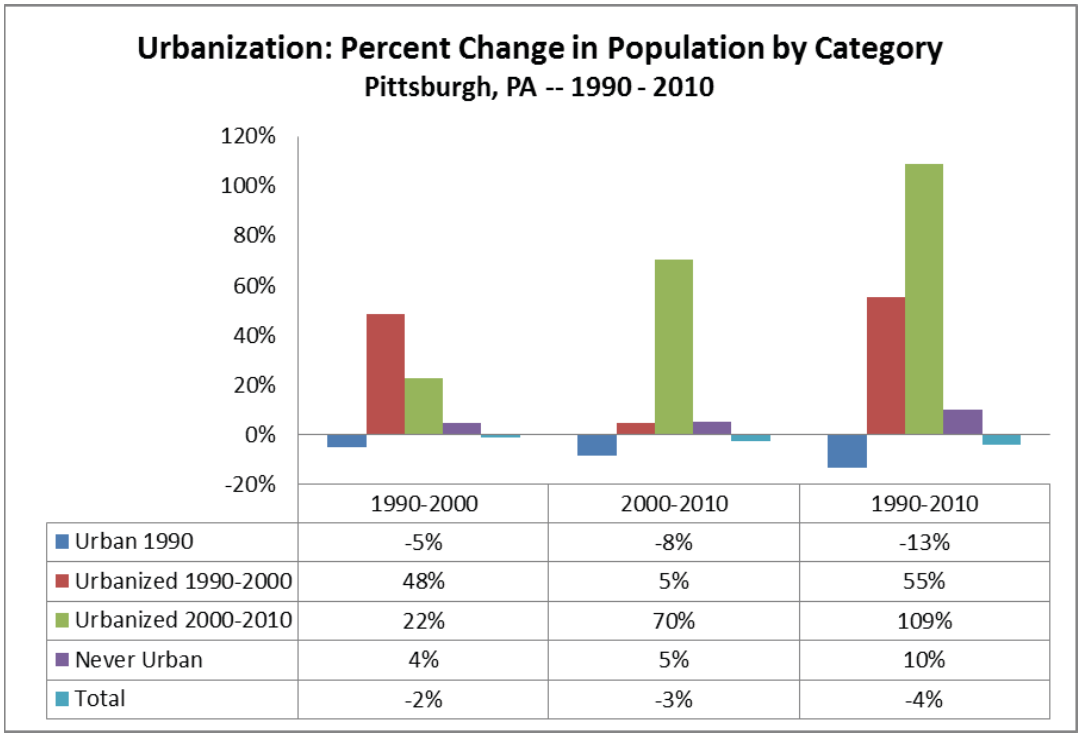


Figure 4: Percent Change in Principal City Density (1990–2010)



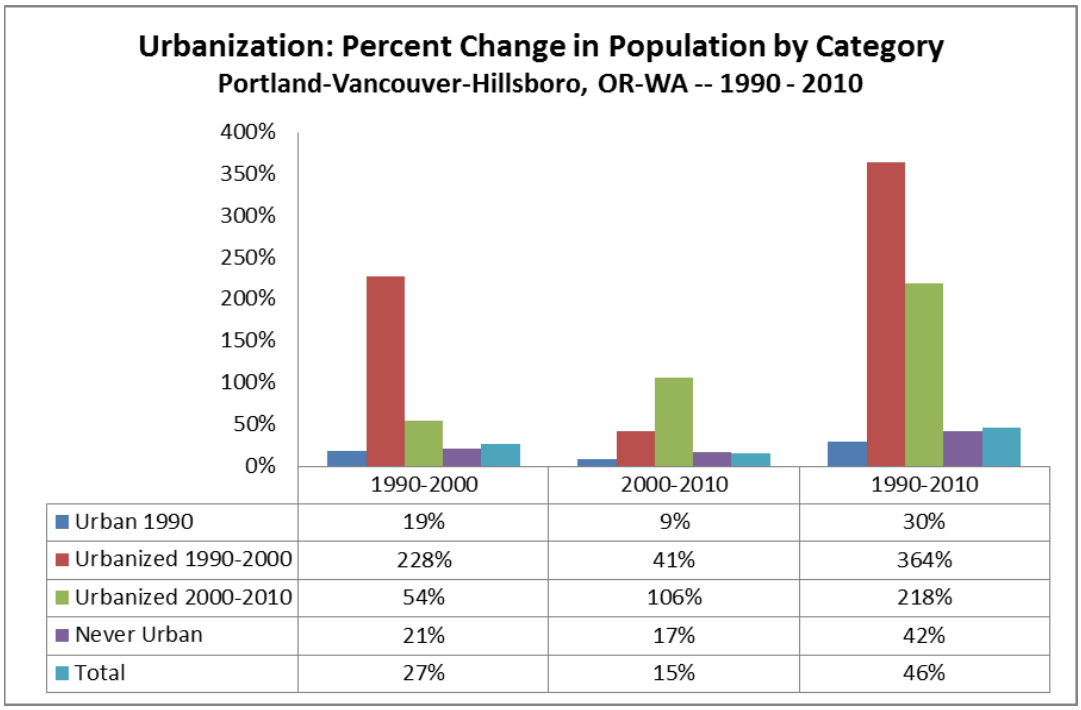
As shown in Figures 3 and 4, changes in population and population densities from 1990 to 2010 follow clear regional patterns: increases in population and population density over the last two decades were considerably greater in the Southern and Western regions of the nation. The Western and Southern cities of Las Vegas, Austin, Phoenix, Orlando, Atlanta and Charlotte had the largest increases in population at the metropolitan area, urbanized area, and principal city levels, although the rank order varies across geographies. Rust belt cities—Detroit, Cleveland, and Pittsburgh—had the lowest, and in some cases negative, rates of growth of population and population densities at all three levels.

Figure 5: Percent Change in Population Distribution within the Pittsburgh Metropolitan Area from 1990 to 2010



	1990-2000	2000-2010	1990-2010
Urban 1990	-5%	-8%	-13%
Urbanized 1990-2000	48%	5%	55%
Urbanized 2000-2010	22%	70%	109%
Never Urban	4%	5%	10%
Total	-2%	-3%	-4%

Figure 6: Percent Change in Population Distribution within the Portland Metropolitan Area from 1990 to 2010



	1990-2000	2000-2010	1990-2010
Urban 1990	19%	9%	30%
Urbanized 1990-2000	228%	41%	364%
Urbanized 2000-2010	54%	106%	218%
Never Urban	21%	17%	42%
Total	27%	15%	46%

To gain insights into where growth is occurring, e.g., how much is infill, how much is suburban, and how much is exurban, we identified how much population growth from 1990 to 2010 occurred in: (i) areas that were urbanized in 1990, (ii) areas that urbanized between 1990 and 2000, (iii) areas that urbanized between 2000 and 2010, and (iv) areas that remain urbanized. The results for Pittsburgh and Portland are presented in Figures 5 and 6 respectively. Not surprisingly, the share of growth that occurred in these geographic areas in the last two decades varied dramatically between these two metropolitan areas. In the Pittsburgh metropolitan area, for example, total population in the metropolitan area and population in the area that was urbanized in 1990 fell in the last two decades. Instead, most population growth in Pittsburgh, over the last two decades, took place in newly urbanizing areas. In Portland, the most rapid growth over the last two decades also took place in newly urbanizing areas; but population in areas already urbanized in 1990 and in areas that have not been urbanized increased by nearly 50 percent as well.

Figure 7: Population Distribution within the Pittsburgh Metropolitan Area, 1990 and 2010

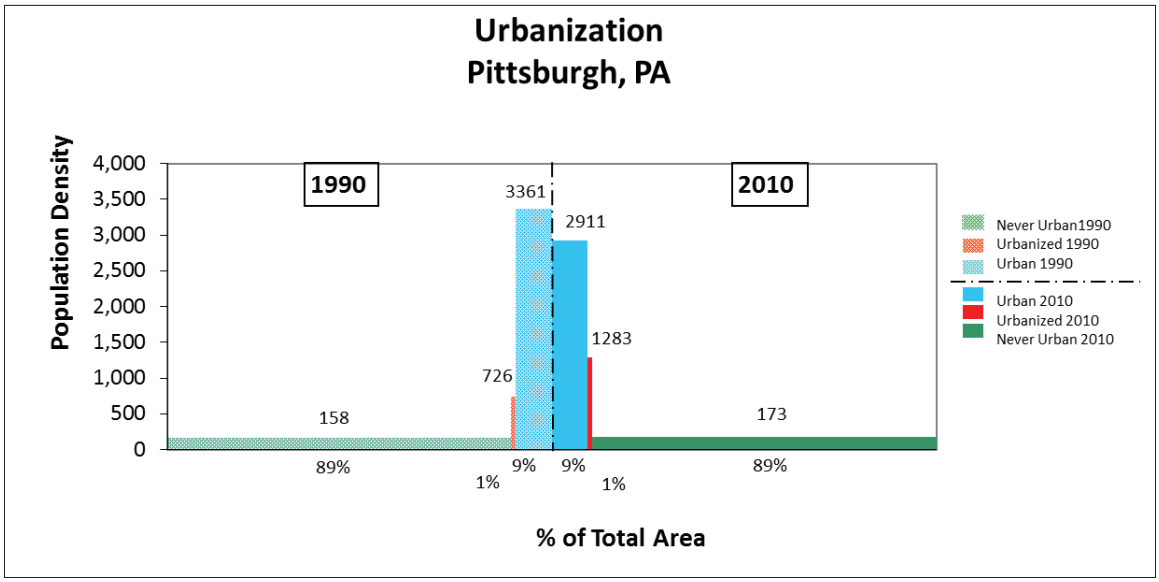
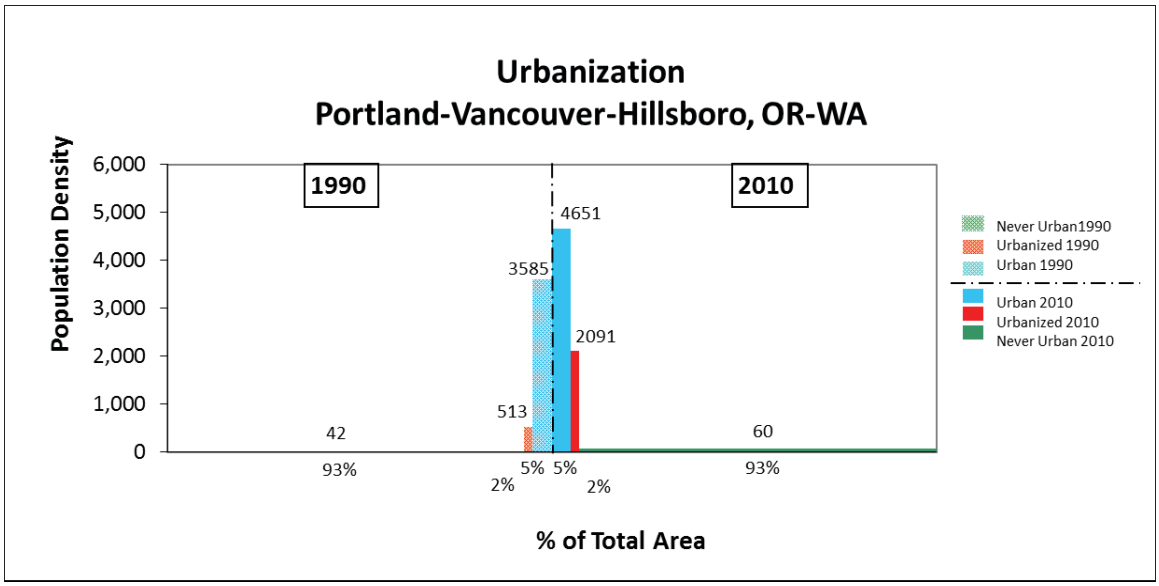


Figure 8: Population Distribution within the Portland Metropolitan Area, 1990 and 2010



These changes in distribution of growth are illustrated another way in Figure 7 and 8. The horizontal axis depicts the share of the metropolitan area in areas urbanized in 1990, areas urbanized between 1990 and 2010, and areas never urbanized. The vertical axis depicts the densities in each of those areas. The left side of the figure illustrates these area and density features in 1990 and the right side illustrates the same for 2010. As shown in Figure 7 for the Pittsburgh metropolitan area, the amount of growth that occurred within the area urbanized by 1990 decreased, thus the population density for the urbanized area in 1990 was lower in 2010 than in 1990. In the Portland metropolitan area, as shown in Figure 8, population in the area urbanized in 1990 grew from 1990 to 2010, causing population density in that area to increase.

Population in the area that urbanized from 2000 to 2010 also increased causing population density to increase in that area as well. Comparing the two figures illustrates that population density in the Portland metropolitan area urbanized in 1990 is considerably higher in Portland than in Pittsburgh, as is population density in the newly urbanized areas.

Figure 9: Frequency Distribution—Charlotte (2010)

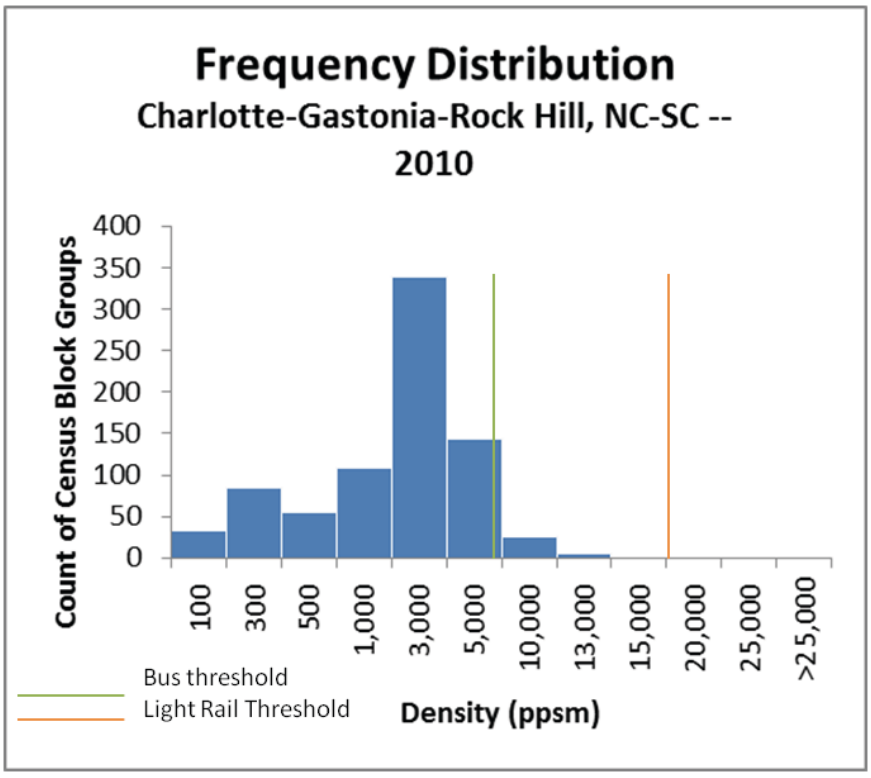
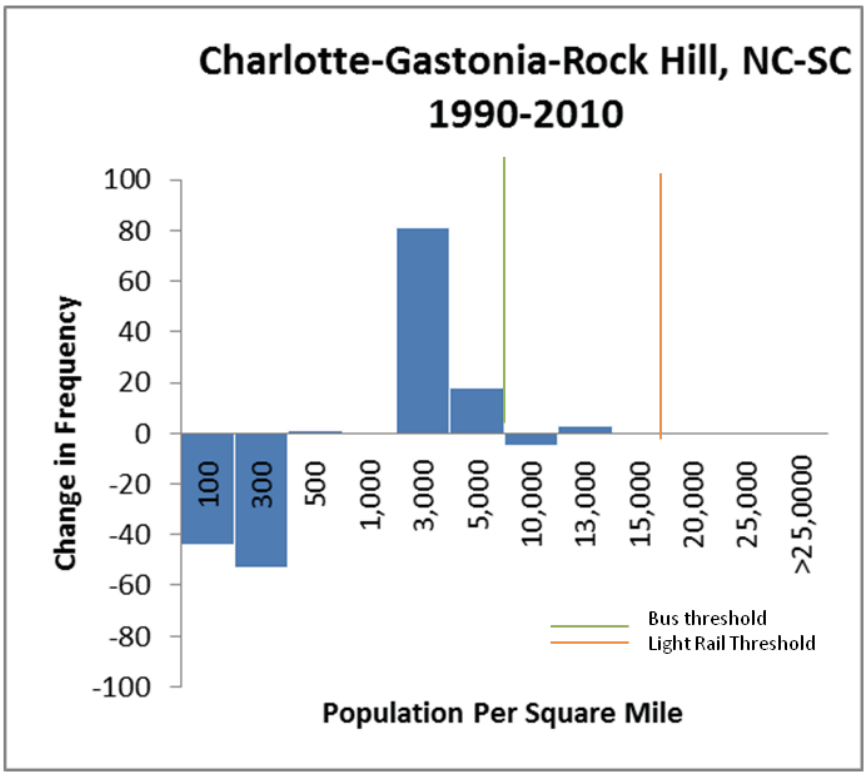


Figure 10: Change in Population Density Frequency Distribution—Charlotte—1990–2010



To gain additional insights into the distribution of populations within metropolitan areas we constructed density histograms. These histograms display the frequency of block groups in categories defined by population density in 2010 and by changes in density over the last two decades. As shown in figure 9 for the Charlotte metropolitan area, most block groups in 2010 have population densities less than 3000 persons per square mile. Only 174 block groups met the density threshold for bus service (5,000 persons per square mile) only one block group met the rail density threshold. (15,000 persons per square mile)

In Charlotte from 1990 to 2010, Charlotte gained 15 block groups with densities above 5,000, and gained 81 block groups with population densities between 3,000 and 5,000.

Figure 11: Population Density Frequency Distribution—New York (2010)

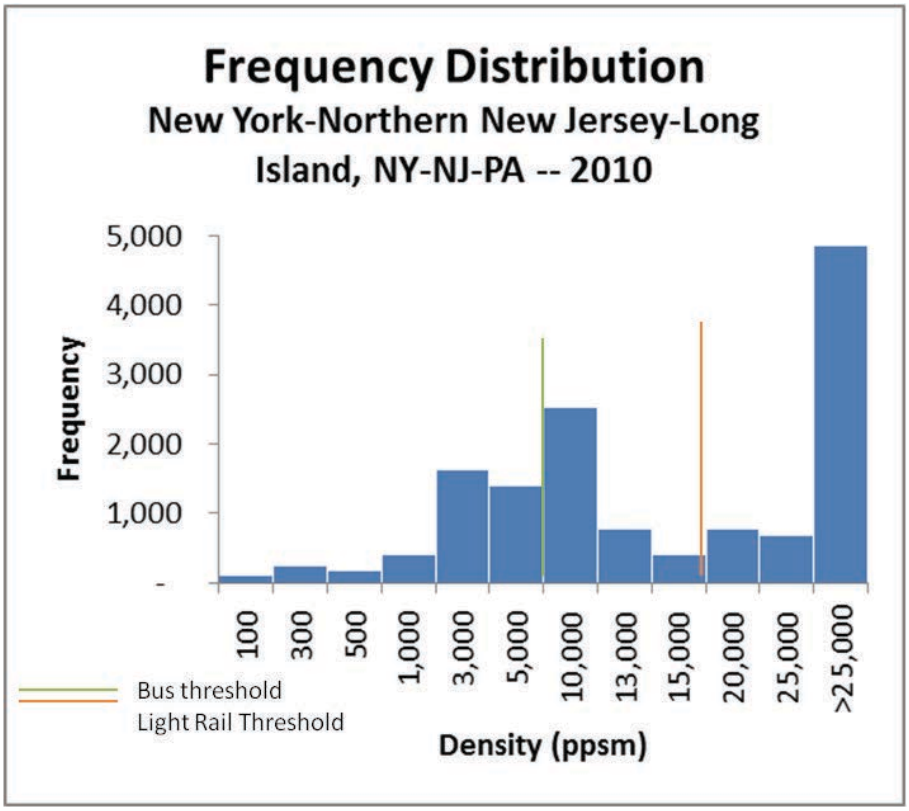
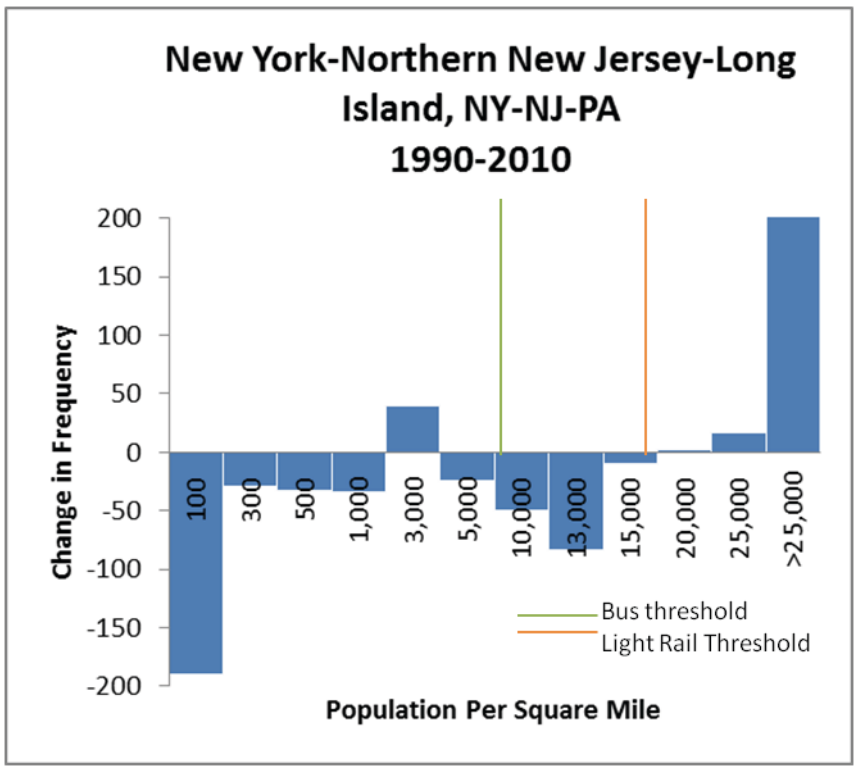


Figure 12: Change in Population Density Frequency Distribution—New York—1990–2010



The majority of block groups in New York in 2010, by contrast, had population densities that met the rail transit threshold; 11,431 block groups met the bus density threshold. From 1990 to 2010, the number of block groups with population densities over 25,000 grew most rapidly.

Figures 13 through 16 illustrate the stark difference in growth patterns between Los Angeles and Detroit. In 2010 most block groups in Los Angeles met the bus density threshold and many met the rail transit threshold. What's more from 1990 to 2010, Los Angeles lost 445 block groups with densities less than 10,000 persons per square mile and gained 445 block groups with more than 10,000 persons per square mile. Detroit, by contrast, had 2,522 block groups that met the bus density threshold in 2010, but from 1990 to 2010 lost 399 block groups with densities greater than 13,000 persons per square mile.

Figure 13: Population Density Frequency Distribution—Los Angeles (2010)

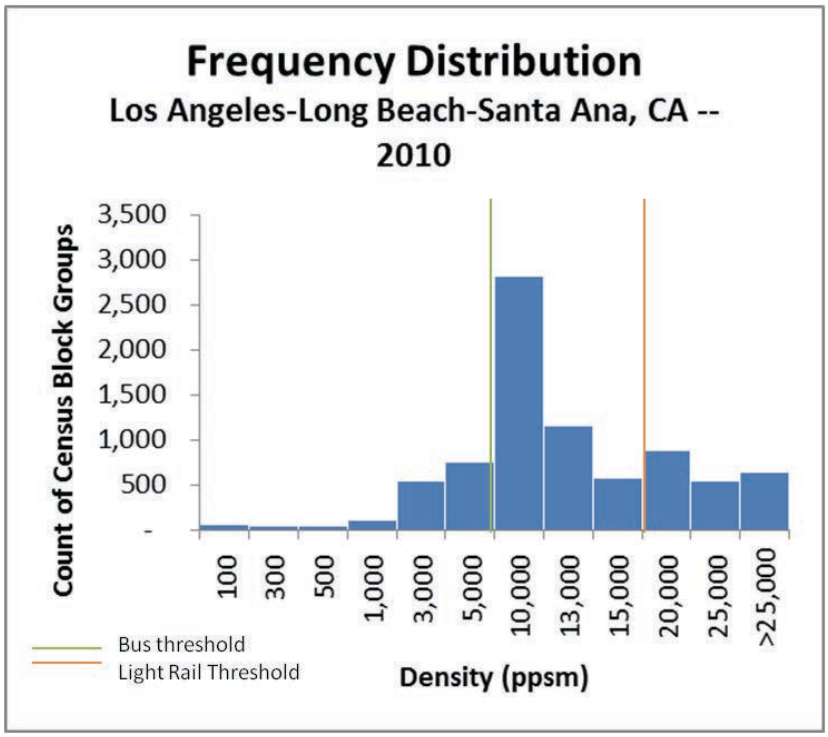


Figure 14: Change in Population Density Frequency Distribution—Los Angeles—1990–2010

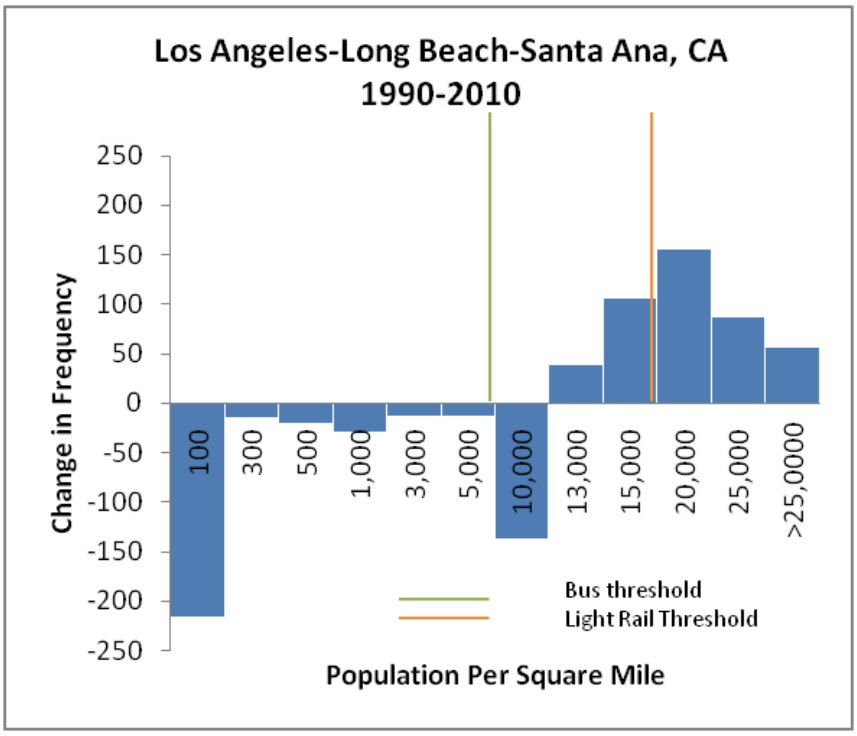


Figure 15: Population Density Frequency Distribution—Detroit (2010)

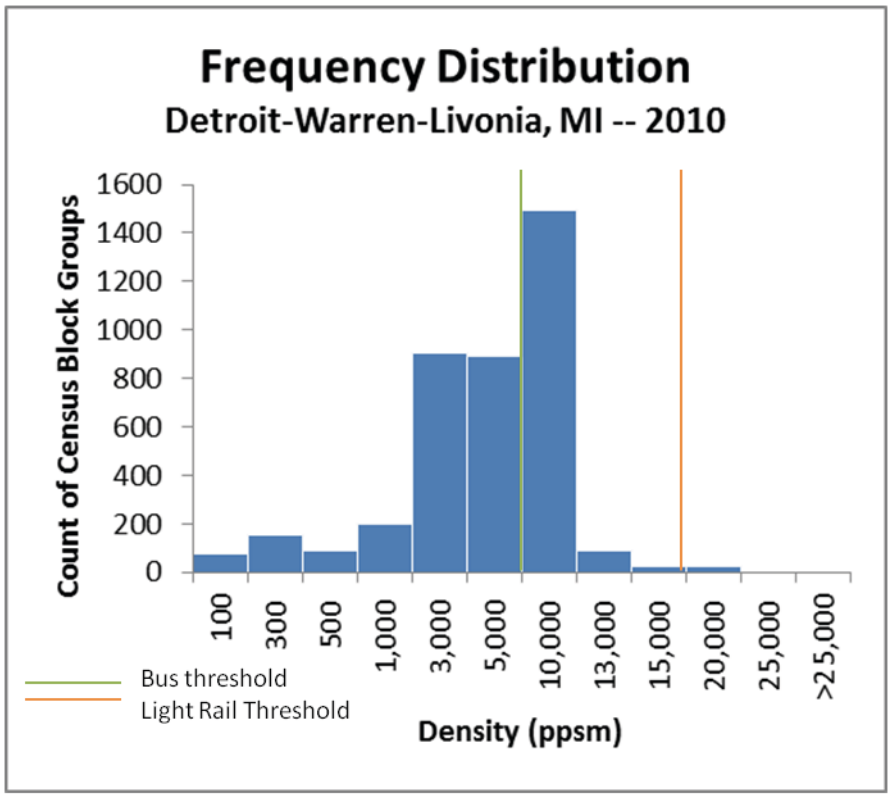
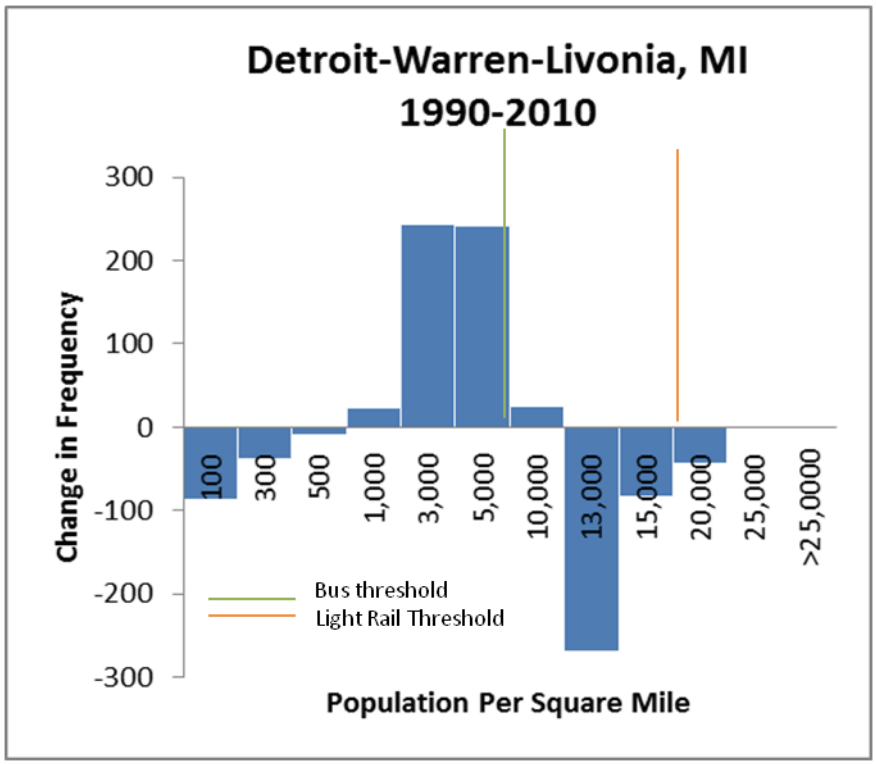


Figure 16: Change in Population Density Frequency Distribution—Detroit—1990–2010



Concentration

Figure 17: Population Distribution in Charlotte (1990–2010)

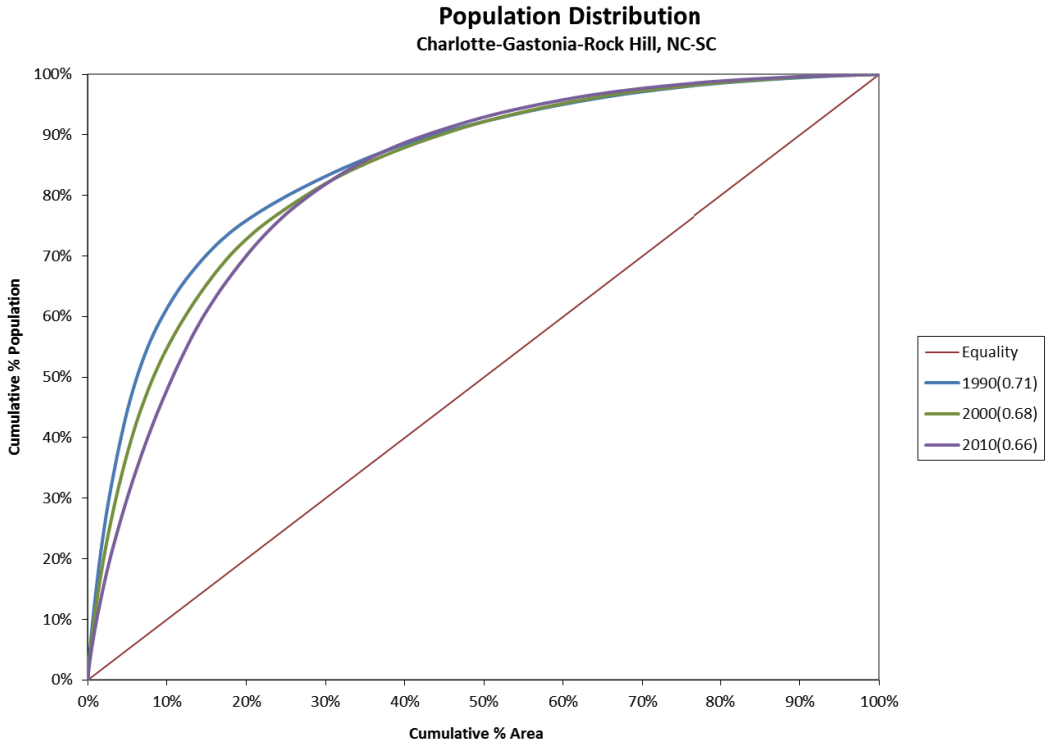
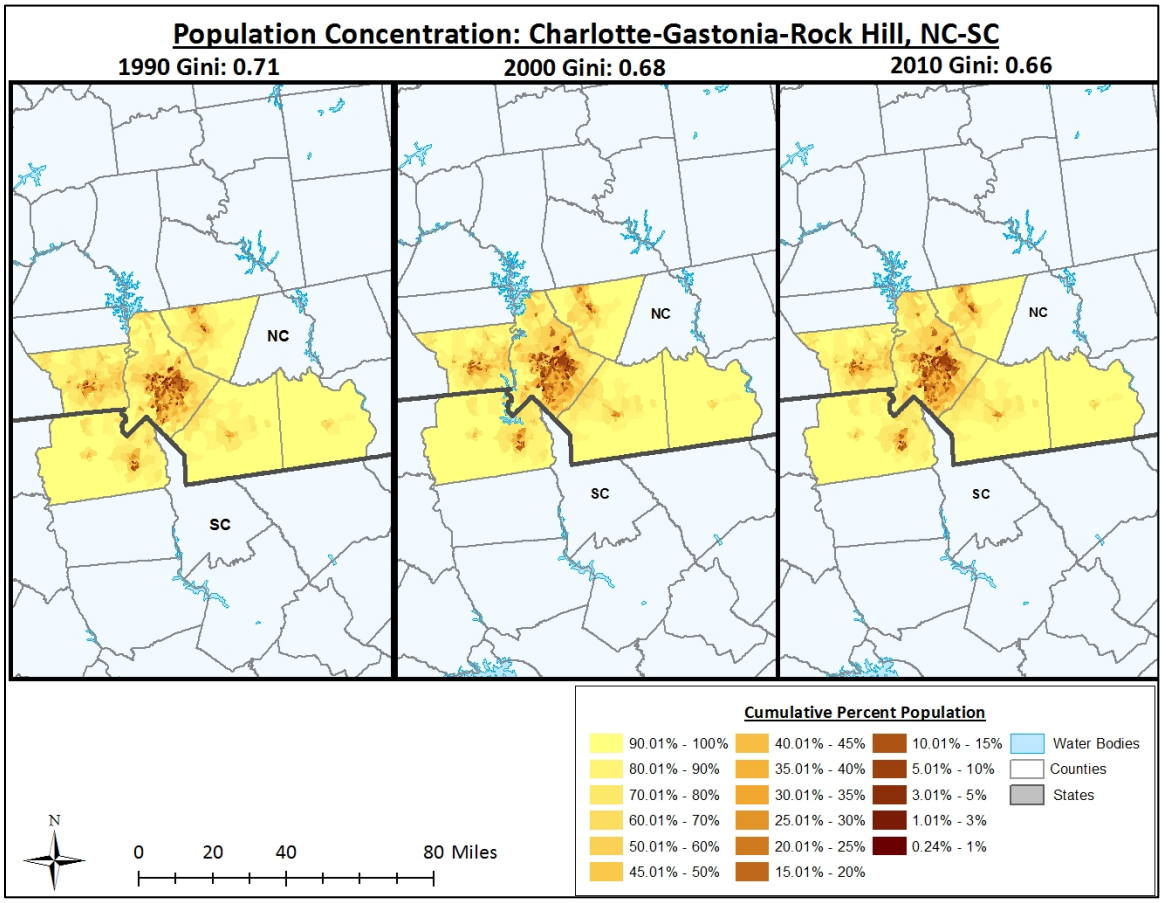


Figure 18: Population Concentration in Charlotte (1990–2010)



To illustrate differences and changes in population concentration we use Lorenz curves and population density maps. Figures 17 and 18 illustrate the extent of population concentration in the Charlotte metropolitan area. The map shows that Charlotte's population is distributed widely throughout the metropolitan areas. The Lorenz curve for Charlotte is thus relatively flat, meaning that the most dense block groups do not contain a disproportionate share of the total population and that the population is not very geographically concentrated.

Figure 19: Population Distribution in Riverside (1990–2010)

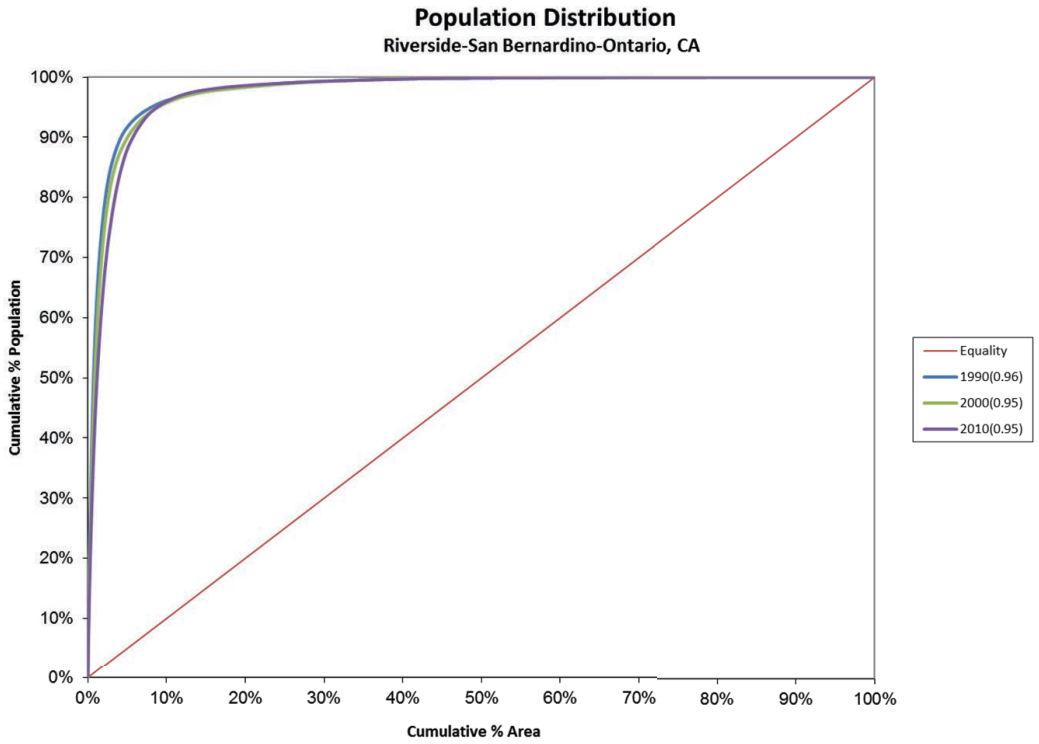
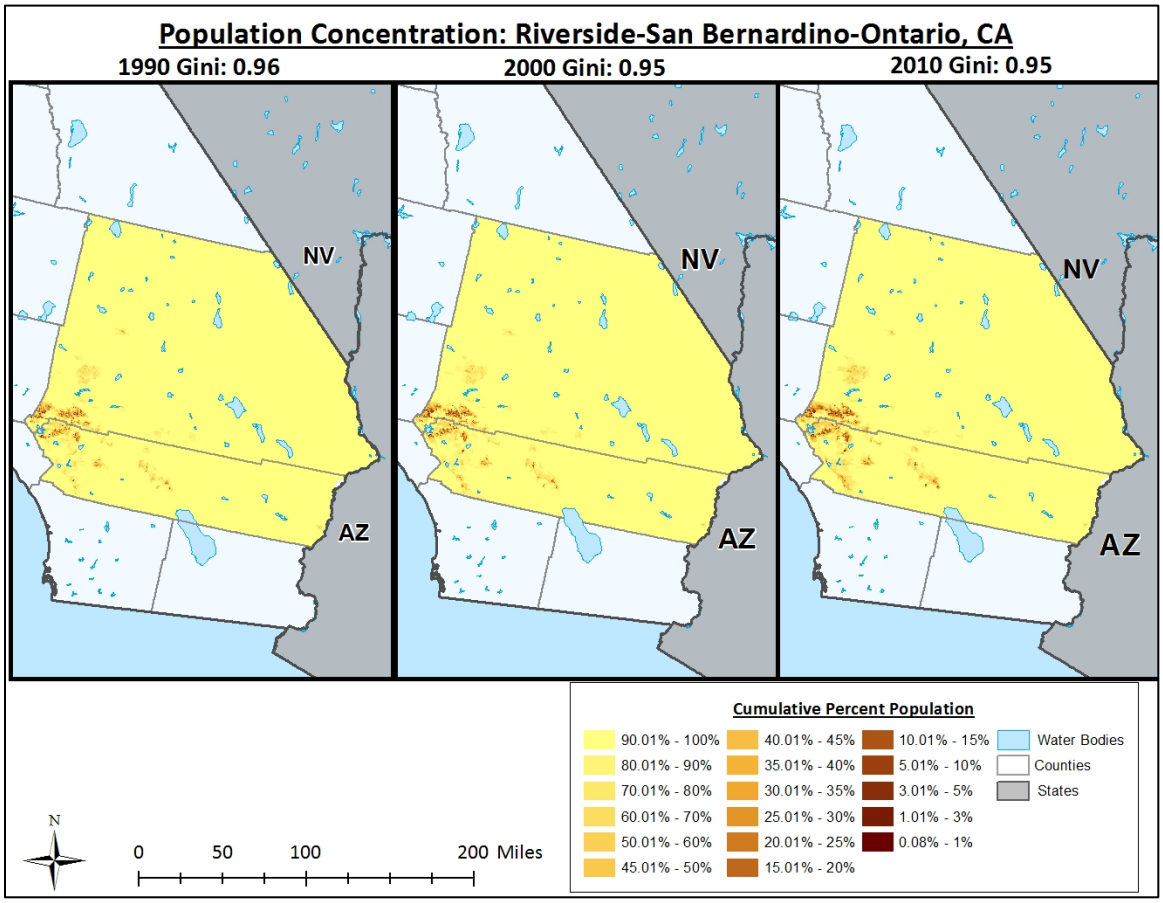


Figure 20: Population Concentration in Riverside (1990–2010)



Figures 19 and 20 illustrate the extent of population concentration in the Riverside metropolitan area. The map shows that most of the Riverside population is concentrated in the southwest corner of the metropolitan area. The Lorenz curve is highly curved, illustrating that the most dense block groups in the metropolitan area contain a large share of the metropolitan population and that the population is highly geographically concentrated.

Figure 21: Population Distribution in Tampa (1990–2010)

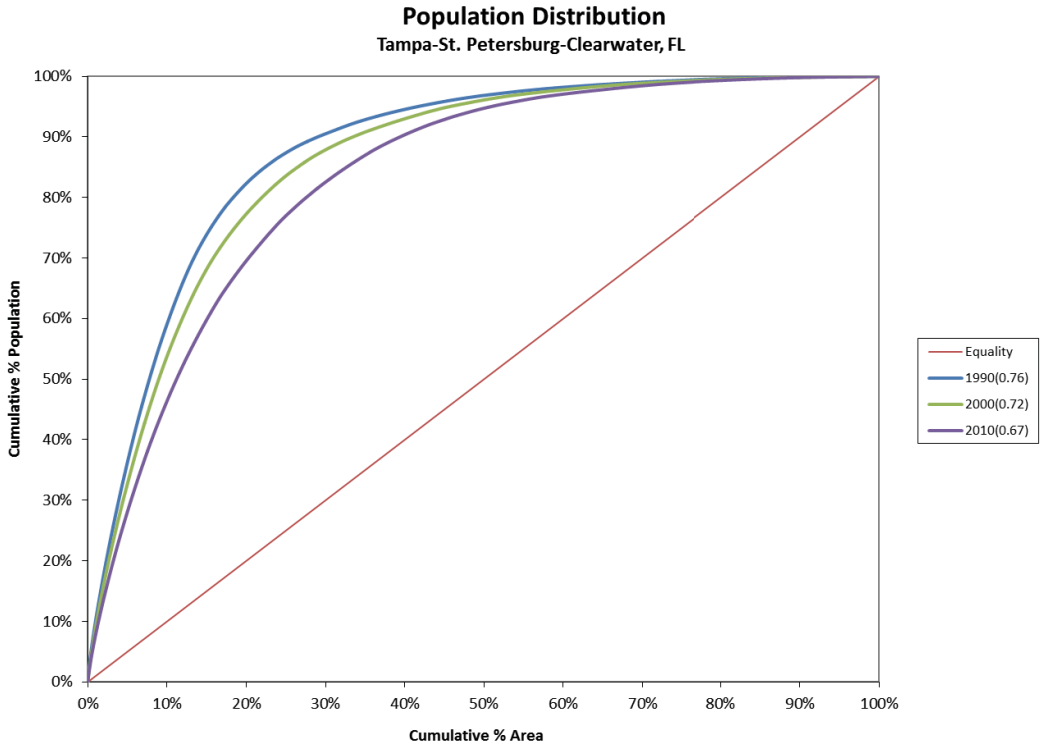
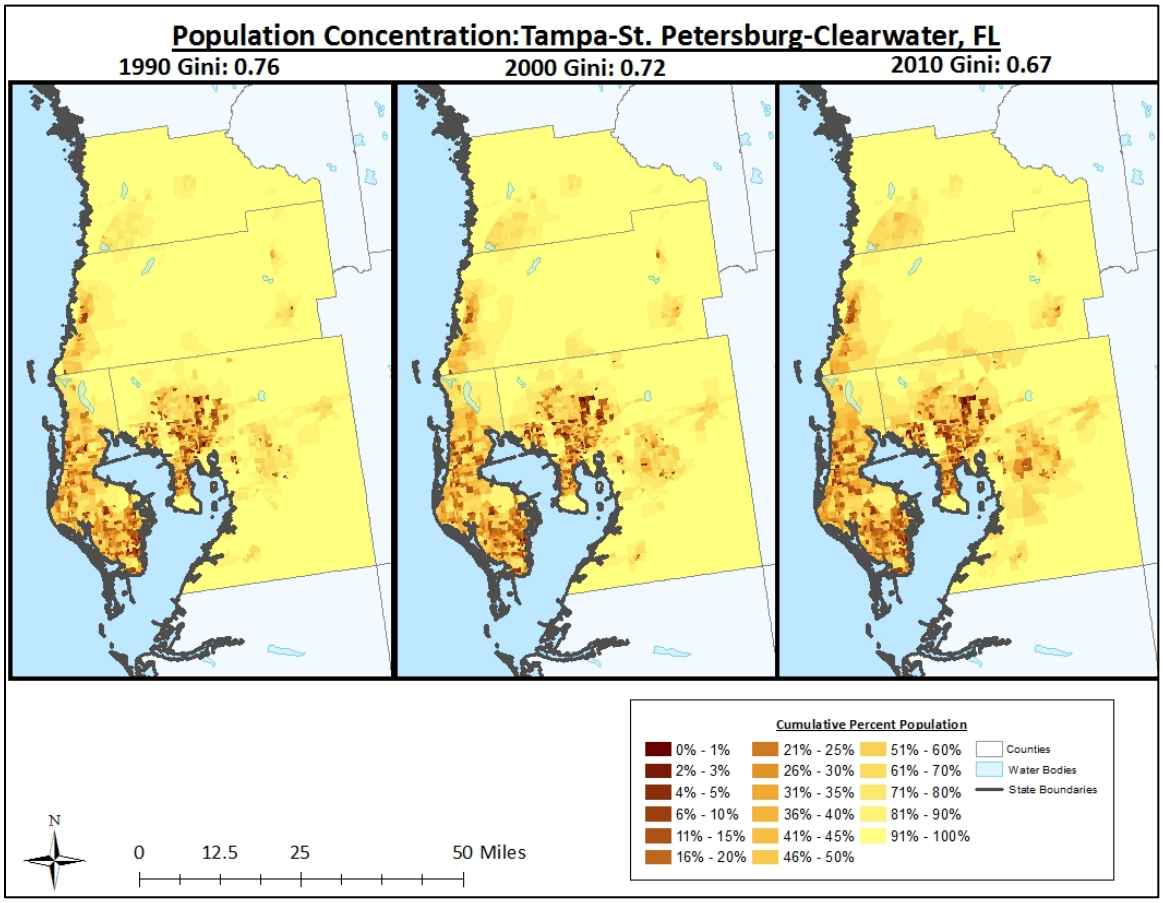


Figure 22: Population Concentration in Tampa (1990–2010)



Figures 21 and 22 illustrate the extent of population concentration and change in concentration in the Tampa metropolitan area. As shown on the map, the population of the Tampa became more widely distributed spread over the period from 1990 to 2010. This is illustrated by the Lorenz curve flattening and moving closer to the diagonal over time.

Figure 23: Population Distribution in Portland (1990–2010)

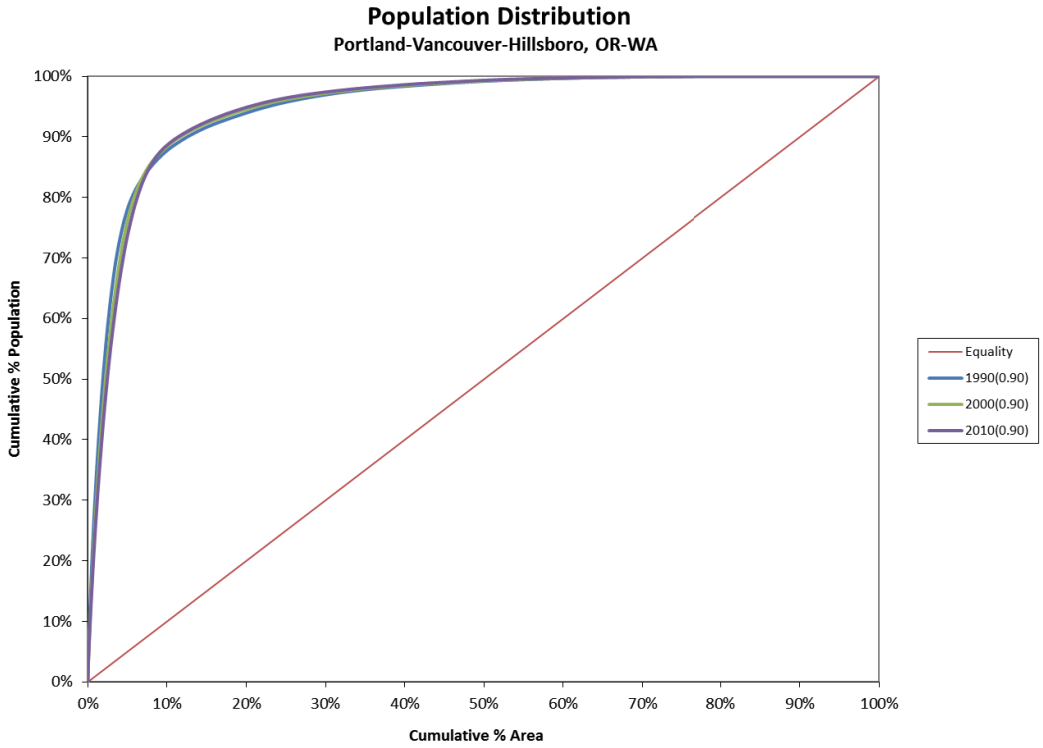
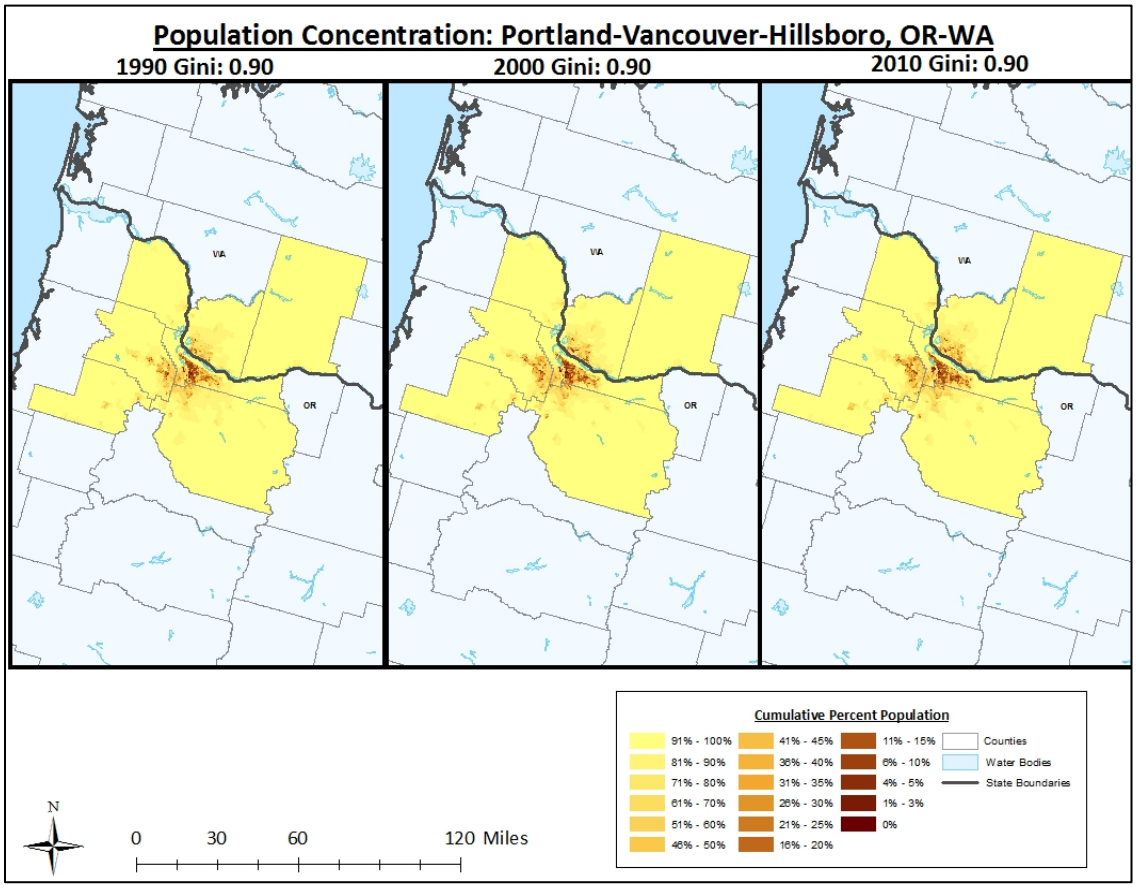


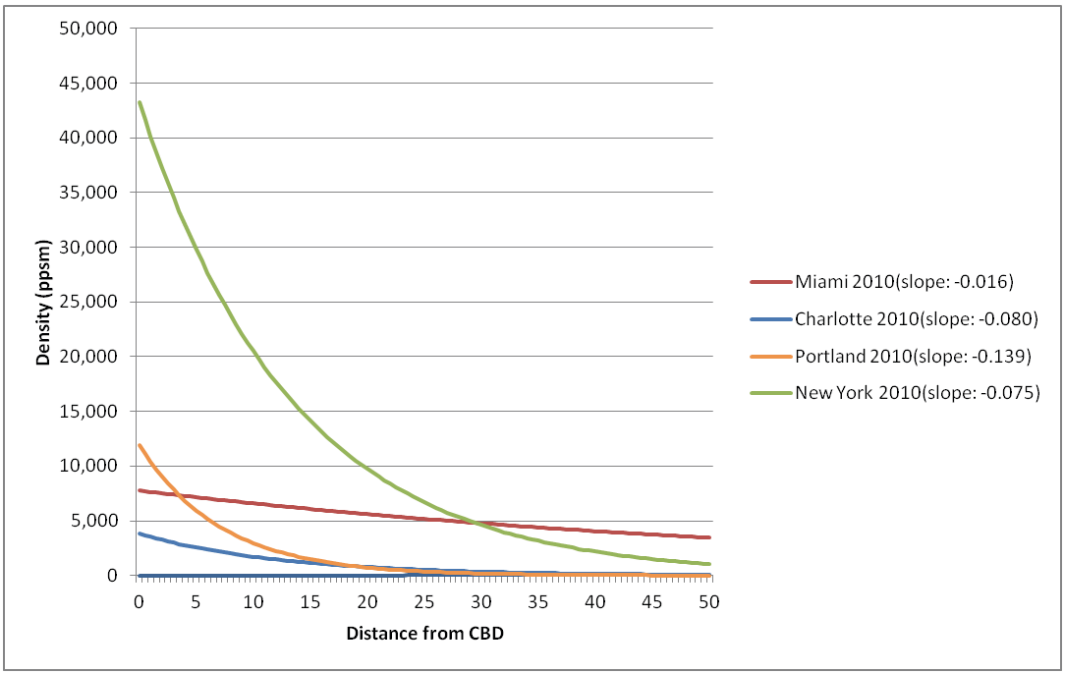
Figure 24: Population Concentration in Portland (1990–2010)



Figures 23 and 24 illustrate the extent of population concentration and change in concentration in the Portland metropolitan area. As shown on the map, the population of Portland became more concentrated near the center of the metropolitan area from 1990 to 2010. This is illustrated by the Lorenz curve becoming more bowed and moving further from the diagonal over time.

Density Gradients

Figure 25: Density Gradients in 2010



To illustrate the relationship between population density and the center of the city we present density gradients and changes in density gradients over time. As shown in figure 25, the density gradient for New York has the highest intercept, with an estimated density of 43,245 persons per square mile in the center of the city. Charlotte by contrast has the lowest intercept with an estimated population density of only 3,822 persons per square mile in the city center. Portland has the steepest density gradient while Miami has the flattest.

Figure 26: Change in Density Gradients from 1990 to 2010

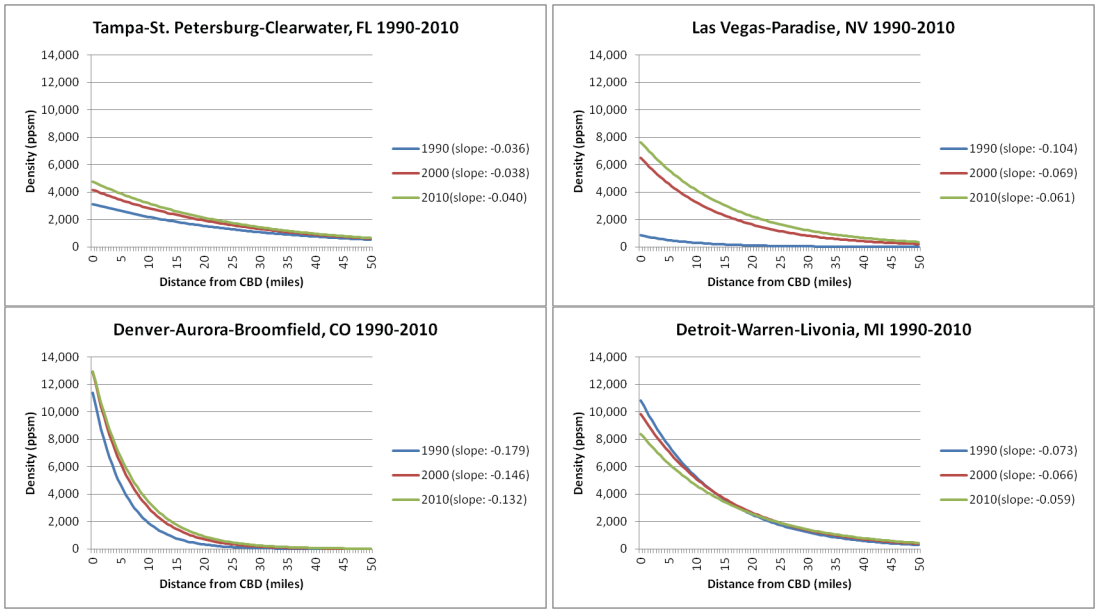


Figure 26 illustrates changes in density gradients over time. As shown, the intercept of the density gradient for Detroit fell from 1990 to 2010 while the slope of the density gradient flattened. The intercept of the density gradient for Las Vegas increased from 1990 to 2010 and the density gradient flattened. The slope on Tampa flattened while the slope of the Denver gradient steepened between 1990 and 2010.

Marginal Density

Figure 27: Change in Population and Urbanized Area by Metropolitan Area from 1990 to 2010

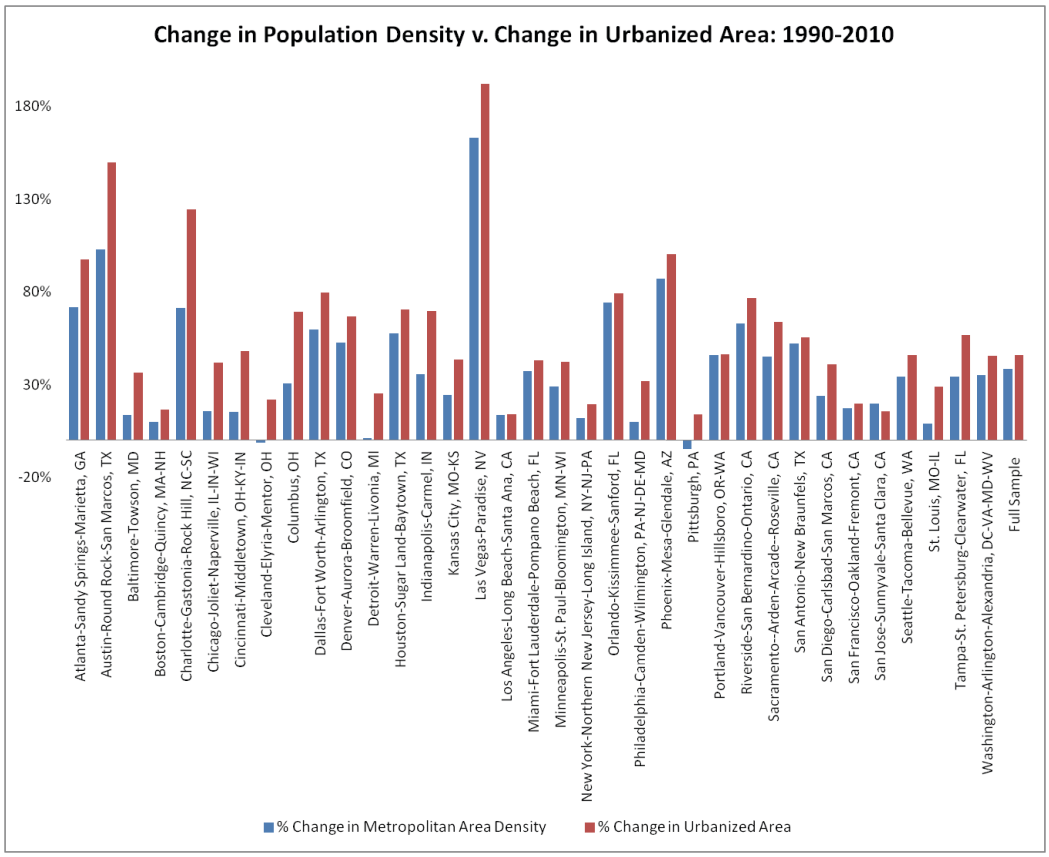
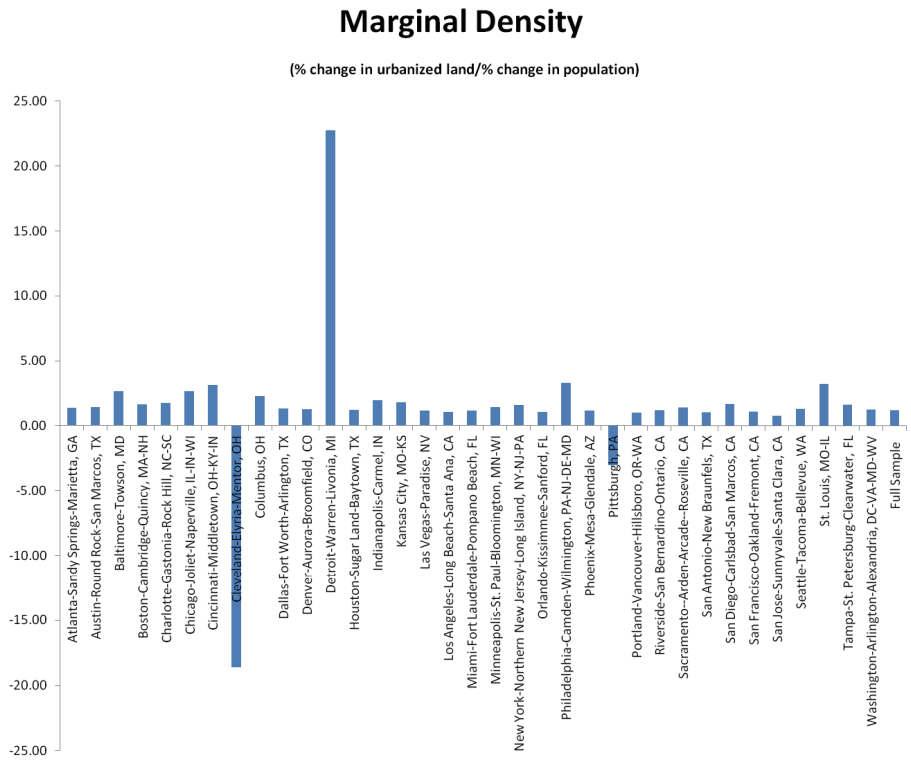


Figure 28: Marginal Density by Metropolitan Area from 1990 to 2010



To compare growth in population within the urbanized area with the spatial growth in the urbanized area from 1990 to 2010 we constructed bar graphs that illustrate population growth and areal growth for each metropolitan area and bar graphs of marginal density in figures 27 and 28, respectively. As shown in Figure 27, the population of the urbanized area increased for all but two metropolitans areas (Pittsburgh and Cleveland) from 1990 to 2010. The size of the urbanized area, however, increased for every metropolitan area. The ratio of the growth of the urbanized area to the growth of population within the urbanized area we call marginal density and is illustrated in Figure 28. As shown, the marginal densities are positive for every metropolitan area except Cleveland and Pittsburgh. The marginal density of Detroit is exceptionally high because its population grew very little while its urbanized area increased substantially. For most metropolitan areas the marginal density falls between 1 and 1.5.

[i] Following Clark (1951), density gradients describe urban population densities using the negative exponential function form, showing that density declines exponentially from the central core towards the outskirts of a metropolitan area. Negative exponential function is defined as follows:

$$D(x) = D_0 e^{-yx}, \quad (1)$$

where $D(x)$ represents population density at distance x from the center; D_0 is the density at the center; and y is the density gradient or the rate at which the population density decreases as one moves away from the center. After taking the natural logarithm of population density, the equation yields the linear equation and density gradient can be estimated via ordinary least squares:

$$\log D(x) = \alpha + \beta (x) + e. \quad (2)$$

As the study will focus on the changes in central urban densities and density gradients in the period between 1990 and 2010, density gradient models are modified as follows and are estimated for three pairs of years - 1990-2000, 2000-2010, and 1990-2010:

$$\log D(x_{2000}) - \log D(x_{1990}) = (\alpha_{2000} - \alpha_{1990}) + (\beta_{2000} - \beta_{1990})x + e \quad (3)$$

where the dependent variable $\log D(x_{2000}) - \log D(x_{1990})$ is measured as a difference between the logged population density variable in year 2000 and year 1990. Equation (3) is repeated for the 2000-2010 and 1990-2010 pairs. x is the explanatory variable measured as distance to the nearest CBSA center in 2010

In equation (3), α measures the intercept and change in population density at the core of the CBSA, and β measures the slope of the density gradient or the change in the rate at which population density decreases away from the core of the CBSA. The CBSA centers are defined as the centroids of the block group where the Central Business District (CBD) was located according to the 1982 Census of Retail Trade.