Density and Sprawl in the Older and Newer Parts of Large Urban Areas in the U.S., 1970-2020

John R. Ottensmann
Indiana University-Purdue University Indianapolis
john.ottensmann@gmail.com
urbanpatternsblog.wordpress.com
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Abstract

To examine housing unit density in the older and newer portions of large urban areas, the urban core is identified as the territory included in the urban area in 1940, with areas added subsequently designated the suburban periphery. And since urban sprawl is frequently associated with development since World War II, density in the periphery can be considered to be a measure of the extent of sprawl. The 56 large urban areas are classified into 4 groups based on low or high density in the core and the periphery. Areas in the two groups having low densities in the periphery are concentrated in the eastern half of the United States, while the areas with high periphery densities are in the South and West. Areas in the classes varied in the change in density over time and the size and rate of growth of the entire urban area. The latter two urban area characteristics along with the presence of water and mountains as barriers to urban expansion are associated with density and the change in density in the urban core and suburban periphery.

Introduction

Central city-suburb comparisons have become a staple of urban area analysis. The most common form dates from the 1950s, following the introduction of Standard Metropolitan Areas, the forerunners of the current Metropolitan Statistical Areas. The largest city or cities in those areas were designated central cities. The census reported data for metropolitan areas and also for the central cities and the remainders of the areas. The latter served as the source for the central city-suburb comparisons, with the remainder of the metropolitan area referred to as the suburbs.

Studies have examined the growth of the populations of central cities and suburbs. Population characteristics ranging from education and income to race and ethnicity were compared. Housing in the suburbs has been contrasted with central city housing. Comparison of the densities of population and housing in these central cities and suburbs is an exception, not receiving comparable attention. Bryan, Minton, and Sarte (2007) present densities for all medium and large cities from 1940 to 2000. They also calculated densities for metropolitan areas. But they acknowledge that these metropolitan area densities are problematic given that the areas are delineated using counties, which vary in size and in the proportions of their areas rural and not part of any reasonable notion of the urban area. They do not present densities for the remainders of the metropolitan areas outside the central cities—the "suburbs"—which would have been even more dubious given the problems associated with the use of counties.

The basic idea of the central city-suburb comparisons is that the central cities are the older portions of the metropolitan areas and the suburbs are the newer areas, developed more recently. The arbitrary nature of the boundaries of central city boundaries that they represent a crude and inconsistent approximation of any concept of the older parts of urban areas. Some metropolitan areas have territory outside the central city that had been developed a century or more earlier, hardly newer suburbs. And in other metropolitan areas, much of the recent new development has taken place in the central cities.

This paper examines the densities in the older and newer parts of large urban areas using consistent definitions of the urban areas and the older and newer areas. In the course of this, an alternative approach to measuring urban sprawl emerges. The next section describes the dataset of the 56 largest urban areas in 2020 with urban areas delineated in a consistent manner from 1940 to 2020 using data on housing unit density. Next comes the definition of the urban core and suburban periphery, the older and newer areas, that constitutes the framework for this analysis. This division forms the basis for reconsidering the urban sprawl and how the degree to which an urban area is sprawling can be measured. Then come the results for density in the urban core and suburban periphery. The urban areas are classified into four groups based on whether they have high or low densities in the urban core and in the suburban periphery. These are distinctive groups of the urban areas having interesting variation on numbers of dimensions. This is followed by examination of how some characteristics of the urban areas affect density in the core and periphery, density change in those areas, and the relationship between core and periphery density. An appendix addresses the difference between the urban cores and the central cities used in the classical central city-suburb comparisons.[1]

The *Urban patterns 2* data

The *Urban patterns 2* dataset includes housing unit counts for census tracts from 1950 to 2020 that have been used to delineate 56 large urban areas in the United States

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[1] An earlier paper (Ottensmann 2020) compared core and periphery densities using an earlier dataset for a different set of urban areas that extended only to 2010. A slightly different definition of core and periphery was used in that paper and the analysis was limited compared to the current paper.

for each census year. Data for 2010 and 2020 are from the Census and from the National Historical Geographic Information System (Manson, *et al.* 2022). Data from the censuses from 1970 to 2000 are from a unique dataset from the Urban Institute and Geolytics (2003) with the data normalized to 2000 census tract boundaries. Housing units for 1950 and 1960 are estimated from the data on housing units by year built from later years, taking the numbers built before 1950 and 1960 as the estimates of the numbers present in those years. These estimates include error resulting from changes to the housing stock over time, especially the loss of units, but analyses suggest that the estimates are reasonable for two decades back in time. Census tract boundaries for 2020 are used for the dataset. The census tract relationship files are used to estimate values for the 2020 tracts from data for earlier years. Detailed documentation of the dataset and listings of all data sources are included in Ottensmann (2023a).

Urban areas consist of contiguous census tracts that meet urban criteria. Some large areas of continuous urban tracts include what should reasonably be considered two or more urban areas. Areas in the northeastern United States are a major example. To distinguish separate urban areas, the Combined Statistical Areas (CSAs) are used (and MSAs that are not included in a CSA). CSAs are used rather than the more commonly used Metropolitan Statistical Areas (MSAs) as they better represent the full extent of urban areas. The CSAs are only used to identify the urban areas, such as Philadelphia, New York, and Hartford. The boundaries are established at the locations where the urban areas have become contiguous as they have expanded. The urban areas included in the dataset are the 56 areas containing more than 300,000 housing units in 2020.

The criteria defining the urban areas are as close as possible to those being used for delineating the 2020 census Urban Areas, which include what were formerly called Urbanized Areas (U.S. Census Bureau 2022). A census tract is considered to be urban and is included in an urban area if it has a housing unit density greater than 200 housing units per square mile. To include urban territory that is nonresidential, a tract is also included if over one-third of its area has impervious surface of 20 percent or more. An additional condition is that a tract is only considered to be urban if it had been designated as urban for the following census year. This is to provide a pattern of cumulative expansion of the urban areas. This direction has been chosen rather than the reverse (if urban, then urban later) because the more recent data are considered to be more accurate.

Some of the urban areas include two or more areas that were originally separate but that have since growth together. Areas that are sufficiently large are considered to be urban centers and are included in an urban area with tracts assigned to one of the urban centers. The Dallas-Fort Worth area is an example. As the areas become contiguous, tracts are assigned to the center growing more rapidly toward the other and to provide more continuous, less irregular boundaries. Areas are considered separate urban centers and are included in an urban area if the number of housing units in 2020 exceeds 16 percent of the total units in the urban area. This cutoff was established by identifying as candidates all initially separate areas deemed large enough to potentially be considered an urban center and then setting the threshold. The smallest urban centers in relation to the total size of the urban area are Providence, with Boston; Tacoma, with Seattle; and High Point, with Greensboro and Winston-Salem. Next highest, at 11 percent are Port Charlotte in the Sarasota-Bradenton area and Winter Haven in the Orlando area. The names given to the urban areas include the names of additional urban centers that have been included.

Defining the urban core and suburban periphery

Using the urban areas defined as described above solves the problem of counties containing significant and varying amounts of rural territory that occurs with the classic central-city suburb comparison. Central cities remain as the other problem. Their arbitrary boundaries mean they do a poor job of identifying the older portions of the urban areas. This section describes the approach that is taken for identifying the older core of the urban areas and the newer suburban areas at the periphery.

If the newer portion of the urban area is to be described as the suburbs, the question then becomes what is generally meant when people refer to the suburbs. To be sure, a suburb is sometimes considered to be any incorporated area outside the large city at the core of the urban area. But more often, the term suburban is used to refer to newer development that differs in character from the older areas in the core. Many people probably would not describe Cambridge or East St. Louis as suburban.

After little housing had been built during the Great Depression or the war, the period following World War II saw an explosion of new housing development at the fringes of urban areas to meet the pent-up demand. This development often came in the form large tract subdivisions, exemplified by Levittown on Long Island and Lakewood in Southern California. The new shopping centers were built to serve the residents. Observers began to comment on this distinctive new “suburban” development, very different from that in older parts of urban areas.

More recent observers have likewise chosen to date the development beginning at this time as the modern suburbs. The report *Beyond Sprawl* (1995) addresses development since 1945 in discussing what it refers to as “suburban” sprawl. Writing about sprawl in 2002, Squires refers to development that has occurred in the previous five decades. Gilliam (2002) describes the “postwar suburban expansion.” Langdon (1994) refers to “the suburbs built since the Second World War.”

It is therefore reasonable to identify the newer suburban portions of urban areas as that territory developed and added to the urban areas after 1945. Areas included the urban areas before that year would then be considered the older core. If the urban areas can only be delineated in census years, this leaves the choice between 1940 and 1950. New new housing development was limited during the war years in the first half of the decade. The remainder of the decade saw the explosion of new housing, including the first Levittown. So it would make sense to identify the extent of the urban area as of 1940 as the urban core, with all areas added to the urban area starting with 1950 as the suburban periphery.

The description of the *Urban patterns 2* dataset in the previous section refers to housing unit counts, densities, and delineation of urban areas beginning in 1950. The housing units by year-built data used to estimate census tract housing units for 1950 and 1960 can also be used to make comparable estimates for 1940 (this is the earliest year possible with that data). However older estimates have error because housing units are lost over time so the number of units still existing in the later year are an underestimate of the units existing at the earlier time. Analysis has suggested that the error is acceptable going back two decades from but not three. For this reason, data are not included for 1940, as counts of housing units for this year are considered to be unreliable.

Nevertheless, housing unit densities can be estimated for 1940 and these values can be used to delineate urban areas for that year. Two reasons support the use of these urban areas as the urban cores. First, inclusion of census tracts within the urban area depends only on whether or not the density exceeds the 200-housing-units-per-square-mile threshold. How much the density of the tract is above or below this is irrelevant. So any error in the 1940 housing unit counts are likely to affect only a few tracts at the margin for inclusion in the urban area. In addition, the error associated with the loss of units over time will almost certainly be greatest for the oldest areas and least for the newest. And the low density tracts at the periphery will have seen much of their development occurring most recently. They are therefore least likely to be affected by the loss of units.[2]

The census tracts included in the urban areas as delineated in 1940 constitute the older parts of the urban areas and are designated the "urban core." Those tracts added to the urban areas in subsequent years beginning in 1950 are designated the "suburban periphery." Note that the urban core is a fixed area that does not change over the period of the analysis up through 2020. The suburban periphery generally expands in each census year with the addition of new census tracts to an urban area.

Since the focus of this paper is on the housing unit densities in the urban core and suburban periphery, one more issue needs to be addressed. While it is certainly appropriate to begin with urban core densities in 1950 and see how they have evolved over time, this is not the case for densities in the suburban periphery. When census

[2] The predecessor to the current dataset included only data back to 1950, so the urban area for that year was designated as the urban core in some earlier analyses (e.g., Ottensmann 2018, 2020).

tracts experience new housing development that increases the density above 200 units per square mile, they are added to an urban area. But such tracts are most often far from fully developed and will continue to see further development and increased densities in subsequent decades. The 1950 urban peripheries include only those tracts added to the urban areas in that year and have low densities reflecting that partial development. Of course new, partially developed tracts will be added each year. It is only in 1970 that densities in the suburban peripheries start approaching the level observed in the later decades. For this reason, the analysis of densities in the core and periphery begins with 1970.

Urban sprawl in the suburban periphery

Describing the extent of sprawl in urban areas requires addressing two questions: How does one measure sprawl? And for what area is sprawl to be measured? The first question has received a considerable amount of attention. The second, very little.

Little agreement exists on the definition of sprawl and its measurement. Some view sprawl as a multi-dimensional phenomenon and have developed elaborate sets of sprawl indices reflecting such assumptions (Galster, *et al.* 2001; Ewing, Pendall, and Chen 2002; Ewing and Himidi 2014). Sprawl has been defined with respect not only to the urban pattern but using either its causes or consequences. Ewing (1994, 1997) reviewed a large number of articles addressing sprawl and identifies four characteristics of sprawl that recur in the literature. These are low-density development, scattered and leapfrog development, and strip development. This is essentially what Harvey and Clark (1965) suggested in one of the early articles on sprawl. The distinction between scattered and leapfrog development is unclear, and strip development sometimes is seen to encompass only commercial development while other times residential strip development is recognized as well. From a measurement perspective, the density of housing units for any but the smallest units reflects all of these types of development. Obviously lower-density development on large lots will be associated with lower census tract densities. But so will scattered or leapfrog development. The greater the degree of scattering in a tract, the larger the amount of undeveloped vacant land and the lower the density. And if strip development is considered to include residential, the same thing will hold.

This suggests that housing unit density can serve as a reasonable measure of urban sprawl. Many have used population density, but since sprawl refers to the physical patterns of urban development, housing unit density may be more appropriate. Various options exist for using density as a measure of sprawl. Density can be calculated in different ways. Numbers of housing units, population, or land area in census tracts having densities below some threshold can be determined. Change in density has been used. But most straightforward is the use of the simple measure of population or housing unit density in an area as the measure of sprawl as various authors have done (Pendall 1999; Fulton, *et al.* 2001; Anthony 2004; Angel, *et al.* 2010). Housing unit density in an area is taken to be the measure of sprawl for this paper.[3]

This brings up the second question: In what area is sprawl (in this case housing unit density) to be measured? Sprawl has been measured for Urbanized Areas. Cutsinger and Galster (2006) define what they termed Extended Urban Areas that add some lower density census tracts to the Urbanized Areas. Urban areas have been defined using census tracts or other small areas in a manner similar to what is being done here. Metropolitan Statistical Areas are often used and sometimes the larger Combined Statistical Areas. Some have used the subdivisions of the larger metropolitan areas called Primary Metropolitan Statistical Areas and later Metropolitan Divisions. These have some issues, not the least of which is that Nassau and Suffolk Counties in New York and Bucks and Montgomery Counties in Pennsylvania, suburbs of New York and Philadelphia, can hardly be considered separate metropolitan areas. One study even used Consolidated Metropolitan Statistical Areas and Primary Metropolitan Statistical areas in different sections without explanation (presumably because one or the other gave better results? I am not going to name the authors or cite the study). The one thing all of the studies have in common is that they measure sprawl across the entire urban areas, however defined.

Most studies of urban sprawl are clearly referring to the patterns of development in the areas developed since 1945, the areas being described here as the suburban periphery. Indeed, rather than saying urban sprawl or simply sprawl, some studies use the alternate descriptor "suburban sprawl" (*Beyond Sprawl* 1995; Sierra Club 2000, 2003). So if sprawl/urban sprawl/suburban sprawl refers to the pattern of development in the suburban periphery, the measure of sprawl should be a measure of the pattern in that area. Housing unit density in the suburban periphery can therefore be the measure of the extent of sprawl in an urban area.

In defense of this approach to the measurement of sprawl, I would suggest that an urban area having higher densities in the urban core should not get a pass from being identified as having a very low density suburban area and high levels of sprawl simply because the overall density is not that low. If the density of the entire urban area is taken as a measure of sprawl, then construction of additional housing near the Central Business District with no changes in the rest of the urban area would result in an increase in density and a reduction in sprawl. Some might argue that the urban area should indeed be considered less sprawling because this might have positive benefits such as reduced auto use. If that is the criterion, then improving public transit could be considered something that would decrease sprawl. Or they might argue that because

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[3] In earlier paper (Ottensmann 2018) I used multiple variables based on density to develop a measure of sprawl. I now believe that the use of the level of density alone is more direct and easier to understand.

the new housing increases the centralization of population and housing in the urban area, it could be seen as reducing sprawl. This raises the question of whether the degree of centralization should be considered as another dimension of urban sprawl. And that gets back to the question of how one chooses to define sprawl.

To reiterate, in this paper, housing unit density in the suburban periphery is considered to be the measure of the level of sprawl in an urban area.

Urban core and suburban periphery density classes

The 56 urban areas are grouped into four classes using the levels of the densities in the urban core and suburban periphery. The first portion of this section describes the classification. Next is an examination of core and periphery density characteristics by class. This is followed by examination of the means of several characteristics of the urban areas in each of the classes.

Classifying urban areas based on density in the core and periphery

Figure 1 plots the housing unit density in the suburban periphery in 2020 versus the density in the urban core for the 56 large urban areas. The urban areas at the extremes and all of the largest urban areas are labeled. It is not possible to label all of the areas.

Areas are considered to have low or high urban core density if their density is below or above the mean core density of 2,819 housing units per square mile for all urban areas. Likewise, areas are designated as having low or high suburban periphery density based on the mean suburban density of 938. Together, these divisions place the urban areas into four classes based on the combination of low or high core and periphery densities. For reference, the urban areas included in each class are listed in Figure 2, displaying the lists in the four quadrants as in the first figure.

The greatest number of urban areas, 36 of the 56, are in the two classes in which core and periphery density levels are the same, low-low and high-high. A smaller but not insignificant number, 20 urban areas, are in the other two classes having differing core and periphery density levels.

If density in the suburban periphery is considered to be the measure of sprawl, the two low suburban periphery classes would include the urban areas that have the higher levels of sprawl. The high core density-low periphery density class shows that high levels of sprawl can exist in areas that have high core densities. These are areas in which the presence of low density sprawl in the suburbs would not have been identified using the overall densities of the urban areas.

The labeled areas in Figure 1 and the lists of areas in each class in Figure 2 make it obvious that the urban areas in the four classes are not distributed uniformly across

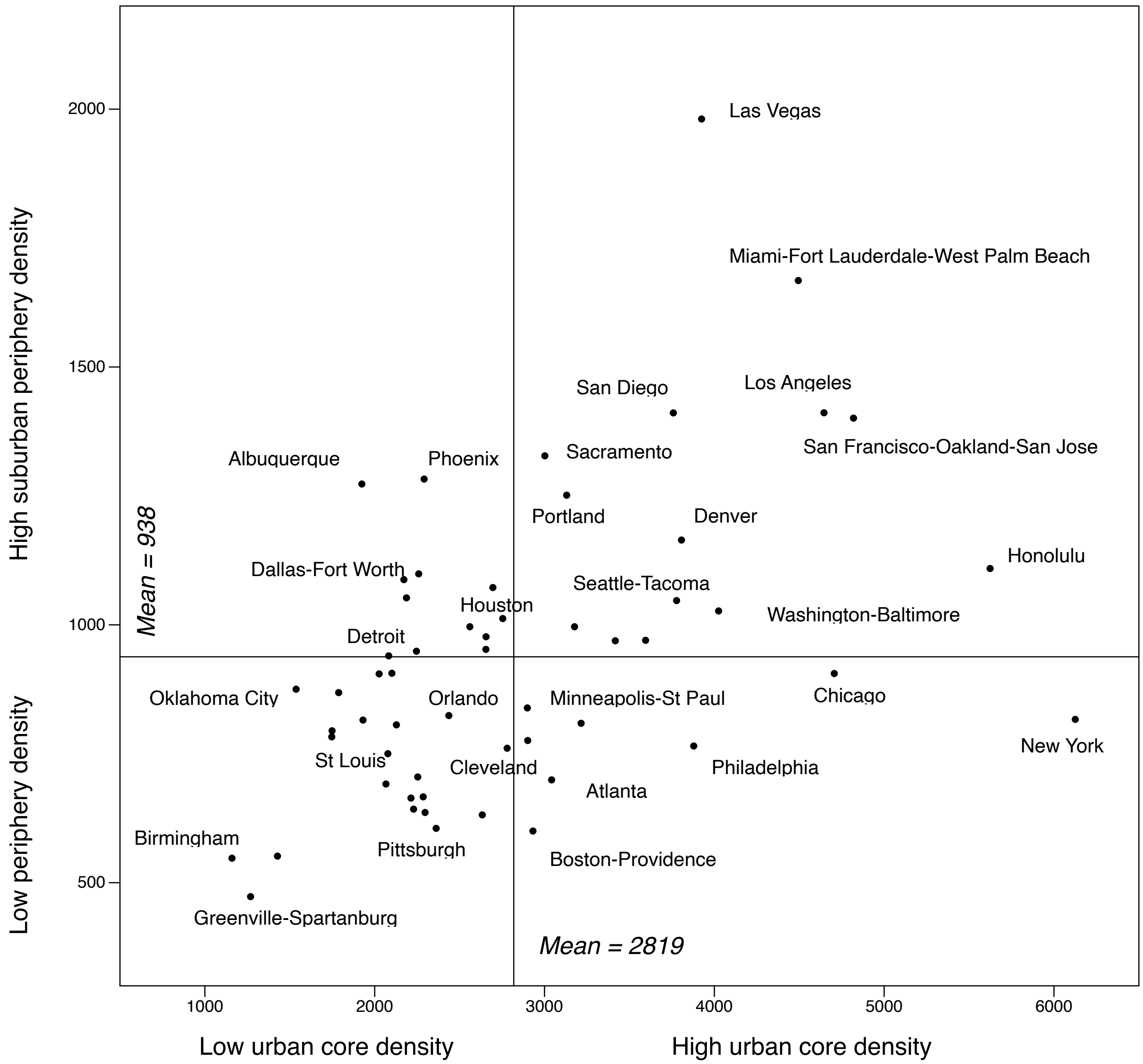

Figure 1. Plot and classification of urban areas by density in the suburban periphery versus density in the urban core.

High suburban periphery density

Albuquerque	Norfolk-Virginia Beach
Cape Coral-Fort Myers-Naples	Phoenix
Columbus OH	San Antonio
Dallas-Fort Worth	Sarasota-Bradenton
Detroit	Tampa-St Petersburg
Houston	Tucson

Austin	Portland
Denver	Sacramento
Honolulu	Salt Lake City-Provo
Las Vegas	San Diego
Los Angeles	San Francisco-Oakland-San Jose
Miami-Fort Lauderdale-West Palm Beach	Seattle-Tacoma
New Orleans	Washington-Baltimore

Low suburban periphery density

Birmingham	Louisville
Charlotte	Memphis
Cincinnati	Nashville
Cleveland-Akron	Oklahoma City
El Paso	Omaha
Greensboro--Winston-Salem--High Point	Orlando
Greenville-Spartanburg	Pittsburgh
Hartford	Raleigh-Durham
Indianapolis	Richmond
Jacksonville	Rochester
Kansas City	St Louis

Atlanta	Milwaukee
Boston-Providence	Minneapolis-St Paul
Buffalo	New York
Chicago	Philadelphia

Low urban core density

High urban core density

Figure 2. Lists of urban areas classified by density in the suburban periphery versus density in the urban core.

the United States. The map in Figure 3 shows the 56 large urban areas, color-coded to indicate their classification based on densities in the urban core and suburban periphery. Starting with the largest class, the low core density-low periphery density areas shown in red are nearly all located in the eastern half of the country, almost all inland, not on a coastline. All of the high core density-low periphery density urban areas, in green, are likewise in this same area, with numbers being larger areas and areas on coastlines. So nearly all of the urban areas with low densities in their suburban peripheries, the more sprawling urban areas, are in this portion of the country.

The locations of the high periphery density urban areas overlaps somewhat with the other areas, but they tend to be concentrated in other parts of the United States. The high core density-high periphery density urban areas, colored blue, are heavily concentrated in the western part of the country, with a large majority of the western urban areas in this class. But Washington-Baltimore, Miami-Fort Lauderdale-West Palm

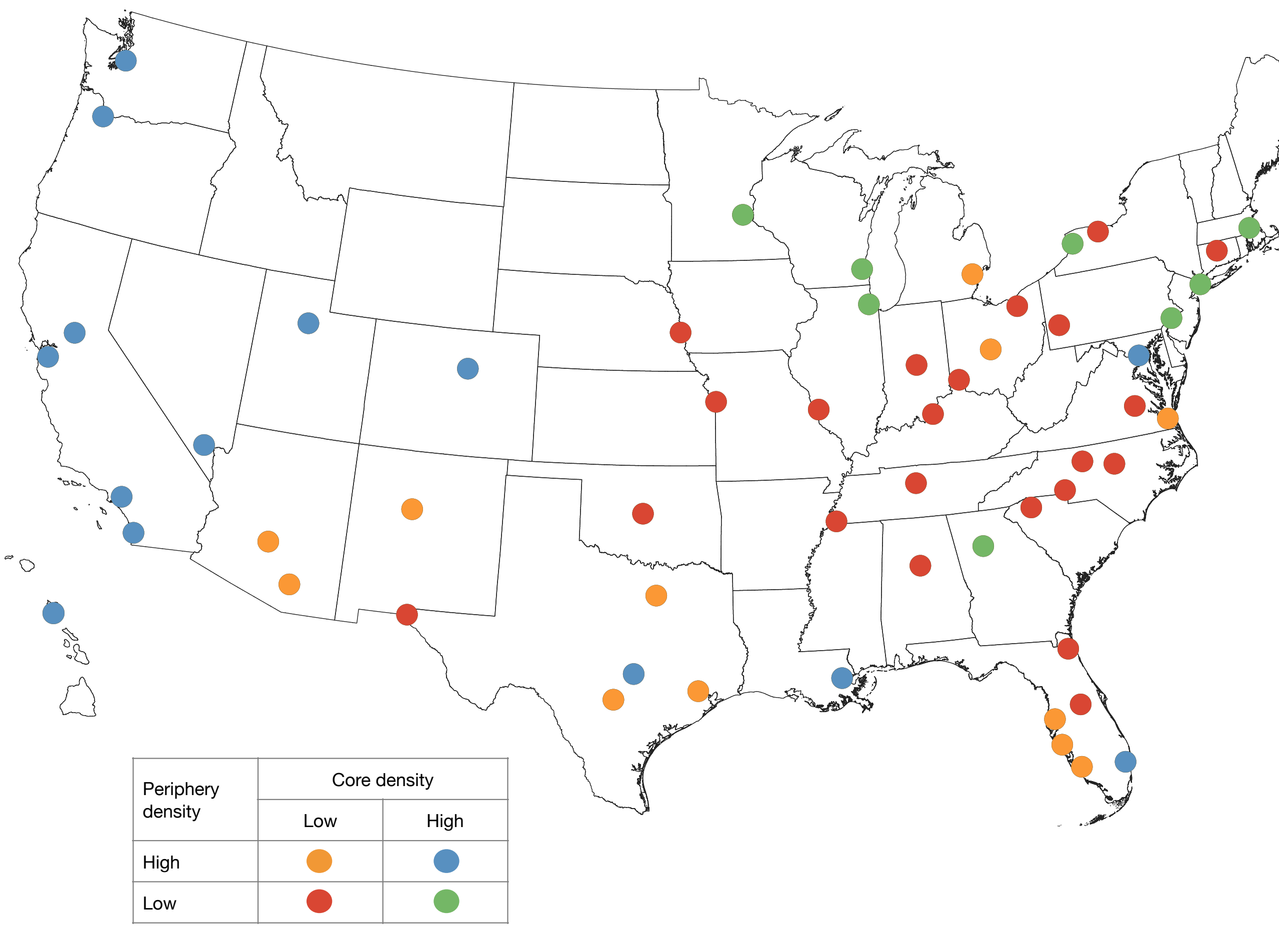

Figure 3. Urban areas classified by density in the suburban periphery versus density in the urban core.

Beach, New Orleans, and Austin also have high densities in both the core and periphery. Finally, the largest share of the low core density-high periphery density urban areas, orange, fall in a band stretching from the Florida Gulf coast to Arizona. All of the urban areas in the West region as defined by the census are in one of the high periphery density classes and therefore have somewhat lower levels of sprawl.

Urban core and suburban periphery density characteristics by class

Given the way the urban areas have been classified, average densities necessarily vary among the classes, but some interesting differences emerge. Table 1 shows the mean densities in 2020 in the urban core and suburban periphery for the urban areas in each of the classes. Of course mean core densities are lower in the two low core density classes. But the average core densities in the high periphery density classes are both higher than for the low periphery classes. For the areas with low core densities, these densities are about 2,000 and almost 2,400. For high core densities, this is 3,700 and over 3,900.

A similar pattern is seen for densities in the suburban periphery where mean densities are higher for the high core density classes than for the corresponding low core density classes. The comparisons are about 720 and 780 for low periphery density classes and 1,060 and 1,270 for high.

More dramatic differences among the classes are seen for the mean changes in density in the urban cores and suburban peripheries from 1970 to 2020 in Table 2. Mean density in the core actually declines by a very small amount in the low core density-low periphery density class. The highest average core density change, an increase of 955 housing units per square mile, is in the high core density-high periphery density class. The other two classes have more modest increases.

Table 1. Mean densities in 2020 in urban core and suburban periphery for urban areas classified by core and periphery density.

Urban core mean density

Periphery density	Core density		Total
	Low	High	
High	2,374	3,943	3,218
Low	2,023	3,712	2,473
Total	2,146	3,859	2,819

Suburban periphery mean density

Periphery density	Core density		Total
	Low	High	
High	1,058	1,267	1,170
Low	723	776	737
Total	841	1,088	938

Table 2. Mean change in densities from 1970 to 2020 in urban core and suburban periphery for urban areas classified by core and periphery density.

Urban core mean density change

Periphery density	Core density		Total
	Low	High	
High	272	955	640
Low	-15	388	92
Total	86	748	346

Suburban periphery mean density change

Periphery density	Core density		Total
	Low	High	
High	252	433	349
Low	119	67	105
Total	166	300	218

Density change in the suburban periphery is again highest in the high core density-high periphery density class, a mean increase of 433. While this is half the increase in core densities for this class, average densities in the periphery are much lower than in the core, so this represents a very large jump. Here, the lowest average increase of only 67 comes in the high core density-low periphery density class.

It is helpful to see the plots of mean core and periphery densities over time for the four density classes, shown in Figure 4. The top graph shows the mean densities for the urban cores. The two low core density classes start with very similar densities in 1970. The low periphery density class, in red, shows little net change over the period. The mean core density for the high periphery density class in orange increases somewhat, widening the gap. The two high density core classes have more substantial increases in their mean core densities. The growth is much higher for the high density periphery class, in blue, which starts with a mean below the other and ends with a higher density.

For average densities in the suburban periphery in the bottom graph, the two low periphery density classes in green and red both have small increases. The high density periphery classes has greater change. By far the greatest increase in mean periphery density occurs in the high density core class, which starts with a density very close to the low density core class but by 2020 has a much higher average density.

The high density core-high density periphery class of urban areas is clearly the distinctive group of urban areas. Mean densities in both the core and periphery are higher than the any of the other classes. Mean change in density is far greater as well. The graphs in Figure 4 shows these larger increases.

The first two sets of tables address density and change in density in the urban core and suburban periphery separately. Now the relationship between core and periphery densities are considered. Two measures are used. First is the ratio of density in the urban core to density in the suburban periphery, a measure of the relative

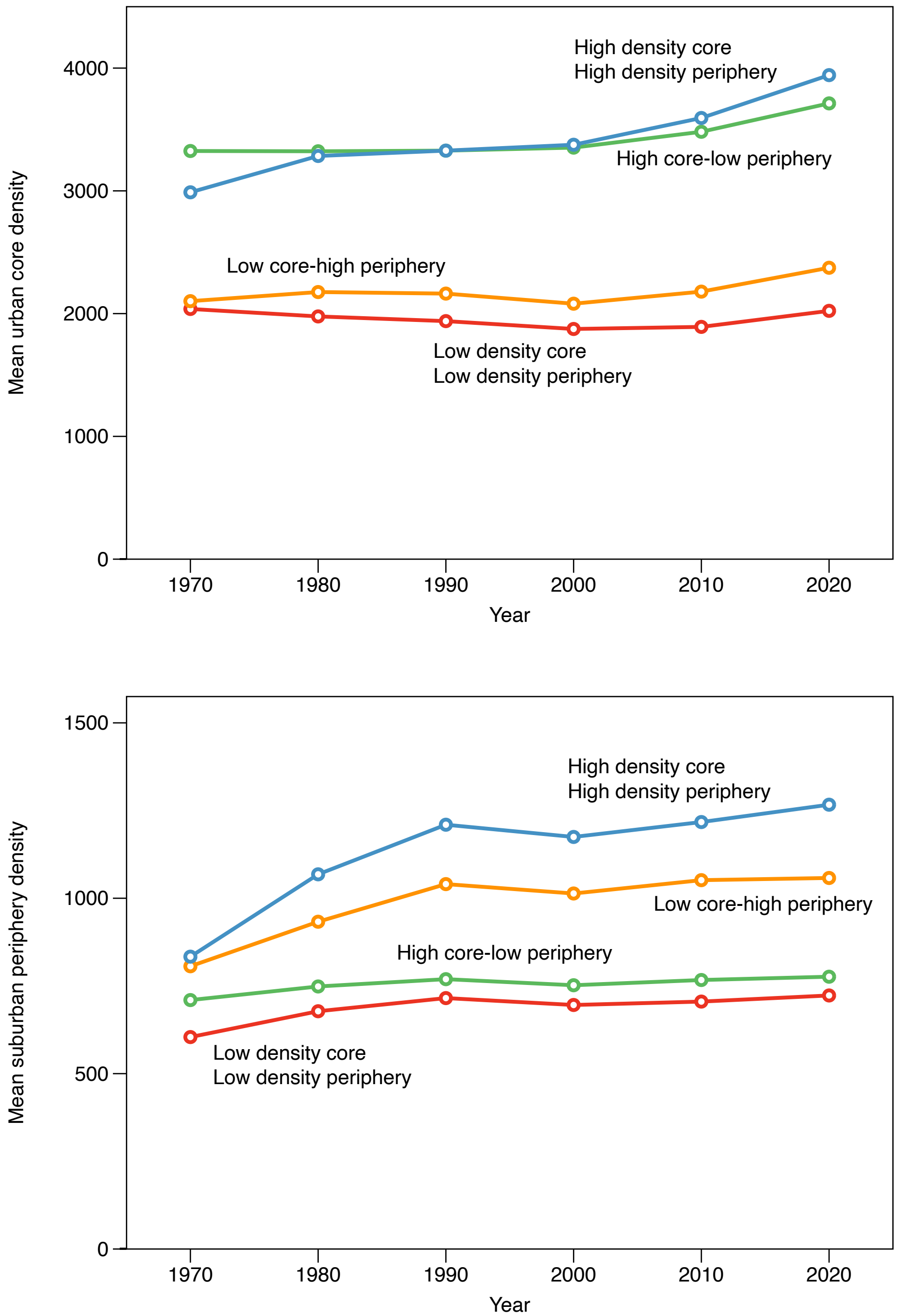

Figure 4. Mean densities in the urban core (top) and suburban periphery (bottom) for urban areas classified by density in the suburban periphery versus density in the urban core, 1970-2020.

Table 3. Mean ratio of core density to periphery density and mean difference between core density and periphery density for urban areas classified by core and periphery density.

Mean core-periphery density ratio

Periphery density	Core density		Total
	Low	High	
High	2.28	3.22	2.79
Low	2.85	4.77	3.36
Total	2.65	3.79	3.09

Mean core-periphery density difference

Periphery density	Core density		Total
	Low	High	
High	1,316	2,676	2,048
Low	1,300	2,936	1,736
Total	1,305	2,771	1,881

difference. The other is the absolute difference between the densities, the extent to which density in the core is greater than density in the periphery.

Table 3 shows the mean core-periphery density ratio ratio and mean core-periphery density difference for the urban areas in each density class. The mean ratio for all of the urban areas is 3.1, but this varies greatly for the urban areas in the different classes. Areas in the low density core-high density periphery class have the highest average ratio of 4.8. The lowest mean is 2.3 for the areas in the low density core-high density periphery class. At the extremes, lowest and highest ratios for all urban areas are 1.5 and 7.5, showing the wide range.

The average difference in core-periphery density for all areas is 1,900. Once again the high density core-low density periphery class has the greatest mean difference of 2,900 housing units per square mile. But here, both of the low-core density classes average close to 1,300, the lowest values. The interesting difference from the ratios comes in the high density core-high density periphery class with an average difference of nearly 2,700, not that much less than the high density core-low density periphery class. So while the mean core-periphery density ratio for the high density core-high density periphery class is not much above than the overall mean, the mean core-periphery difference is higher because overall density levels and hence differences are higher. Once again, the overall range is very large, with differences extending from about 600 to over 5,000 units per square mile.

Urban area characteristics by class

The followinig tables describe some average characteristics of the urban areas included in each of the density classes. Table 4 addresses the sizes of the urban areas, the mean number of housing units in 2020 and the mean percent change in housing

Table 4. Mean number of housing units in 2020 and mean percent change in housing units from 1970 to 2020 for urban areas classified by core and periphery density.

Mean number of housing units 2020

Periphery density	Core density		Total
	Low	High	
High	1,155,000	1,614,083	1,402,198
Low	588,951	2,699,086	1,151,653
Total	788,733	2,008,629	1,267,978

Mean percent change in units 1970-2020

Periphery density	Core density		Total
	Low	High	
High	431	291	355
Low	248	125	215
Total	313	230	280

units from 1970 to 2020. The average size for all 56 of the urban areas is over 1,200,000, but this varies across the four density classes. Urban areas in the low urban core density-low suburban periphery density class are on average the smallest by far, with a mean of fewer than 600,000 thousand units. Highest are the high core density-low periphery density areas. That New York is included certainly increases the mean number of housing units, but even without New York the urban areas in this groups would still be the highest. With 1,600,000, the urban areas in the high core density-high suburban density group are also well above the mean for all of the urban areas, while the remaining class, low core density-high periphery density have an average size very close to that for all of the urban areas.

The urban areas experienced large increases in size from 1970 to 2020, with the mean percent change in housing units of 280 percent, nearly a quadrupling of the number of housing units. Here the differences among the density classes are especially dramatic. The high core density-low periphery density areas increased by only 125 percent on average. The low core density-high periphery density areas have a mean increase of 431 percent. Urban areas in the other two classes experienced gains much closer to the overall mean.

The earlier paper examining the overall means for these urban areas gives special attention to the effect of barriers to urban expansion on densities (Ottensmann 2023b). The presence of water and mountains are each found to be associated with higher densities, with the effects being both statistically and substantively significant. Measures of the extent of the barriers are the proportion of the areas of five-mile rings surrounding the 2020 urban areas included in the barrier. For the water barrier, these are areas in the oceans and Great Lakes, with land areas outside the boundaries of the United States also included. Data on mountainous landforms are used to identify the extent of the mountains barriers (Karagulle, *et al.* 2017).

Table 5. Barriers to urban expansion. Mean percent of areas of five-mile rings around urban areas water and mountains for urban areas classified by core and periphery density.

Mean percent ring area water

Periphery density	Core density		Total
	Low	High	
High	19.6	19.4	19.5
Low	3.9	22.5	8.9
Total	9.5	20.6	13.8

Mean percent ring area mountains

Periphery density	Core density		Total
	Low	High	
High	15.6	39.6	28.5
Low	2.9	0.8	2.4
Total	7.4	25.5	14.5

Mean proportions of the rings covered by water and mountains are shown in Table 5. The relationships of the water and mountains barriers to the densities of the urban core and suburban periphery are very clear. For the water barrier, the three classes with either high-density core, high-densities suburban peripheries, or both all average around 20 percent of the ring areas water. The areas in the low density core-low density periphery class have a mean proportion water of less than four percent. The mountains barrier has a somewhat different pattern. Both of the classes having high densities in their peripheries have the higher average presence of mountains, with the mean being especially high, 40 percent, for the high density core-high density periphery areas. The two classes with low-density peripheries have very low levels of mountains barriers. It is easy to see how the combinations of these barriers contributes to the differences in densities among the areas in the four classes.

Models predicting variation in density measures for core and periphery

This section explores the relationships of some basic characteristics of the urban areas to the variation in density measure for the urban core and suburban periphery, presenting results from regression models. The first part looks at models predicting housing unit densities in the core and periphery. Next are models examining density change in those areas. The final part addresses the ratios and differences in density between the core and periphery.

Models predicting core and periphery densities

The first models predict the densities in the urban core and suburban periphery in 2020. Results are presented in Table 6. Four characteristics are used to predict the densities for both the core and periphery. All are statistically significant for both core and periphery. Each model accounts for well over half of the variation in densities, with R^2 values exceeding 0.6.

Larger areas have more households competing for space near the center, which would be expected to result in higher land prices. Less land would be used for each housing unit, resulting in higher densities in those urban areas. The total number of housing units in 2020 is the first predictor, with the log form used. This is positively related to housing unit density.

Older urban areas have a greater proportion of their housing stock built much earlier when urban densities were higher. The expectation would be that densities in their urban cores would be higher than urban areas experiencing more of their development more recently with relatively smaller urban cores. Any relationship to density in the periphery is uncertain. The number of housing units in the urban area in 1950 is the oldest measure of size in the dataset and is used as the measure of age. It is indeed positively related to the density of the urban core. The effect is substantial. An increase in the size of the urban area in 1950 of one million housing units is associated with an increase in density of nearly 600 units per square mile. But this is negatively

Table 6. Models predicting housing unit densities in 2020 in the urban core and suburban periphery (standard errors in parentheses).

	Housing unit density urban core 2020		Housing unit density suburban periphery 2020	
Log housing units 2020	424.4	**	167.0	***
	(145.1)		(41.3)	
Housing units 1950 (millions)	580.7	*	-233.0	**
	(239.7)		(68.2)	
Proportion ring area water	1,989.7	***	426.3	**
	(497.5)		(141.6)	
Proportion ring area mountains	1,525.1	***	705.7	***
	(342.9)		(97.6)	
Constant	-3,628.9		-1,449.5	*
	(1,940.3)		(552.4)	
***R*²**	0.652	***	0.620	***

** p < 0.05   ** p < 0.01   *** p < 0.001* related to density in the suburban periphery. Older urban areas tend to have lower density, more sprawling suburbs. The explanation for this is not obvious, but it is certainly consistent with the set of urban areas included in the high density core-low density periphery class, which includes numbers of the older large urban areas.

Barriers to urban expansion limit the supply of land available for development and increase densities.The greater the extent of the barriers, the larger the effect on density. The water and mountains barriers, described in the previous section, are strongly and highly significantly related to density in both the urban core and suburban periphery. For water, the regression coefficient of nearly 2,000 for the urban core implies that an increase in the proportion of the ring area water of just 0.1 would be associated with an increased core density of about 200 persons per square mile. Given that the proportion water exceeds 0.5 for some of the urban areas, the magnitude of the effects on density is considerable. The coefficient is smaller for the suburban periphery, something over 400. But given that densities in the periphery are much lower than densities in the core, this is still a substantial effect.

Confidence in the magnitude of the effects of water on core density should be tempered by the observation that urban areas that developed earlier were often located along coastlines because of the importance of water transportation. The inclusion a measure of the age of urban areas, housing units in 1950, is important in trying to control for this. No claim is being made that this is the ideal measure of age fully accounting for its effect on density. That the regression coefficient on the water barrier is not dramatically changed when 1950 housing units is added to the model, declining by only a small amount while that variable remains significant gives confidence in the existence of a significant effect of water on core density. Also, the significant effect of water on periphery density adds to the confirmation of its importance as a barrier increasing density, as there is less reason to expect age to have a comparable effect in the suburbs.

Similar large effects can be seen for mountains, with the coefficient somewhat smaller for the core, around 1,500, but significantly greater for the periphery, over 700. This suggests mountains are relatively more important than water for density in the periphery compared to the core. And the magnitude of the effects on densities can be greater for mountains than water as eight urban areas had over half of their ring areas mountains, with the maximum of 0.97 for Las Vegas. This explains why Las Vegas is an outlier in the plot in Figure 1 with by far the highest density in the suburban periphery. While it does fall into the high core density category as well, it is not among the most dense in this respect. But this is explained by the effect age has on density, as the Las Vegas urban area had only 6,222 housing units in 1950 compared to a mean of over 250,000 for all of the areas, second smallest among the 56 urban areas.

Mountains are a relatively more significant barrier than water to urban expansion in the periphery compared to the urban core. A hypothesis as to why this might be the case: Urban areas with water as a barrier have generally been established on the shoreline due to the importance of water transport. So that barrier would have had an effect on the development of the core from the beginning. For urban areas with mountains as a barrier, the original settlement is generally not up against the mountains. Only over time as the suburban periphery expands do mountains become more of a barrier to urban expansion.. In addition, knowledge that the supply of land will later be more limited can have contributed to higher land prices and densities earlier.

For these reasons, it is important to consider the changes in the effects of the barriers over time by doing models for each year starting in 1970 (results not shown). Starting with densities in the urban core: For 1970, the regression coefficients for both water and mountains are much lower than in later years. The reason is unclear. But moving back from 2020 to 1980, the regression coefficients for both water and mountains decline gradually but steadily. The 1980 coefficients are 29 percent lower than the 2020 coefficients for water and 26 percent lower for mountains. The models all do a good job of predicting core densities, with R^2 values over 0.6 for every year.

Predictions of density in the suburban periphery for earlier years show a slightly different pattern. For water, not only do the regression coefficients decline in earlier years, they are not even statistically significant in two of the first three years from 1970 to 1990. The coefficients for mountains also become smaller moving back in time but they remain highly significant. And unlike the predictions of density in the core, the R^2 values steadily decline to 0.36 in 1970 compared to 0.62 in 1970. So mountains have an increasing effect on density in the periphery over time.

Models predicting core and periphery density change

The next set of models predicts the percent change in housing unit densities from 1970 to 2020 in the urban core and suburban periphery. The results are in Table 7. Three predictors are included in both models, change in size and the water and mountains barriers.

Since density has been shown to be related to the size of an urban area, it is reasonable to expect that the change in density would likewise be related to the change in size. The difference in the log of density from 1970 to 2020 is the measure included in the model. It is significantly and positively related to the percent change in density in both the core and periphery.

The water and mountains barriers are the other two predictors. The more extensive these barriers, the higher the percent change in housing units in both the core and periphery. The greatest effect—the largest coefficient—is for the mountains barrier in the suburban periphery. Expanding urban areas pushing up against mountains

Table 7. Models predicting percent change in housing unit densities from 1970 to 2020 in the urban core and suburban periphery.

	Percent change housing unit density in urban core 1970-2020		Percent change housing unit density in suburban periphery 1970-2020	
Change in log housing units 1970-2020	26.42	***	17.66	**
	(4.54)		(5.4)	
Proportion ring area water	49.38	**	36.80	*
	(14.81)		(17.5)	
Proportion ring area mountains	22.00	*	57.60	***
	(10.76)		(12.7)	
Constant	-24.22	***	-1.58	
	(6.30)		(7.4)	
R^2	0.486	***	0.428	***

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

produce greater increases in density. The effects of both barriers on percent change in density in the core and periphery are all statistically significant. The R^2 values of 0.49 and 0.43 in the core and periphery are measures of the overall performance of the models in the prediction of percent change in density.

Models predicting core-periphery density ratios and differences

The models in the previous sections addressed the densities in the urban core and suburban periphery separately. Now the relationship between core and periphery densities, their differences, are considered. Two measures of the differences are used. First is the ratio of density in the urban core to density in the suburban periphery, a measure of the relative difference. The other is the absolute difference between the densities, the extent to which density in the core is greater than density in the periphery.

Results for regression models predicting the core-periphery ratio and difference are in Table 8. Three predictors were significant in one or both models—the number of housing units in 2020, the change in the number of housing units from 1970 to 2020, and water as a barrier to urban expansion. The mountains barrier was not significant and is not included in the models.

Table 8. Models predicting core-periphery density ratio and core-periphery difference.

	Core-periphery density ratio		Core-periphery density difference	
Housing units 2020 (millions)	0.833	***	525.4	***
	(0.170)		(138.5)	
Change in housing units 1970-2020 (millions)	-1.056	**	-328.5	
	(0.368)		(299.5)	
Proportion ring area water	0.758		1,460.3	**
	(0.626)		(508.9)	
Constant	2.699	***	1,251.0	***
	(0.178)		(144.8)	
R^2	0.447	***	0.539	***

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

The size of the urban area, housing units in 2020, was highly significant and the only variable significant in both models. And size had a considerable effect on both measures. An increase in size of one million housing units was associated with an increase in the core-periphery ratio of 0.83 and an increase in the difference between core and periphery densities of over 500 persons per square mile.

The change in housing units since 1970 had the opposite effect, with larger changes. being associated with lower ratios and differences. This is consistent with the classification of the urban areas. The urban areas high density core-low density periphery class had by far the lowest rate of growth among the four classes. And the low density core-high density periphery class had the highest growth rate (see Table 2).

The proportion of the ring area water was positively related to both measures but was statistically significant only in the model predicting the core-periphery difference.

Conclusion

Wide variations exist across the large urban areas in densities in both the older urban core and newer suburban periphery. It might have been expected that urban areas with higher densities in the core would also have higher densities in the periphery. And while this is true for some of the urban areas, others have contrasting core and periphery densities: lower density in the urban core compared to the other urban areas and relatively higher density in the suburban periphery, and the reverse, higher core combined with lower periphery densities.

This variation led to the classification of the urban areas into four classes by whether they had low or high densities in the core and low or high densities in the periphery. The urban areas in these classes differ in the change in core and periphery densities over time. The mean increase in core density is higher for the urban areas in the two high density core classes. Periphery densities increased more in the high density periphery classes. The low density core-lower density periphery areas are on average the smallest of the urban areas. The high density core-low density periphery areas are largest but grew more slowly than the other areas. Especially striking are the differences in the locations of the urban areas in these density classes. The urban areas in the two classes with low densities in the suburban periphery are nearly all in the eastern half of the United States. The high core density-high periphery density areas are especially concentrated in the west. Many of the low core density-high periphery density areas are in the sunbelt, stretching from the southeast to the southwest.

Some combinations of the size of the urban area, change in size since 1970, and the extent to which water and mountains served as barriers to urban expansion are associated with densities in the core and periphery, percent change in these densities since 1970, and the extent to which core density was greater than the density in the periphery. The magnitude of the effects of the barriers is especially noteworthy. The constraint posed by mountains for many of the urban areas in the West is associated with the higher densities in their urban cores and suburban peripheries. And water—urban areas being location on a coastline—is also associated with higher densities for those areas compared to the urban areas in the interior.

The argument has been made that the density in the suburban periphery can be considered a reasonable measure of the degree of urban sprawl in an area. This raises question of which urban areas are the lower densities in the periphery—and are thus the most sprawling—and which have the higher periphery densities and the lower levels of sprawl. Table 9 lists the areas with the lowest and highest densities in the suburban periphery in 2020. The three lowest density areas, the highest levels of sprawl, are somewhat smaller areas in the South. No surprise here—these are areas that also have some of the lowest core densities and overall densities among all of the large urban areas. But then come Boston-Providence and Pittsburgh, older urban areas in the Northeast that one might not have though of as exemplars of sprawl. Boston-Providence has a high density urban core. But this has not prevented post-war development in the suburban periphery from being some of the most sprawling in the country with a density of only 600 housing units per square mile. That is a density of less than one unit per acre. These are very low densities.

Even more surprising is the list of the urban areas with the highest densities in the suburban periphery. Least sprawling is Las Vegas, with the density in the suburban

Table 9. Urban areas with the lowest densities in the suburban periphery (higher levels of sprawl) and highest densities in the periphery (lower levels of sprawl) in 2020.

Area	Density in suburban periphery
Greenville-Spartanburg	473
Birmingham	547
Greensboro--Winston-Salem--High Point	552
Boston-Providence	600
Pittsburgh	605
...	...
San Francisco-Oakland-San Jose	1,401
San Diego	1,411
Los Angeles	1,411
Miami-Fort Lauderdale-West Palm Beach	1,668
Las Vegas	1,981

periphery of nearly 2,000 housing units per square mile. This is over three times the density of any of the five lowest-density areas. This exceeds the density *in the urban core* for nine of the urban areas. And it is slightly more than the overall density of the entire New York urban area in 2020. Las Vegas is followed by Miami-Fort Lauderdale-West Palm Beach and then the three largest urban areas in California. Based on its density in the suburban periphery of 1,411, Los Angeles is the third least sprawling urban area in the United States. Contrast this with the New York area with the density in its suburban periphery of 817 housing units per square mile, making it the thirty-fourth most dense of the 56 urban areas.

The listing of the areas having the highest densities in the periphery and the lowest levels of sprawl should not be taken to conclude that these areas are not sprawling. While the periphery densities are much higher than in the most sprawling areas, these areas still have low densities in the urban periphery. Densities ranging from 1,400 to 2,000 housing units per square mile for the least sprawling areas are still very low densities of only about two to three units per acre. Such suburban areas will still be automobile-oriented. They are still consuming large amounts of land per housing unit, even if far less than the most sprawling areas. But measures to mitigate the negative effects of sprawl and transform the areas into less sprawling environments may be more feasible in these areas than in the areas with the extremely high levels of sprawl.

Looking at densities in the urban core and suburban periphery provides a different perspective on densities in urban areas. The overall densities of urban areas do not reveal the existence of urban areas with high densities in the core but low densities in the periphery and the reverse. And if sprawl is considered to be a characteristic of development in the newer portions of urban areas, then measuring the density in the periphery is important in assessing levels of sprawl.

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Appendix: Comparing urban cores with central cities

The urban core-suburban periphery division of the urban areas was made in response to the crude way in which central cities identify the older portions of those areas, rendering the traditional central city-suburb distinction problematic. This section quantifies this by comparing the percentage of the housing units in each urban area in

2020 in the central city or cities with the percentage in the urban core. The comparison will be done for the 56 large urban areas, with the total numbers of housing units in the areas used for both the urban core and central city percentages.

As described above, the urban core is the area that was included in the 1940 urban area. It is necessary to specify the central city or cities for each area. These areas do not correspond to any existing areas delineated by the Census Bureau. Numbers include multiple Metropolitan Statistical Areas. And definitions have changed over time. Through the 1980 census, the central cities for a metropolitan area included the largest city and up to the two next largest cities if their populations were over one-third the population of the largest city. Starting with the 1990 census, the definition included as central cities any number of cities above a small minimum size that had significant employment relative to population (see Ottensmann 1996). As this change led to confusion and some central cities that were definitely not central (Palm Springs!), the term central cities was later changed to principal cities.

The definition of the urban areas used here includes the identification of multiple urban centers around which urban development occurred prior to the separate urban areas becoming contiguous. As explained in the description of the dataset, areas were identified as additional urban centers of the number of housing units in the tracts assigned to the center exceeded 16 percent of the total in the urban area in 2020. As this is the share of the entire urban area, it is a threshold of similar magnitude to the older standard of including as central cities those with populations exceeding a third of the population of just the largest city.

The 1980 census was the last to use the classic definition of central cities based on size in relation to the largest city, so the list of urban centers in the current dataset is compared to the central cities of Standard Metropolitan Statistical Areas (SMSAs) for that year. Every urban center was a central city except for Naples, Florida, in the Cape Coral-Fort Myers-Naples area identified here. Only three of the SMSAs with the largest city in the urban area had additional central cities not included here as urban centers—Boulder, with Denver; Gastonia, with Charlotte; and Ogden, with Salt Lake City. The current populations of the first two are not close one-third the population of the larger city in 2020. And the Ogden urban area is not contiguous with the Salt Lake City area and is thus not included. Therefore using the cities associated with the urban centers as proxies for current central cities is very reasonable.

Figure A-1 plots the percent of the 2020 urban area housing units in the central cities (corresponding to the urban centers) versus the percent in the urban core. To say these are not clearly related to one another is an understatement. The correlation is actually negative, -0.196 (not statistically significant). The line on the diagonal presents values where the central city and urban core percentages are equal. Urban areas below have a lower percent units in the central cities than in the urban cores; those above have

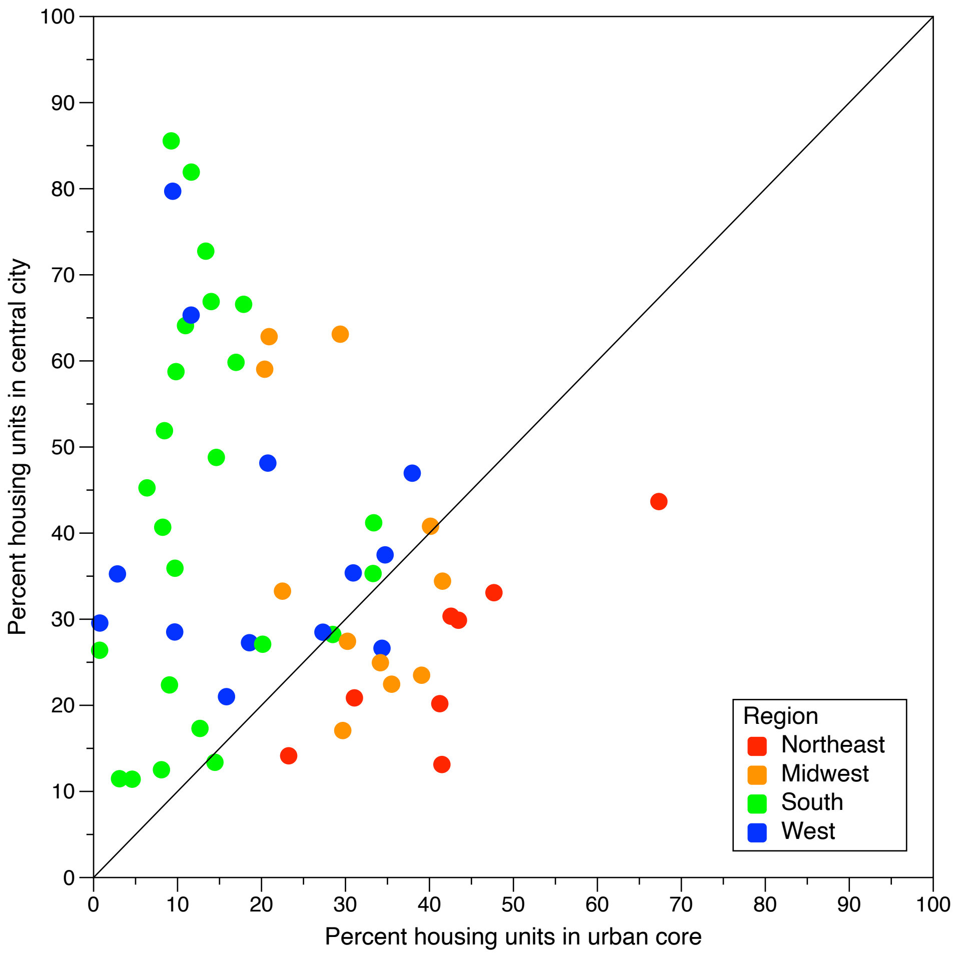

Figure A-1. Plot of urban area percent housing units in the central cities versus percent housing units in the urban core.

more in the central cities. To the extent that the urban cores reasonably represent the older parts of the urban areas, those below have older areas outside their central cities while those above have newer areas inside their central cities.

The differences between the percentages in the central cities and urban cores can be very large. Table A-1 lists the five areas with the largest differences (higher percent in central cities than in urban core) and the five with smallest (negative) differences. The top five had differences of more than 50, with three exceeding 70. These are areas in which a very large amount of the newer housing is located within the central cities. At the other extreme, five areas had nearly fifteen or more percentage points less in the central cities than in the urban cores. Areas of older housing are located outside those central cities.

Table A-1. The urban areas with the largest and smallest differences between percent 2020 housing units in the central city and percent in the urban core.

Urban area	Percent housing units in		Difference in percent housing units
	Urban core	Central cities	
El Paso	9.2	85.6	76.3
Jacksonville	11.6	81.9	70.3
Albuquerque	9.4	79.7	70.3
San Antonio	13.4	72.7	59.4
Tucson	11.6	65.3	53.7
...	...	...	...
Rochester	47.7	33.1	-14.6
Cleveland-Akron	39.1	23.5	-15.6
Pittsburgh	41.2	20.2	-21.0
New York	67.3	43.7	-23.7
Boston-Providence	41.5	13.1	-28.4

The urban areas at the extremes suggest regional differences in the extent to which central cities include more or less of the urban areas than in the urban cores. All five areas at the top of the list are in the Sunbelt, in the south and west regions. Four of the five at the bottom are in the northeast, with Cleveland-Akron just outside in the midwest. This regional pattern occurs more broadly across the urban areas. Returning to Figure A-1, the urban areas are color-coded by the census region with one exception. Because the Washington-Baltimore area is part of the large urban conglomeration stretching up past Boston, variously referred to as the northeast corridor or megalopolis, it is included in the northeast for this research rather than in the south.

All of the urban areas in the northeast, in red, are below the diagonal. The central cities understate the extent of the older portions of those urban areas. The majority of the areas in the midwest, orange, are also below. Two are above but not that far from the diagonal, while for three areas the percent in the central cities is very much greater than the percent in the core, including significant areas of newer suburban development. The pattern is pretty much just reversed for the urban areas in the south, in green, and the west, in blue. Two areas in the south are just barely below the diagonal. The others include a line of areas somewhat above and roughly parallel to the diagonal and a set of areas with less than 20 percent in the core that extents up to over 80 percent in the central cities. One urban area in the west is below the diagonal, half of the other areas are modest amounts above the diagonal, and the remainder are much farther above.

The distribution of the differences between central city percent and. urban core percent is illustrated in the histogram in Figure A-2. Negative differences (lower percent in the central cities than in the urban core) are in red. Positive differences are to the right, in green. More areas have positive differences; more of the 56 urban areas are in the South than in any other region. Percent in the central cities compared to the core ranges up to just under 30 percentage points lower in the Boston-Providence area. But differences can be far greater in the other direction, with percent in the central cities up top 75 percentage points higher in the El Paso area.

The consequences of using the central city-suburb distinction rather than the urban core-suburban periphery division when comparing older and newer parts of urban areas will vary with the research question. Consider, for example, the effects if the focus is on characteristics thought to be especially associated with older areas such as some types of housing problems. Then for urban areas with lower percent in central cities than in the core, the difference will be less of a problem because at least most of the area included in the central city will be older. To be sure, some of the older areas are outside the central cities will be older as well, affecting the values for the suburbs, but the latter will still be dominated by the newer areas. But in those areas with much higher percent in the central cities than in the core, the central city will include newer

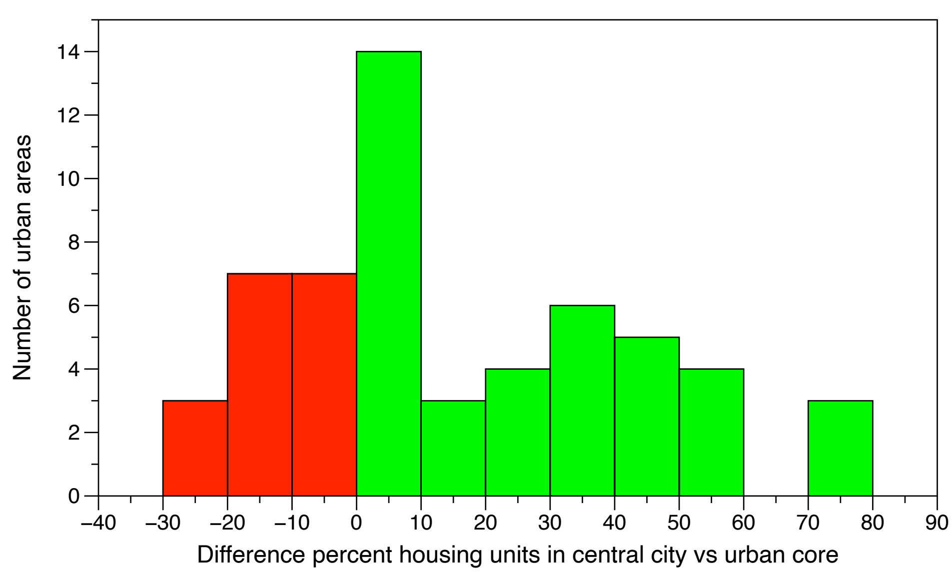

Figure A-2. Histogram of distribution of differences between percent housing units in central city and percent housing units in urban core.

areas as well as older. And for some urban areas, the central cities will actually be dominated by the newer areas. And this varies by region. Now if the phenomenon of interest is also associated with other characteristics that vary by region, untangling the those effects with the problems introduced by using central cities will likely be very difficult indeed.