Shock & Ossification: The Durable Hierarchy of Neighborhoods in U.S. Metropolitan Areas from 1970 to 2010

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Abstract

In this paper, we examine patterns of neighborhood stability within and across US metropolitan areas. Using Census tract data covering over 200 U.S metropolitan areas from 1970 to 2010 we use several socioeconomic variables to define a neighborhood hierarchy and ask how durable it is over time. Despite the substantial changes that have occurred in metropolitan America over the sample period, we find remarkable persistence in the rank of Census tracts by population density, income, education, and house prices, with many cities having rank correlations of over 0.75. And while racial and ethnic variables appear to be less persistent, all seven variables exhibit a significant trend toward more stability over time. Even in the presence of large shocks to the metropolitan economy, a majority of MSAs retain the same basic spatial hierarchy they had decades ago. When hierarchies are disturbed it appears that shocks are highly spatially correlated. This pattern of stability and change has significant implications for how we analyze and understand urban areas and their change.

1 Introduction

Neighborhood change is well-studied. Gentrification, suburbanization, filtering, racial tipping, local economic development, and more broadly, the dynamics of firm and household location choice all have rich and long-established literatures.[1] However, there has been little study of what the cumulative, net effects of these changes are on how households reorganize themselves in response. That is, we routinely find significant partial equilibrium results in these literatures but generally do not ask about the larger context in which they occur. To this point there has been little thorough

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[1] See Card, Mas, and Rothstein (2008), Guerrieri, Hartley, and Hurst (2013), Brueckner and Rosenthal (2009), Rosenthal (2008), Baum-Snow (2007), Bayer, Ferreira, and McMillan (2007) for just a few examples.

documentation of just how stable neighborhoods are relative to each other. Most studies focus on change in a particular variable on interest, in a particular geographic area, or at a particular point in time, and often with a specific policy in mind.[2] Indeed, we often go to great lengths to hold constant the larger context so that we can isolate and identify these individual dynamics. This is a gap in the literature that we believe this study addresses.

The intent of this research is to provide a broader context for this large and growing literature on neighborhood change. In particular, we study the opposite of change, looking at broad patterns in the stability of neighborhoods with regard to their rank within a metropolitan area. While the long-term stability of the hierarchy of cities well-established, little is known about how stable neighborhoods are within them.[3] We look at more locally, at the hierarchy of neighborhoods within metropolitan areas. We make several contributions that address this gap in the literature.

We find that density begets more density. The Census tract ranks of population density is consistently the most stable over time. Be it Los Angeles – with 9 million new residents during our sample period – or Bridgeport, Connecticut – with its consistent small declines over time – places that were the most dense in 1970 remain the most dense in 2010. But, while population density is broadly stable over time, variables correlated with human capital (here education, income, and house prices) are also highly correlated over time. The least persistent are race and ethnicity, but these relationships appear to change significantly over time.

We document both the level of persistence in the hierarchies of neighborhoods within metropolitan areas over the last 40 years and the fact that this persistence is rising. This is true across a diverse set of metropolitan areas. Despite the widely different starting points and shocks over time, the overt regularity that appears is that stability is the norm.

Interestingly, we find a high degree of spatial correlation in movement amongst the hierarchy. That is, when a tract moves up or down within the hierarchy, those nearby tend to move in kind. This implies that most tract changes within a metropolitan area are not drawn from a common distribution and instead are a product of larger shocks that cause new development in large areas

[2]Exceptions to this include Rosenthal (2008) that documents long running cyclical behavior in neighborhood income, and Lee and Lin (2013) that shows natural amenities (like beaches) can 'anchor' a neighborhood so that it remains high income.

[3] Gabaix (1999) gives an excellent summary of this insights from this literature.

of the city. However, as time goes forward and more cities edge towards stasis, spatial correlation also seems to be subsiding. Collectively, these results suggest that there exists a durable hierarchy of neighborhoods emerges within a metro as a metro area is development and ossifies after initial waves of development.

Consider the evolution of Los Angeles. Over the course of the last 45 years, the Los Angeles metropolitan statistical area (MSA) grew from less than 10 million residents to over 19 million residents. The employment base in the Los Angeles MSA more than doubled from 4.5 million to more than 9 million jobs – adding approximately the entire labor force of Chicago. New homes, new commercial real estate, and new freeways were built. A whole new mass transit system was added. At the same time the nature of the employment base changed significantly, with wholesale changes in the types of work and workers associated with the long evolution from traditional manufacturing to a service – and higher-human capital – economy. But, perhaps the most notable changes were seen in the racial/ethnic composition of the region. In 1970, Los Angeles county had 1.2 million Hispanic residents. This grew to almost 5 million in 2010, becoming the largest ethnic group in the regions.

Despite these extraordinary shocks to fundamentals, the correlation of neighborhood housing price ranks from 1970 to 2010 is greater than 0.6, the rank correlation of income is 0.75, for population density it is a high 0.85[4]. Los Angeles could easily be described as the most dynamic metropolitan area in the country over this this period, but much of how it is organized hierarchically and spatially remains very similar to what it was 40 years ago.

In this paper, we find that this persistence is not unique to Los Angeles and, in fact, is quite common in US metropolitan areas. For the full sample of 263 metropolitan areas in the US, we find many MSAs at or above these levels of persistence. And, among those that don't exhibit high rank persistence from 1970 to 2010, we find regular patterns of stability and change within the subsamples. These include a broad secular trend toward increasing stability over time, particularly the ranks of race and ethnic concentration. Moreover, we find that when reordering happens, the changes in Census tract ranks are significantly correlated spatially. Indeed, in some MSAs

[4] Our proxy for a neighborhood are 2010 Census tracts. Throughout the paper, tract and neighborhood are used interchangeably. This is discussed below.

we can see a low overall rank stability explained not by individual shocks across the MSA, but rather by large contiguous neighborhoods that move together up or down in ranking. Around these neighborhoods of change, there is often a great deal of stability. It is rare to find a single tract deviate significant from its surrounding tracts.

More generally, these findings should give pause to those considering many common approaches to analyzing urban and housing markets. We find a great deal of stability, but certainly not statis. Change is a given in urban areas, but we find that a common feature of change is by neighborhood or submarket – geographies that encompass many Census tracts. It is common for urban phenomena to be studied using these tracts as units of analysis. We find that this approach may mislead when it may be the case that tracts are not drawn from the same distributions. Moreover, it is common to use fixed effects or, in the case of differences-in-differences methods, impose a parallel shift assumption. We find that these assumptions may be inappropriate in precisely the areas of change we want to study. Here, neighborhoods are not fixed nor are their positions relative to other neighborhoods.

There are several likely explanations for why persistence is common and that it may be increasing over time. In the case of declining MSAs, it could be fixed-investment. Expanding on the ideas of Glaeser and Gyourko (2005), not only houses, but commercial real estate and infrastructure are long-lived, influencing metropolitan spatial organization for decades. In growing MSAs, it could be that regulation pushes new development into places that are already comfortable with higher density, perpetuating populations density ranks. It could be most shocks are at the household level which result the households moving up or down the housing hierarchy, thereby preserving the ranks of house prices, income, or education. Or, it could be that as MSAs grow the supply of available land for major development are in increasing lower-quality locations, making it impossible for a new development at the far periphery to enter this hierarchy near the top. This discussion of the causes of stability are left for future research. We discuss these briefly while summarizing results, but the task here is to document and organize the regularities we find.

The rest of the paper proceeds as follows: we begin by placing this research among the several literatures that touch it in Section 2. We discuss how we chose “hierarchy” as an organizing framework and introduce how we measure it in Section 3. In Section 4, we document a broad set of tendencies within and across U.S. metropolitan areas. We conclude with some suggestions for paths forward in Section 5.

2 Urban Stability & Change

Our pivot from focusing on neighborhood change to the stability of neighborhood hierarchy falls into several literatures. An obvious starting point echoes the literature on path dependence and the system of cities. It addresses natural advantages from the distant past as important determinants of the characteristics of cities, even after they become obsolete (Arthur 1989, Bleakley and Lin 2012, Cronon 2009, Ellison and Glaeser 1999). Beyond these, studies on path dependence show a connection between economic growth and such things as early legal systems (La Porta, Lopez-de Silanes, Shleifer, and Vishny (1998)), constitutions (North and Weingast (1989)), and colonial origins (Acemoglu, Johnson, and Robinson (2001)). Similar studies have been applied in an urban context, such as Davis and Weinstein (2002), and Brakman, Garretsen, and Schramm (2004) that show urban form can persist in cities even after they experience large-scale destruction that would allow decision makers to re optimize land uses. The division of Germany resulted in a permanent diversion of air traffic from Berlin to Frankfurt (Ahlfeldt, Redding, Sturm, and Wolf (2015)), temporary reductions in the market for cotton during the U.S Civil War had persistent effects on British towns that were heavy producers (Hanlon (2014)). And, both Jedwab, Kerby, and Moradi (2015) and Brooks and Lutz (2013) finds that rail facilities create changes in urban form and density that remain even after those facilities are long gone.

Within metropolitan areas we certainly depend on Tiebout (1956) and the enormous literature that grew from it. While we appeal to a larger bundle of local goods and amenities, public goods are among them. Equally relevant is the quality-of-life literature (Roback 1982) address wages and house prices to understand location specific amenities such as beaches or good weather. These bundles have emerged as a result of extensive sorting. It is this sorting that may act as the most important underlying cause of stability over time.

Another area in which the these literatures are related is Glaeser and Gyourko (2005), who show that urban growth is rapid process, but decline is slow because housing is durable. We find that population growth, but not decline is associated with lower rank correlations for all variables. For our purposes, these papers suggest a common structure in terms of the questions being asked. However, we ask them of Census tracts within metropolitan areas.

Others look at contributing factors that lead to neighborhood change or stability. Redfearn (2009) documents the lasting explanatory power of significant locations within Los Angeles. He shows that these maps almost 100 years old can better explain the current organization of employment than do current maps. He finds very high levels of persistence in the density of employment spanning decades. Aaronson (2001) uses a VAR to look at race and income persistence, finding racial composition is highly persistent and that income and racial sorting are independent of each other.

Other types of papers discuss stability and change but along more narrow dimensions. Bayer, Ferreira, and McMillan (2007) finds that schools have a direct and indirect impact on housing prices. Good schools attract households that offer other socioeconomic benefits to the neighborhoods, suggesting correlation among human capital variables. Ellen and O'Regan (2008) looks at the stability and change of poorer neighborhoods in urban areas. Though from different perspectives, both Boustan and Margo (2013) and(Baum-Snow 2007) look at a broad pattern of suburbanization. And there is now a growing literature on gentrification as households seem to be rediscovering urban living (Kolko 2007, Guerrieri, Hartley, and Hurst 2013, Vigdor, Massey, and Rivlin 2002). Indeed, the literatures around these and others are quite large. Collectively, these represent precisely why we pursued stability and change more generally; each of these papers are successful research efforts aimed at finding robust results on a particular question, issue, or geography. All require careful control of the larger context, but none address that context in any depth.

One last additional literature that we refer to somewhat is income mobility. Our motivation for looking at neighborhood stability is thus similar to those studies that look at income mobility. Income mobility is generally regarded as an important issue because a person's income significantly impacts their well-being. Likewise, given the existence of neighborhood effects, we should also care about the mobility (or stability) of neighborhoods too. Thus, our measures for neighborhood stability mirror measures of income mobility found in studies such as Chetty, Hendren, Kline, and Saez (2014), and Dahl, Congress, and DeLeire (2008), where the rank of a child's income is regressed on the rank of their parents income to identify the correlation between a child and parent relative positions in the income distribution. We measure persistence, simply the converse of mobility, by finding the correlation between a neighborhoods within-city rank in one time period with its within-city rank in another time period. Since ranks are relative they avoid issues of interpreting the change in levels between Censuses that allows for much easier comparisons across time.

We are hopeful that our focus on aggregate stability may be useful for learning more about specific dynamics. For example, filtering/cycling and tipping make strong predictions about rank stability. In the case of filtering works such as Brueckner and Rosenthal (2009) and Rosenthal (2008), describe neighborhoods as undergoing long cycles where new housing starts off having a high value, and as it depreciates the neighborhood filters down into a lower class neighborhood. This process of filtering continues until a minimum value is reached at which redevelopment begins anew. This would be manifest in the ranks over time, wherein low ranked tracts jumped to much higher rankings while the rest of the tracts slowly declined with depreciation until it was their turn to be redeveloped. We find no evidence of this process at work in describing macro-level changes in the arrangement of neighborhood hierarchy. This does not mean that this process of cycling is not happening, but that it is happening parcel by parcel, and in likely situations in which the new housing isn't built to significantly surpass the local market for housing given its location.

Tipping may be more famous example of a particular urban dynamic (e.g.Schelling (1969). Card, Mas, and Rothstein (2008) and others invoke various measures of neighborhood 'tolerance' to different types of racial compositions, while others add human capital (Redfearn and Ethingtion 2014), and income (Malone 2016) as additional factors that influence rapidly changing neighborhoods. All three of the cited papers find significant tipping, but the two latter papers look at tipping's relevance with regard to the larger evolution of their MSAs in question. Neither find that tipping was a regular factor in explaining the vast majority of urban change along other dimensions.

The goal is not to deny the micro-structure that underpins individual firm and household location choice. Rather it is to understand how all of these dynamics aggregate to the metropolitan arrangement of economic activity. Despite the many good papers on changes, stability is a dominant theme that warrants closer inspection.

3 Measuring Hierarchy & Its Persistence

Since a chief goal of this work will be to provide a broader and more holistic view of neighborhood persistence and change than has generally been provided in the literature up to this point, we use a wide range of variables to examine neighborhood change and persistence. The list includes household income, house prices, population density, share of people over age 25 with a bachelors degree, percent white, percent black, and percent non-white Hispanics. For all these variables, we use two measures to document their persistence. For long-term stability we use the correlation between a neighborhoods within metropolitan rank in 1970 and within metropolitan rank in 2010 (or, equivalently, the correlation between percentiles). For short-term stability, we use rank correlations over 10-year periods (for example, the correlation between a tracts' rank in 1970 and 1980).

A key challenge in this investigation is how to measure neighborhood persistence and change in a way that is generalizable across different variables observed in different times and places. Any empirical investigation into neighborhood change will inherently be looking at the same neighborhoods across multiple time periods, so we use the Neighborhood Change Database to hold geography constant over the five Census years from 1970 to 2010 [5].

Several variables in our data have consistent support over time (from 0 to 1, for the race/ethnicity, and unemployment variables), but others do not. The other variables have distributions that can shift over time, making comparisons difficult. Consider the meaning of a college degree over the last 40 years. In 1970, the proportion of college graduates of people aged over 25 in the United States was 0.11, by 2010 this number had increased to 0.31. As such, looking at the change in people with a bachelor degree outright in a particular neighborhood may not give the most useful view of how the place is changing, since it does not take into account how other neighborhoods

[5]The Neighborhood Change Database is a Propriety database from Geolytics Inc. It covers all censuses from 1970 to 2010, giving tract level data that has been normalized so that the unit of observation is the 2010 census tract, regardless of what year we are looking at. More information on the data can be found on Geolytics website:www.geolytics.com

are changing. The same could be said for looking at a characteristic like mean tract income or house price, both of which are in nominal terms, and rise both with inflation and local supply and demand fundamentals.

In order to take into account the broader context of change, we consider the position of a neighborhood relative to other neighborhoods. As is common in the literature, we assume that a metropolitan area constitutes a housing market, and only consider neighborhoods relative to those in the same city. For example, in the case of income, the neighborhood with the highest average income would receive the rank 1, the neighborhood with the second highest income would receive the rank 2, and so on. We denote this as $R_{ic,t}$; where the i, c, and t subscripts denote the neighborhood, the city it is being ranked within, and for what year respectively.

Using the ranks, we can then create a measures of how a neighborhood moves within a metropolitan area over time. The one we use the most is the correlation between a neighborhoods income rank in 1970,and its income rank in 2010. The correlations can be interpreted as measure of persistence (and conversely mobility or change), that takes into account the broader context of how the other neighborhoods within a metropolitan area are changing as a whole.

Using ranks certainly provides a strong measure of metropolitan-level persistence and change, but it does have disadvantages too. It is not directly comparable across metropolitan areas, since the rank cannot exceed the amount of tracts in the metro area. Being ranked as the 100th richest neighborhood in Los Angeles, a city with 2929 Census tracts is actually a higher position in the city distribution than, say, being ranked 10th in Santa Cruz, CA; a city with only 53 Census tracts. To get around this issue the percentile of the tract within the city distribution can be used. This can be computed as:

$$P_{ic,t} = 1 - \frac{R_{ic,t}}{N_{c,t}} \tag{1}$$

where P indicates the percentile of neighborhood i, within city c in the year t and N the total number of Census tracts in city c in year t. A neighborhood's percentile is directly comparable across cities, so we can more fully use the panel capabilities of data on neighborhoods that has normalized boundaries. Such a capability is being able to compute the variance, $V(P_{ic,t})$, or change of an individual neighborhoods percentile, $\Delta P_{ic,t} = P_{ic,t} - P_{ic,t-1}$, across time.

There is one caveat to the use of percentiles; changes in the denominator, $N_{c,t}$ of equation 1 can produce non-meaningful shifts in the percentile. This is a prevalent issue from 1970 to 1980; between these two Censuses, 5945 of the 2010 geography tracts went from being uninhabited to having non-zero populations. This can substantially move a neighborhood's percentile even when its rank has not changed, especially in smaller cities. As an example of the problem, suppose we have a city with 10 tracts in 1970, and that this doubled in 1980 to 20; if a city was ranked 1st in both decades its percentile would shift from 0.9 to 0.95. This does not exclude the use of percentiles to analyze neighborhood persistence and change, but it is an important fact to keep in mind.

4 Metropolitan Area Stability

We begin with simple summary correlations for eight case study metropolitan areas. There are Bridgeport (CT), Charlotte (NC), Detroit (MI), Houston (TX), Indianapolis (IN), Las Vegas (NV), Los Angeles (CA), and Philadelphia (PA). We chose these eight MSAs for their diversity, spanning small and large, growing and shrinking, constrained and unconstrained, etc. The goal of this section is to give some understanding of what the correlations mean. In particular, we want to demonstrate the many ways a high and low rank persistence can be achieved.

Table 1 reports on the level of stability for our eight case MSAs with regard to "Human Capital" variables – population density, education, house prices, and income.[6] While population density is not inherently about human capital, we have begun to see downtowns where population density is highest as places that are attracting high human capital households.

The rank of population density is clearly the most stable of all the variables and across all the eight MSAs. Bridgeport is small and has been losing population for 40 years. There is little new development in downtown, and what new housing has been built is done on larger lots at the periphery. Los Angeles on the other hand has added millions of residents and dwellings, but the rank stability with regard to density is not too dissimilar from Bridgeport's. Detroit's populations has halved during this sample and yet it's rank stability with regard to population density is the

[6]Population density is defined as the tract population divided by the land area of the tract, education is measured by share of adults in the tract who have a college degree, house prices are the tract mean house price according to self-reported census data, and income in the average family income for the tract.

same as Los Angeles'. Houston and Charlotte are the exceptions. It may be that these reflect their particular types of growth – with ample land in the case of Charlotte and little regulation in the case of Houston. This will be discussed below.

Table 1: Rank Correlation for 1970 - 2010 in 8 Cities, Human Capital Variables

MSA	Density	Education	House Price	Income
Bridgeport	0.956	0.912	0.870	0.920
Charlotte	0.601	0.232	0.046	0.193
Detroit	0.820	0.673	0.537	0.623
Houston	0.593	0.446	0.325	0.270
Indianapolis	0.798	0.578	0.380	0.455
Las Vegas	0.519	-0.035	0.077	0.143
Los Angeles	0.848	0.790	0.644	0.756
Philadelphia	0.953	0.771	0.689	0.705

The other three variables reflect somewhat different patterns. Here, Los Angeles, Philadelphia, and Bridgeport share high long-run rank stability. But, the others change more, with Charlotte and Las Vegas showing whole sale reordering of the ranks in house prices. In these MSAs, education and income also show little persistence. The remaining MSAs show somewhat high persistence over a period of marked change for all of them.

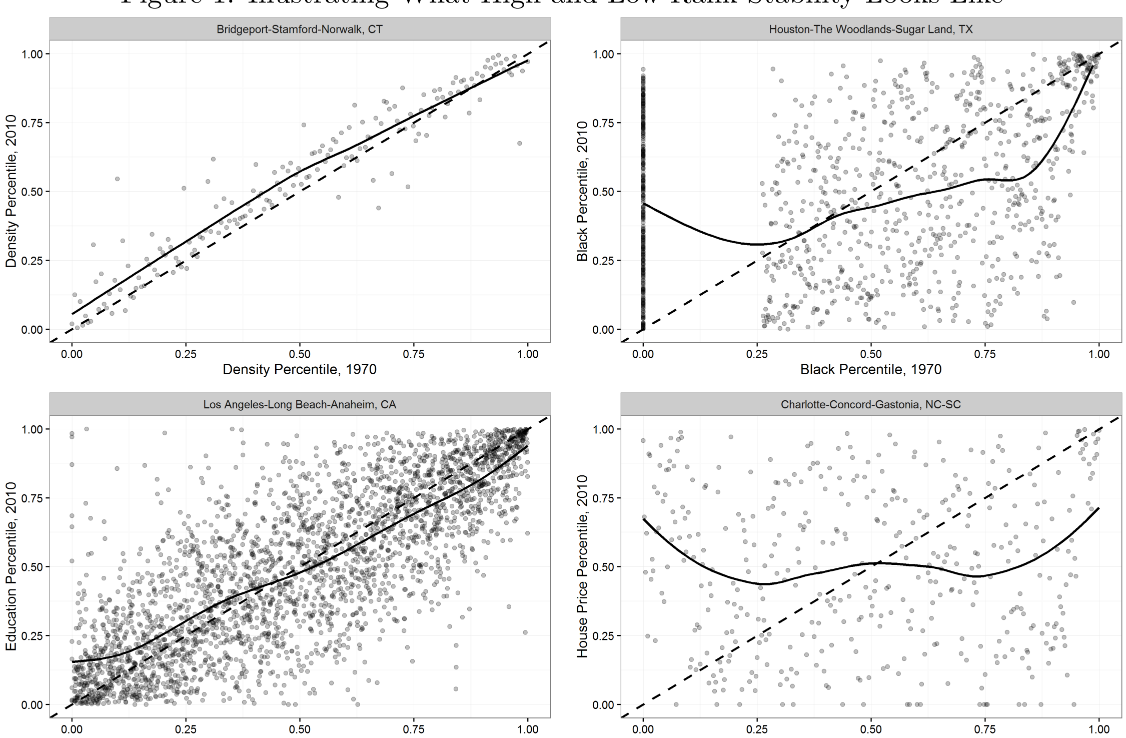
Table 2 reports on the level of stability for three racial and ethnic variables. The rank of black share within an MSA's Census tracts is the most stable of the three, with white's showing some rank stability and Hispanic show little expect in Los Angeles.

Table 2: Rank Correlation for 1970 - 2010 in 8 Cities, Racial and Ethnic Variables

MSA	Black	White	Hispanic
Bridgeport	0.633	0.709	0.529
Charlotte	0.150	0.088	0.114
Detroit	0.400	0.462	0.141
Houston	0.301	0.260	0.206
Indianapolis	0.578	0.607	0.288
Las Vegas	0.242	0.296	0.382
Los Angeles	0.453	0.527	0.600
Philadelphia	0.546	0.531	0.227

To give some understanding of what these rank correlations look like, look at Figure 1. These figures show Bridgeport's rank of population density in 1970 on the x-axis and the same for 2010 on the y-axis. The dotted 45 degree line is echoed in the data and the smoothing spline in solid black. That is what a 96 percent rank correlation looks like. The upper right panel plots Houston's 37 percent correlation of ranks for black shares of Census tracts in 1970 and 2010. There is some concentration in the upper right where suggesting that the highest concentration of blacks in 1970 remained the most highly concentrated 40-years later. But, more interesting in this panel is the vertical line to the right. This shows what new growth looks like. Here, the dots along the vertical line were places that had no blacks in 1970. 40 years later these place have added a wide variety of households, some have high shares of blacks, others don't. But, these tracts begin to hint at where the low overall stability may be found. The lower left panel shows education persistence in Los Angeles. The smoothing spline closely follows the 45 degree line, but the data points suggest something far from highly stable as each dot off the 45 degree line reflects changes in rank. Finally, Charlotte's house price ranks in the bottom right panel suggest no correlation.

Figure 1: Illustrating What High and Low Rank Stability Looks Like



Collectively, these exhibits would not surprise many, except perhaps Los Angeles and Detroit. Las Vegas, Houston, and Charlotte are places of growth and change. Indianapolis, Bridgeport, and Philadelphia are different places in many ways, but both have been relatively stable in terms of population – and without large shocks, maybe there is little incentive to remake these hierarchies. Los Angeles and Detroit are more surprising because they have both had large shocks – one negative, one positive – but the two share some common stability.

We next push deeper into the analysis that will help push past common wisdom about these broad stories above. We start with Table 3. This repeats the same table above but reports the correlation decade by decade. Cases where the correlation dropped by 0.05 or more from the previous decade are underlined. Once again Bridgeport matches expectations – little changes in any period for any of the human capital variables, just as it did for the 40-year correlation. Among the other more long-term stable MSAs, Detroit, Los Angeles, and Philadelphia all report consistently high correlations for all the human capital variables. But, note the decade-by-decade correlations among the other. Here Charlotte, Houston, and Indianapolis all have many periods of marked stability. Indeed, Houston appears to be sorting itself out after an economic/housing boom in the 1970s, but from 1980 on, the rank stabilities are all quite high. Indianapolis appears to be same but for it being somewhat rearranged by the housing boom and bust in the 2000s. Las Vegas and Charlotte, which both experienced significant growth and development exhibit a general trend toward more stability decade by decade for all variables but density.

It is here we see one of the surprising trends from this diverse set of MSAs. There appears to be a broad trend toward rank preservation over time. Of 96 possibilities in table 1, only 10 show a decline of 0.05 or more from decade to decade. Such drops only exist for House Prices and Density, so are probably due the massive amounts of development and house price fluctuations during the boom and bust in the 2000s.

It is interesting to contrast the human capital variables with the racial and ethnic variables using the same decade-by-decade format. There is broadly more variation in rank correlations here than in the previous table, but the movement toward more stability is more clear. With the exception of Las Vegas, every one of the variables and MSAs show monotonically increasing rank

Table 3: Decade by Decade Rank Correlations in 8 Cities, Density and Human Capital Variables

MSA	Variable	1970-80	1980-90	1990-00	2000-10
Bridgeport	Education	0.963	0.970	0.973	0.972
Bridgeport	Density	0.986	0.996	0.995	0.985
Bridgeport	Income	0.945	0.963	0.968	0.971
Bridgeport	House Price	0.930	0.974	0.987	0.941
Charlotte	Education	0.701	0.814	0.844	0.878
Charlotte	Density	0.973	0.974	0.910	0.871
Charlotte	Income	0.666	0.807	0.831	0.852
Charlotte	House Price	0.586	0.769	0.874	0.709
Detroit	Education	0.815	0.923	0.913	0.926
Detroit	Density	0.960	0.983	0.982	0.959
Detroit	Income	0.816	0.912	0.907	0.919
Detroit	House Price	0.813	0.941	0.917	0.899
Houston	Education	0.664	0.900	0.913	0.900
Houston	Density	0.909	0.933	0.963	0.913
Houston	Income	0.588	0.863	0.890	0.880
Houston	House Price	0.557	0.871	0.900	0.826
Indianapolis	Education	0.844	0.921	0.951	0.923
Indianapolis	Density	0.978	0.983	0.972	0.958
Indianapolis	Income	0.780	0.911	0.934	0.886
Indianapolis	House Price	0.802	0.914	0.906	0.848
Las Vegas	Education	0.672	0.685	0.729	0.736
Las Vegas	Density	0.905	0.955	0.889	0.741
Las Vegas	Income	0.637	0.700	0.649	0.785
Las Vegas	House Price	0.638	0.771	0.740	0.754
Los Angeles	Education	0.903	0.933	0.952	0.949
Los Angeles	Density	0.949	0.967	0.984	0.952
Los Angeles	Income	0.901	0.944	0.928	0.912
Los Angeles	House Price	0.851	0.891	0.893	0.785
Philadelphia	Education	0.889	0.944	0.951	0.939
Philadelphia	Density	0.988	0.991	0.993	0.992
Philadelphia	Income	0.883	0.932	0.938	0.917
Philadelphia	House Price	0.891	0.956	0.954	0.898

stability over time.

Table 4: Decade by Decade Rank Correlations in 8 Cities, Racial and Ethnic Variables

MSA	Variable	1970-80	1980-90	1990-00	2000-10
Bridgeport	Black	0.762	0.838	0.887	0.933
Bridgeport	Hispanic	0.605	0.791	0.841	0.923
Bridgeport	White	0.809	0.863	0.916	0.957
Charlotte	Black	0.700	0.748	0.879	0.895
Charlotte	Hispanic	0.156	0.118	0.270	0.701
Charlotte	White	0.698	0.720	0.873	0.889
Detroit	Black	0.582	0.782	0.817	0.903
Detroit	Hispanic	0.241	0.380	0.458	0.628
Detroit	White	0.625	0.846	0.853	0.934
Houston	Black	0.515	0.836	0.923	0.912
Houston	Hispanic	0.578	0.816	0.894	0.923
Houston	White	0.516	0.862	0.926	0.898
Indianapolis	Black	0.662	0.852	0.894	0.916
Indianapolis	Hispanic	0.259	0.330	0.345	0.704
Indianapolis	White	0.697	0.886	0.899	0.933
Las Vegas	Black	0.524	0.714	0.640	0.606
Las Vegas	Hispanic	0.631	0.620	0.729	0.787
Las Vegas	White	0.545	0.720	0.588	0.713
Los Angeles	Black	0.633	0.823	0.827	0.893
Los Angeles	Hispanic	0.838	0.931	0.959	0.963
Los Angeles	White	0.720	0.915	0.926	0.930
Philadelphia	Black	0.825	0.903	0.865	0.932
Philadelphia	Hispanic	0.338	0.486	0.562	0.757
Philadelphia	White	0.810	0.898	0.886	0.940

While these broad trends are revealing, they mask how change occurs. That is, ranks could be shocked randomly. But, we could not use rank correlation to differentiate these random shocks from, say, a process like filtering/cycling if it were driving the reordering of Census tracts. In Figure 2 we plot the distribution of rank changes in percent. If shocks were just noise, we'd see a familiar bell curve. If, on the other had filtering/cycling were at work alone á la the sawtooth pattern in Brueckner and Rosenthal (2009) and Rosenthal (2008), we'd see asymmetry in the distrubion of changes in rank: many small changes in rank moving down and then a big move up in rank as redevelopment occurs. This is not apparent in any MSA we examine. But, note that this does not deny that the long-cycle of depreciation and redevelopment is at work. Rather, this points out that the micro-dynamics at work in the larger literture on neighborhood change focuses on margins, not the cumulation of them.

Figure 2 shows just how different are the patterns of change are among the different MSAs. This figure is for changes in house price rank with the frequency of change along the y-axis; the magnitude and direction of changes are on the x-axis. Clearly, there are differences among the distributions of change. None of the distributions are normal. Some are close to symmetric, many are far clearly asymmetric. The patterns that are consistent are the three sharper peaked distributions are the "stable" MSAs – Los Angeles, Bridgeport, and Philadelphia. Charlotte, Houston, and Las Vegas are asymmetric blobs. Las Vegas shows a pronounced skew to the left.

But it would again be premature to see the "unstable" MSAs as being evidence that there is little stability even among the MSAs with high-variance distributions. Figure 3 shows the decade-by-decade distributions of change look. The "blob" that was the distribution in the previous figure has these four as the steps along the way. They show three highly stable and clearly peaked distributions and only one that is not. It seems that Houston's hierarchy was more malleable in 1970s, but after that first wave of development things became more solidified.

These figures and tables are all drawn from the eight case study MSAs. We examine the same trends among the full 263 MSAs in our sample. The first of these is shown in Figure 4. The scale compresses the results, but make a larger point about stability. The rank stability of population density among the full set of MSAs is very high. Rank stability for education and income show a broad trend toward higher stability over the full sample of MSAs. Only house prices are an exception. And, here, the exception only in the final period from 2000 to 2010, during which America experienced it's largest housing bubble and bust in generations.

Figure 5 makes clear the trend toward more rank stability. All three variables start with a smaller modal rank correlation than the other variables, and all three of them show marked movement in the distribution of rank correlations to the right - toward more stability.

These results document stability as a regular feature of urban areas. At some level, these regularities are obvious. We know that the street grid in downtown Boston looks similar as it did hundreds of years ago. But, while some features of urban areas are clearly persistent, we have not

Figure 2: Distribution of % Change in Rank of Census Tract for House Price

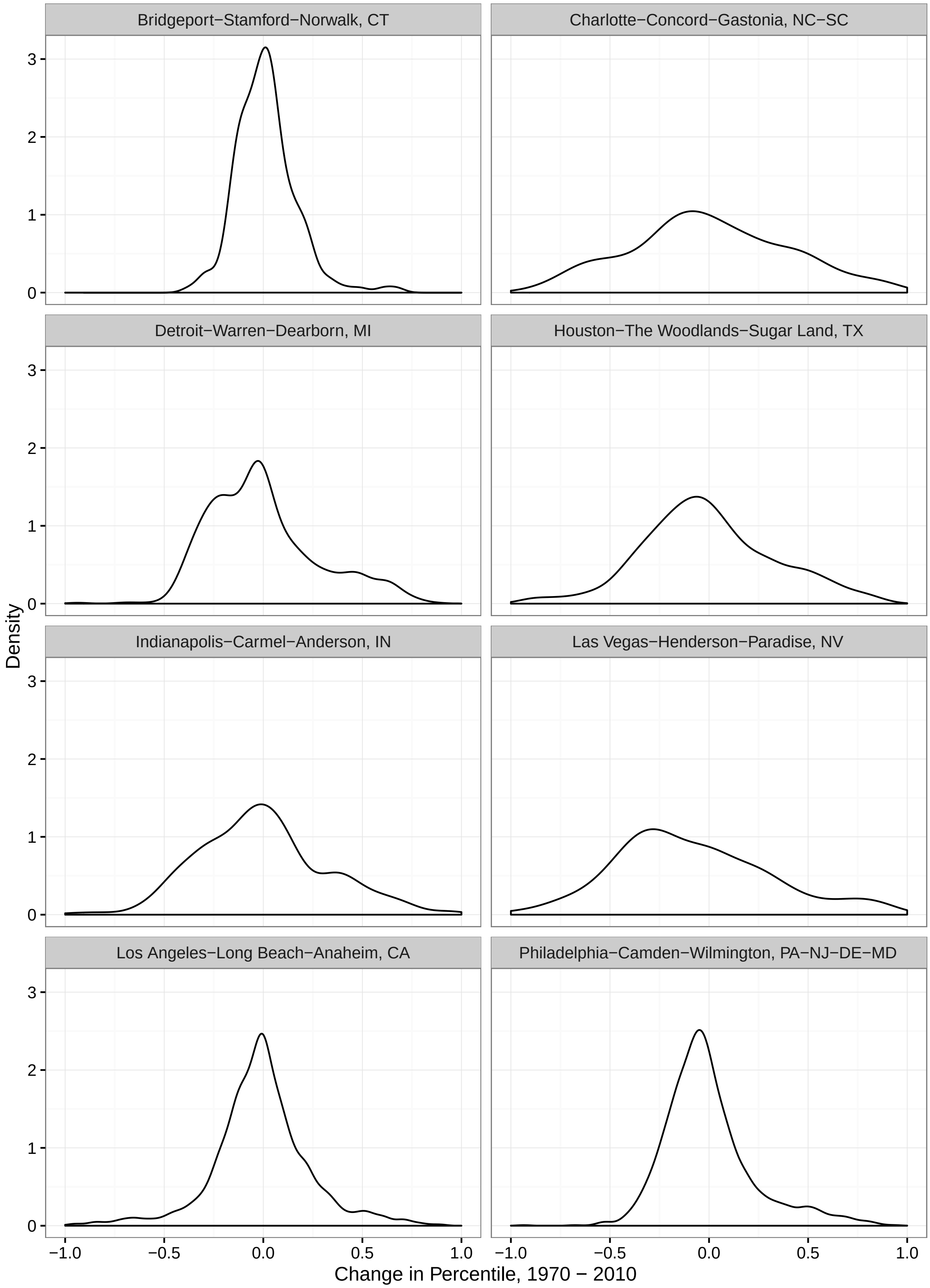
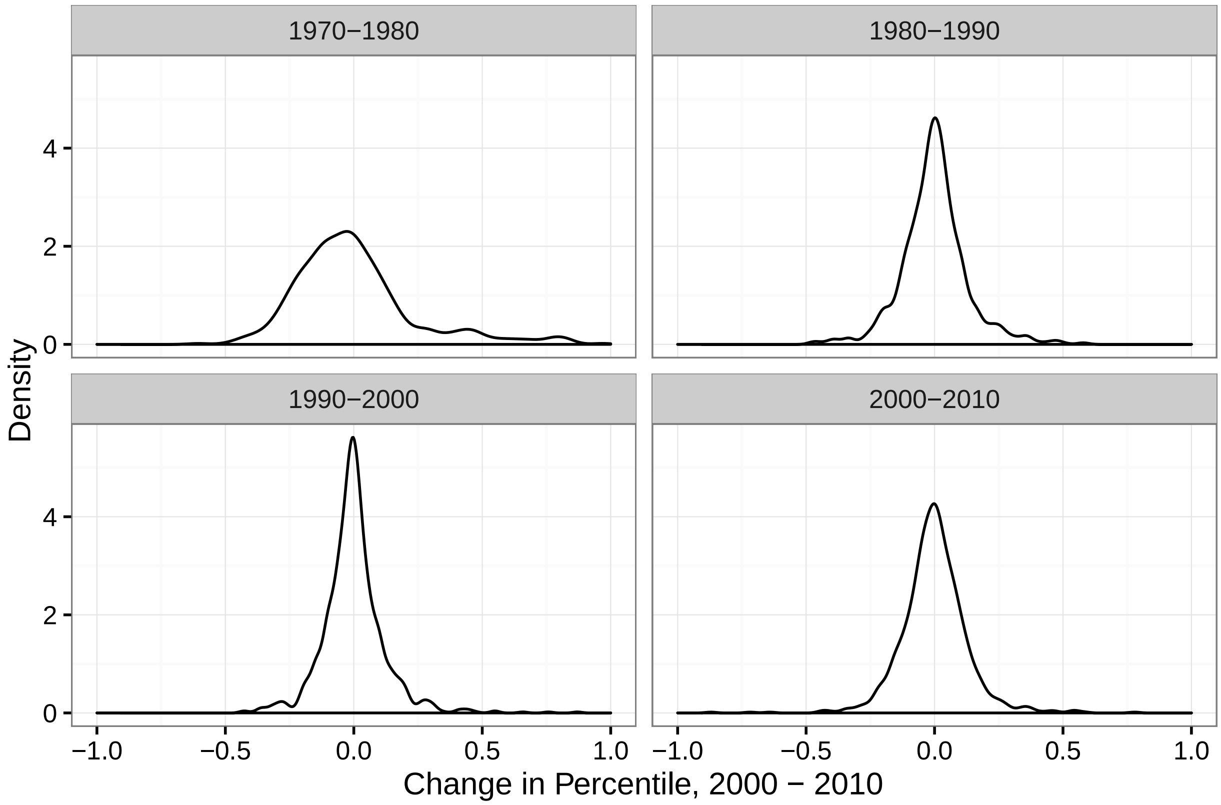


Figure 3: Distribution of Education Percentile Changes in each Decade, Houston



looked at how persistent other features and how pervasive persistence is. Among the older cities of the East Coast, the stability is not a surprise. New York's extensive investment in its subways work to offer a durable locational advantage over others. But, what we found surprising is the high and rising stability in places that are famous for their change. Houston is well-known for the absence of zoning. Why would stability rise to levels that match Los Angeles who is equally infamous for its ability to choke development? There are number of possibilities. Natural amenities (beaches, hills, etc), durable fixed investments (houses, roads, etc), regulation, and neighbors (i.e. endogenous factors that depend on others) surely all play roles in this. Finding how to weight such factors contributions to stability would be a strong contribution to the literature and will be be pursued in future companion papers. But it is beyond the scope of this paper, which is intended to be largely descriptive.

We offer one final set of exhibits on the patterns of stability and change: maps. The four decade-

Figure 4: Densities of Rank Correlation in Each Decade for all Cities, Human Capital Variables

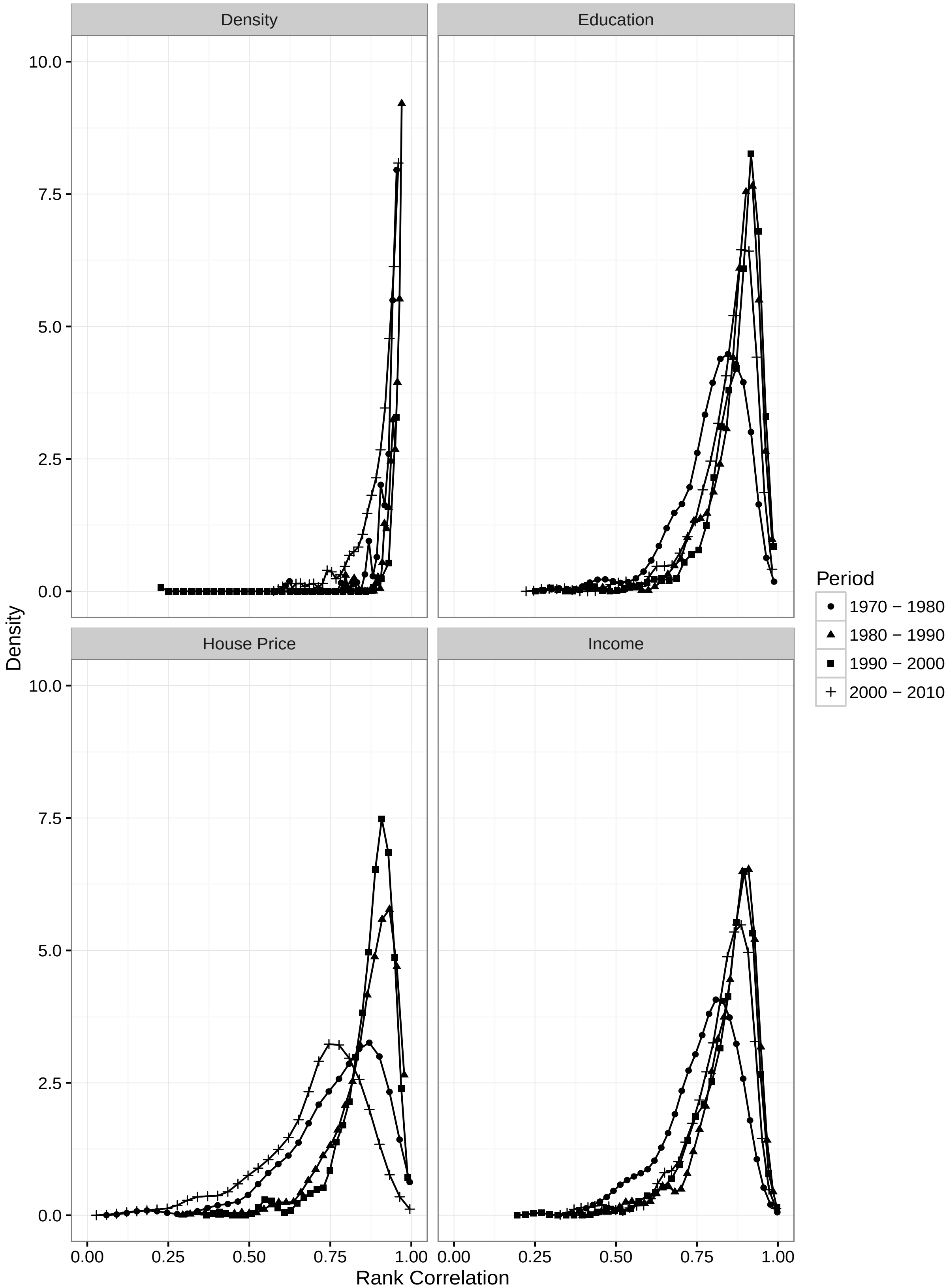
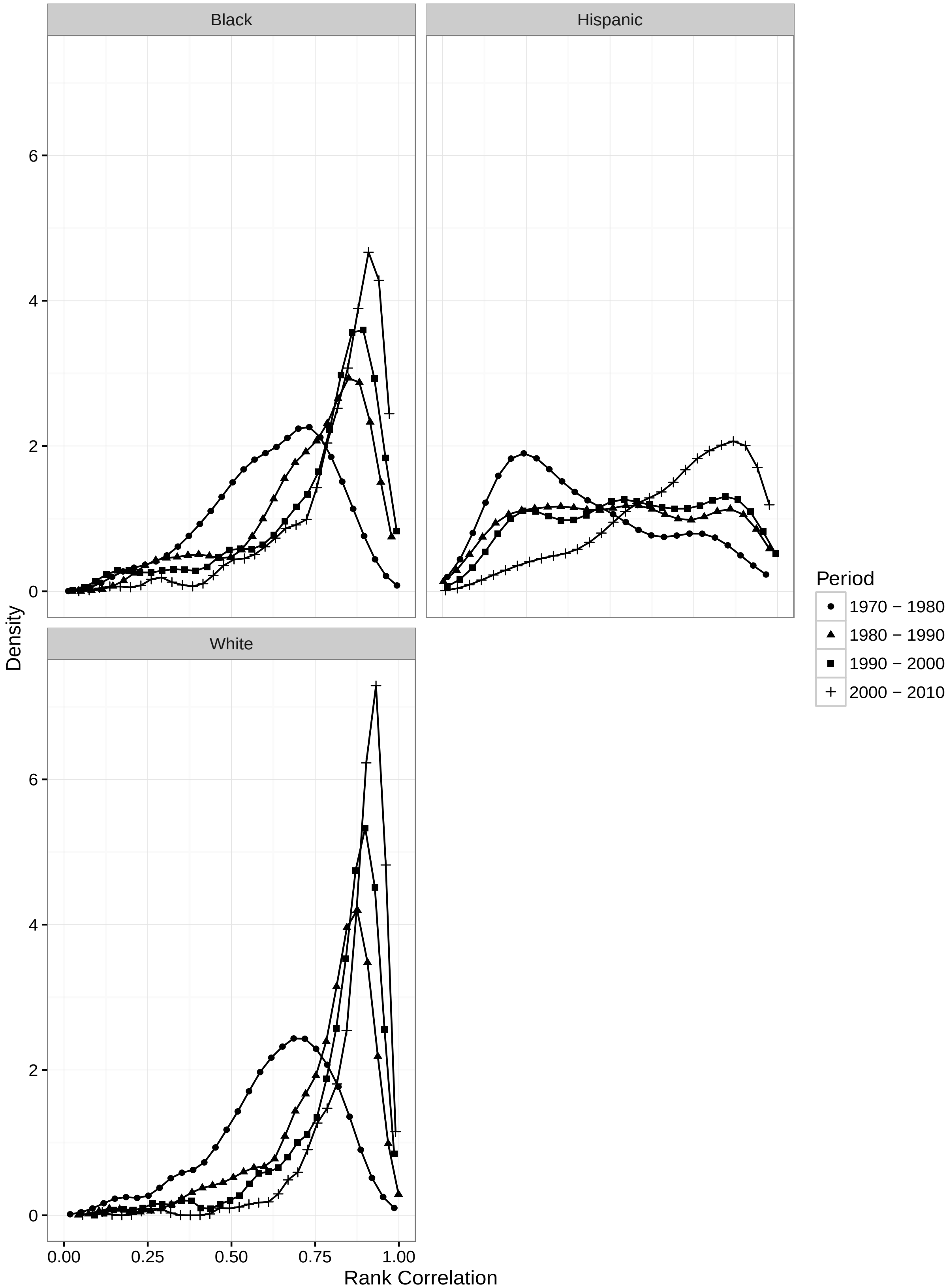
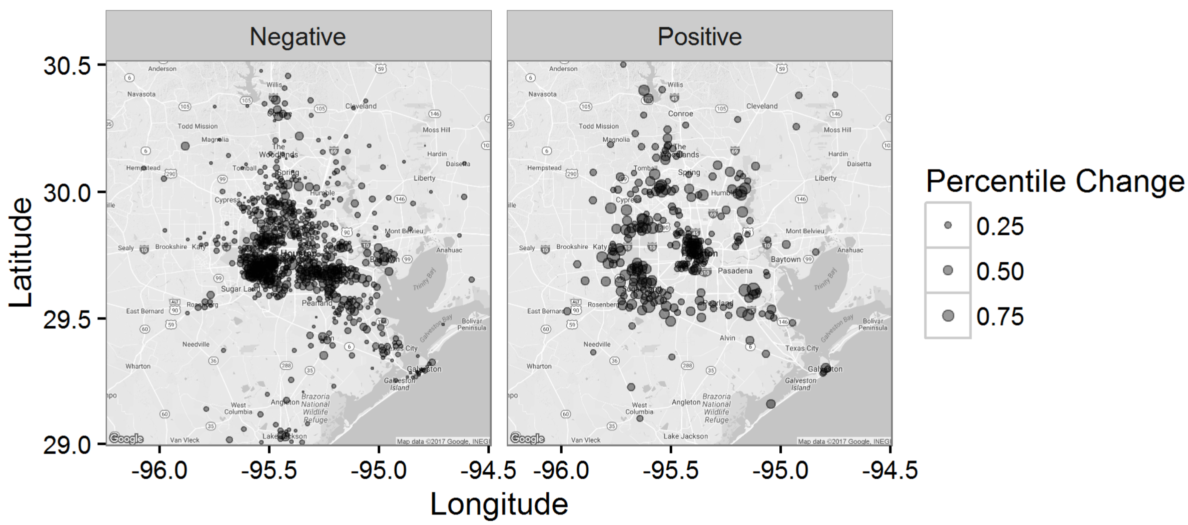


Figure 5: Densities of Rank Correlation in Each Decade for all Cities, Racial and Ethnic Variables



by-decade distributions of Houston's change in the ranks of education did not display where these changes were occurring. Figure 6 shows the spatial distribution of the changes in rank form 1970

Figure 6: Map of Education Percentile Change from 1970 to 2010, Houston



to 2010. Figures 2 and 3 suggested a "blob" – lots of noise in rank change over the 40-year sample period. This figure makes immediately clear that "noise" is not the right way to describe the pattern of change. The right panel shows positive changes in ranks, while the left panel shows declining ranks. The size of the dot represents the absolute value of percentile change. The map is best described by 'neighborhood' change – not random shocks to individual tracts. The marked cluster around the city-center in the reflect a systematic decline in the rank of college graduates there relative to the ranks elsewhere. Where did the most educated go? Largely to the outer ring suburbs - to the immediate west and southwest, and to downtown.

Figure 7 shows that it wasn't a simple linear process. The 1970s were a period of much dislocation – many dark blue and brown dots – as Houston reorganized itself during its oil boom and bust.

But in time, the number of significant changes in rank declined as the hierarchy ossified. As this has happened, the percentile changes do appear to become more clustered over time. This is clear despite a 40-year period in which so much changed and where regulation, lakes, oceans, or hillsides didn't constrain development. It is here that the notion of a durable hierarchy seems strongest. Once Houston when through its boom in the 1970s, it established a neighborhood hierarchy that still is apparent today.

Even the other two highly "unstable" MSAs – Las Vegas and Charlotte exhibit distinct patterns of change. Over the full sample, much of the ranks for the seven variables have changed. But along the way change was highly clustered. Recall that by the end of the sample the correlations are systematically higher and frequently as high as the other MSAs. It is then the that maps show more randomness in the rank changes. Before that, whole regions within the MSA appear to experience shared changes to fundamentals – both rises and falls in their collective ranks. The rise of more randomness is expected if neighborhoods mature and stabilize, then it will be local shocks to tracts around the ossified hierarchy that we see Las Vegas and Charlotte.

The strength of this spatial correlation can also be measured by modeling the correlation between any two neighborhoods within a metros percentile change and their distance from one another. Figures 10-12 mimic the maps in Figures 6-9. All 3 cities confirm the basic facts we saw in the maps. Immediately adjacent tracts change together with correlations usually around 0.5. The correlation declines as tracts become further apart and is close to zero by around 10 kilometers in most cases.

The extent of spatial correlation also appear to declining as time goes forward. This coincides with our observed increase in stability over the sample period. As a hierarchy solidifies, cities are becoming less subject to significant reorganization when met with systematic shocks, and changes in the hierarchy are becoming smaller. Furthermore, they are more and more looking like random draws from a shared distribution.

We extend this to our entire sample of 263 metros by running the Moran's I test for spatial

Figure 7: Map of Education Percentile Change in each Decade, Houston

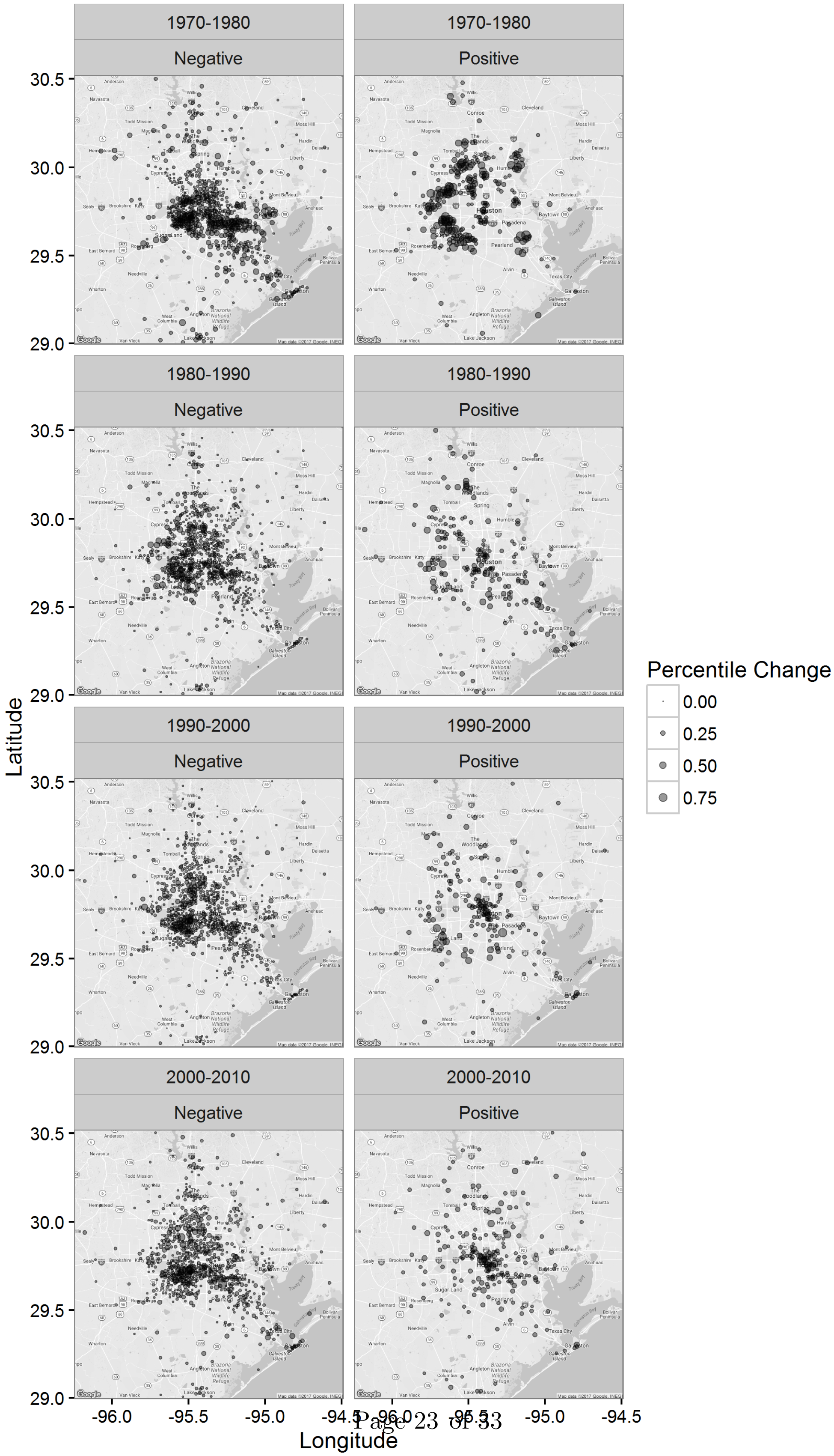


Figure 8: Map of House Price Percentile Change in each Decade, Las Vegas

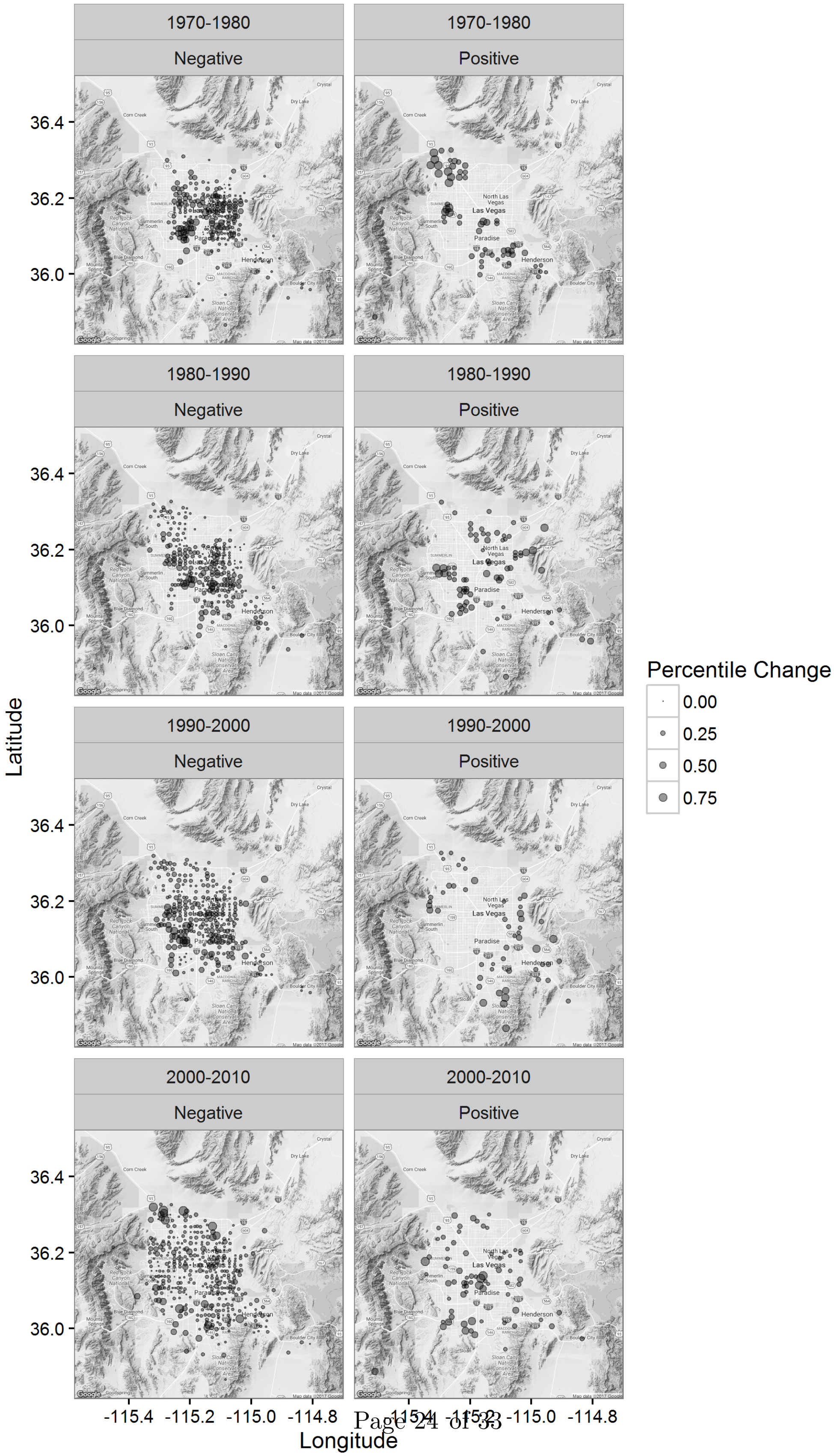


Figure 9: Map of Income Percentile Change in each Decade, Charlotte

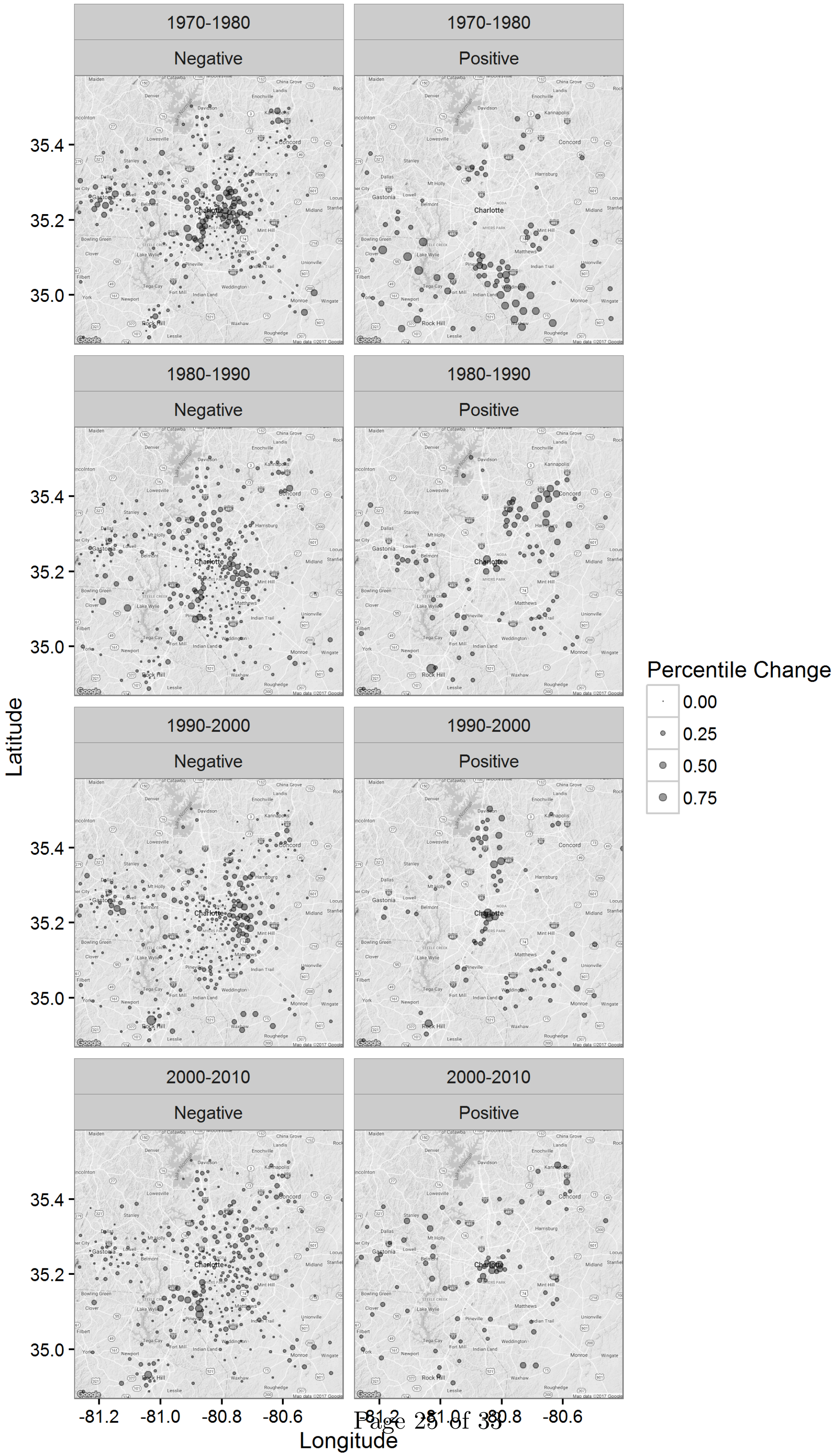


Figure 10: Spatial Correlation in Education Percentile Changes in each Decade, Houston

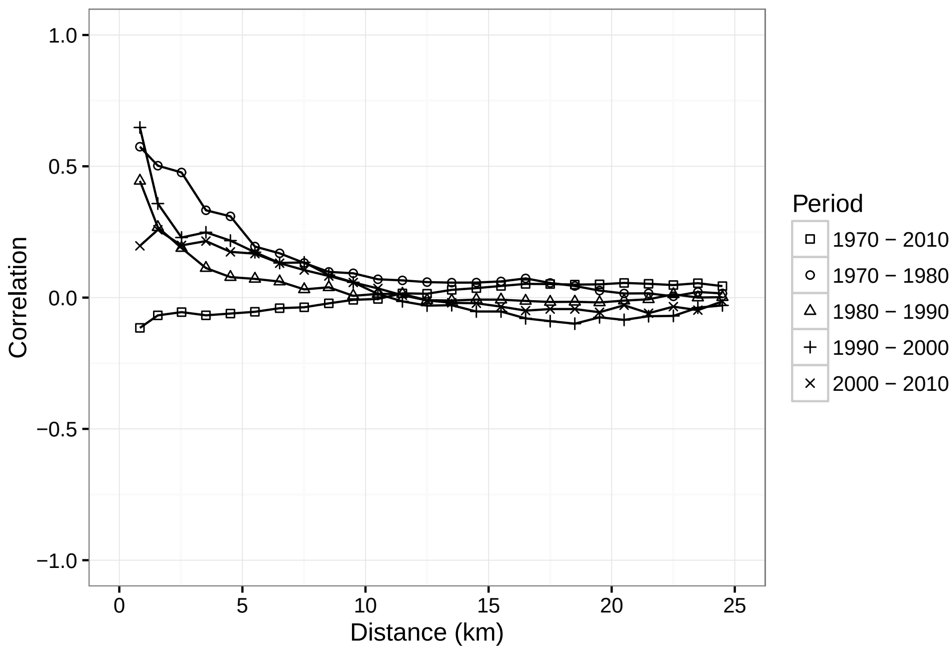


Figure 11: Spatial Correlation in House Price Percentile Changes in each Decade, Las Vegas

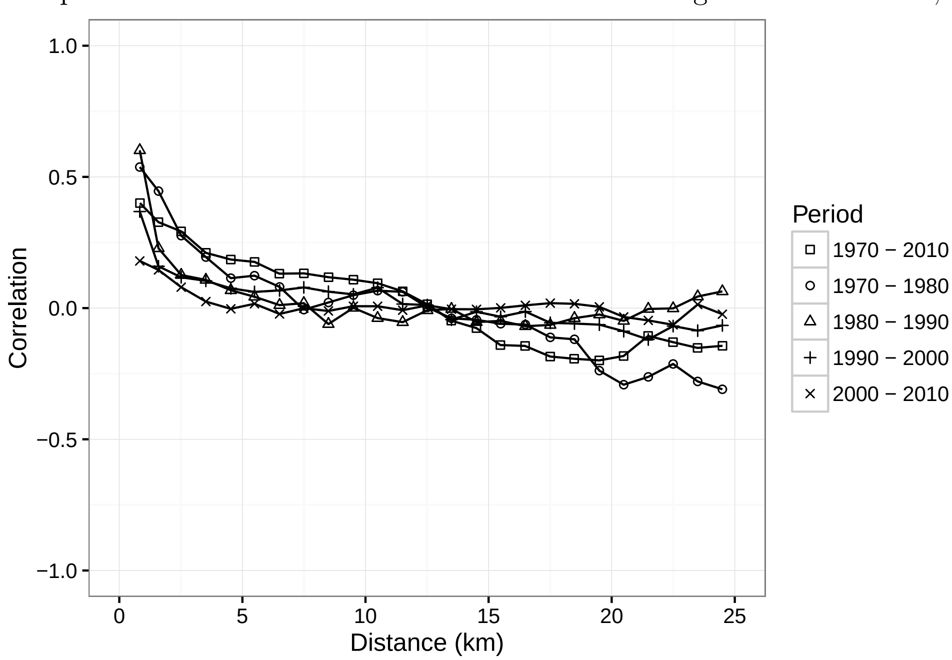
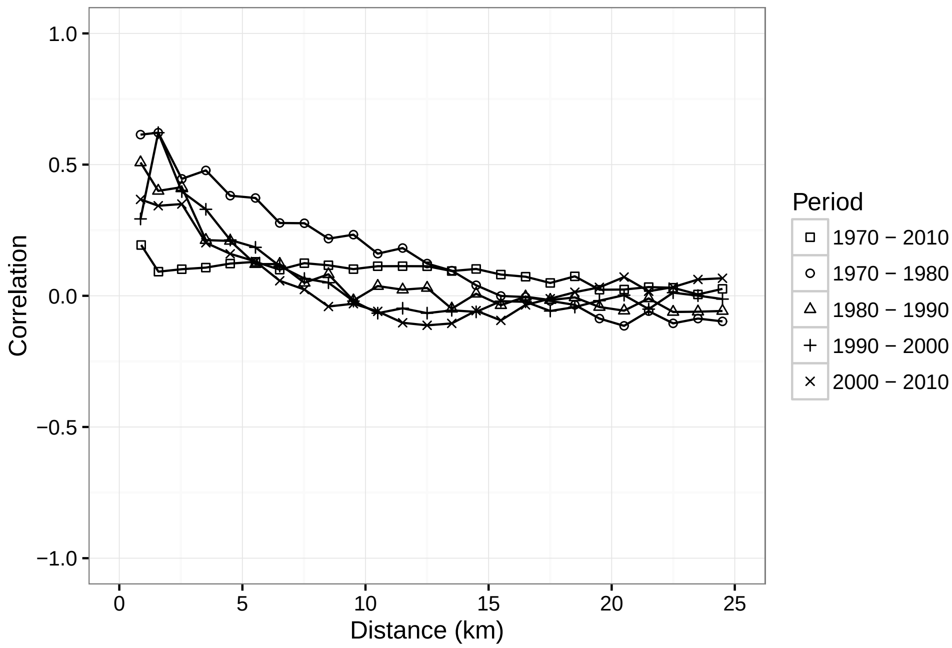


Figure 12: Spatial Correlation in Income Percentile Changes in each Decade, Charlotte



autocorrelation in each city [7]. This tests the null hypothesis of no spatial correlation by comparing the actual value of I against an expected value of I that is computed by randomly distributing the observed percentile changes of the city's tracts that decade 1000 time then taking the average I from these randomizations. If the observed value of I is significantly greater than the expected value, then then movement throughout the hierarchy is spatially correlated.

Figure 14 shows the distribution of p-values for this test for all 7 variables in each decade. Figure 13 does the same for entire 40-year period. The trends we found in our case studies appear to carry over to the entire sample. In each decade, the overwhelming majority of cities reject the null hypothesis of no spatial autocorrelation at the 5 percent level (shaded in grey). This is true whether we look at change over the entire 40 year period or decade-by-decade.

These eight case study MSAs were selected because of the diversity, but all eight show some

[7] The specfic formula for Moran's I is $I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$, where w_{ij} is the weight between observation i and j, and S_0 is the sum of all w_{ij}'s: $S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$.

convergence toward high rank stability and a high degree spatial correlation. Obviously, there are different fundamentals at works across our 263 MSAs over 40 years, but these patterns are common throughout all of the metropolitan United States.

5 Conclusion

In this paper we address the converse of most papers in urban economics. Unlike these which ask why things change, we ask about the opposite of change. We aim to understand metropolitan areas and their internal stability over time. While there is some work on the system of cities, its hierarchy, and its stability, much less has been undertaken on the persistence of hierarchies within metropolitan areas. We find that not only are metropolitan hierarchies firmly established, but also that these hierarchies are becoming more stable over time. Persistence is a strong, even dominant, feature of U.S. metropolitan areas even as much of the research on urban topics overlooks this larger context.

We find high levels of persistence – and exceptions to it – that are consistent with what we know about change. Metropolitan areas that are lagging with regard to population growth exhibit more stability than do places that grow faster. Indeed, the least stable places are those that have the fastest population growth and had large amounts of redevelopment, such as Las Vegas and Houston. But, there are many places in which population growth is robust and yet rank stability is quite high (e.g. Los Angeles). Where there is change sufficient to cause reordering of the census tracts within their hierarchies, the change is often highly spatial correlated. Importantly, those MSAs that do undergo reordering don't all experience shocks, rather beyond these spatially correlated shocks, relative ranks remain stable. This suggests that shocks are not drawn from a single metropolitan-level distribution. This has important implications for understanding metropolitan areas.

To the extent that these hierarchies exist, they act to resist change from other fundamentals. The introduction of a new passenger line that cuts through different neighborhoods is likely to experience differential responses. But, importantly, a fixed effect model that would control for omitted variables at the neighborhood level could be highly problematic when the distributions for the surrounding areas may be drawn from different distributions. This is more true of "diff-in-diff"

Figure 13: Distributions of P-Values for Spatial Correlation Tests for 40 Year Percentile Change, All Variables

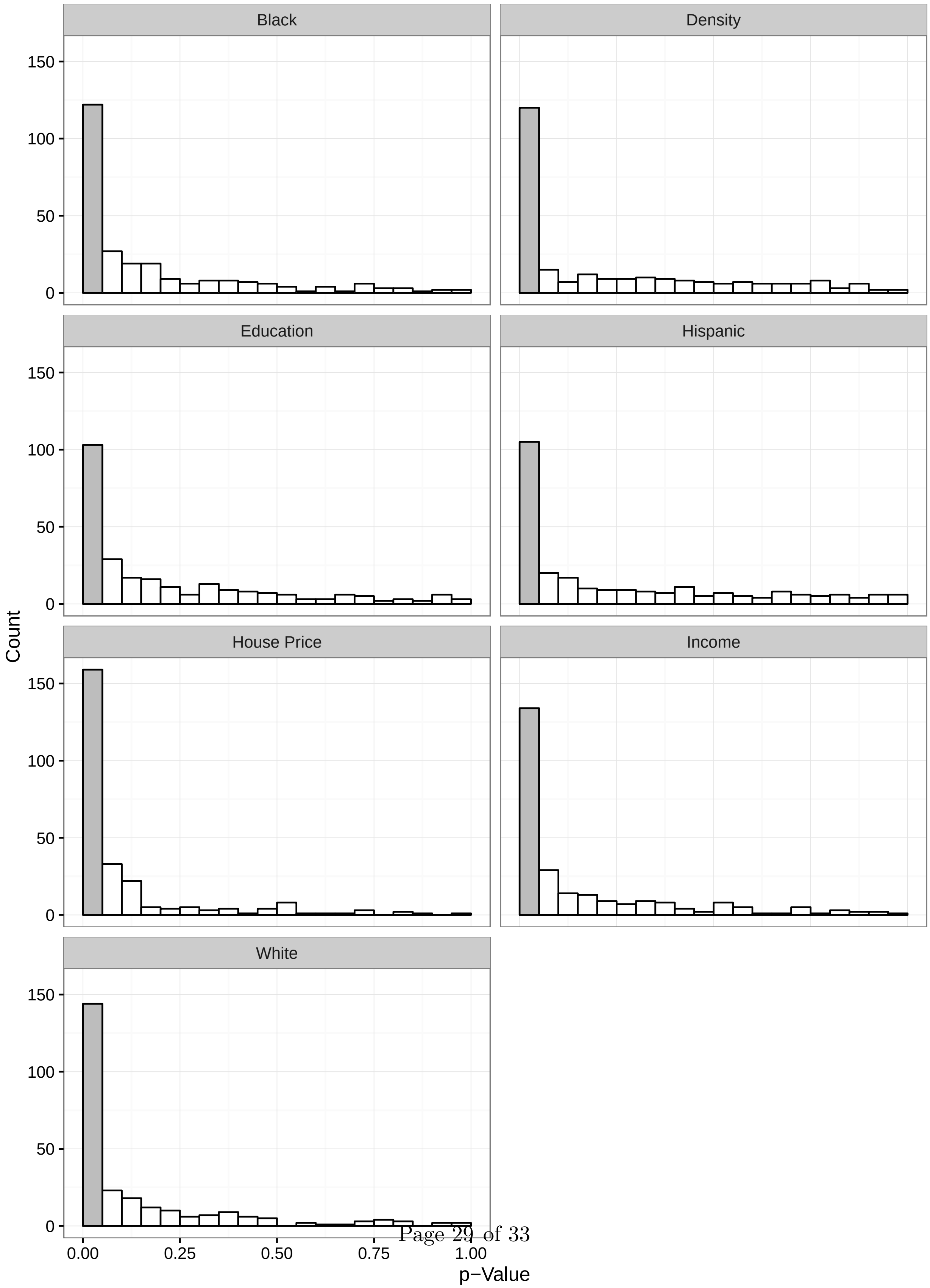
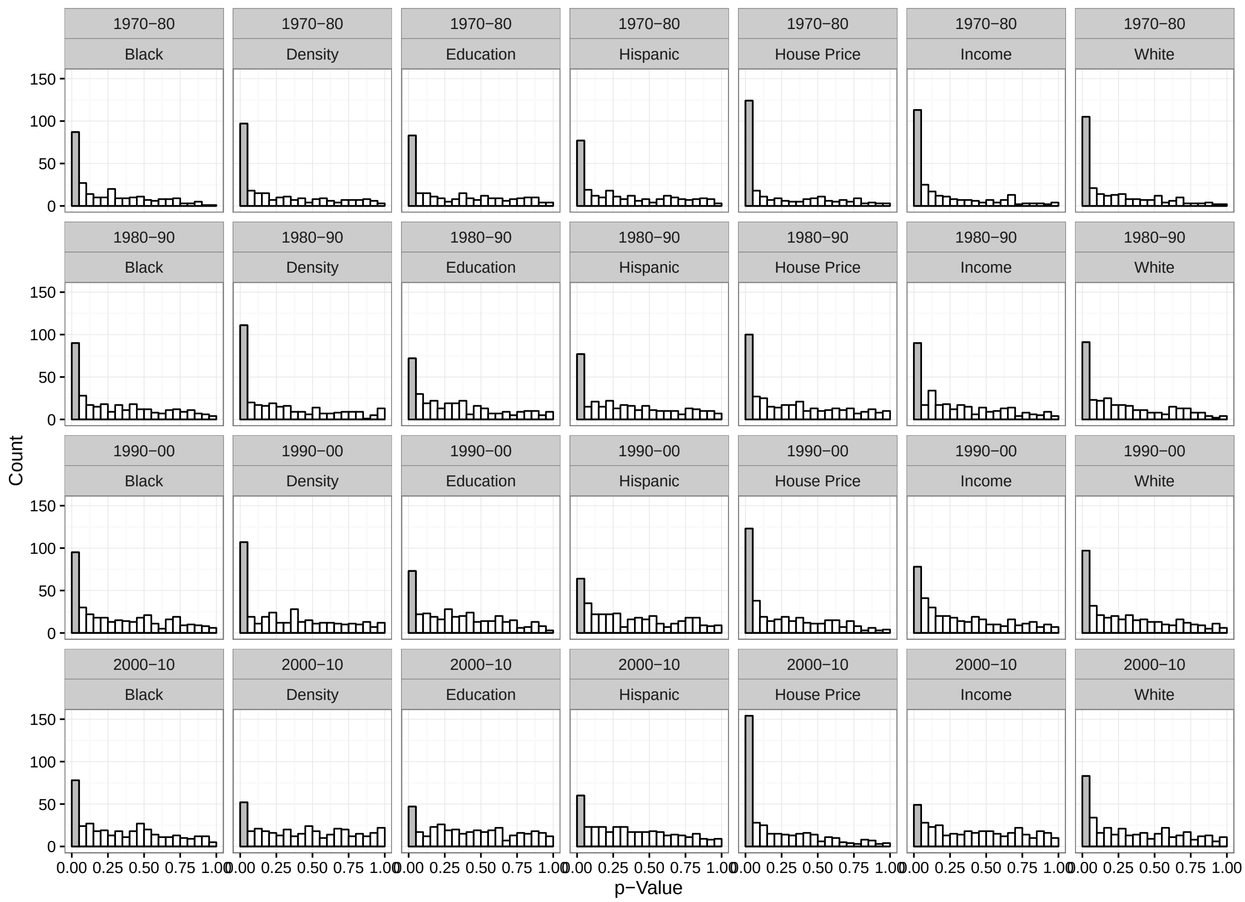


Figure 14: Distributions of P-Values for Spatial Correlation Tests in Each Decade, All Variables



models that require a parallel shift among the treatment and control areas to recover an unbiased estimate.

In this paper, we have focused on documenting these regularities and less on explaining them. In a follow-up paper, we have begun with several simple models that support the notion of a durable hierarchy. These include an a household-level set of shocks that induce households to move up or down the hierarchy but otherwise preserve the hierarchy. We also are including the distribution of location qualities and the limited abilty of developers to create high-quality locations. However these explorations evolve, this work suggests that there are durable hierarchies within metropolitan areas that should condition our view of urban phenomena and give us pause when we pool urban data within a metropolitan area. While they may share a common labor market and common set of fundamentals, it appears that housing markets within metropolitan areas have acted to sort locations and that these there are other fundamentals are at work across them. This should color the way we view data aggregated to the MSA-level and caution against pooling simply beause of shared membership in a metropolitan area.

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