How "dependent" are we?

A spatiotemporal analysis of the young and the older adult populations in the US

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Abstract

The shifting of a country's age structure has far-reaching socioeconomic and policy implications. In the US, the changing age structure at the sub-national level has received little research attention. To address this gap, we examine age dependencies across states in the US between 1990 and 2010 using decennial census data. We find that dependency changes have been gradual with a distinct graying of states during this period. Within this overarching trend, the sources of states' dependencies follow complicated trajectories without clear spatiotemporal patterns. Nevertheless, changes in states' old-age dependency contributions to respective total dependencies are geographically clustered and the inverse link between old-age dependency and economic productivity across states may be waning. Additional research is justified to further unravel these trends in old-age dependencies. The analytic framework that we apply can be adopted to conduct sub-national age dependency studies for other countries, including some European nations with relatively large proportions of older adults and many developing nations with an increasing share of older adults.

Keywords: Dependency ratios, spatiotemporal, youth, older adults, gross state domestic product

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Introduction

In the US, age transition will continue to raise the share of dependents in the population. In 2020, the country will have about two dependents for every three working-age adults and a decade later, one in every five Americans will be an older adult (US Census 2017). Given these national projections, many social and economic policies and their directions rest upon one question: how dependent are populations within and across regions of the US? Indeed, the distribution of the dependent pool across geographies in the US will dictate whether national and local resources and service delivery mechanisms will be sufficient to meet the demands generated by this population (Bongaarts 2009; Brucker 2006; Pezzulo et al. 2017; Vespa 2018).

Yet, research on the sub-national geographic variations over time in dependency ratios –the young and the older adults in comparison to the working-age groups – in the US is limited. Some studies examined the historical trends and predicted the dependencies of the nation as a whole without sub-national details (e.g., Ortman et al. 2014). While some studies of dependencies were conducted at the sub-national levels, they relied on data from a single year without considering the population dynamics over time (e.g., File and Kominski 2012). Given the graying trend of the US population, it is also important to determine the variation in the sources of burden derived from the young and older adult populations across different regions in the US. To address these gaps in the geography of age dependency research, we estimate state-level age dependency ratios and conduct a spatiotemporal analysis of dependency patterns from 1990 to 2010.

The broader aim of our study is to analyze changes in state-level dependency by type. More specifically, we compute the contributions of dependency burden from the young and old-age populations for each state, analyze their spatial variations across the US, and corresponding trends between 1990 and 2010. Many studies that employed dependency ratios attempted to assess the economic burdens of dependent populations levied onto the society.[1] Therefore, in tandem, we also survey the contours of geographical connection between dependency by type and state economic outputs. The framework that we apply to examine sources of dependency burden by type (young and old-age dependencies) has broad significance. It can be adopted to conduct sub-national age-dependency research for other countries to support local or regional planning and derive an accurate perspective on the spatial variations in dependency over time.

The findings of our study establish the salient need of sub-national dependency research. The rest of this paper is organized as follows. In Section 2, we present a summary background on measuring dependents and relevant age dependency studies. In the third section, we provide a summary on data and methods. In the following section, we introduce descriptive findings on age dependencies and present a compare-contrast of state-level spatiotemporal variations in types of dependency. We also inspect the contours of spatial connection between dependency by type and state economic outputs. In the final section we conclude with policy implications and directions for future research.

Background: Dependency Ratios and their Application in Prior Studies

Dependency ratio is a summary demographic indicator of the age profile of a population. It is also used to summarize the age dependency of populations (Sanderson & Shervob, 2015; Brucker, 2006). Classifying population into the three age categories of the working, the non-working youths, and the non-working older adults yields three different dependency ratios – youth dependency ratio (YDR), old-age or elderly dependency ratio (EDR), and total dependency ratio (TDR) (Weeks

[1] See for example, Bloom, Canning, & Fink (2011), and Ingham, Chirijevskis, & Carmicael (2009).

2005). While YDR is the ratio of the young dependents to the working-age population, the EDR, in contrast, is the ratio of the older adult dependents to the working-age population. The TDR, as the name suggests, is the total age dependency combining both the young and the older adults in the population and, therefore, is the ratio of the non-working dependents to the working-age population. The YDR, EDR, and TDR are expressed respectively as the number of youths, older adults, and total dependents per 100 working-age population. A higher youth, elderly, or total dependency ratio indicates a potentially higher burden to respectively support the youth, the older adults, or a combination of both in the population.

Hence, the three demographic groups, the young, the old and the non-dependent working group, which are age groups in operation, are used to define the three dependency ratios, YDR, EDR and TDR. However, a variety of age boundaries have been considered to demarcate the three age groups in estimating the three dependency ratios. In fact, the United Nations publishes five sets of YDR, EDR, and TDR with the young (0-14, 0-19, and 0-24), the older adults (65+, and 70+), and the working age (15-64, 20-64, 20-69, 25-64, 25-69) defined with alternative age limits (UN, 2017). These variations reflect that (economic) dependency is a country/culture-specific demographic state. Even within the US, different federal government agencies define the three age groups inconsistently.[2]

Between all the variations, the age-limits that have been traditionally used to construct dependency ratios are: 0-14 (young), 15-64 (working middle), and 65 and older (older adults) (Sanderson & Shervob, 2015). These three conventional age categories and the term total dependency ratio (TDR) originated in the work conducted by Notestein et al. (1944). Although the

[2] For example, the US Bureau of Labor Statistics (BLS) uses the three age groups of 0-15, 16-64, and 65 and older (BLS, 2017). The US Bureau of Census employs 0-17, 18-64, and 65 and older as the three age-groups (Vespa, Armstrong, & Medina, 2018). The US Social Security Administration (SSA) uses 0-20, 20-64, and 65 and older (SSA, n.d.).

terms YDR and EDR are not referred in Notestein et al., they nonetheless present analyses on youth and old-age dependency (Sanderson & Shervob 2015). Since this first use, the three age cut-offs have been consistently applied in the computation of TDR for populations in countries across the world and have been adopted by the United Nations (Sanderson & Shervob 2015).

Despite its widespread use as a composite index, dependency ratio is not without flaws. More recently, analysts have underscored that the conventional demographic dependency ratio is not sensitive to various factors (Istenič, Ograjenšek, & Sambt 2018; Lau, & Tsui 2017; Loichinger, Hammer, Prskawetz, Freiberger, & Sambt 2017; Sanderson, Scherbov, & Gerland 2017; Sanderson & Shervob 2015; Lutz, Sanderson & Shervob 2008). For example, the traditional dependency ratio "usually defines the period of dependency with arbitrary age limits that are independent of country, year, gender and other factors." (Istenič, Ograjenšek, & Sambt 2018, p. 188) Thus, the population subgroups defined by the traditional age limits may not be entirely dependent, even within a country.

Alternative conceptualizations of dependency have included, for example, labor market activity (economic dependency)[3], and disability status (medical dependency)[4]. However, these approaches are also less than perfect – for example, as a concept, economic dependency fails to handle economically inactive but wealthy "non-dependents." Instead of focusing on a multiplicity of such nuances around one's status as a worker/non-worker and/or as a dependent/non-dependent, we employ the traditional age categories—i) youth: 0-14, ii) working age: 15-64, and iii) older adults: 65 and older to derive YDR, EDR, and TDR for the US states.[5]

[3] See for example the discussion in Loichinger, Hammer, Prskawetz, Freiberger, & Sambt (2017).

[4] See for example discussions in Skirbekk, Loichinger, and Weber (2012), Sanderson & Scherbov (2010), and Harwood, Sayer, & Hirschfeld (2004).

[5] These three age categories closely match the age boundaries adopted by the US Bureau of Labor Statistics (BLS) as we noted in an earlier footnote. These categories are also compatible with the conventional definition of dependency ratio applied in the field of demography and population research. Despite recent criticism (Morgan, 2019; Sanderson &

The YDR, EDR, and TDR indicate burden levels to support the dependents – the youth, the older adults, or a combination of both – in the population. It is therefore imperative to interpret all three dependency ratios at the sub-national levels in order to ascertain whether higher (or lower) dependency in a region is on account of the youth, or the older adults, or both and, in turn, what particular mix of service demands is needed in that region (Lammens, & Deboosere 2010; Brucker 2006). In synergy, tracking changes in the three dependency ratios over time is equally important to derive the trajectory of future service demands within and across regions of the US (Anderson et al. 2012). Nevertheless, such systematic geographical comparison of dependency ratios over time has not yet been conducted to understand the source and/or type of age dependency across states or substate regions of the US (File & Kominski 2009, Conway & Houtenville 2003).

Instead, as an aggregate measure, dependency ratio has most widely been applied in the economic literature (Lee & Mason, 2010; Gwartney, et al. 1999; Krugman 1994). These studies can be broadly grouped into two categories – those that examine demographic dividend[6] and others that assess labor market and other macroeconomic impacts of population aging.[7] Additionally, studies and reports have applied dependency ratios to examine the impacts of migration on age dependency.[8] Irrespective of the research focus, dependency studies are predominantly country-level analyses. A factor that may have limited these studies to national-level applications of

Scherbov, 2015), demographic or age-based dependency ratios are still used as standardized indices (Lau, & Tsui, 2017; Sanderson & Shervob, 2015; Jahan et al., 2014). Currently, organizations as the United Nations, United States Bureau of Census, and the World Bank utilize this measure at the global, national, and subnational levels.

[6] Demographic dividend is a one-time economic benefit that often result after a period of low dependency in countries undergoing demographic transition.

[7] For studies examining demographic dividend, see for example, Bloom et al. 2007; Kelley & Schmidt 2005; Bloom, Canning, & Malaney 2000; Bloom & Williamson, 1998. For studies evaluating macroeconomic impacts of a changing population age structure, see for example, Lee & Mason, 2010; Ingham, Chirijevskis, & Carmicael, 2009; Verdugo, 2007; Paes de Barros et al., 2001.

[8] See for example, IMF (2019); UN (2017), Zaiceva (2014); Muszyńska & Rau (2012).

dependency ratio is the availability of data (Sanderson & Shervob 2015). The United Nations, and subsequently the International Labor Organization (ILO), are the two major sources of data that cover a broad swath of countries in the world. Both organizations produce aggregate national estimates and projections respectively for population characteristics and labor force participation of countries (UN 2017; ILO 2019).

The group of studies, albeit a substantially smaller number, that does present local-level dependency ratio analyses incorporate disaggregated (micro-level) data to mostly estimate healthcare impacts of population aging in a single country.[9] An additional collection of studies interpret geographic distribution of dependents at the sub-national local levels for countries in Europe, Asia and Africa.[10] The population of studies examining dependency ratios in the US at the subnational level is similarly small in number. More than two decades back, Bean et al. (1994) highlighted the need for subnational studies of US population aging and examined the changing concentration of older adults across subregions within the US between 1980 and 1990. Findings in Rogers and Raymer (2001) highlight aging in place as a major factor driving geographical pattern and profile of older adults across regions of the US. However, while Bean et al. did not employ the dependency approach, Rogers and Raymer disaggregate total dependency but consider only the population subgroup older adults but not the youth.

Brucker (2006) compared various economic dependency ratios for the 50 states. He emphasized that the spatiotemporal dynamics of the youth and the older populations across US states have far-reaching resource allocation and service delivery implications and conducted an assessment of state-level macroeconomic (fiscal) impacts of youth and old-age dependencies for the

[9] See for example, Conway et al. 2015; Sandberg et al. 2012; Cournane et al. 2015.

[10] See for example, Li, et al. (2016); Pezzulo et al. 2017.

year 2000. In addition, Brucker also assessed the dependencies based on the Census Bureau population projection for the year 2030. However, historical temporal trends of dependencies were not analyzed and the spatial variations of the dependency ratios across US regions, if any, were not examined.

More recently, the Census Bureau published several reports related to US age dependency mostly at the national level. Based on projected populations from 2012 to 2050, Ortman et al. (2014) show that although historically YDR has been much higher than EDR, by 2050, both ratios will converge such that their relative contributions toward TDR will be about the same. Without referring to dependency ratios directly, Vespa (2018) employs an updated population projection and reports that by 2035 the number of people age 64 and over will be about 77 million, similar in size to "children under age 18." Both these reports however do not analyze subnational trends and spatial patterns in dependency.

In contrast, File and Kominski (2012) use the 2009 single-year American Community Survey (ACS) data at the state and metropolitan levels to examine age-dependency in the US. Arguing that those who work usually are 18 or older, File and Kominski adopt the age definitions of 0-17 and 65 and older respectively as the youths and the older adults and provide descriptive statistical analyses on the dependency ratios with results presented in maps. However, this analysis was for a single year thereby failing to reveal the spatiotemporal trends of the two types of dependency over time.

Data/Methods

In our study, we conduct an analysis of state-level age dependency ratios and identify the relative burden from YDR and EDR and corresponding trends between 1990 and 2010. Our explicit focus is on state-level spatiotemporal dependency dynamics. Demographic processes operate at multiple geographical levels. Using state as the geographical unit of comparison in this study merely reflects our focus on the patterns resulting from state-level processes, leaving substate-level analysis to subsequent studies. Therefore, patterns and findings from this study are not necessarily applicable to sub-state level situations. The two decades between 1990 and 2010 is defined as our study period partly because this period includes the population groups that are of salience in the demographic structure and history of the US. These age-groups include the cohort born before World War II (those reaching 65 in 1990) and the earliest cohort of baby boomers (those reaching 65 in 2010) and their children, the so-called "echo boomers."

Additionally, we examine the changing spatial connections between dependency by type and economic setting across the US states. As many national-level studies employing dependency ratios focus on the impact of age dependencies on economic performance, we therefore explore the link between the two types of dependencies, youth and old-age, and state economic performance at the sub-national level. More specifically, we try to identify the relation between age dependencies and states' economies, and if such a relation exists, assess how it may vary over space across the three census years. Our purpose here is therefore not to present a formal model that quantifies the impact of age dependencies on state economic outputs and output growths net of other covarying predictors. And by the same token, the findings we present here should not be interpreted to indicate a causal relation between the two factors – age dependency and state economic performance. Instead, the explicit objective of our analysis is to unfold the spatial contours of the link, if any, between age dependencies and state economies.

To conduct the above examination, we employ various techniques and methods in geographical analysis. As our objective is to analyze the spatiotemporal patterns of dependencies, mapping dependencies and their changes across the decades serve our purpose effectively. To visualize spatial patterns, we leverage micromaps, which combine maps with statistical graphics.

Formation of spatial clusters is a common reason for the emergence of spatial patterns. We therefore use global and local Moran's I, respectively to quantify the degree of clustering and the presence of local clusters. As we are interested in analyzing the spatial heterogeneous relations between dependencies and economic performance across states, we employ Geographically Weighted Regression (GWR), which is a local regression model. Details on each of these techniques are provided in the next section. The population counts for the three demographic groups – youth, working-age, and older adults – for the three decennial censuses of 1990, 2000 and 2010 were obtained from the National Historical Geographic Information System (NHGIS).[11]

Results: Dependencies over the Two Decades

National estimates and state-level averages

We computed the three dependency ratios for the entire country and for each state. State averages were also derived. These statistics are reported in Table 1. Regardless of whether considering the country as a whole or individual states, national TDR and mean of state TDR declined slightly over the two decades. This trend of slow decline is attributable to the longer-term decline in YDR, which was partly affected by a modest decline in fertility rates.[12] In comparison, EDR, both the national and state-level averages declined between 1990 and 2000 but rose back up between 2000 and 2010. Because the increases in EDRs during the latter decade were substantial, these increases greatly exceeded the declines during the first decade. Consequently, the EDRs at the end of the two decades

[11]The NHGIS dataset, housed under the Integrated Public Use Microdata Series (IPUMS) website, provides U.S. Census data and GIS boundary files that can be downloaded from: https://nhgis.org/.

[12] In the period between 1976 and 2010, the (general) fertility rates in the US continued to fluctuate; it nevertheless exhibited a trend of slight decline – from 65 in 1976 to 64.1 per 1,000 women aged 15-44 in 2010 (CDC, 2019). More importantly, we found that at the state-level, the correlations between total fertility rate (TFR) and YDR were 0.60, 0.87 and 0.80 in 1990, 2000, and 2010 respectively, and all were significant at the 1% significance level.

were higher than that at the beginning of our study period. This reversing trend that typifies EDR is most likely the result of the baby boomer cohort starting to enter the retirement age (65). Figure 1 shows the population pyramids for the three census years. As the baby boomer has been the largest cohort in the US demographic structure, their departure from the working age (15-64) and entrance into the retirement age dramatized the upward swing of the EDR between 2000 and 2010.

<TABLE 1 ABOUT HERE>

<FIGURE 1 ABOUT HERE>

Table 1 also reports the ratio of EDR to TDR. This ratio can be interpreted as the contribution of the older adults to the total dependency considering the entire population. Thus, the balance of this ratio is the contribution of the youth to the total dependency. Over the two decades, EDR contributions have been below or around 0.40. Thus, the older adults have constituted only the minority of the dependency, although this EDR-TDR ratio is on an upward trajectory.

Spatial patterns in dependency ratios, dependency clusters, and average-dependency states

Dependency ratios: Figure 2 presents the geographical distributions of the three dependency ratios of TDR, YDR, and EDR across the US states for the three census years, 1990, 2000 and 2010. For comparability across these years, we apply the same five class break values in these choropleth maps. The maps in Figure 2 – Panel 1 indicate that TDR values did not exhibit a clear systematic spatial pattern over time. Although one may suggest that the central-Midwest[13] together with

[13] A reference map of the US states with Census regions and divisions is provided in the Appendix and can be found in https://www2.census.gov/geo/maps/general_ref/pgsz_ref/CensusRegDiv.pdf.

Florida tend to have higher rates throughout the two decades, the boundary of the higher-rate region has not been persistent and Colorado in the middle has always been a low TDR state.

The maps of YDR (Panel 2) partially explain the lack of a systematic spatial pattern of TDR over the decades. Although the US has been experiencing a modest trend of decline in fertility and, in consort, in the YDR (Table 1), these declines have not been uniform across the country. On the other hand, as the older adult population in the US has been increasing overall, the maps in Figure 2 – Panel 3 show increase in EDR across most states, but very unevenly. The cluster of states with high EDR from the northern Mountain region to the Midwest has been persistent. In addition, the states with extreme YDR and EDR, such as Utah, Idaho, and Florida seem to be quite consistent over the years. The correlations of TDR, YDR and EDR between the census years are reasonably high (Table 2). This finding indicates that states with high (or low) total, youth, or old-age dependency in 1990 continued to record similarly high (or low) dependencies over the two decades. Overall, such a trajectory reveals dependency changes across the 50 US states have been in general gradual.

<FIGURE 2 ABOUT HERE>

<TABLE 2 ABOUT HERE>

<u>Dependency clusters:</u> Figure 2 above indicates various degrees of spatial clustering for the three dependency ratios. In order to evaluate the varying degrees of clustering for the three ratios, we computed the local Moran for each of the maps in Figure 2 (Anselin, 1995). Local Moran reflects the similarity between value in the unit and values in neighboring units. The results are presented as

clusters of high-high values, low-low values, high-low values, and low-high values. Our emphases here are the high-high (hot spot) and low-low (cold spot) clusters.

<FIGURE 3 ABOUT HERE>

Local Moran for TDR in 1990 indicated a high-high cluster (hot spot) stretching from Montana and Wyoming to North and South Dakota and a low-low cluster (cold spot) from Maryland to Virginia and North Carolina. However, the hot spot-cold spot patterns of TDR disintegrated over time and there were no major and consistent clusters of TDR in 2000 and 2010. We therefore do not include the local Moran maps for TDR here. As TDR is controlled by the two often complementary forces of YDR and EDR, it is therefore more meaningful to evaluate the spatial patterns of these two dependency ratios than their aggregates. Figure 3 reports the local Moran results for YDR and EDR for the three census years.

Clearly, along the Mountain region from the north to the south, YDR has a hot spot that evolved over time. States in the north (Montana and Idaho) dropped out of the hot spot cluster in 2000 partly because some of their neighboring states had lowered YDR over the years. According to the concept of local Moran, a hot- or cold-spot cluster is not determined only by its own values, but also neighboring values. Most states in the hot spot, such as Arizona, New Mexico, Utah, and Wyoming had relatively high YDR throughout the study period. Nevada had relatively high YDR to start with. Later, it joined the YDR hot spot. Colorado started with moderate YDR, but its levels have been stable while the YDR of the entire US have been slowly declining. As a result, Colorado became part of the hot spot. Cold spot clusters in YDR were found in the northeast, extending from New Hampshire to Virginia. However, this contiguous cold-spot cluster dissolved in subsequent census years.

For EDR, the cold spots seem to have been persistent in North Carolina along the east coast, and Utah and New Mexico in 1990 and 2000, and a clear hot spot was found in Iowa and Missouri, but only for 1990. Subsequent years have no clear hot spot identified by local Moran. Still, we found states with high and low values that exist in relative isolation or randomly. For instance, despite Florida having a very high EDR in all years, neighboring states do not have high EDRs and therefore, there is no hot-spot cluster around Florida. The moderately high EDR for the neighboring state of Alabama in 2010 was not sufficient to form a hot spot cluster with Florida.

In other words, states with high (or, low) EDR did not form geographical clusters, implying that some state-based characteristics, which may be high-quality medical and retiree services, certain health and tax policies, or cultural and economic factors affect the concentration of older adults by states, but not cross-state regional factors such as climate or landscape. On the other hand, the disappearance of hot and cold spot clusters of EDR over the two decades implies that different states were converging to the averages, as reflected by the decreasing standard deviation of EDR distributions across states (Table 1).

<u>Average-dependency states:</u> The statistical distributions of the two dependency ratios, YDR and EDR, have considerable variations and reveal changes in the state demographic structures between 1990 and 2010. To summarize these spatiotemporal changes, in Table 3 – panel 1, we forward a taxonomy that classifies states' demographic profile according to their YDR and EDR values. Using the statistical distributions of the two dependency ratios, we classify states into low, medium or high levels of youth and old-age dependencies.[14] As a result, we obtain a nine-type scheme (Table 3 – panel 1) in which the category "average" includes medium YDR and medium EDR values that are within one standard deviation of the state-level averages for these two dependency ratios. We then

[14] This nine-class categorization is more detailed than the above- vs. below-average used by File and Kominski (2012).

assigned each state into a type for 1990 and 2010, and assessed the changes in types over the two decades.

In Table 3, we list the set of states that in 1990 (panel 2) and in 2010 (panel 3) had a combination of YDR and EDR other than medium-medium, and therefore these were the states that fell outside of the average-dependency category.[15] Over the two decades, nine of these states outside of the average-dependency category remained in their classes. Eleven states moved into the average-dependency category by 2010. Only two states outside of the average-dependency category – Texas and West Virginia – changed their positions. By 2010, while Texas had become a “younger” state on account of YDR increasing but EDR remaining low, West Virginia in contrast converted into a “many older adults” state due to YDR decreasing but EDR remaining high.

Conversely, over the two decades, six average dependency states, California, Arkansas, New Hampshire, Vermont, Arizona and Maine, moved out of this type into one of the extreme categories. Similar to the West Virginia situation, decline in YDR was the reason that the two New England states, New Hampshire and Vermont joined Rhode Island in the “few youth” category, and Maine moved from average to “older.” Most part of the New England had experienced relatively low fertility rates.[16] On the other hand, higher fertility rate could be the reason to drive Arizona from the average to the “many youth” category. California moved into the “few older adults” with lower EDR, likely the result of some older adults moving away from California, which is in general expensive (Uhler & Garosi 2018; Johnson 2000).

Figure 4 shows the states in the “average” categories considering both YDR and EDR in the three years. Apparently, the number of states moving into the average categories grew over time from the center of the country. In other words, whereas in 1990 most states fell outside of the

[15] Over the two decades, none of the states had a low-low combination of the two dependency ratios.

[16] These state-level birth and fertility trends are discussed in CDC (2003; 2012).

average-dependency category, two decades later, the situation reversed with only seventeen in the non-average category. Those states persistently in the non-average category (with extreme YDR and/or extreme EDR) throughout the decades were found in the South (Texas, Georgia, and Florida), Mountain (Idaho, Utah and Colorado), and mid-Atlantic (Pennsylvania and West Virginia) regions, plus Iowa. Although some of these states are neighbors, they did not necessarily share similar demographic structure (e.g., the relatively young Georgia versus the relatively old Florida). These results partly corroborate our earlier finding about the importance of state-level factors in affecting the spatial patterns of YDR and EDR. Some of these states will be analyzed further below.

<TABLE 3 ABOUT HERE>

<FIGURE 4 ABOUT HERE>

Sources of dependency and spatiotemporal variations

To track the sources of dependency over the three census years, we first visualize the dependency ratios using micromaps (Carr and Pickle, 2010; Pickle et al., 2015).[17] Micromaps is a geovisualization framework combining choropleth maps with statistical graphics enhanced by sorted data. Values of one of the mapped variables are sorted either in ascending or descending order. As the sorted values and other variables are plotted, the sorted values are also shown on small maps allowing the readers to detect the geographical patterns with changing values. Figures 5-7 are three sets of micromaps for the three census years and depict TDR and EDR contributions to TDR (Proportion EDR) with Proportion EDR in descending order.

[17] These micromaps were created using MicromapST - Version 1.98.5, which can be downloaded from https://cran.r-project.org/web/packages/micromapST/index.html.

<FIGURES 5-7 ABOUT HERE>

By definitions, YDR and EDR are in general characterized by a complementary relationship. The correlations between YDR and EDR for 1990, 2000, and 2010, which respectively are -0.1970 ($p > 0.05$), -0.4236 ($p < 0.05$) and -0.3193 ($p < 0.05$), indicate a weak inverse relation. In other words, for each state, when one is high, the other may be low, although both ratios may increase or decrease simultaneously thereby creating a major change in TDR. The latter possibility explains the weak negative correlations between YDR and EDR.

Over the two decades, the highest TDR values have been lowering from 0.65 to 0.56, indicating a general decrease in TDR over time. Next, the rightmost panels in Figures 5-7, "Proportion EDR," indicate that EDR contribution to TDR for most states, except a few such as Florida, hovered within the range of <0.15-0.4. In other words, for most states, YDR has been the dominant contributor to TDR. Nevertheless, the three figures highlight the varying degree with which EDR and YDR have been driving the decrease in TDR over the two decades. Although the plots of EDR contribution to TDR (Proportion EDR) are relatively smooth, the plots for TDR are rather chaotic, indicating high (or low) TDR values might be controlled by EDR, YDR, or both. Despite the wide spatial variations across the two decades, states with high EDR contribution to TDR were mostly found in the Northeast and the mid-Atlantic regions plus Florida. A few Mountain and Midwest states were also on the high side. States with low EDR contribution were mostly found in the West and the Southwest regions with a few states in the southeast.

We computed Moran's I for EDR contribution to TDR (proportion EDR) in each census year. Although Moran's I values are relatively low (0.1921 in 1990, 0.1431 in 2000 and 0.2103 in 2010), all are statistically significant at 95%. These low but significant statistics imply that some similar values are in proximity. States with similar proportions of EDR contribution to TDR formed large and small regions. For instance, regions with similar high proportions include the neighboring states of Pennsylvania and West Virginia, Montana and North Dakota, and Alabama and Florida. The formation of high proportion clusters means that large contribution of EDR toward TDR was not limited to individual states, but was a characteristic shared among states within certain regions. These states exhibited a similar demographic trend of increasing their EDR shares to TDR.

We also sorted the micromaps for the two decades according to TDR in descending order.[18] The 1990 micromaps show that dependency in the ten highest TDR states were driven by either high YDR values (such as, Utah) or, high EDR values (such as Florida). Similarly, for the lowest TDR states, Alaska was driven by low EDR contribution and DC by low YDR contribution. In between the ten highest and ten lowest TDR states, some fluctuations include the high EDR contributions in West Virginia, Pennsylvania, Rhode Island and Massachusetts (and to some extent, New Jersey and Connecticut). In contrast, YDR contributions of New Mexico, Louisiana, Wyoming, and Texas were relatively high. The situation in 2010 remained quite similar: states with similar TDR levels exhibited dependency contributions from the two different sources.

Figure 8 summarizes the spatiotemporal dynamics of EDR contribution to TDR in two maps by showing the changes of EDR share in TDR between the two decades: 1990 to 2000, and 2000 to 2010. Between 1990 and 2000, a number of states along the west coast, Midwest, and several in the east, including Florida, experienced a decline (negative in the differences) in the contribution of EDR to TDR. The state that had the largest increase in EDR contribution to TDR was Wyoming. But between 2000 and 2010, all states without exception increased their EDR contributions to TDR. The smallest increases were found in Utah and in those states in the central US stretching from

[18] We do not include these micromaps due to space limitations and also as TDR exhibited no clear spatial pattern over the decades.

North Dakota in the north to Texas in the south. States on two sides away from this central strip had larger increases in EDR contributions to TDR than states in the central US. Over the two decades, states on both sides of the country increased their contributions of EDR to TDR. Some states in the central section had relatively high EDR contribution already (except Texas) and the rest of the country has been converging to a high EDR proportion.

<FIGURE 8 ABOUT HERE>

In summary, it is evident that an analytic focus resting solely on TDR will fail to facilitate understanding on what factors drive the spatiotemporal dynamics, as its subcomponents, YDR and EDR, contribute to TDR differently over time and space (states). Although YDR has been the dominant contribution to TDR, its contribution level varied tremendously across states and has been diminishing over time. On the other hand, the last decade (2000-2010) saw all states increase their EDR contributions to TDR. Together, these dynamics indicate a distinct graying of the state populations across the US.

Connecting Dependencies and State Economies across Space

Our findings in the previous subsection indicated weak clustering of similar values of dependency ratios, although these hot- and cold-spots varied over the study period. Anticipating a similar spatially heterogeneous relation between age dependencies and state economic performance, we employ geographically weighted regression (GWR) using states as the local units of analysis. Different from the traditional regression framework which may be labeled as global models where relations between dependent and independent variables are constant across the study region, GWR allows these relations to vary geographically (Fotheringham et al. 2002). Thus, a regression is derived locally focusing on each unit and its neighbors in the study area.

In our GWR models, we define the extent of the local relation such that each state, irrespective of its size, has about the same number of neighbors – 5 to 6 neighboring states – equivalent to a contiguity based spatial relation.[19] We consider gross state domestic product (GSP) per capita as the indicator representing the landscape of economic performance across states. The GSP per capita values for 1990, 2000, and 2010 are estimates published by the US Bureau of Economic Analysis. The GWR model for each of the census years is as shown in equation (1) below.

$$\boldsymbol{y_i = \alpha_i + \beta_1(u_i, v_i)x_{1,i} + \beta_2(u_i, v_i)x_{2,i} + \varepsilon_i} \qquad (1)$$

where,

y_i	= dependent variable at location i = GSP per capita of i
$x_{1,i}$	= independent variable 1 at location i = YDR of i
$x_{2,i}$	= independent variable 2 at location i = EDR of i
ε_i	= error at location i
(u_i, v_i)	= x-y coordinate of the ith location
$\beta_1(u_i, v_i)$, $\beta_2(u_i, v_i)$	= regression coefficients conditional on the location
α_i	= regression intercept at location i

The GWR4 software was used to run the regression models.[20] Descriptive statistics of the variables are reported in Table 4.

<TABLES 4-6 ABOUT HERE>

[19] In the GWR4 software, the local model fitting process allows the use of an adaptive kernel function for geographical weighting using data from *k*-nearest neighbors. The number of *k* nearest neighbors needs to be specified with an upper (maximum) and lower (minimum) limit. In our GWR models, we defined this range as 5-6 nearest neighbors.

[20] The GWR4 is a Windows based statistical software housed at the Arizona State University Spatial Analysis Research Center at https://sgsup.asu.edu/sparc/gwr4.

Correlation statistics in Table 4 indicate an inverse relation between GSP per capita and both YDR and EDR, and the relation is consistent over the decades. Scatter plots (not shown here) confirmed the linearity in the relations between the independent (YDR and EDR) and dependent (GSP per capita) variables between 1990 and 2010. We compare the GWR models for 1990, 2000, and 2010 with: i) the corresponding classical linear regression models with non-varying regression coefficients (global models) (Table 5) and, ii) switched GWR regression models with one of the regression coefficients remaining fixed and the other varying across space (mixed GWR models) (Table 6).

Although the regression coefficients for both dependencies in all the three global models are statistically significant ($p < 0.01$), the adjusted R^2 values for 1990 and 2000 in the vicinity of 28 percent are low (Table 5). In 2010, the situation is however different with about half of the variation in GSP per capita linked to the two dependency ratios, YDR and EDR. The negative global regression coefficients for the two types of dependencies consistently indicate an inverse association between GSP per capita and both dependencies between 1990 and 2010. However, the AICc values (Table 5) indicate that the GWR model for each census year is superior to the respective global model.[21] Furthermore, the geographical variability tests (Difference of Criterion in Table 6) reveal strong evidence in favor of locally varying coefficients for both YDR and EDR and across all the census years. Together these results provide strong indication that the GWR specification (equation 1 above) provide better fits to the data across the study period when compared to the global and the mixed GWR models.

<FIGURE 9 ABOUT HERE>

[21] AICc provides the small-sample bias corrected Akaike Information Criterion.

Between 1990 and 2010, for both YDR and EDR, the local regression coefficients were consistently negative across all states indicating an inverse association between each state's GSP (per capita) and its dependency ratios. The only exception was in 2010 where the local regression coefficient for YDR was positive but insignificant ($p > 0.05$) for the state of New Hampshire. The local regression coefficients exhibit considerable spatial variations, indicating that the magnitudes of the inverse association between state economic performance and the two dependencies vary geographically across the US. Considering the absolute values of the local regression coefficients, we classify these coefficients into the three categories of low (less than 1 standard deviation from the mean), medium (within 1 standard deviation from the mean), and high (greater than 1 standard deviation from the mean). In Figure 9, we present the local regression coefficients for both YDR and EDR classified using this low/medium/high scheme.

In both the YDR and EDR maps, the magnitudes of local regression coefficients exhibited a general east-west geographical trend, ranging from high (absolute) in the east to low or insignificant in the west. In the case of YDR, the high negative values of the local coefficients (darkest shade) in 1990 formed a contiguous cluster stretching across states in the eastern seaboard between New York and North Carolina. By 2010, this region had expanded southward along the eastern seaboard and westward to cover Ohio, and Kentucky. Conversely, for EDR, the high negative associations with GSP per capita (darkest shade) in both 1990 and 2010 produced a large contiguous cluster spanning across the New England states as well as New York and New Jersey. However, in the decade in between, this region had covered states south of the New England region.

Together the above spatial arrangement along the eastern seaboard may indicate that the negative associations of both dependencies with economic productivity (GSP per capita) were larger in the East/Northeast than in the rest of the country. However, the medium negative association of EDR with economic productivity in 1990 for most part of the country shifted to low or insignificant levels in 2010. This spatiotemporal dynamics of EDR indicates that the negative association between old-age dependencies and state economies may be waning. However, the adverse association between youth dependency and economic productivity of states may have been getting statistically stronger. Figure 9 shows that the local coefficients of YDR outside the east-coast cluster shifted from mostly insignificant to becoming statistically significant over the decades.

In prior economic studies that investigate the relations between old-age dependency and economic performance, an implicit assumption is that older adults are likely to be a burden to the economy and therefore, a high old-age dependency ratio may be viewed as undesirable to economic performance.[22] This assumption is probably accurate for the nation as a whole. However, our state-level temporal analysis seems to suggest that such an assumption may not hold at this geographic level over time. While the negative association between EDR and state economic productivity seems to be quite persistent in the New England and some east coastal states, the negative association however became weaker in some Midwest and Mountain states, including some states such as Arizona and New Mexico that are attractive to the retirement population (Conway & Houtenville 2003).

Conclusion and Discussion

For the nation as a whole, TDR shifted from slightly above 0.5 in 1990 to slightly below 0.5 in 2010. This decline was mainly attributable to the lowering of YDR, likely due to the longer-term decline in fertility in the US. However, over the two decades US also experienced a gradual increase in EDR and its contributions to TDR. Together these trends highlight that an analytic focus resting solely on TDR instead of all the three dependency ratios will preclude any interpretation

[22] See for example Bloom, Canning, & Fink (2011).

around the changing contribution of the two dependent population groups over time. Indeed, our state-level spatiotemporal analysis revealed that, within the national dependency trajectory, changes in youth (YDR) and old-age (EDR) dependencies were not just far from uniform across the country, but in fact were quite complicated. Our analysis provides several key insights into the evolution of this complex process.

Dependency changes across the 50 US states have been in general gradual. While YDR has been the dominant contribution to states' TDR, its contribution has been diminishing over time but the EDR-TDR ratio has been on an upward trajectory. These findings indicate a distinct graying of states' populations across the US with dependency shifting more to the older adults. This trend will be of particular relevance to state and local policies cutting across multiple domains (such as housing, transportation, and healthcare, to name a few) especially since older adults mostly prefer to age in place (WHO 2018, Jeste et al. 2016; Anderson et al. 2012; Buffel, Phillipson, and Scharf 2012; Farber & Shinkle 2011; Lui, Everingham, Warburton, Cuthill, & Bartlett 2009).

Our analysis identified the formation of high YDR clusters in several Mountain states and low-YDR clusters in several Northeast states over the years. To a certain degree, the general locations of these clusters reflect the geographical disparities of fertility levels across the country. Indeed, we found strong and significant correlations between YDR and fertility (total fertility rate) of states consistently across the three decadal years of 1990, 2000, and 2010.[23] Certain immigrant groups, including the Hispanic/Latino population, have higher fertility rates than other groups (Bohn & Lopez-Velasco 2019; Parrado & Flippen 2012). Additionally, evidence from prior studies indicate that economic considerations, such as state income tax, influence family-size decisions (Whittington 1993). Thus, one may speculate that the higher concentration of Hispanic/Latino population at the regional level across multiple states and/or low state income tax might contribute

[23] See footnote 12.

to higher YDR. But we found that percent Hispanic/Latino population was mildly (but significantly) correlated with YDR only in 2000, out of the three census years.[24] Likewise, state-income tax, an economic variable, share a significant but a low correlation with YDR only in 2000.[25]

EDR however, exhibited no clear high- or low-value clusters over the two decades. This outcome could have been on account of states converging to a higher EDR level over the last two decades. Our analysis revealed that the central-Midwest section of the country already had relatively high EDR in 1990. This trend combined with the increase in EDR in recent decades in the eastern and the western sections of the country indicated a national convergence to a higher EDR level. Thus, high and low EDR values may not have been significant enough to be identified as high- or low-value clusters.

The absence of high- and low-EDR clusters may also mean that states with high and low EDR remained in relative isolation, implying that some state-based characteristics, which may be high-quality medical and retiree services, certain health and tax policies, or cultural and policy factors, affected the concentration of older adult by states, but not cross-state regional factors such as climate or landscape. Such an interpretation would be compatible with the concept of "destination" state discussed in the prior age-migration literature (Conway & Houtenville 2003; Walters 2002, 2000; Serow 2001; Bean et al. 1994). States, such as Florida, offering "location-specific amenities" (Rogers & Raymer 2001; Greenwood and Hunt 1989) attract older adults (Rogers and Watkins 1987; Rowles 1986) who, in comparison to the younger, are more focused in selecting a destination state for their migration (Rogers, 1992). If neighboring states share similar

[24] The correlations between YDR and percent Hispanic/Latino at the state-level were 0.07, 0.32 ($p < 0.05$), and 0.18 for year 1990, 2000 and 2010, respectively.

[25] We computed correlations between YDR and state income tax rate (lowest rate) for the year 2000 and 2010 which were 0.35 ($p < 0.05$) and 0.23 respectively.

age-friendly policies besides environmental factors, they together may generate some forms of agglomeration effect influencing the concentration of older adults. (Conway & Houtenville 2003).

However, we found that temperature, a cross-state regional climatic factor, is only minimally correlated with EDR across states and over time.[26] On the other hand, state income tax, a state-specific factor that may be influential in determining the residential location of the retired population (Edwards 2018), also turned out to have no significant correlations to EDR. A paucity of space will not allow us to explore if other state-specific factors, such as health-care quality and policy, are significantly related to the variations in EDR across US states. Nevertheless, the counterintuitive findings may imply that factors attracting older adults may be spatiotemporally heterogeneous such that no one state-specific factor is significant over an extended geographical region (across states) over time. By the same token, factors significant in some states may not be consistently significant over time for those same states or in other states. For instance, the neighboring states of Florida and Georgia share the milder winter climate, but they fall at the opposite ends of the EDR spectrum. Similarly, Florida, Texas, South Dakota and Nevada have no/low income state tax.[27] However, while Nevada had a low EDR and South Dakota a high EDR in 1990, both however moved to the medium EDR-category subsequently. In contrast, Florida and Texas remained in the same EDR category over time (Table 3).

Our discussion hitherto has omitted one aspect of the spatial dynamic of population – migration of younger adults. Dependent children most likely move with their parents (Benetsky & Burd 2015). If families with children move from one state to another, this type of migration will not change the YDR of either the state of origin or the destination. But migration of young adults

[26] We used average annual temperature as an indicator of individual's perception of climate. The correlation of this indicator was low (<0.30) and not significant ($p > 0.05$).

[27] Approaches to tax personal income has varied over time and across the US with some states levying no income tax to others adopting either a regressive or a progressive or a flat rate in taxing individual income, and/or wage and salary income or dividend and interest incomes.

without children (in the 15-64 working category) will in the immediate term increase the YDR and EDR in the origin state but lower both these ratios in the destination state. However, as young adults will likely engage in reproduction later, the over-time and longer-run impact of such migration to destination states would be a raising of the YDR. In other words, migration of young adults will likely augment the disparities in YDR and EDR across states.

Within the overarching trend of graying of the US states, the sources of states' dependencies followed complicated spatiotemporal trajectories. EDR contribution to TDR (proportion EDR) was mildly clustered with a general trend of higher proportions in the northeast-east and lower proportions in the southwest-west. Some local clusters included Pennsylvania and West Virginia, and Alabama and Florida. In addition, changes in EDR contribution to TDR were also mildly clustered geographically. These findings are indeed curious and additional research is justified to further unravel and interpret these spatial trends in older adult dependencies.

Finally, the results of our state-level GWR analysis indicated considerable non stationarity in the association between the two types of dependencies, YDR and EDR, and states' economic performance, a finding that has not been previously identified using aspatial methods. The GWR results also indicated that the inverse association between youth dependency and economic productivity of states may be getting stronger. Although additional analyses would be warranted, preliminary policy implication of this finding would support state prioritization of programs catering to the needs of the youth and not just older adults. This strategy may be of significance as typically revenue and expenditure to support children and youth programs have primarily been the purview of states and localities as opposed to the federal government (Brucker 2006; Isaacs 2009).

The GWR results also reveal that the number of states characterized by low to medium inverse associations between EDR and state economic performance have been growing over the two decades. Such a finding may merit a reexamination of the economic potential of the older adults.

While the assumption that the older adults are not engaged in formal economic production may be accurate to a large degree (Santacreu 2016, Bloom, Canning, & Fink 2011), an extension of this assumption has been portraying this population to be economically conservative or even poor such that they may draw resources from local communities (Borjas 1990). But this picture may only be partially correct as some retirees are economically well off as indicated by recent rising wealth accumulation among this group (Chien & Sun 2019; Wolff & Zacharias 2009).[28] Thus, retired population could be a blessing to the local economy (Conway & Houtenville 2003; Day & Barlett 2000; Sastry 1992; Glasgow & Reeder 1990; Longino and Crown 1989). For instance, retirees are entitled to Medicare that partially pays the medical services of the older adults. These federal medical funds, similar to other health spending, may even boost state and local economies (Gitterman, Spetz, & Fellowes 2004).

While our study highlighted the changing contributions of the older adults (and the young) to total dependencies across the states and over time until 2010, the same analysis can be repeated with projected population data, which can be a separate study. Although exploratory in nature, the state-level spatiotemporal dependency trends that we highlighted warrant follow-up research. Although our study revealed state-specific trend scenarios related to the dependencies of the two sub-populations, the youth and the older adults, this analysis nonetheless concealed the variations within each state. Such intra-state variations are governed by a separate set of variables operating at the sub-state level, including urban-rural differences. For instance, factors such as higher-quality health facilities and older-care, lower property tax rates, and older-adult friendly amenities and infrastructure may attract the older adult population, but these factors vary across local jurisdictions at the sub-state level. Future endeavors should pursue a sub-state level spatiotemporal analysis of YDR and EDR.

[28] Wealth may include personal wealth and social security benefits (Gustman & Steinmeier 2001; Gustman et al. 1999).

Our study also presented a framework to analyzing the spatiotemporal patterns of age dependency. Although the focus was on the US demographic structure, the framework of our analysis should be highly transferrable to study other regions and countries. The data requirement for this framework is rather minimal – population counts by age groups. Given the graying trend in many parts of the globe (Davies and James 2011; McCracken and Phillips 2004), including Europe and parts of Asia, assessing the sources of dependencies at the sub-national level spatiotemporally can provide significant policy insights.

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Tables

Table 1: National estimates and state-level averages for dependency ratios, 1990-2010

	National Level Dependency Ratios			
	Total Dependency (TDR)	*Youth Dependency (YDR)*	*Elderly Dependency (EDR)*	*Ratio (EDR/TDR)*
1990	0.5174	0.3268	0.1906	0.3684
2000	0.5116	0.3236	0.1879	0.3674
2010	0.4901	0.2955	0.1946	0.3971
	Descriptive Statistics of State Dependency Ratios (mean / standard deviation)			
	Total Dependency (TDR)	*Youth Dependency (YDR)*	*Elderly Dependency (EDR)*	*Ratio (EDR/TDR)*
1990	0.5285 / 0.0502	0.3372 / 0.0436	0.1912 / 0.0348	0.3617 / 0.0562
2000	0.5096 / 0.0300	0.3202 / 0.0247	0.1895 / 0.0305	0.3707 / 0.0488
2010	0.4909 / 0.0347	0.2930 / 0.0326	0.1979 / 0.0262	0.4034 / 0.0475

Table 2. Correlation for dependency ratios between the three census years

TDR	*2000*	*2010*	***YDR***	*2000*	*2010*	***EDR***	*2000*	*2010*
1990	0.9255	0.9397	*1990*	0.8965	0.9130	*1990*	0.9617	0.8977
2000	-	0.9680	*2000*	-	0.9523	*2000*	-	0.9616

Table 3: A taxonomy of demographic dependency

Panel 1

	Low EDR	Medium	High EDR
Low YDR	Very young (least burden)	few youth	older
Medium	few older adults	"Average"	many older adults
High YDR	younger	many youth	dumbbell, extreme (most burden)

Panel 2

1990	Low EDR	Medium	High EDR
Low YDR		**MA, RI**, CT, NJ	
Medium	**CO, GA**, ***TX***, NV, VA		~~**IA, PA, FL**~~, ND, AR, ***WV***
High YDR	AK, **UT**	**ID**, MT, NM, LA	SD

Panel 3

2010	Low EDR	Medium	High EDR
Low YDR		**MA, RI**, NH, VT	ME, ***WV***
Medium	**CO, GA**, CA, AK		**IA, PA, FL**
High YDR	**UT**, ***TX***	**ID**, AZ	

1. States in **bold-normal** font stayed in their non-average categories over the two decades.
2. States in ***bold-italics*** moved to the more extreme categories.
3. In Panel 2, states with normal font moved to the more average categories while in Panel 3, states with normal font moved from the average to the more extreme categories.

Table 4: Descriptive Statistics

Variable		1990	2000	2010
GSP per capita[a]	Min.	0.02*(Montana)*	0.02*(Mississippi)*	0.03*(Mississippi)*
	Max.	0.07*(DC)*	0.11*(DC)*	0.18 *(DC)*
	Mean	0.0223	0.0356	0.0491
YDR	Min.	0.23*(DC)*	0.24*(DC)*	0.19*(DC)*
	Max.	0.52*(Utah)*	0.41*(Utah)*	0.42*(Utah)*
	Mean	0.3364	0.3195	0.2930
	Correlation[b]	-0.50***	-0.419***	-0.505***
EDR	Min.	0.14*(Utah)*	0.13*(Utah)*	0.14*(Utah)*
	Max.	0.29*(Florida)*	0.28*(Florida)*	0.27*(Florida)*
	Mean	0.1944	0.1915	0.1994
	Correlation[b]	-0.221	-0.214	-0.356**

[a] Millions of current dollars; [b] correlation with GSP per capita; *** $p < 0.01$; ** $p < 0.05$

Table 5: Global Regression Coefficients, 1990, 2000, 2010

Variable		1990	2000	2010
Intercept		0.0652***	0.1608***	0.2700***
YDR		-0.0879***	-0.2815***	-0.4191***
EDR		-0.0688***	-0.1847***	-0.4923***
Adj. R^2		0.2853	0.2798	0.5201
AICc	Global	-355.4762	-303.8845	-273.5802
	Local (GWR)	-395.6924	-311.7344	-305.2197

GSP per capita (Millions of current dollars) = dependent variable in all models; *** $p < 0.01$

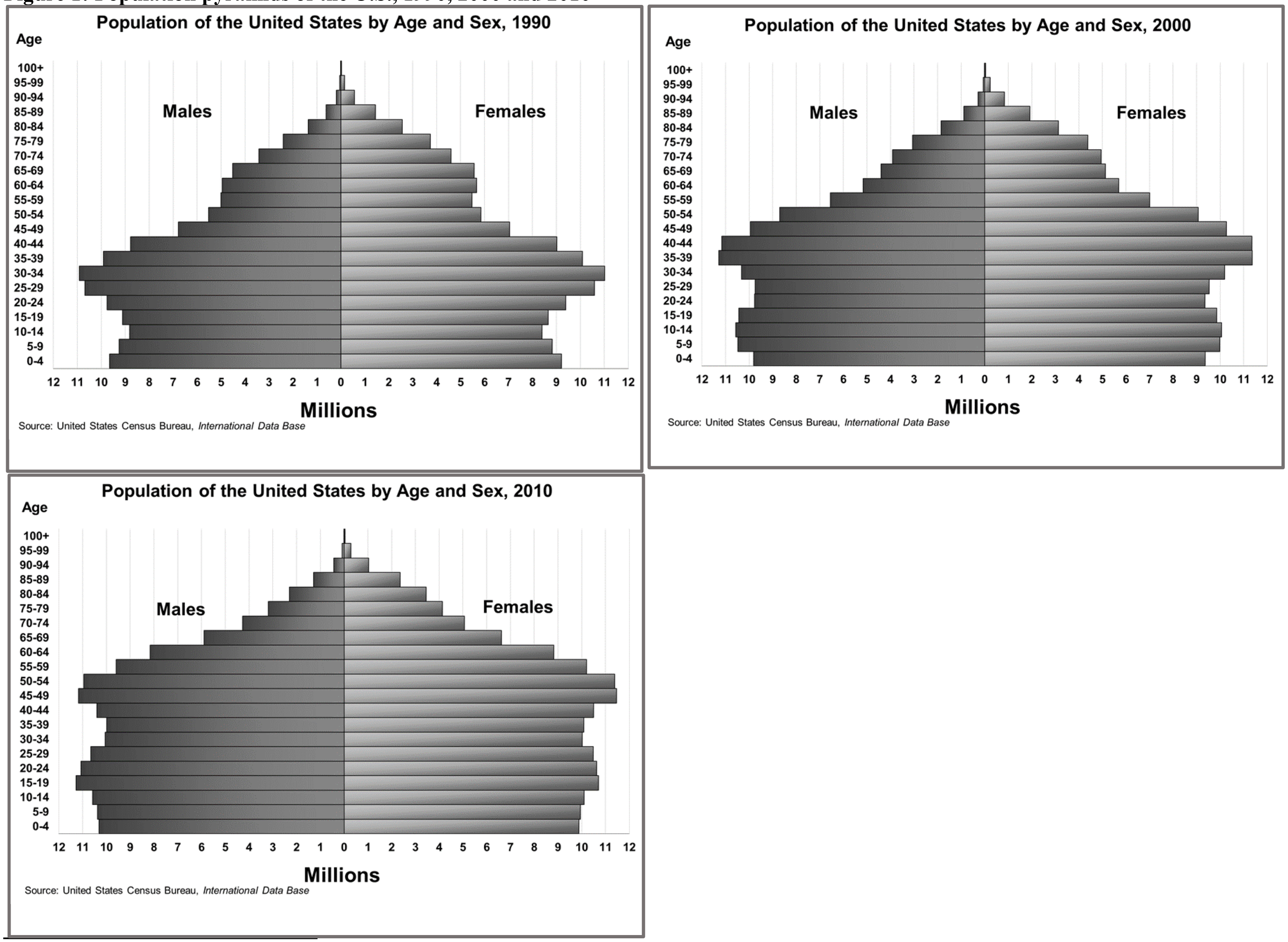
Table 6: Difference of Criterion† comparing GWR against Mixed GWR models, 1990, 2000, 2010

Variable	1990	2000	2010
Intercept	-106.9921	-191.1632	-146.2780
YDR	-68.6609	-63.2447	-64.0947
EDR	-45.1309	-16.3742	-14.7930

† The "Difference of Criterion" statistic is a model comparison indicator which is the difference in the AICc values obtained from the original GWR model and the switched GWR model. If the switched GWR model does not attain a statistically better fit, then the difference of criterion value is negative indicating spatial variability in the switched local term (regression variable). If the difference of criterion is greater than -4, then the case for spatial variability of the switched term is clearly supported.

Figures

Figure 1: Population pyramids of the U.S., 1990, 2000 and 2010[29]



[29] We generated the population pyramids using data available from the U.S. Census International Data Base at https://www.census.gov/data-tools/demo/idb/informationGateway.php.

Figure 2: Geographical distributions of TDR, YDR, and EDR across the US states, 1990, 2000, 2010

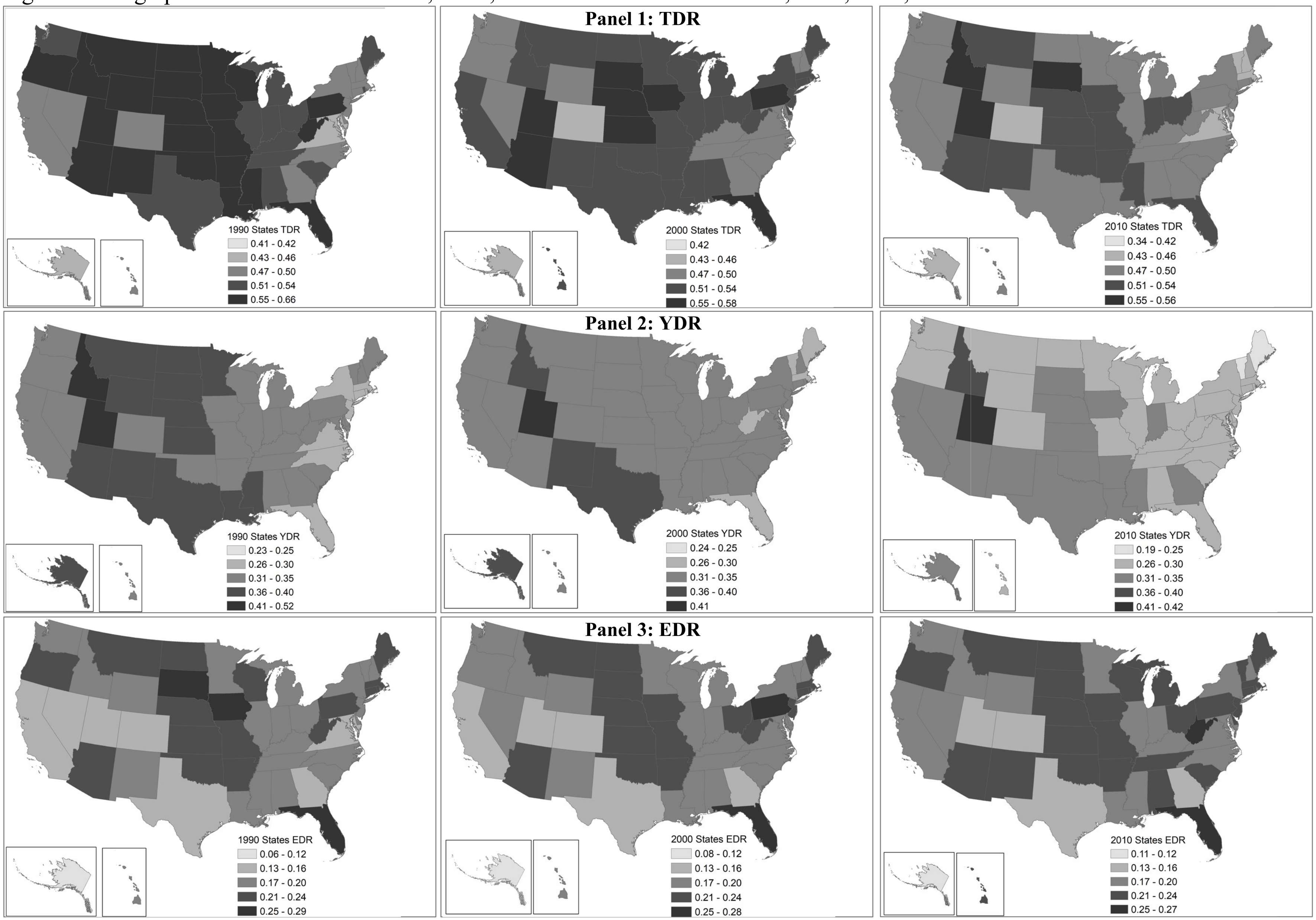


Figure 3: Maps of local Moran for YDR and EDR, 1990, 2000, and 2010

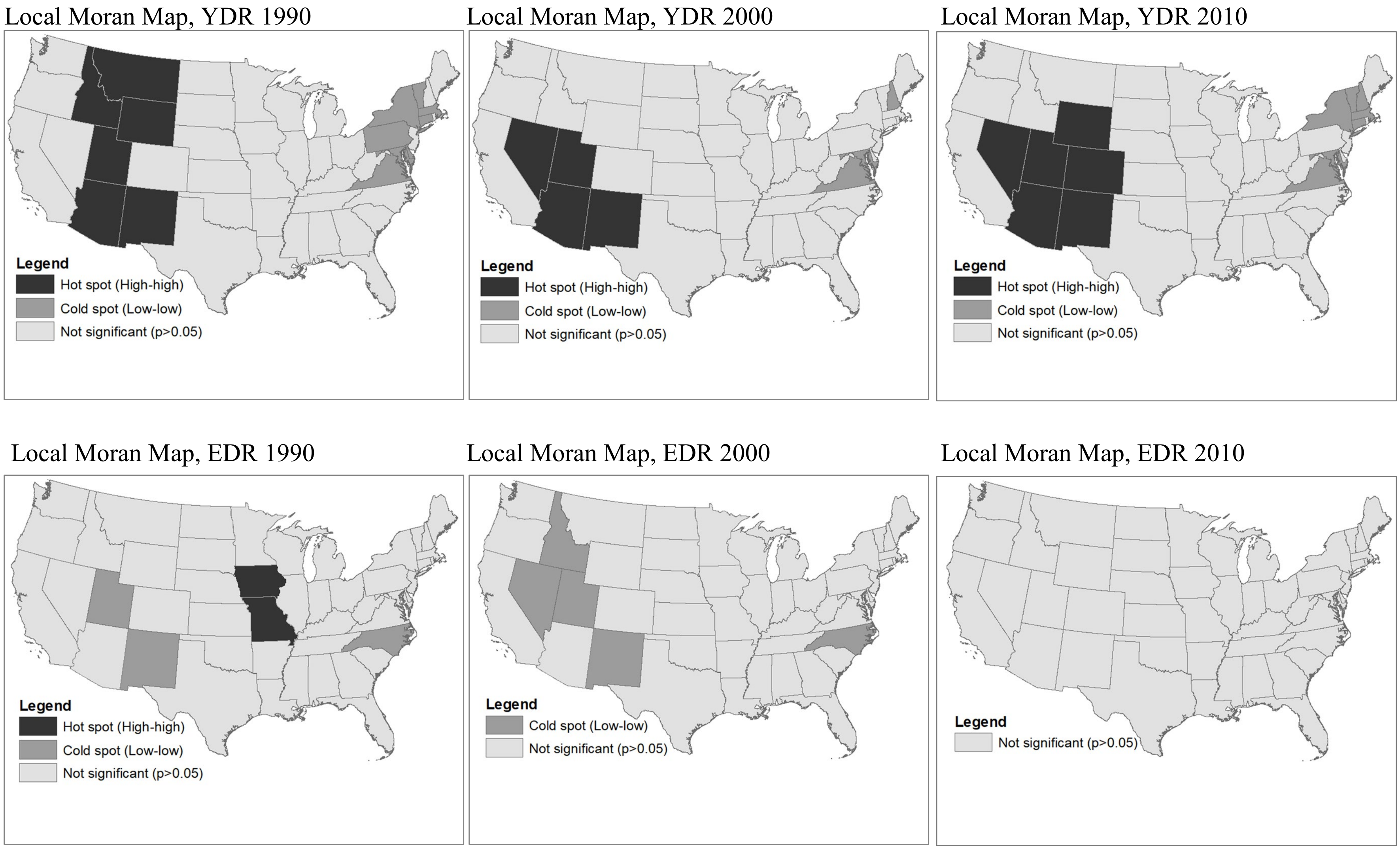


Figure 4: Geographic distributions of states in the "average" categories in both YDR and EDR, 1990, 2000, and 2010

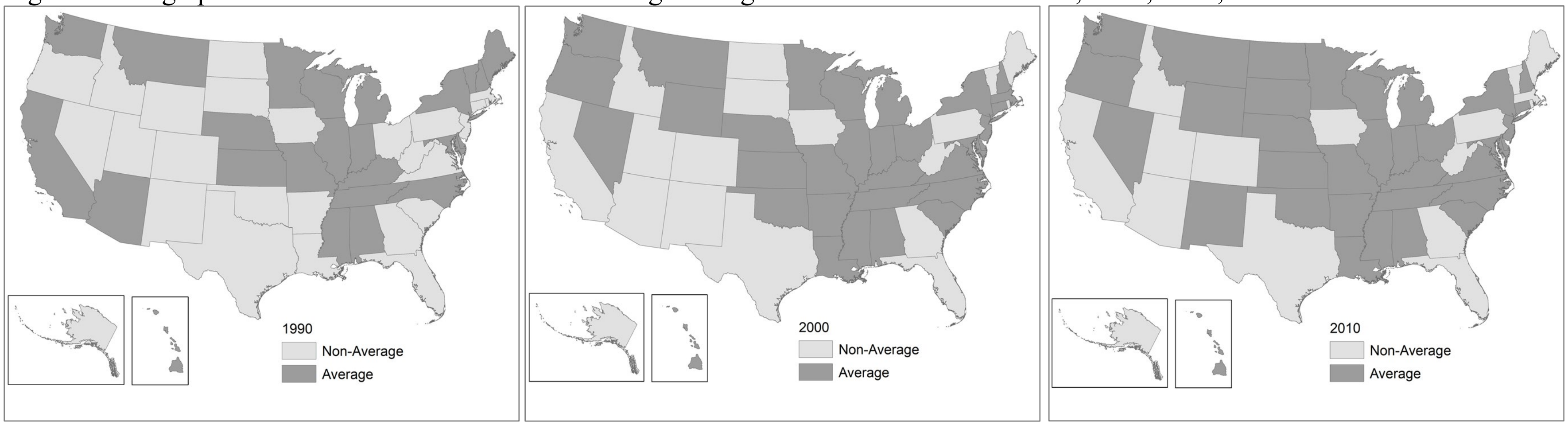


Figure 5: Micromap††, 1990

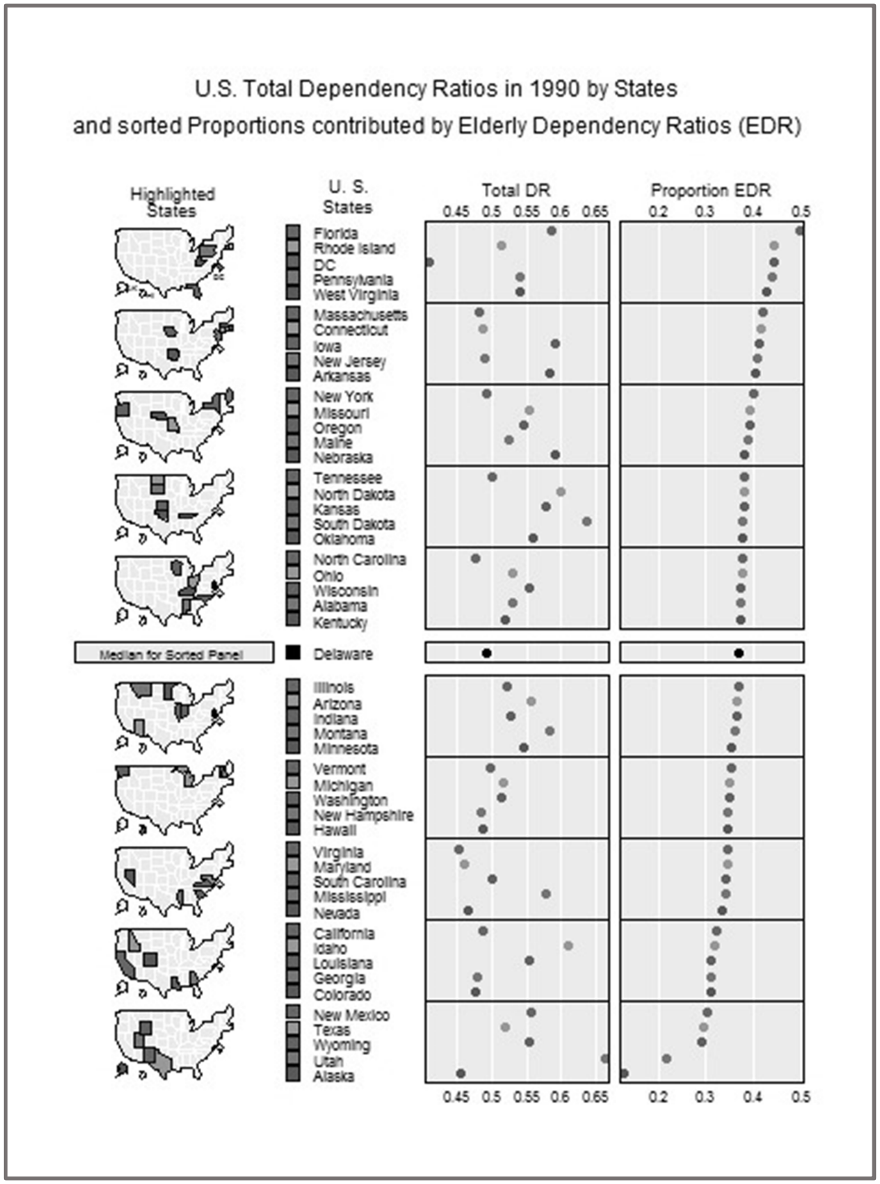


Figure 6: Micromap††, 2000

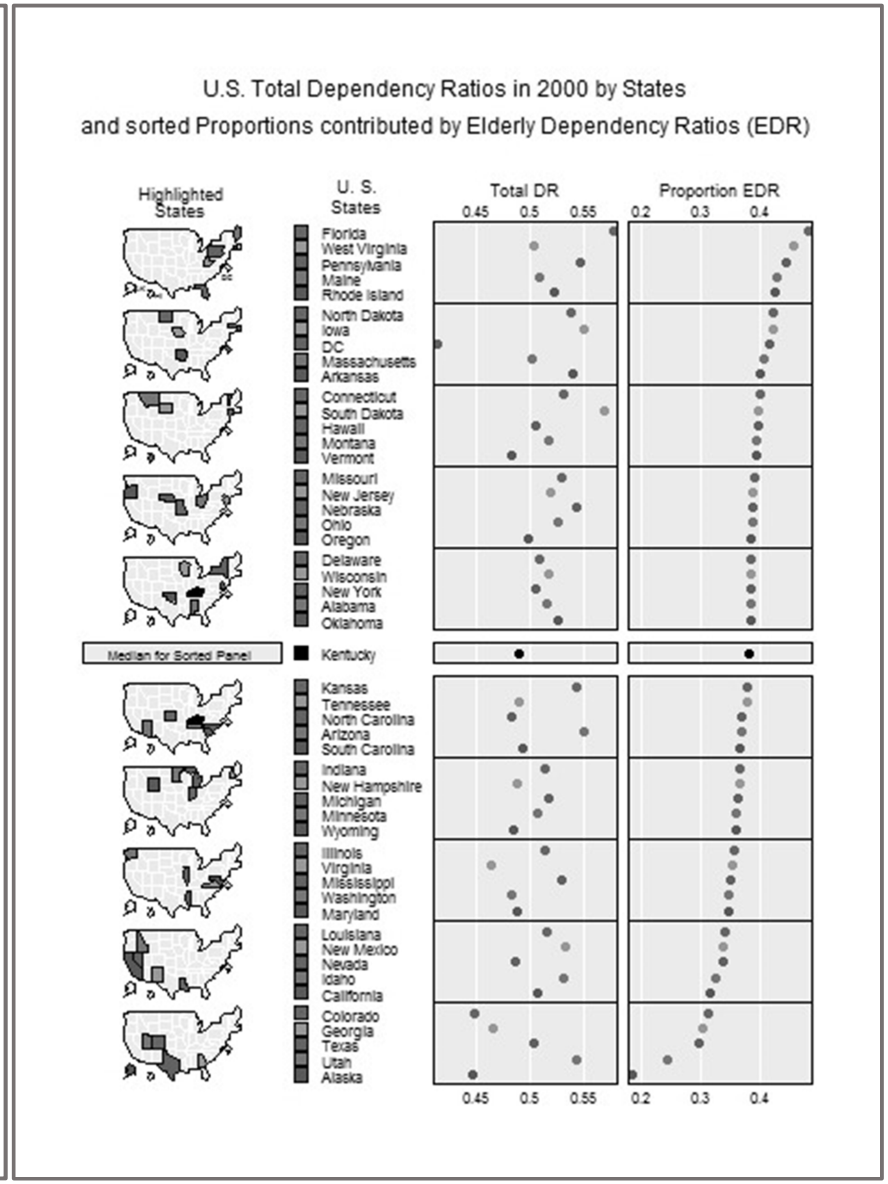
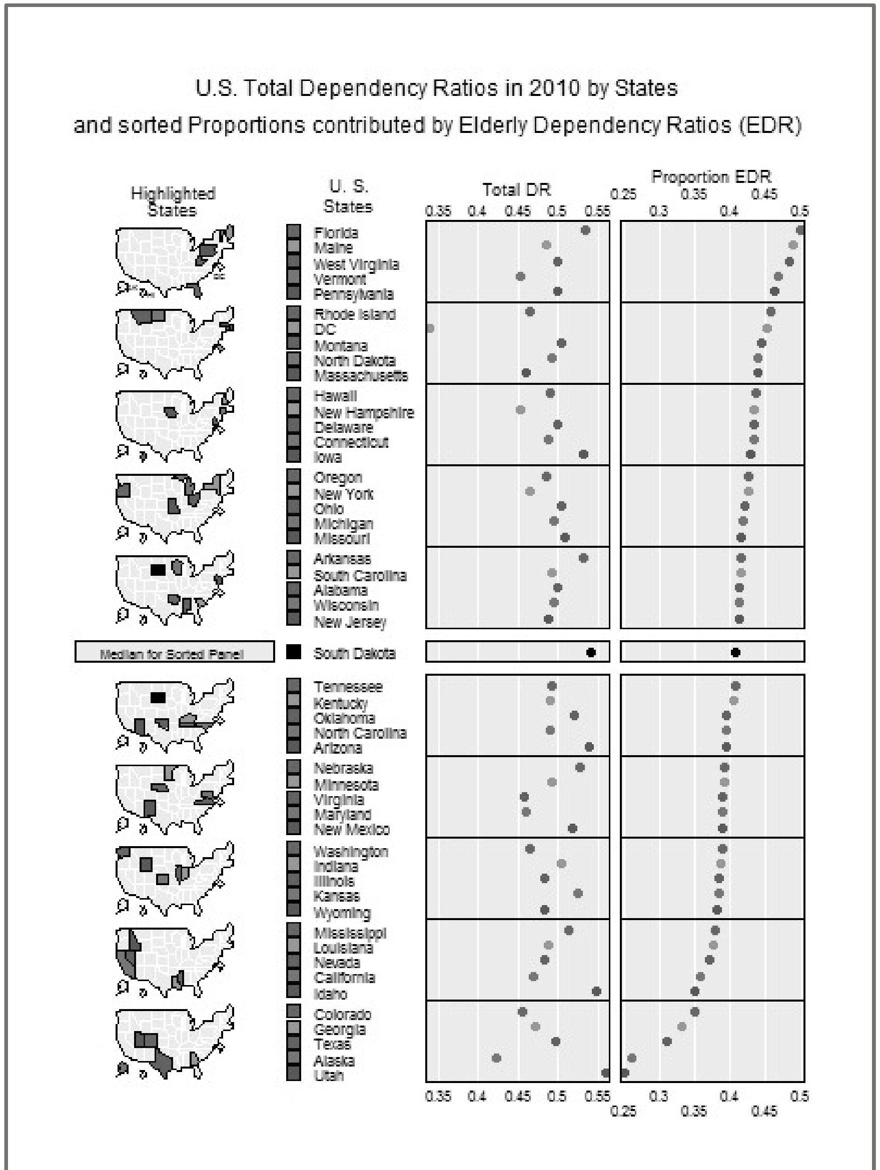


Figure 7: Micromap††, 2010



††The original design of micromaps uses a five-color scheme in each sub-panel for the five states on the map corresponding to the five color dots on the parallel plots. High-resolution color micromaps figures are available from the authors.

Figure 8: Change in Proportion of EDR contributing to TDR, 2000–1990 and 2010–2000

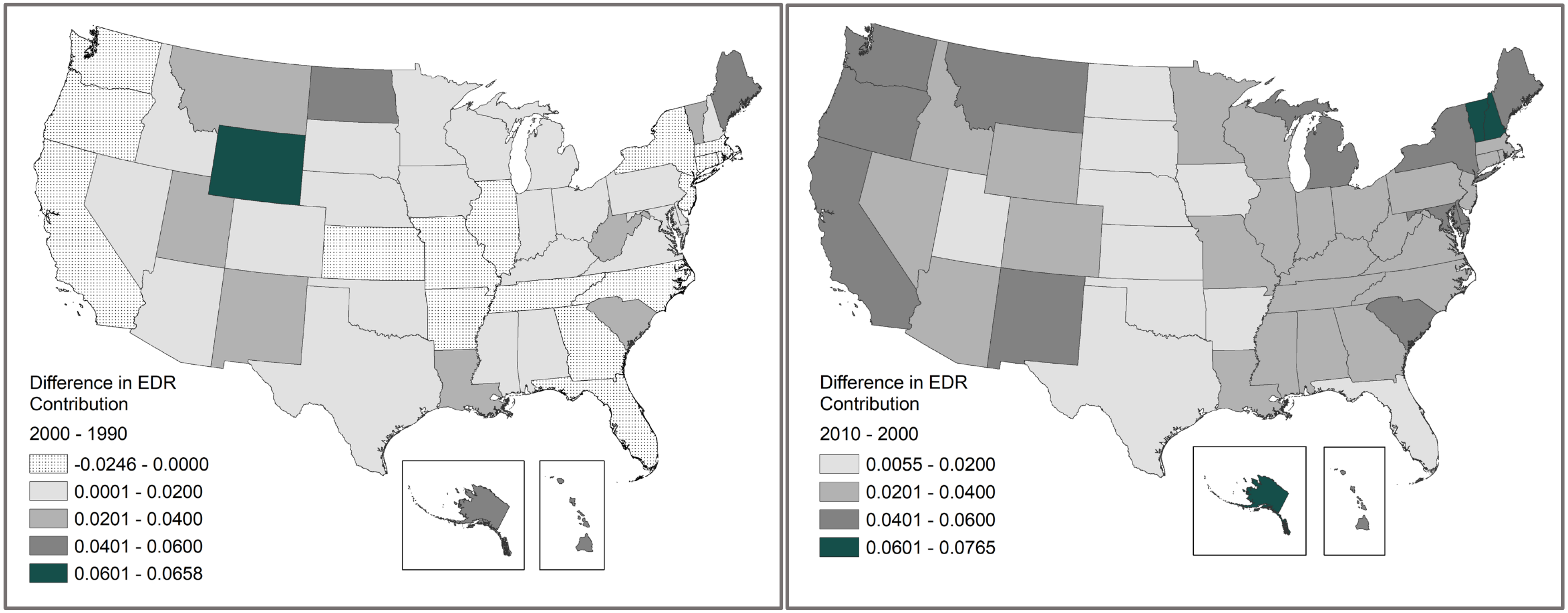
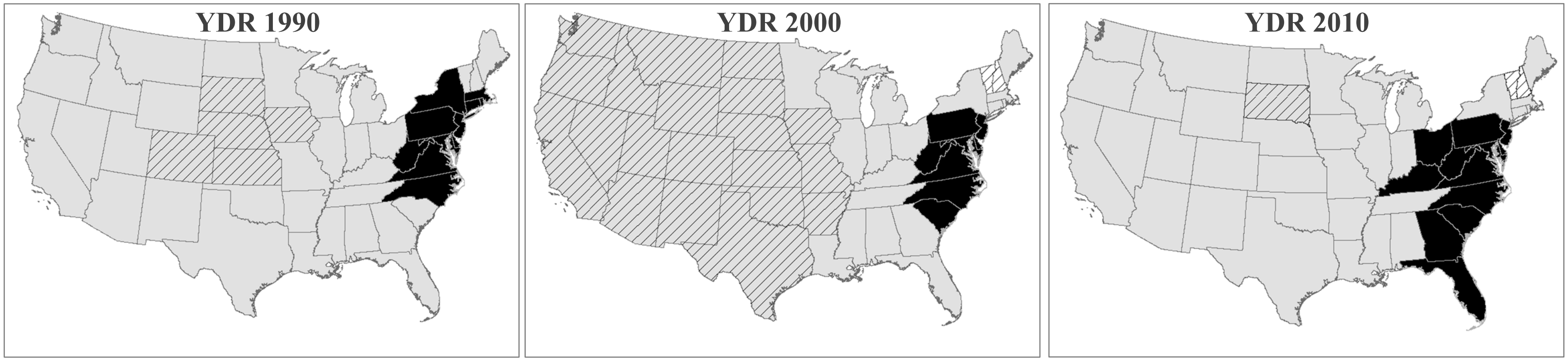
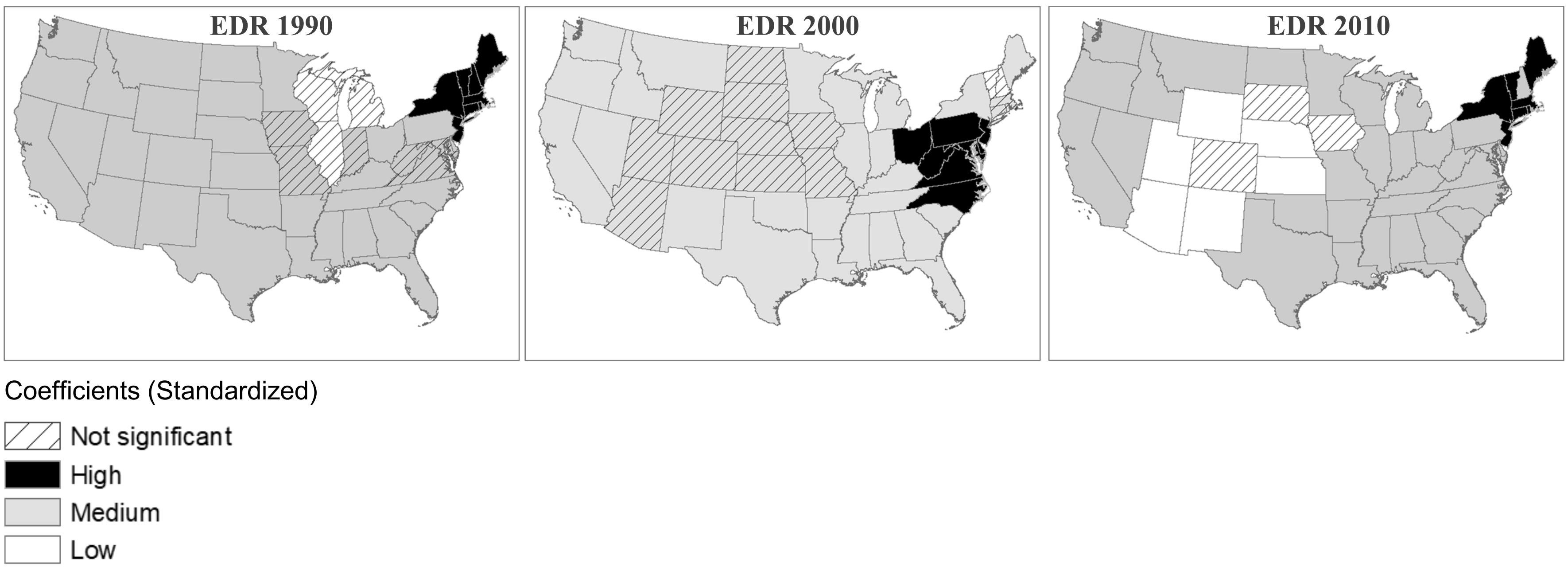


Figure 9: Spatial variation in local coefficients for YDR and EDR, 1990, 2000, and 2010

Panel 1: YDR local coefficients



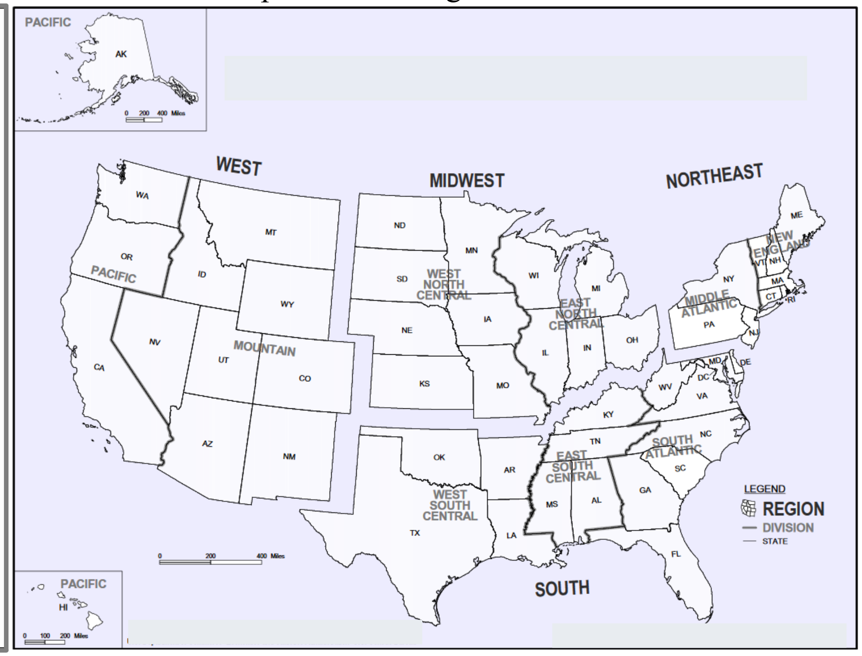
Panel 2: EDR local coefficients



Appendix

A1: Reference map of states of the US

A2: Reference map of Census regions and divisions in the US



Source: Us Bureau of Census, Geography Division, Department of Commerce, Economics, and Statistics Administration. Retrieved from https://www2.census.gov/geo/maps/general_ref/pgsz_ref/CensusRegDiv.pdf