Measuring Residential Segregation

Trevon D. Logan*and John M. Parman‡

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Abstract

This paper introduces a new measure of residential segregation based on individual-level data. Our measure allows us to analyze segregation consistently and comprehensively for all areas in the United States. We exploit complete census manuscript files to derive a measure of segregation based upon the racial similarity of next door neighbors. This measure overcomes several of the shortcomings of traditional segregation indices and allows for a richer view of the variation in segregation patterns across time and space. This measure can distinguish between the effects of increasing racial homogeneity of a location and the tendency to segregate within a location given a particular racial composition. We provide estimates of how our new measure relates to traditional segregation measures, showing that our measure reveals aspects of racial distributions not captured in traditional indices. We find that segregation increased significantly nationwide from 1880 to 1940. This dramatic increase in segregation was not driven by black migratory patterns, but rather resulted from a nationwide decrease in interracial neighbors. The likelihood that an African American household had a non-African American neighbor declined by more than 15 percentage points (more than a 25% decrease) in the early twentieth century. In all areas of the United States – North and South, urban and rural – racial segregation increased dramatically.

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PRELIMINARY DRAFT

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*Department of Economics, The Ohio State University and NBER, 1945 N. High Street, 410 Arps Hall, Columbus, OH 43210 e-mail: logan.155@osu.edu

†Department of Economics, College of William and Mary and NBER, 130 Morton Hall, Williamsburg, VA 23187 e-mail: jmparman@wm.edu

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"We make our friends; we make our enemies; but God makes our next door neighbor."

- Gilbert K. Chesterton, *Heretics* (1905)

1 Introduction

This paper introduces a new measure of residential segregation. Our measure uses the complete manuscript pages of the federal census to identify the races of next-door neighbors. We measure segregation by comparing the number of household heads in an area living next to neighbors of a different race to the expected number under complete segregation and under no segregation (random assignment). The resulting statistic provides a measure of how much residents tend to segregate themselves given a particular racial composition for an area. The measure allows us to distinguish between the effects of differences in racial composition and the tendency to segregate *given* a particular racial composition. Our measure can be consistently applied over time. A particular advantage is that we can aggregate our measure to any boundary without losing the underlying properties since it is defined at the individual level.

To our knowledge, our measure of segregation is the first to exploit actual residential living patterns of households and the first to be equally applicable to rural and urban areas. Previous advances in the measurement of segregation have attempted to use smaller geographic units (Reardon & Sullivan, 2004; Echenique & Fryer, 2007; Reardon et al., 2008), but none have comprehensively exploited the actual pattern of household location as we do here. As such, our measure is the first to give a complete picture of segregation for the entire United States, not only urban areas. While analysis of segregation has primarily been focused on cities, there are few theoretical reasons to believe that rural segregation is unimportant or unrelated to socioeconomic outcomes for rural residents (Lichter et al., 2007).

Traditional segregation measures, with their focus on cities, are ill-suited to describe the evolution of segregation over time. For example, between Reconstruction and World War II there was dramatic change in urban locations. In 1870 roughly 90 percent of blacks lived outside of cities and by 1940 more than half lived in urban areas (see Figure 1). A broad, long-run view of segregation that encompasses both urban and rural areas is required if we are to understand its function and change over time. If

migratory patterns and geographic dispersion are the product of equilibrium processes, we must have information on all areas to properly analyze national economic change and its impact on incentives to migrate, population flows, urbanization, agglomeration, and resulting segregation patterns in rural and urban communities.

The traditional narrative of segregation in the United States supposes that migration of African Americans from the rural South to urban communities, especially in the North, gave rise to segregated cities that persist to this day. Missing from this narrative is any analysis of the national trend in segregation. We do not know if segregation is an urban phenomena or equally likely to exist in rural communities. Even more, we do not know if population flows from rural to urban areas were the result of rural segregation patterns or what effect (if any) that segregation had on schooling, public goods, wages, inequality, and labor markets. Similarly, we do not know if increasing segregation in urban areas was related to increases or decreases in rural segregation.

It is clear that any explanation of modern racial differences in socioeconomic outcomes must account for the effects of residential segregation on a host of factors. The literature suggests that the effects of segregation on socioeconomic outcomes are potentially strong but also complicated. The effects depend on the precise pattern of segregation, the extent of social interactions within and between groups, and the extent to which residential segregation leads to differential access to schools, health care and labor markets. There are a variety of studies linking segregation in the United States to schooling and labor market outcomes for blacks (Kain, 1968; Cutler et al., 1999; Cutler & Glaeser, 1997; Collins & Margo, 2000). Segregation has also been shown to impact the health of the black community through a lack of access to health care (Almond et al., 2006; Chay et al., 2009). Additionally, there is a growing literature on the importance of neighborhood effects and social networks suggesting that segregated communities could contribute to racial gaps in a variety of socioeconomic outcomes (Case & Katz, 1991; Brooks-Gunn et al., 1993; Borjas, 1995; Cutler et al., 2008; Ananat, 2011; Ananat & Washington, 2009; Echenique & Fryer, 2007).

A comprehensive measure of segregation is an important empirical element in a growing literature which seeks to analyze the institutional development of the United States. Local labor markets, agricultural productivity, capital accumulation, income inequality, suffrage, human capital and migration

have all been linked to institutional structures which began and diverged in the antebellum era. While regional income differences are well known, scholars have found strong evidence in support of the persistence of regional-specific institutions on a range of economic outcomes (Naidu, 2012; Alston & Ferrie, 1993; Wright, 1986; Margo, 1990; Hornbeck & Naidu, 2014; Ramcharan, 2010). The effects of these institutional developments have obvious implications for the residential living patterns of black and white residents in rural communities. To date, however, we do not know if or how institutional development was related to residential segregation.

Our project fills a large gap in our knowledge of segregation and its change over time. This not only answers the question of how segregation changed but also the question of how persistent segregation was as a national phenomena. Questions regarding the strength of the relationship between segregation and racial inequality hinge on issues of selection into segregated areas that requires a comprehensive measure of segregation. Moreover, existing segregation measures inherently obscure the effects of sub-district segregation, making empirical progress on this issue difficult. The debate over the effect of neighborhood-level mechanisms and socioeconomic outcomes has shown that neighborhood effects may or may not be strong and persistent depending on the outcome (Kling et al., 2007). Progress in this area requires a measure of neighborhood segregation that moves beyond tract-level population shares and exploits a finer level of detail, giving researchers a more accurate description residential dispersion.

In what follows we derive our measure of segregation, which is based on the similarity of residential neighbors. (Our measure has the additional advantage of being flexible to any definition of neighbor.) Next, we perform a simulation exercise to verify the properties of the measure. The simulation establishes that our measure captures residential housing patterns and performs as predicted as the dispersion of households by race and the underlying racial composition of the area vary. In particular, we show that our measure works well in areas with small numbers of black households and works in the presence of missing households in enumeration. We then apply our measure to the full, 100% census for both 1880 and 1940, exploiting the census takers' sequenced alignment of households to identify the race of household heads and their neighbors.

The results uncover a substantial amount of heterogeneity in segregation within and across regions

in both cities and rural areas. We also show how our measure of segregation differs significantly from the existing segregation measures in important ways. While our measure is correlated with the percentage of black households in a county we also find that the percentage of black households hides a considerable amount of residential racial segregation and integration in both rural and urban communities. Similarly, our measure is weakly correlated with standard segregation measures such as dissimilarity and isolation. A key result in our comparison is that we show that traditional measures are very sensitive to geographic boundaries while our measure is not.

Finally, we show that our segregation measure reveals that increasing segregation in the United States was not confined to urban areas. Segregation, as measured with next door neighbors, doubled nationally from 1880 to 1940. Even more, our measure shows that the likelihood of a black family having an opposite race neighbor declined by more than 15 percentage points from 1880 to 1940, more than a 25% decline in the likelihood of opposite race neighbors. Rather than being the product of black migratory patterns or regional differences in black location patterns, we show that the increase in racial segregation was quite general. Rural and urban areas, North and South, saw dramatic increases in racial segregation. We conclude by noting how our new measure of segregation calls for a reinterpretation of segregation patterns over time and how our measure can be used to answer a broader range of questions about both the historical and contemporary effects of segregation.

2 A New Measures of Segregation

Our measure is an intuitive approach to residential segregation. We assert that the location of households in adjacent units can be used to measure the degree of integration or segregation in a community, similar to Schelling's classic model of household alignment. At its core, the Schelling concept of segregation is based on next-door neighbors.[1] The popular discussions of segregation and preferences for racial integration, particularly in survey data, use neighbors as the criteria. A standard approach is Farley et al. (1997), which shows examples of a neighborhood layout and a reference household or Bobo & Zubrinsky (1996) and Zubrinsky & Bobo (1996), which elicit preferences for

[1] In the classic formulation, segregation is the product of household preferences over the race of their neighbor and their neighbor's neighbor. For a recent example of the test of Schelling's tipping model see Card et al. (2008).

same race neighbors.[2] As such, our measure of segregation is well-aligned to the definition of residential segregation.

We take the Schelling model to enumeration, where households are aligned on a line with neighbors. Areas that are well integrated will have a greater likelihood of opposite race neighbors that corresponds to the underlying racial proportion of households in the area. The opposite is also true— segregated areas will have a lower likelihood of opposite race neighbors than the racial proportions would predict.

We calculate the predicted number of black households with white neighbors given the number of black and white households in the area assuming that households are randomly located by race and assuming that households are completely segregated (only the households on the edge of the all black community have white neighbors and vice versa). The segregation measure is then simply an estimate of how far the actual number of black households with white neighbors is between these two extremes. In essence, our measure is a counterfactual between the observed and hypothetical distributions of households in a given area.

This measure uses the census enumeration ordering of households to define neighbors, exploiting the fact that adjacent households along each side of a street appear next to each other on the census manuscript page. This is a one-dimensional approach to neighbors given the limitations of the data; the census manuscript pages do not identify neighbors living behind or across the street from a household. Whether one has an opposite race neighbor across the street or across a back alley, however, is highly correlated with the likelihood of an opposite race neighbor next door. Our measure is, then, a one dimensional measure that is a sample from the total set of next-door neighbors. There is not a reason to believe that this measure would be biased by not including the neighbors in front or behind of the household, especially since these neighbors are still included as next-door neighbors of another household in the data.[3]

The advantages of our approach are most apparent when comparing them to the most popular existing measures of segregation– the index of dissimilarity (a measure of eveness) and the index of isolation (a measure of exposure).[4] The index of dissimilarity is a measure of how similar the

[2]Studies such as Clark (1991) ask respondents about racial proportions, but these are rare.

[3]In many rural areas at the time neighbors really are situated along a line. For example, a row of homes along a road may not have neighbors in any other dimension.

[4]See Massey & Denton (1988) for a complete list of traditional segregation measures.

distribution of minority residents among geographical units is to the distribution of non-minority residents among those same units.[5]

One way to interpret this index is as measure of how evenly black residents are distributed across tracts within a city. If black residents are distributed identically to white residents (a tract with 10 percent of the black residents also has 10 percent of the white residents), the index of dissimilarity will be zero. As black residents become less evenly dispersed across census tracts, the index of dissimilarity takes on a larger value.

The index of isolation provides a measure of the exposure of minority residents to other individuals outside of their group.[6] This is a measure of the racial composition of the census tract for the average black resident, where racial composition is measured as the percentage of the residents in the tract who are black. If there is little segregation, this measure will approach the percent black for the city as a whole. If there is extensive segregation (blacks are highly isolated), this measure will get larger as the tracts containing black residents become more and more homogeneous.

Cutler et al., Collins & Margo and Troesken demonstrate that these traditional measures of segregation can be applied to historical data for cities. Cutler et al. (1999) and Collins & Margo (2000) use these measures to consider the changes in urban residential patterns over the twentieth century. These patterns across cities tended to persist over time, with the most segregated cities at the turn of the century also being the most segregated cities at the end of the century.[7]

One problem of these traditional measures is that they are inherently aspatial within any given area. While our measure exploits household alignment along a line, the traditional measures only use

[5]Formally, if i is an index for the N census tracts within a city, B_i is the number of black residents in tract i, B_{total} is the total number of black residents in the city, W_i is the number of white residents in tract i, and W_{total} is the total number of white residents, the index of dissimilarity for the city is:

$$\text{Dissimilarity} = \frac{1}{2}\sum_{i=1}^{N}\left|\frac{B_i}{B_{\text{total}}} - \frac{W_i}{W_{\text{total}}}\right|$$

[6]Using the same notation, the index of isolation for a city is given by:

$$\text{Isolation} = \sum_{i=1}^{N}\left(\frac{B_i}{B_{\text{total}}} \cdot \frac{B_i}{B_i + W_i}\right)$$

[7]It is this variation in segregation across cities that Troesken (2002) exploits when looking at the health improvements resulting from the provision of water and sewerage service during the Jim Crow era. Cities that were more segregated as measured by the index of isolation saw smaller health improvements for black residents relative to white residents.

population shares with a given area. This is particularly problematic for segregation as a proxy for social interactions, social networks, and interpersonal exchange. As the level of aggregation increases, within-area segregation is inherently obscured in traditional measures.[8]

There is a second critique of using isolation and dissimilarity to measure segregation that has special importance when considering the history and evolution of segregation. Echenique & Fryer (2007) and Lee et al. (2008) note that these measures are highly dependent on the way the boundaries of the geographical subunits are drawn. Indeed, it is an issue that Cutler et al. must deal with when the available data switches from ward-level data to census tract-level data in 1950. In the cases where Cutler et al. have data at both the ward and census tract levels, the correlation between the index of dissimilarity using wards and the same index using census tracts is only 0.59— 0.35 with one outlier removed.

What makes this particularly problematic for historical segregation is that political motivations when drawing ward boundaries can have dramatic effects on segregation measures and the inference we draw from those measures. A city in which wards are drawn to minimize the voting power of black residents by dispersing their votes across wards may appear to be highly integrated. If the same city had wards drawn to make it easier to discriminate in the provision of public services by placing black residents in a small number of wards it would appear completely segregated according to the segregation measures. The endogenous nature of political boundaries makes it difficult to analyze segregation as the cause or consequence of institutional development using traditional measures.[9]

Our new measure does not suffer from the limitations of using political boundaries for geographical subunits and in fact does not require geographical subunits at all, making it possible to look at

[8]Rhode & Strumpf (2003) analyze inequality in counties, but they do not calculate traditional segregation measures for all counties. Lichter et al. calculate dissimilarity for rural areas using 1990 and 2000 census data using census blocks. They find that the pattern of segregation is rural communities is very similar to the pattern in urban communities. African Americans are the most segregated racial group in both rural and urban areas. They note that the highly aggregated nature of the census block in rural communities limits their ability to speak to the forces shaping the segregation patterns they observe due to the aspatial nature of the measure.

[9]For example, consider the case of Richmond, in the which the ward lines were drawn to include over one third of the city's black population within the Jackson Ward, making that ward 80 percent black in 1880 (Rabinowitz, 1996, page 98). The efforts to minimize black voting power through gerrymandering were publicly discussed in cases such as Raleigh, where the Republican leaders advised black residents to move to the Fifth Ward which had not been gerrymandered. The local newspaper noted that blacks attempting this would find it "difficult to get houses when it is known they move only to carry the election and keep control of a much plundered city" (from the *Daily Sun* as quoted in Rabinowitz (1996, page 105)).

segregation in *any* geographical area, a key innovation of our approach. At the same time, our measure is inherently spatial in that it uses enumeration and the nearest household to define neighbors. Rather than asking whether an individual lives in a ward or tract with many black residents, a question that hinges on how wards or tracts are defined, we can ask whether an individual's nearest neighbor is of the same race, a question that can be consistently and universally applied to all households.[10]

Our approach has a number of additional advantages. First, we focus on households as opposed to the population. The degree of residential segregation depends on the number of *households* of different types, not the number of individuals. If members of one group have larger household sizes or different household structure (for example, more likely to live in multiple generation households) there will be a difference between the population share and the household share. Household structure and size are known to vary by race historically and at present (Ruggles et al., 2009). Another advantage is that this measure is also an intuitive proxy for social interactions. Neighbors are quite likely to have some sustained interactions with each other, and an increasing likelihood of opposite race neighbors implies that the average level of interactions across racial lines would be higher. Indeed, social interaction models of segregation are inherently spatial and assume that close proximity is related to social interactions both directly and indirectly (Echenique & Fryer, 2007; Reardon et al., 2008).[11] At the same time, while we exploit the ordered fashion of census enumeration, we do not assume that entire enumeration districts were surveyed in a linear fashion. Lastly, our measure can be decomposed to analyze the determinants of changes in segregation. For example, one can calculate how much of the change in segregation is due to changes in the number of blacks with opposite race neighbors, the

[10] Grigoryeva & Ruef (2014) build on the method of Agresti (1980) and calculate a sequenced index of segregation that counts of "runs" (sequences) of households by race. While related to our measure, their measure requires the strong assumption that the entire enumeration district was surveyed in a linear fashion. As described below, our measure deals directly with this issue and the simulation results described later show that our measure is robust to measurement error due to the mapping of non-linear geographic locations into linear rosters.

[11] We are careful to stress that our approach to segregation is focused on a measure of residential segregation. We do not propose a model of optimal household location choice as household location decisions are a function of their own preferences and the location of neighbors of preferred type. The problems of aggregating such measures over a community are further compounded by inherent geographic differences in locations that may be related to household location decisions. Here, our concern is deriving an intuitive measure that captures a key feature of residential living patterns by race. Models which apply a network approach to segregation assume that a person's social network is closely tied to their residential living pattern, and without direct information on the actual social network such measures may not capture actual exposure to more or less segregated individuals. Similarly, any model proposed with preferences over racial composition would need to account for changing preferences over time, which themselves could vary by racial group and geographic location (Card et al., 2008).

expected number of blacks with opposite race neighbors under random assignment, or changes in the minimum number of opposite race neighbors under perfect segregation.

2.1 Next Door Neighbors and Census Enumeration

We exploit a feature of historical census enumeration to derive our segregation measure. Census enumerators went door-to-door to survey households. This implies that the position on the manuscript census form gives us the best possible measure of the actual location and composition of households as one would "walk down the street" from residence to residence. Proximity in the manuscript census form is, by design, a measure of residential proximity. We assume that adjacent appearance on the manuscript census form as evidence of being neighbors.

There are several historical facts which support our assumption (Magnuson & King, 1995; Grigoryeva & Ruef, 2014; Agresti, 1980). First, enumerators were expected to be from the districts they were enumerating and to be familiar with the area and its residents. Second, the official training of enumerators specifically required an accurate accounting of dwellings containing persons in order of enumeration. A personal visit to each household was required. As enumerators were allowed to obtain information when household members were not present, it is highly likely that ordering in the census was in alignment to actual living patterns. Third, enumeration instructions strongly encouraged that households be recorded as they were aligned. For example, enumerator instructions explicitly directed enumerators to leave blank spaces for households who could not be surveyed upon the first visit, filling in those entries in a subsequent visit. Fourth, enumeration was publicly checked– after enumeration, census law required the public posting of each enumeration for public comment and correction. Specifically, enumeration was to be publicly posted for comment for a period of several days. In some large cities local newspapers and other local contingents checked the early returns for accuracy. This was allowed to ensure that complete counting was performed and also to ensure that household assignment of individuals was correct. Fifth, enumeration was often cross-checked with external sources such as voting records and other municipal information that would be recorded in sequenced household order. Sixth, the accuracy of the records had to be ascertained before the enumerator received payment. Census officials adopted a rough tracking system that allowed them

to detect gross over- or under-counting of households.

Moreover, the monitoring and training of census takers became standardized with the tenth decennial census (in 1880). For our purposes, the advances in census enumeration beginning in 1880 are key. Earlier censuses are known to be controversial and demographic historians dispute their accounting of the population. In fact, the misreporting on census forms and the public outcry against the 1870 returns prompted reforms in the appointment, training and monitoring of census takers. For example, census officials did deny the appointment of enumerators who were politically connected or judged to be unqualified. This is very important for the South, as early enumeration (in 1870) was criticized as enumerators did not venture to homes as required by law. Magnuson (2009) notes that "[beginning in] 1880, 'they went from cabin to cabin and did what the census laws require– paid personal visits to every place where it was likely that a person could find shelter.'" In northern and urban areas contemporary commentary concerning census enumeration in 1880 was positive– enumerators were found to be careful and thorough.[12] Grigoryeva & Ruef (2014) provide confirmation of this assessment, documenting that the census enumeration of Washington, D.C. in 1880 followed an ordered process. However, the linear path cannot be verified for other locations due to data limitations and the incomplete records pertaining to the specifics of enumeration in each locality.[13] Census enumeration does not typically contain addresses, even for urban areas. In general, the policies and procedures of enumeration since 1880 give us confidence that our approach is the best available proxy for household adjacency.

An obvious concern for rural communities would be the distance between neighbors identified in census manuscript files. Since enumeration districts were quite compact, even for rural areas, these adjacent households were closer than one may be led to believe. Those at quite a distance would be placed in a different enumeration district. A second consideration is that African Americans were far less likely to be landowners and therefore distant from their neighbors. This greatly impacted the residential location of the average African American family– they were usually not living on independent farms but rather more likely to live in compact tenant farming communities (Ransom & Sutch, 2001). In short, living in a rural community with less dense population did not necessarily

[12]Some locations rescinded this praise when final counts revealed population levels lower than expected.

[13]We deal with this issue of how this impacts the segregation measure directly in our simulation results below.

imply that neighbors were more distant than those in urban areas.

2.2 Deriving the Segregation Measure

Construction of the measure begins by identifying neighbors in manuscript census records.[14] Our method requires the complete, 100% census since all households are needed. The complete set of households in the census are sorted by reel number, microfilm sequence number, page number and line number. This orders the household heads by the order in which they appear on the original census manuscript pages, meaning that next-door neighbors appear next to one another. Institutions, boarding houses and other non-households (dormitories, etc.) are excluded from the calculation. Households in apartments or other multi-family units are recorded as separate households and are retained. We restrict our analysis to black and white households. All other racial groups were less than 0.5% of the total population from 1870 to 1940 in census returns. As such, a black household with a neighbor of a different race is the equivalent to saying he has a white neighbor.[15] Given the extremely low levels of interracial marriage in the past (fewer than 0.2% of households had opposite race spouses from 1870 to 1940) we assume the race of the household head applies to all household members.

There are two different methods for identifying each household's next-door neighbors. The first is to define the next-door neighbors as the household appearing before the individual on the census manuscript page and the household appearing after the individual on the census manuscript page. An individual that is either the first or last household on a particular census page will only have one next door neighbor identified using this method. To allow for the next door neighbor appearing on either the previous or next census page and to account for the possibility that two different streets are covered on the same census manuscript page an alternative method for identifying neighbors is also used that relies on street name rather than census manuscript page. In this alternative measure next-door neighbors are now identified by looking at the observations directly before and after the household in question and declaring them next-door neighbors if and only if the street name matches

[14] The full derivation of the segregation measure is given in the appendix.

[15] For our purposes people with their race given as 'mulatto' are considered to be in the same category as people with their race given as 'black'.

the street name of the individual of interest (and the street name must be given, two blank street names are not considered a match). This approach has the advantage of finding the last household on the previous page if an individual is the first household on his census manuscript page or the first household on the next page if the individual was the last household on a manuscript page. However, the number of observations is reduced substantially relative to the first method because many individuals have no street name given. Few roads had names in historical census records. This is particularly true in rural areas.

Once next door neighbors are identified, an indicator variable is constructed that equals one if the individual has a next door neighbor of a different race and zero if all observed next-door neighbors are of the same race as the household based on the race assigned at enumeration. As such, the measure of opposite race neighbors is measured at the extensive margin and is measured for each household in the manuscript census.

Summing this indicator variable across all black households for the entire county gives us the number of black households with a next-door neighbor of the opposite race, x_b. The segregation measure compares this number of black households with opposite-race neighbors to the expected number under complete segregation, $E(\underline{x_b})$, and the expected number under complete integration (random assignment of neighbors), $E(\overline{x_b})$. These two values are calculated based on the total number of black households and white households in a county. $E(\underline{x_b})$ is calculated assuming that only the two households on either end of the black neighborhood have white neighbors.[16] $E(\overline{x_b})$ is calculated assuming that households are randomly assigned by race: the probability of a next-door neighbor being of the opposite race is given by the fraction of the households in the county of that race.[17]

The degree of segregation in an area, which we call α, can then be defined as the distance between

[16]This value is a function of the probability of observing one or both of the two black households with white neighbors (a non-trivial number of households in the census do not have races given for their neighbors). Defining the number of black households with both neighbors' races observed as n_b and the total number of black households in the county as b_{all}, the value of $E(\underline{x_b})$ is calculated as $\frac{1}{\frac{1}{2}(n_b+1)}\left(1-\prod_{i=0}^{n_b-1}\frac{b_{all}-i-2}{b_{all}-i}\right)+2\left(1-\frac{1}{\frac{1}{2}(n_b+1)}\right)\left(1-\prod_{i=0}^{n_b-1}\frac{b_{all}-i-2}{b_{all}-i}\right)$. In the case of including households with only one observed neighbor, this equation must be modified somewhat to account for the possibility of observing one of the black households with a white neighbor but not observing the white neighbor. Full details are provided in the appendix.

[17]Following the same notation as the previous footnote and defining the total number of white households in the county as w_{all}, the value of $E(\overline{x_b})$ is calculated as $n_b\left(1-\frac{b_{all}-1}{b_{all}-1+w_{all}}\cdot\frac{b_{all}-2}{b_{all}-2+w_{all}}\right)$. As with $E(\underline{x_b})$, the equation must be modified when including households with only one observed neighbor. Details are provided in the appendix.

these two extremes, measured from the case of no segregation:

$$\alpha = \frac{E(\overline{x_b}) - x_b}{E(\overline{x_b}) - E(\underline{x_b})} \tag{1}$$

This segregation measure increases as black residents become more segregated within an area. The measure equals zero in the case of random assignment of neighbors (no segregation) and equals one in the case of complete segregation. There are a total of four versions of the segregation measure. Each of these versions corresponds to one of the two different methods of defining next-door neighbors (whether the specific street of residence is identified on the census manuscript form) and whether all individuals with a neighbor present are included or only those individuals with both neighbors identified are used.

We have derived the segregation measure for analysis of neighbors situated along a line in order to match the way in which neighbors can be identified in the census manuscript pages. However, it should be noted that the measure can be easily extended to considering two-dimensional residential patterns rather than simply household sequences along a line. Expanding the definition of next-door neighbors to include those living behind a household or across the street from the household simply requires adjusting the probability terms in the definition of $E(\overline{x_b})$ to account for the probability that any one of the four next-door neighbors is white and adjusting $E(\underline{x_b})$ to account for all of the black households on the perimeter of the two-dimensional black neighborhood having white neighbors rather than simply the two households on the ends of the one-dimensional neighborhood. This highlights the advantages of constructing a household-level measure of segregation; unlike traditional segregation measures based on geographic subunits or runs in the sequence of households, our measure can accommodate any definition of next-door neighbors fully exploiting available information on household location. While existing federal census information limits us to considering neighbors to the right and left of a household, our measure will be able to accommodate less restrictive definitions of next-door neighbors as richer household-level spatial data become available.

3 Simulations of the Segregation Measure

To confirm that our measure accurately reflects segregation as we have defined it, the distance an area is between the extremes of randomly assigned neighbors and completely segregated neighbors, we performed a series of simulations to check that these two benchmarks are properly calculated as the number of black households, the racial composition of the area and the overall population of the area vary. The simulation also checks for the potential of our measure to be biased by the enumeration process– enumeration maps non-linear spaces to adjacent households on rosters. If this process is not isomorphic, our estimates of segregation in the underlying area would be biased due to the transformation of actual living spaces to a household roster.

The simulation begins by creating a community with a given level of segregation and then sampling within that community and estimating the segregation measure. Simulated areas were generated containing between 20 and 1000 white households in increments of 20 households. For each particular number of white households, areas were simulated containing between one and 1000 black households in increments of one household. For each combination of white and black households, we calculated the number of observed black household heads living next to a white neighbor under complete segregation and under no segregation given a particular level of missing households. This accounts for the fact that census enumeration may be incomplete.

For the case of no segregation, we generated a random number for each household and then sort the households on the basis of this number. Neighbors are defined as households next to each other on this sorted list. This gives us neighbor locations that are completely independent of race. We then randomly drew the appropriate number of households given the chosen percent missing and count the number of black households with white neighbors in this sample. For the case of complete segregation, we randomly assigned two black households as the two households with white neighbors (the households on either side of the black neighborhood). We then randomly drew the appropriate percentage of households based on the fraction of households that are missing and saw whether one or both of the households with a white neighbor was in the randomly drawn sample.

Both of these calculations were repeated for 1000 different draws of random numbers generating 1000 simulated areas for each particular combination of black and white households. The result is

1000 observations of the number of observed black households with white neighbors and the number of observed black households with no white neighbors under complete segregation and under no segregation for each combination of the total number of black households and total number of white households in an area. These values let us calculate our segregation measure and check whether the value is equal to one on average for the completely segregated simulated area and equal to zero on average for the areas with no segregation. Equally important, the simulation allows us to see if the measure accurately captures underlying segregation when households are missing from enumeration.

Figure 2 shows the mean, 5th percentile and 95th percentile for these simulated values of the segregation measure by number of black households and by percent black. We include graphs for both simulations in which five percent of the observations are missing and simulations in which twenty percent of the observations are missing. For all of the graphs, we use observations with either one or both neighbors observed (the results look quite similar when restricting the sample to only those observations with both neighbors observed). From the graphs it is clear that our measure is well behaved, equalling one on average when an area is completely segregated and zero on average when an area has no segregation. The simulation also establishes that our measure captures underlying segregation even in the presence of missing observations.

One feature worth noting is that the measure is less well behaved when the number of black households is very small. At very small numbers of black households (typically at fewer than five black households) it becomes difficult to distinguish between randomly located households and segregated households since the majority of black households will have a white neighbors in either case. This is a natural product of the fact that segregation is difficult to define without critical masses of both groups. Once there are over five black households, however, we get a clear distinction between the segregated and unsegregated cases. We take the simulation results as suggestive evidence that the measure is effective at identifying segregation even in areas with relatively small numbers (say ten) black households. This is particularly important as the properties of other spatial historical measures of segregation have not been verified and have been restricted to urban areas as a result.

The values of our segregation index vary a fair amount for completely integrated counties, particularly for counties with a higher percentage of black residents. This is a product of the number

of black households located next to white households varying a fair amount when households are randomly assigned, causing deviations from the expected number of black households with white neighbors. For the completely segregated counties, the only variation comes from whether the two black households with white neighbors are observed, leading to far fewer (and far smaller) deviations from the expected number. Even with this inherent variation, the measure captures the degree of residential segregation as intended. Overall, the simulations show that our measure of segregation accurately reflects the racial residential patterns in the underlying community, can detect segregation with very small numbers of black households, and can properly distinguish between integrated and segregated communities even in the presence of undercounts of households and the inherent difficulties of mapping non-linear residential geography to sequenced rosters.

4 Comparison of Segregation Measures

Our measure begins from a fundamentally different unit of analysis than existing measures, making it difficult to perform a direct comparison of the methods. Analytically, aggregating our measure to the level of the census tract and block reveals different information about segregation in the subunit than the population shares used in traditional measures. The traditional measures, at their base, require only population shares by race, while our measure uses alignment and is not hierarchical. Subunit differences in segregation measure would reflect subtle, but potentially important, differences in spatial distribution.[18]

A useful illustration of this problem would be schools. Suppose that a school district had a large number of schools and students were of only two races, white and black, each of whom was fifty percent of the student population. If each school was fifty percent white both isolation and dissimilarity, defined at the school level (the subunit of the school district) would imply that the school district was integrated. If every *classroom* were segregated, however, no student *within* a school would have a classmate of a different race. Our segregation measure, defined from the likelihood that

[18]One critique of traditional segregation measures is that they may fail to capture the emergence of separate neighborhoods housing members of the same race but of different socioeconomic status. For example, Bayer et al. argue that increasing wealth among African Americans led to the development of middle-class black communities which increased measures of segregation.

the student next to you is of a different race, would capture this segregation. Since our measure, calculated both within schools and for the entire school districts, reveals different information the analytical comparison is not as informative as we would like. Indeed, under this extreme example our segregation measure would predict complete segregation while the traditional measures would imply complete integration.

Despite these difficulties in interpreting comparisons, it is still instructive to see how our measure correlates with traditional measures as a means of assessing the extent to which this new measure captures dimensions of segregation that are not captured by traditional measures. Our unit of analysis throughout is the county. We choose counties as the unit because it allows us to analyze the differences in segregation between urban and rural areas, counties are well-defined civil jurisdictions and additional information is available at the county level which allows us to analyze the correlates of segregation using our measure in addition to traditional measures. We assess how our segregation measure compares to traditional measures by calculating our segregation measure, the index of dissimilarity and the index of isolation using the federal census. To our knowledge, this produces the first estimates of dissimilarity and isolation for every county in the United States.

As noted earlier, dissimilarity and isolation are typically only calculated at the city level using wards as the geographic subunit for the calculation. Given our interest in applying our measure to both urban and rural counties, we cannot take this approach. Rural areas do not have such subdivisions. We need a geographic subunit that will be available for both urban and rural areas for comparison. One of the few candidates for such a unit is the census enumeration district. The enumeration district is on average a smaller unit in terms of population than a ward but still contains several hundred households, on average.[19] The typical rural enumeration district in the 1880 census contains 350 households while the typical urban enumeration district contains 450 households.[20] The mean number of enumeration districts in a rural county is 10 while the mean for urban counties is 39. Given that ward-level data is not available for rural counties and that the values of the traditional segregation measures vary with the fineness of the geographical subunit, we calculate the traditional

[19] An enumeration district is actually more comparable in size to a census block, the geographical subunit used by Echenique & Fryer (2007), than a ward or census tract.

[20] Enumeration districts averaged roughly 1,500 persons.

segregation measures using the enumeration district as the subunit for both urban and rural counties in order to make meaningful comparisons across counties. A key advantage of enumeration districts is that they were designed to maintain the boundaries of civil divisions (towns, election districts, wards, precincts, etc.). The use of enumeration districts guards against finding differences between the measures that are simply the product of higher level aggregation (calculating dissimilarity and isolation over a larger area) as opposed to actual differences in living arrangements by race.[21]

We calculate our segregation measure at the county level and dissimilarity and isolation at the county level using enumeration districts as the subunit.[22] Figure 3 depicts the variation in our segregation measure and the traditional measures for rural counties across regions. The figure depicts ranges of the measures with the end points of the range being one standard deviation above and below the mean. For simplicity, the results presented in this section focus only on the samples using the manuscript page definition of neighbors and requiring that at least one neighbor's race be observed. This gives us a larger number of households producing less noisy data, particularly for counties with very small numbers of black households overall.[23] When calculating the means and standard deviations, counties are weighted by the number of black household heads to provide a more accurate picture of the experience of the typical black household and to minimize the effects of outlier counties with few black households. The figure focuses on only those regions in which over one percent of the population is black. Means and standard deviations for the measures across all regions are in Table 1 giving unweighted values and Table 2 giving values weighted by the number of black households. These tables also include means and standard deviations for the counties.

These figures reveal a substantial amount of heterogeneity in segregation within regions, across

[21]Note that on average, since the enumeration districts are smaller units than wards, our estimates of dissimilarity and isolation in urban counties will tend to be higher than those of Cutler et al. (1999) and Troesken (2002).

[22]To make the sample used for calculating the index of isolation and the index of dissimilarity comparable to the sample used in the calculation of our segregation measure, we drop all household heads for which race is not observed and neighbor's race is not observed. As with the calculation of our segregation statistic, this leads to four different samples: all household heads for which at least one neighbor's race is observed using the manuscript page definition of neighbor, only those household heads for which both neighbors' races are observed using the manuscript page definition of neighbor, and both of these samples using the street name definition of neighbor. When calculating the index of isolation, we follow the approach of Cutler et al. (1999) and rescale the index given in Footnote 6 by subtracting the percent black for the county and then normalize the statistic by dividing by the maximum theoretical value of this rescaled isolation index for the county, resulting in an index that is normalized to range between zero and one and is independent of the overall size of the black population.

[23]Comparisons of the segregation measures when using the other sample restrictions are available upon request.

regions and between urban and rural areas. However, the data also reveal that the patterns of segregation depend heavily on the chosen measure of segregation. The rankings of regions in terms of how segregated they are and the differences in segregation between rural and urban counties differ significantly depending on the measure. To get a better sense of how the measures relate to one another, correlations between the measures are provided in Table 3. Our measure is positively correlated with the percentage of households who are black and with the index of isolation. Surprisingly, our measure is negatively correlated with the index of dissimilarity for both rural and urban counties. However, after weighting by the number of black households in each county this correlation turns positive.

In general, the correlations in Table 3 show that our measure is weakly correlated with traditional measures of segregation. This is likely due to the fineness of our measure as opposed to the groupings required of traditional measures. For example, Echenique & Fryer propose a spectral index of segregation that is well correlated with the percent black (.90) and isolation (.93), but less well correlated with dissimilarity (.42). Our measure is substantially less well correlated with any of these measures (.43, .70 and .29 for percent black, isolation and dissimilarity respectively) but does share the same general pattern of correlations.[24]

For a more detailed view of how the geographical distribution of segregation varies by measure, maps of the United States and maps of the regions where blacks constitute more than one percent of the population are given in Figure 4 and Figure 5, respectively. The most striking feature is that the index of dissimilarity shows the North and, more generally, areas with a low percentage of black residents as more segregated on average while our measure identifies the South as more segregated (but not necessarily the areas of the South with dense populations). That is, the percent black and the index of dissimilarity do not reveal the same spatial pattern of segregation as our neighbor-measure does.

Also worth noting is that there is a distinct, discontinuous change in the index of dissimilarity when moving from the South to the North; the southern borders of Pennsylvania, Ohio and Indiana in particular stand out. These patterns are likely due to differences across states in the way enumeration

[24]Measures such as the sequence index of segregation, described in Grigoryeva & Ruef (2014) and Agresti (1980) are well correlated with dissimilarity in all regions except the South. Our measure is weakly correlated with dissimilarity and isolation over all regions.

districts are drawn, which occurred at the state level. The index of dissimilarity is particularly sensitive to the way these subunits are defined. Our measure, based on individual-level data, does not depend on these definitions of enumeration districts and shows a much more gradual transition in levels of segregation across space. This highlights the importance of having a measure that is not dependent on the boundaries of geographic subunits. Residential segregation just north of the Mason-Dixon line is quite similar to residential segregation just south of the line. While it would be tempting to conclude from the index of dissimilarity that institutional or cultural differences led to dramatic differences in residential segregation between the North and South, our measure shows that no such discontinuity exists.[25]

The results of the comparison show that our new measure of segregation is not redundant but rather yields new information about spatial sorting by race. The relatively low correlation of our measure of segregation with other indices of segregation and the population share by race shows that knowledge of dissimilarity, isolation, or racial composition would not predict our segregation measure. The simulation results show that our measure does reflect underlying segregation patterns even in the presence of measurement error or missing enumeration. Both of these results imply that our measure captures a dimension of segregation not reflected in traditional segregation indices.

5 Segregation Over Time

As 100 percent samples of more recent federal censuses become available to researchers, our segregation measure can be extended well into the twentieth century, allowing us to trace changes in segregation over time, determine whether these time trends in segregation differ between urban and rural areas, and assess how the trends vary across regions. With the 72-year-rule, complete census returns are publicly available up through the 1940 federal census. Below, we analyze changes in the neighbor-based measure of segregation from 1880 to 1940.

The 1940 census offers a fascinating time period to bookend our study of residential segregation.

[25]Given the maps for the traditional measures, one could make the argument that *de jure* racial restrictions in Southern states led to low levels of racial segregation. That is, the argument is that segregation in the Jim Crow era was of little consequence. In essence, if blacks were systematically restricted from access to public spaces, schools and the like the residential pattern would not need to be segregated. The results show that this was not the case.

Indeed, the time period of the two census measures is particularly important. The 1880 census comes after the Civil War and before the nation moved to Jim Crow. For example, at the time of the 1880 census the Civil Rights Act of 1875, which guaranteed equal protection in public accommodation, was still enforced at the time of enumeration. The 1940 census depicts residential patterns after the rise of Jim Crow, the Great Migration, and the influx of European immigrants. Importantly, the 1940 census comes largely before the rise of suburbanization seen in the post war years. It is this period that Cutler, Glaeser and Vigdor cite as the rise of the American ghetto. The complete census returns for 1880 and 1940 allow us to see whether our segregation index shows a similar rise in urban segregation and whether a comparable change in segregation occurred in rural areas.

Table 4 shows the variation in our segregation index by census region in both 1880 and 1940.[26] All statistics are weighted by the number of black households in the county so they should be interpreted as representing the level of segregation experienced by the average black household. Counties are divided between rural and urban to distinguish between the segregation patterns described by Cutler, Glaeser and Vigdor specific to cities and more general patterns affecting the rest of the population. For our purposes, we designate a county as urban if more than one quarter of the households from that county live in an urban area and rural if less than one quarter of the households live in an urban area. For 1880, this leads to 88 percent of counties being classified as rural. For 1940, 60 percent of counties are classified as rural.[27]

The table reinforces several conclusions from the previous section and demonstrates several stark time trends. First, segregation varied substantially across regions, with the Southern regions and in particular the East South Central and West South Central regions substantially more segregated than the North or the Midwest. This is true in both 1880 and 1940 and for both rural and urban counties.

The truly striking feature of Table 4 is the difference between the 1880 and 1940 segregation levels,

[26]Equivalent statistics are shown for the index of dissimilarity and the index of isolation in Table 6 and Table 7, respectively. The patterns described for the the changes over time in our segregation index hold for dissimilarity and isolation as well. All regions saw a pronounced increase in the levels of segregation as measured by dissimilarity and isolation. The only exceptions are decreases in the index of isolation for the Mountain and Pacific regions. However, these regions had incredibly small numbers of black residents in 1880, making it very difficult to draw any strong inferences related to the segregation statistics in 1880 or the change in those statistics from 1880 to 1940.

[27]Note that the urban-rural distinction in the census data is not defined at the county level. Some residents in a county may be living in an urban area while other residents in the same county may be considered to be living in a rural area.

given in columns (5) and (10) for rural and urban counties, respectively. In all regions, there is a substantial increase in segregation in urban areas. These increases are particularly large in those regions that were receiving large inflows of black residents during the Great Migration; the largest changes in segregation are for the urban areas in the East North Central and West North Central regions.[28] However, the table suggests that the story of rising segregation levels is not strictly an urban story. While the first decades of the twentieth century may have seen the rise of the American ghetto, they also witnessed a substantial rise in rural segregation levels. All of the regions show substantial increases in segregation comparable in size to one to two standard deviations of the county-level segregation index distribution. Between 1880 and 1940 the United States became more segregated overall— urban and rural, North and South.

It is worth noting that this rise in segregation across all regions is not simply a story of black households becoming concentrated in selected counties. Table 5 shows the variation in percent black by region and over time. Once again, the counties are weighted by the number of black households and correspond to the experience of the average black household, not the average county. Table 5 shows that there were modest increases in the percentage of households with black household heads by county in the Northeast and Midwest but there were actually declines in the percentage of black households for the South. These patterns hold for both rural and urban counties and are consistent with mass migration. Despite the North and the South experiencing very different demographic change in terms of the distribution of black households across counties, *all* regions experienced an increase in segregation within counties whether those counties were urban or rural. These changes in segregation over time suggest that the rise of the American ghetto described by Cutler, Glaeser and Vigdor is one piece of a much larger story of increasing residential segregation in the United States over the first half of the twentieth century.

A simple time series regression of the change in segregation over time reveals the strong persistence of segregation. We show a series of time series regressions in Table 8. The regression of 1940 segregation on 1880 segregation yields

[28]It is important to note that this rise in segregation precedes the larger outflows of whites from central cities in the postwar era. Boustan (2010) estimates that each black migrant after WWII resulted in more than one white exodus from the central city.

$$\begin{aligned} \alpha_{1940} &= 0.242 + 0.800\alpha_{1880} + \epsilon \\ & \quad (0.009)^{***}\ (0.030)^{***}\ R^2 = 0.27 \end{aligned}$$

Given that the average level of segregation measured in 1880 was 0.215, the intercept suggest that county-level segregation essentially doubled from 1880 to 1940.[29] Regional controls do not alter the substantive implications, the regression has an intercept of 0.153 (0.027 s.e.) and a coefficient on 1880 segregation of 0.561 (0.034 s.e.). Even when adding changes in the percent black, regional controls and urban population to the regression above, the point estimates for segregation and the intercept remain the same (0.555 (0.035 s.e.) and 0.148 (0.026 s.e.), respectively), which is consistent with the results in Table 4. In short, time series results in Table 8 suggest a doubling of neighbor-based segregation from 1880 to 1940. Even more, this result was not confined to urban areas but was instead a national phenomena.

While the level change segregation is noteworthy, it is important to establish that the increase in segregation is not simply a mechanical function of population growth or driven by outliers where either the population or racial composition changed dramatically. For example, the measure could increase (decrease) as more counties gained (lost) black residents with the Great Migration. This is best seen graphically, as regression analysis can obscure the influence of outliers. We address these concerns in Figure 6 and Figure 7. In Figure 6 we show that the change in segregation was quite general. The level changes in α are not concentrated in a small number of counties nor one region of the country. Consistent with the results of Table 8, every area saw substantial increases in segregation.

In Figure 7 we show the distribution of the change in the α measure against other measures of population change. In panel (a) of Figure 7 we show that the change in the segregation measure is not driven mechanically by increases in the number of black households. When we plot the change in the segregation measure by the change in the number of black households the relationship shows little trend. In panel (b) of Figure 7 we plot the change in the segregation measure against the log of the number of households in 1880. The figure shows that the change in segregation was observed for both large and small counties. In panel (c) we plot the change against the percent black in 1880, and

[29] Although there is strong persistence, tests of a unit root in the segregation measure were rejected at all conventional levels. A basic Dickey Fuller test of the change in the segregation measure on the 1880 segregation measure yields a slope coefficient of -0.199 (0.030 s.e.).

the figure shows that counties with small and large proportions black experienced similar changes in segregation. In panel (d) we plot the change in segregation against the change in the percent of black from 1880-1940. The figure shows that the result is not driven by counties where African American population grew substantially.[30]

Our analysis also allows us to investigate changes in segregation using traditional measures. As noted earlier, in Table 6 and Table 7 we report the regional and national changes in dissimilarity and isolation for bothy rural and urban counties, respectively. While our neighbor-based measure of segregation shows that both rural and urban segregation increased by roughly the same amount (62 percent for rural areas and 68 percent for urban areas), dissimilarity and isolation measures imply that the change in segregation was concentrated in urban areas. Using dissimilarity, rural segregation increased 48 percent while urban segregation increased by 86 percent. Using isolation, rural segregation increased 112 percent while urban segregation increased by more than 300 percent. Using either the results of Table 6 or Table 7, one would be left with the false inference that segregation increased much faster in urban communities than rural communities. As we showed in Figure 7, the increase in neighbor-based segregation was not driven by urbanization. The comparison of the measures reveals that segregation did in fact increase nationally. While urban areas became more segregated, rural residents sorted by race as well in a way that is not easily captured in existing segregation measures.[31]

An important advantage of our segregation measure is that it allows us to directly investigate the likelihood of opposite race interaction and its change over time. The probability of an African American household having an opposite race neighbor is a component of our segregation measure.[32] Overall, in the median county in 1880 a black household had roughly a 50% chance of having a white neighbor. By 1940, however, this likelihood declined by more than 15 percentage points, a decrease of more than 25% in the likelihood of an opposite race neighbor. Using only areas where blacks

[30]The results in Figure 7 are for all counties, but the results hold when looking at Northern and Southern counties separately.

[31]The time series of the traditional segregation measures is also consistent with the results of Table 6 and Table 7 in that they show much less persistence of the traditional segregation measures over time and suggest that segregation increased faster in urban areas than rural areas.

[32]The probability of opposite race neighbors is simply the number of black households with opposite race neighbors, x_b, divided by the total number of black households, b_{all}.

were greater than 1% of the population in 1880 results in more than a 25 percentage point decline in the likelihood, a decrease of more than 35%.[33] In Table 8 we present a series of regressions where the dependent variable is the change in the likelihood of opposite race neighbors. The first set of results shows that the change in the likelihood of opposite race neighbors declined both in regions that received black migratory flows from 1880 to 1940 and those that experienced declines. The East North Central, Mid Atlantic, South Atlantic and East South Central saw significant declines in opposite race neighbors. This regional decline holds when changes in the percent black, being in an urban county, and urban population are included in the specification. Naturally, the decline was also related to changes in segregation. Once the change in segregation is included the regional effect vanishes. This is due to the fact that the likelihood of opposite race neigbors is a component of the segregation measure. This significant change in the degree of opposite race neighbors, which holds across regions that saw relative declines and increases in the black population, adds a new dimension to the changing residential patterns of the late nineteenth and early twentieth centuries. At a minimum, the results suggest that increasing racial isolation was not driven by urbanization or the Great Migration, but was rather a national phenomena.

Overall, the results of Table 8, Table 4, Figure 6, and Figure 7 show that segregation was both persistent and increasing from the late nineteenth to early twentieth centuries. The result was not restricted to urban counties nor was the increase only seen in counties that changed significantly in the proportion black. These results are consistent with a general, national increase in racial segregation in the United States. Even more, we show that the result of changing segregation led to substantial declines in the likelihood of opposite race interaction. The decline was national and did not concentrate in particular regions of the country. As with the the change in segregation, the decline in opposite race neighbors was nationwide. Overall, our results show that racial residential sorting increased dramatically in the United States from 1880 to 1940.

[33]The result holds for larger percentages of the black population in 1880. In general, the increase in racial isolation is not driven by black migration to areas where the black population was small in 1880.

6 Conclusion

In this paper we have derived a new measure of segregation from the complete 1880 census and used the simple criteria of the race of a neighbor. Our measure gives a direct assessment of the likelihood of interracial interaction in residential communities. If neighbors are less much likely to be of a different race than random assignment would predict then that location is more segregated than another that is closer to random assignment. We first showed how this measure has distinct advantages over the most commonly used measures of segregation in the literature. Indeed, we showed that our measure is weakly correlated with the most common measures of segregation. Next, we showed how segregation varied in significant ways in the United States in the late 19th through mid 20th centuries. There was substantial heterogeneity in segregation across regions, within regions and between rural and urban areas.

In analyzing segregation over time we see that our measure of segregation shows that the United States became a more segregated society from 1880 to 1940. The traditional story of increasing segregation in urban areas in response to black migration to urban centers must be augmented with a discussion of the increasing racial segregation of rural areas. Both rural and urban areas in every region experienced marked increases in segregation. Our findings showed that the likelihood of opposite-race neighbors declined precipitously in every region in the United States.

Our findings complicate traditional explanations of blacks clustering in small areas abutting white communities (Kellogg, 1977), and of racial segregation being driven by restrictive covenants (Gotham, 2000), as both of these were urban phenomena. The increase in rural segregation also complicates historical narratives which view population dynamics in rural areas as stagnant. The focus on urban segregation has neglected the fact that rural areas were segregated and, as we have discovered, became increasingly segregated over time. While there are studies which seek to look at the causal effect of black social networks in rural areas on outcomes (Chay & Munshi, 2013), they use county proportions which we show are relatively poorly correlated with residential segregation. Overall, the national trend in increasing segregation in the twentieth century adds a new chapter to American history.

An entirely new set of economic outcomes may be related to segregation in ways not previously known. These include agricultural productivity, racial violence in rural areas (lynchings), capital

intensity in agriculture, land tenure systems, and the growth and maintenance of the share cropping system. In addition, socioeconomic outcomes such as election returns, public finance, and schooling quality may be related to neighbor-based segregation. While we leave for future research the correlates and consequences of the segregation results we find here, we note that the scope of segregation research is now broader with this neighbor-based measure.

Our estimates show that segregation is a national phenomena that changed dramatically in both rural and urban areas. Understanding the relationship between segregation and urbanization will help us understand the dynamics of segregation in cities and rural communities in the twentieth century. These links have important implications for the skill mix of cities, public finance, education, health and other measures of social well-being. The strong persistence of our segregation measure suggests that the roots of contemporary segregation may be more varied that previously thought. Both rural and urban areas had different levels of segregation that were highly persistent over time. The national pattern of increasing segregation and racial isolation merits continued analysis and exploration. This finding also poses a range of questions about the impact of Jim Crow, racial violence, European immigration, internal migration and the differences and similarities between racial segregation in rural and urban areas in the United States.

Understanding the evolution of racial residential segregation in the United States requires a consistent and comprehensive approach. While this project estimates historical segregation patterns to 1940, it is not limited to historical analysis. The differences in segregation and the time pattern of segregation, which we document from the beginning of the post-bellum era, may have long-standing effects on contemporary outcomes. Better knowledge of segregation's past will give us the tools to outline its full impact in the past and, most important, the roots of segregation's effect on contemporary racial disparities.

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Table 1: Means of county-level segregation measures by region, 1880.

	Rural counties				Urban counties			
	Alpha	Percent black	Dissimilarity	Isolation	Alpha	Percent black	Dissimilarity	Isolation
New England	0.101	0.007	0.581	0.075	0.191	0.014	0.582	0.061
	(0.127)	(0.010)	(0.219)	(0.115)	(0.172)	(0.014)	(0.136)	(0.054)
Middle Atlantic	0.145	0.015	0.541	0.076	0.201	0.017	0.527	0.048
	(0.145)	(0.020)	(0.146)	(0.105)	(0.135)	(0.014)	(0.118)	(0.048)
East North Central	0.120	0.012	0.523	0.126	0.143	0.025	0.506	0.061
	(0.144)	(0.026)	(0.257)	(0.168)	(0.133)	(0.047)	(0.186)	(0.058)
West North Central	0.139	0.015	0.366	0.113	0.184	0.047	0.479	0.065
	(0.156)	(0.034)	(0.323)	(0.173)	(0.164)	(0.057)	(0.138)	(0.043)
South Atlantic	0.275	0.338	0.201	0.056	0.459	0.484	0.28	0.107
	(0.132)	(0.231)	(0.127)	(0.065)	(0.114)	(0.196)	(0.123)	(0.077)
East South Central	0.276	0.266	0.289	0.091	0.378	0.306	0.314	0.083
	(0.129)	(0.234)	(0.119)	(0.093)	(0.12)	(0.234)	(0.079)	(0.043)
West South Central	0.336	0.233	0.241	0.09	0.391	0.398	0.218	0.073
	(0.161)	(0.248)	(0.197)	(0.127)	(0.147)	(0.26)	(0.137)	(0.046)
Mountain	0.079	0.010	0.303	0.134	0.07	0.005	0.536	0.018
	(0.146)	(0.024)	(0.267)	(0.218)	(0)	(0)	(0)	(0)
Pacific	0.048	0.005	0.357	0.119	0.066	0.01	0.484	0.041
	(0.119)	(0.006)	(0.258)	(0.17)	(0.071)	(0.007)	(0.147)	(0.022)

Notes: Standard deviations are given in parentheses. The rural/urban distinction is based on the 1880 census definition of an urban area being a place with more than 8,000 inhabitants.

Table 2: Means of county-level segregation measures by region with counties weighted by number of black households, 1880.

	Rural counties				Urban counties			
	Alpha	Percent black	Dissimilarity	Isolation	Alpha	Percent black	Dissimilarity	Isolation
New England	0.241	0.015	0.512	0.053	0.373	0.02	0.611	0.12
	(0.135)	(0.009)	(0.115)	(0.057)	(0.127)	(0.008)	(0.098)	(0.052)
Middle Atlantic	0.282	0.041	0.496	0.08	0.419	0.027	0.609	0.126
	(0.158)	(0.03)	(0.112)	(0.069)	(0.165)	(0.013)	(0.131)	(0.087)
East North Central	0.233	0.051	0.484	0.083	0.299	0.066	0.467	0.076
	(0.129)	(0.064)	(0.147)	(0.067)	(0.115)	(0.08)	(0.141)	(0.037)
West North Central	0.259	0.101	0.386	0.078	0.386	0.101	0.405	0.089
	(0.116)	(0.071)	(0.145)	(0.066)	(0.127)	(0.046)	(0.101)	(0.035)
South Atlantic	0.311	0.521	0.199	0.057	0.518	0.509	0.323	0.127
	(0.107)	(0.179)	(0.092)	(0.048)	(0.116)	(0.189)	(0.089)	(0.051)
East South Central	0.374	0.536	0.286	0.099	0.448	0.468	0.314	0.112
	(0.093)	(0.234)	(0.099)	(0.063)	(0.04)	(0.211)	(0.066)	(0.026)
West South Central	0.433	0.527	0.261	0.096	0.412	0.446	0.254	0.09
	(0.092)	(0.218)	(0.118)	(0.076)	(0.079)	(0.189)	(0.096)	(0.037)
Mountain	0.274	0.057	0.481	0.192	0.07	0.005	0.536	0.018
	(0.241)	(0.074)	(0.198)	(0.173)	(0)	(0)	(0)	(0)
Pacific	0.059	0.011	0.395	0.082	0.064	0.013	0.494	0.029
	(0.121)	(0.007)	(0.138)	(0.099)	(0.047)	(0.005)	(0.107)	(0.012)

Notes: Standard deviations are given in parentheses. The rural/urban distinction is based on the 1880 census definition of an urban area being a place with more than 8,000 inhabitants.

Table 3: Correlations in segregation measures for rural and urban counties, 1880.

Rural counties									
	Unweighted					Weighted by number of black households			
	Alpha	Percent black	Dissimilarity	Isolation		Alpha	Percent black	Dissimilarity	Isolation
Alpha	1				Alpha	1			
Percent black	0.6065	1			Percent black	0.4303	1		
Dissimilarity	-0.36	-0.5199	1		Dissimilarity	0.2853	-0.2055	1	
Isolation	-0.0201	-0.1643	0.5303	1	Isolation	0.5476	0.0763	0.7624	1
Urban counties									
	Unweighted					Weighted by number of black households			
	Alpha	Percent black	Dissimilarity	Isolation		Alpha	Percent black	Dissimilarity	Isolation
Alpha	1				Alpha	1			
Percent black	0.6819	1			Percent black	0.2769	1		
Dissimilarity	-0.4438	-0.5503	1		Dissimilarity	0.1411	-0.5316	1	
Isolation	0.4999	0.3471	0.18	1	Isolation	0.6931	0.0627	0.5046	1

Table 4: Changes in the county-level segregation index from 1880 to 1940 by region, counties weighted by number of black households.

	Rural counties					Urban counties				
Region	Mean, 1880 (1)	Standard deviation, 1880 (2)	Mean, 1940 (3)	Standard deviation, 1940 (4)	1940 - 1880, (3)-(1) (5)	Mean, 1880 (6)	Standard deviation, 1880 (7)	Mean, 1940 (8)	Standard deviation, 1940 (9)	1940 - 1880, (8)-(6) (10)
New England	0.12	0.10	0.33	0.17	0.21	0.33	0.12	0.56	0.18	0.22
Middle Atlantic	0.23	0.13	0.39	0.11	0.16	0.40	0.17	0.75	0.15	0.35
East North Central	0.23	0.13	0.43	0.23	0.20	0.28	0.12	0.80	0.17	0.51
West North Central	0.25	0.10	0.43	0.13	0.18	0.37	0.14	0.73	0.20	0.36
South Atlantic	0.30	0.10	0.54	0.16	0.24	0.51	0.11	0.74	0.13	0.23
East South Central	0.37	0.09	0.57	0.09	0.20	0.44	0.05	0.78	0.10	0.34
West South Central	0.44	0.09	0.61	0.09	0.18	0.39	0.08	0.71	0.12	0.33
Mountain	0.28	0.29	0.40	0.31	0.12	0.26	0.15	0.53	0.18	0.27
Pacific	0.07	0.12	0.40	0.31	0.33	0.06	0.05	0.59	0.19	0.53
Entire country	0.35	0.11	0.57	0.13	0.22	0.44	0.13	0.75	0.15	0.30

Notes: All means and standard deviations are weighted by the number of black households in the county. The urban-rural distinction is based on the year the statistic corresponds to, so some of the counties in the 1880 rural calculations appear in the 1940 urban calculations.

Table 5: Changes in county level percent black from 1880 to 1940 by region, counties weighted by number of black households.

	Rural counties					Urban counties				
Region	Mean, 1880 (1)	Standard deviation, 1880 (2)	Mean, 1940 (3)	Standard deviation, 1940 (4)	1940 - 1880, (3)-(1) (5)	Mean, 1880 (6)	Standard deviation, 1880 (7)	Mean, 1940 (8)	Standard deviation, 1940 (9)	1940 - 1880, (8)-(6) (10)
New England	0.01	0.01	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.00
Middle Atlantic	0.04	0.03	0.04	0.02	0.00	0.03	0.02	0.09	0.05	0.06
East North Central	0.05	0.07	0.13	0.15	0.08	0.06	0.07	0.07	0.04	0.01
West North Central	0.10	0.07	0.11	0.09	0.02	0.10	0.06	0.18	0.19	0.07
South Atlantic	0.52	0.18	0.38	0.18	-0.14	0.50	0.18	0.34	0.13	-0.17
East South Central	0.53	0.24	0.50	0.24	-0.03	0.53	0.20	0.39	0.18	-0.14
West South Central	0.54	0.21	0.41	0.18	-0.13	0.35	0.15	0.28	0.14	-0.07
Mountain	0.07	0.09	0.03	0.03	-0.03	0.04	0.03	0.10	0.06	0.05
Pacific	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.03	0.05	0.02
Entire country	0.51	0.23	0.42	0.21	-0.08	0.37	0.25	0.23	0.18	-0.14

Notes: All means and standard deviations are weighted by the number of black households in the county. The urban-rural distinction is based on the year the statistic corresponds to, so some of the counties in the 1880 rural calculations appear in the 1940 urban calculations.

Table 6: Changes in the county-level dissimilarity index from 1880 to 1940 by region, counties weighted by number of black households.

	Rural counties					Urban counties				
Region	Mean, 1880 (1)	Standard deviation, 1880 (2)	Mean, 1940 (3)	Standard deviation, 1940 (4)	1940 - 1880, (3)-(1) (5)	Mean, 1880 (6)	Standard deviation, 1880 (7)	Mean, 1940 (8)	Standard deviation, 1940 (9)	1940 - 1880, (8)-(6) (10)
New England	0.47	0.13	0.60	0.14	0.13	0.57	0.11	0.80	0.08	0.23
Middle Atlantic	0.46	0.11	0.55	0.09	0.09	0.59	0.12	0.83	0.10	0.24
East North Central	0.49	0.15	0.59	0.17	0.10	0.47	0.14	0.87	0.10	0.40
West North Central	0.39	0.15	0.48	0.16	0.09	0.40	0.10	0.71	0.22	0.31
South Atlantic	0.20	0.09	0.36	0.19	0.16	0.30	0.11	0.54	0.16	0.24
East South Central	0.28	0.10	0.38	0.09	0.10	0.32	0.09	0.57	0.13	0.25
West South Central	0.26	0.12	0.37	0.10	0.11	0.28	0.10	0.56	0.13	0.28
Mountain	0.45	0.21	0.67	0.18	0.22	0.52	0.17	0.63	0.11	0.11
Pacific	0.41	0.14	0.69	0.11	0.28	0.48	0.11	0.84	0.11	0.36
Entire country	0.25	0.12	0.37	0.15	0.12	0.36	0.15	0.67	0.19	0.31

Notes: All means and standard deviations are weighted by the number of black households in the county. The urban-rural distinction is based on the year the statistic corresponds to, so some of the counties in the 1880 rural calculations appear in the 1940 urban calculations.

Table 7: Changes in the county-level isolation index from 1880 to 1940 by region, counties weighted by number of black households.

	Rural counties					Urban counties				
Region	Mean, 1880 (1)	Standard deviation, 1880 (2)	Mean, 1940 (3)	Standard deviation, 1940 (4)	1940 - 1880, (3)-(1) (5)	Mean, 1880 (6)	Standard deviation, 1880 (7)	Mean, 1940 (8)	Standard deviation, 1940 (9)	1940 - 1880, (8)-(6) (10)
New England	0.05	0.09	0.07	0.04	0.02	0.09	0.05	0.31	0.19	0.22
Middle Atlantic	0.06	0.05	0.08	0.04	0.02	0.12	0.09	0.55	0.24	0.43
East North Central	0.09	0.07	0.14	0.12	0.05	0.07	0.04	0.64	0.24	0.57
West North Central	0.08	0.07	0.10	0.05	0.02	0.08	0.03	0.48	0.28	0.40
South Atlantic	0.06	0.04	0.18	0.18	0.12	0.12	0.06	0.37	0.18	0.25
East South Central	0.10	0.06	0.16	0.06	0.06	0.11	0.04	0.40	0.16	0.29
West South Central	0.09	0.07	0.17	0.08	0.08	0.10	0.06	0.37	0.16	0.27
Mountain	0.23	0.19	0.10	0.11	-0.13	0.14	0.13	0.26	0.13	0.12
Pacific	0.08	0.10	0.06	0.06	-0.02	0.03	0.02	0.45	0.23	0.42
Entire country	0.08	0.06	0.17	0.17	0.09	0.11	0.06	0.45	0.23	0.34

Notes: All means and standard deviations are weighted by the number of black households in the county. The urban-rural distinction is based on the year the statistic corresponds to, so some of the counties in the 1880 rural calculations appear in the 1940 urban calculations.

Table 8: The Time Series of Segregation and Opposite Race Neighbors, 1880-1940

Panel A: The Time Series of Segregation, 1880-1940. DV: Segregation in 1940					
Segregation in 1880	0.800***	0.561***	0.590***	0.566***	0.545***
	(0.0305)	(0.0340)	(0.0348)	(0.0346)	(0.0349)
Change in Percent Black, 1880-1940			0.219***	0.241***	0.215***
			(0.0609)	(0.0602)	(0.0603)
Urban County in 1880				0.113***	0.0934***
				(0.0164)	(0.0170)
Urban Population					4.52e-05***
					(1.15e-05)
Constant	0.242***	0.153***	0.149***	0.132***	0.134***
	(0.00864)	(0.0271)	(0.0270)	(0.0268)	(0.0267)
Census Region Fixed Effects		X	X	X	X
Observations	1,876	1,876	1,876	1,876	1,876
R-squared	0.269	0.348	0.352	0.368	0.373
Panel B: Opposite Race Neighbors, 1880-1940. DV: Change in Probability of Different Race Neighbor					
Middle Atlantic	-0.0732**	-0.0711**	-0.0653**	-0.0628**	-0.00518
	(0.0318)	(0.0300)	(0.0297)	(0.0297)	(0.00703)
East North Central	-0.0788***	-0.0801***	-0.0789***	-0.0796***	-0.00691
	(0.0293)	(0.0276)	(0.0274)	(0.0274)	(0.00648)
West North Central	-0.0242	-0.0267	-0.0316	-0.0323	-0.00115
	(0.0298)	(0.0281)	(0.0279)	(0.0279)	(0.00659)
South Atlantic	-0.0787***	-0.146***	-0.160***	-0.160***	0.00480
	(0.0284)	(0.0271)	(0.0270)	(0.0270)	(0.00644)
East South Central	-0.0980***	-0.148***	-0.163***	-0.163***	-0.00465
	(0.0289)	(0.0275)	(0.0274)	(0.0274)	(0.00652)
West South Central	-0.0569*	-0.114***	-0.129***	-0.129***	-0.00189
	(0.0295)	(0.0281)	(0.0280)	(0.0279)	(0.00664)
Mountain	0.0375	0.0351	0.0208	0.0205	0.00202
	(0.0400)	(0.0378)	(0.0375)	(0.0375)	(0.00886)
Pacific	-0.0575	-0.0583*	-0.0609*	-0.0613*	-0.0127
	(0.0372)	(0.0351)	(0.0348)	(0.0348)	(0.00822)
Change in Percent Black, 1880-1940		-0.852***	-0.877***	-0.870***	-0.517***
		(0.0561)	(0.0557)	(0.0559)	(0.0134)
Urban County in 1880			-0.0924***	-0.0842***	-0.0109***
			(0.0155)	(0.0162)	(0.00385)
Urban Population				-1.81e-05*	1.55e-06
				(1.08e-05)	(2.56e-06)
Change in Segregation 1880-1940					-0.886***
					(0.00499)
Constant	-0.992***	-0.1003***	-0.0841***	-0.0839***	-0.0104*
	(0.0267)	(0.0252)	(0.0252)	(0.0251)	(0.0059)
Observations	1,876	1,876	1,876	1,876	1,876
R-squared	0.021	0.129	0.145	0.146	0.952

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

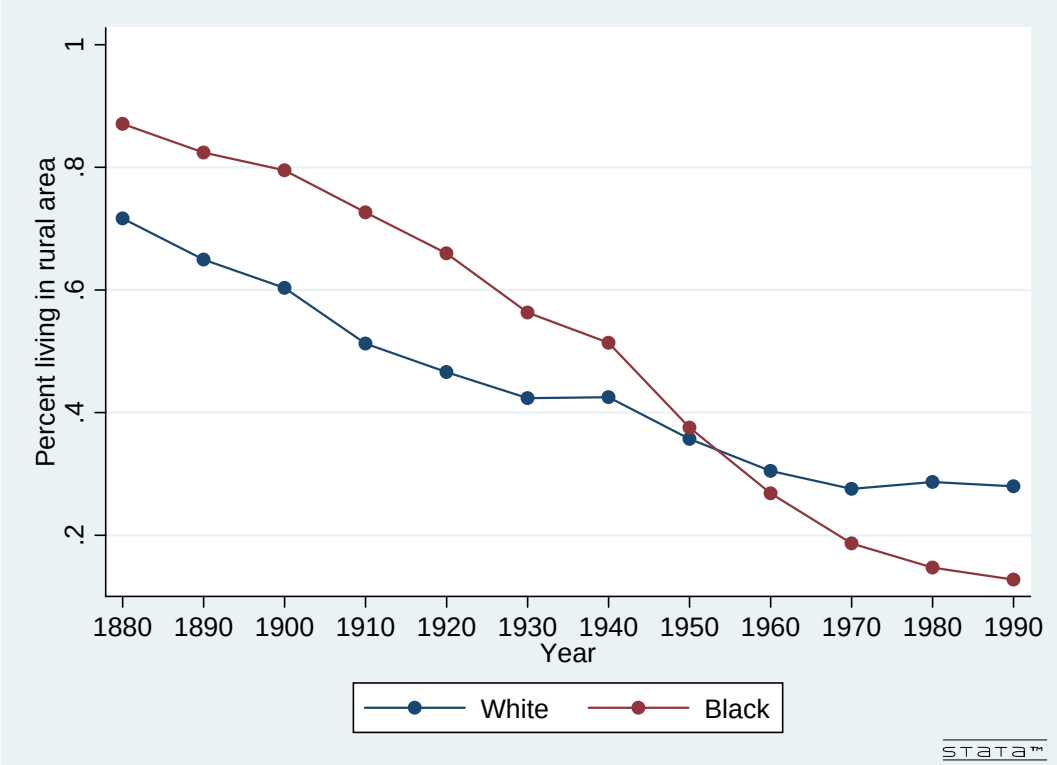

Figure 1: Percentage of population living in rural areas, 1880-1990. Source: Historical Statistics of the United States, Table Aa716-775.

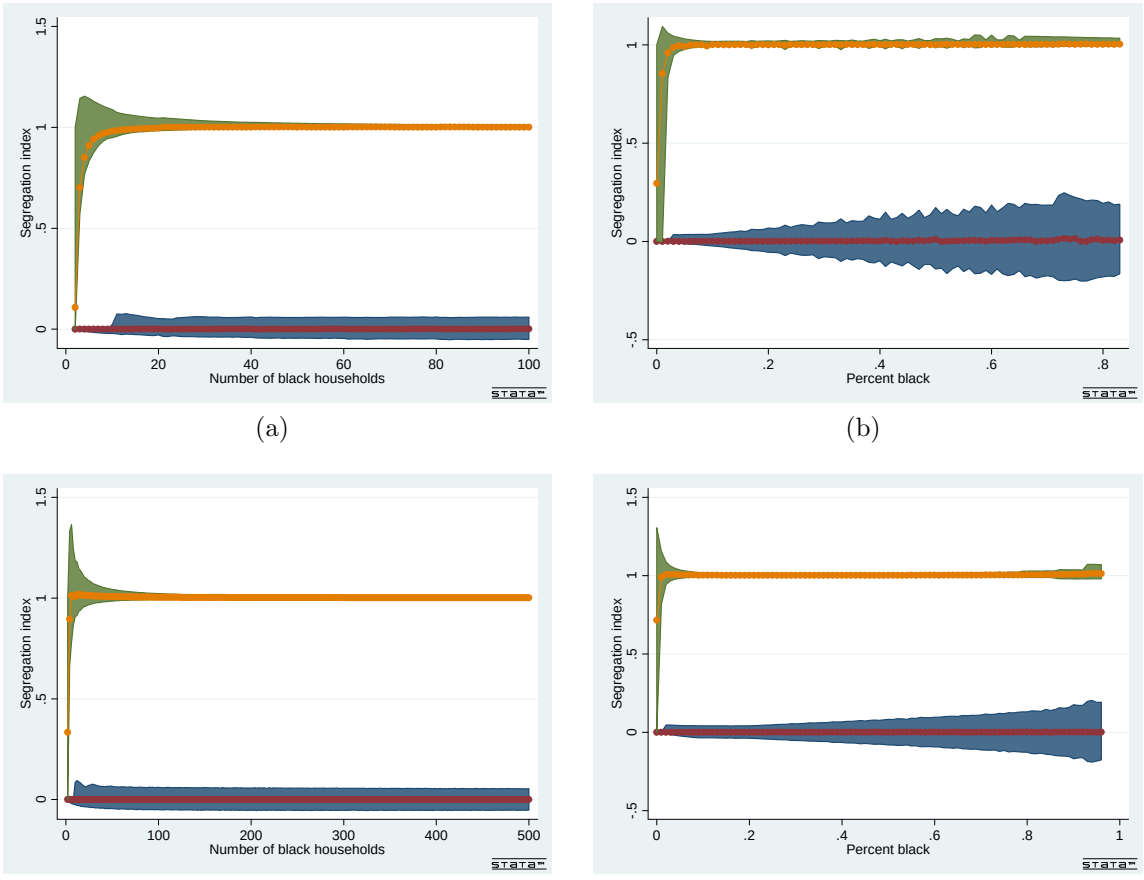

Figure 2: Simulated values for α under no segregation and complete segregation (points give the mean of α while the bands represent the 5th and 95th percentiles): (a) by number of black households with 5% of households missing; (b) by percent black with 5% of households missing; (c) by number of black houeholds with 20% of households missing; and, (d) by percent black with 20% of households missing.

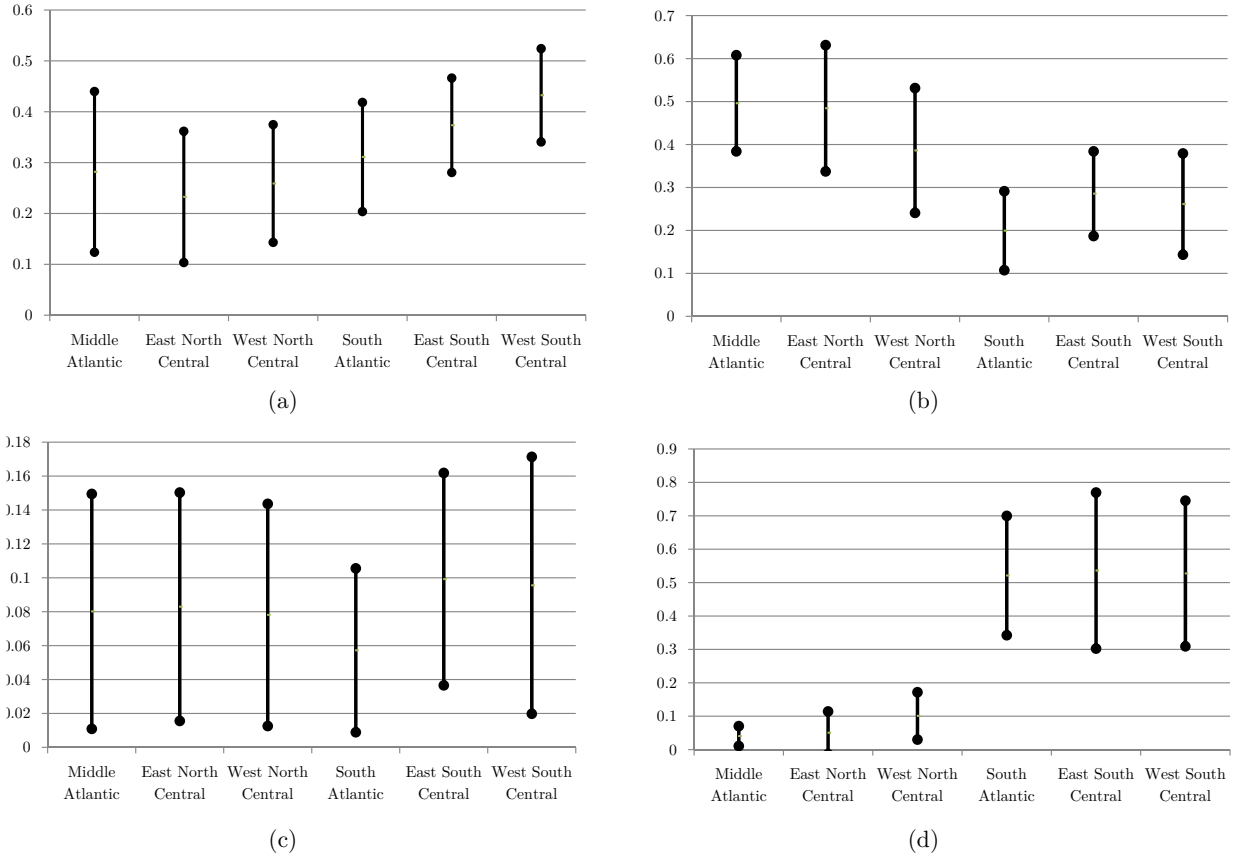

Figure 3: Black household weighted measures of segregation for rural counties by region. Upper and lower endpoints of bars correspond to one standard deviation above and below the mean, respectively. The measures in each panel are: (a) our α measure, (b) the index of dissimilarlity, (c) the index of isolation, and (d) the percentage of household heads who are black.

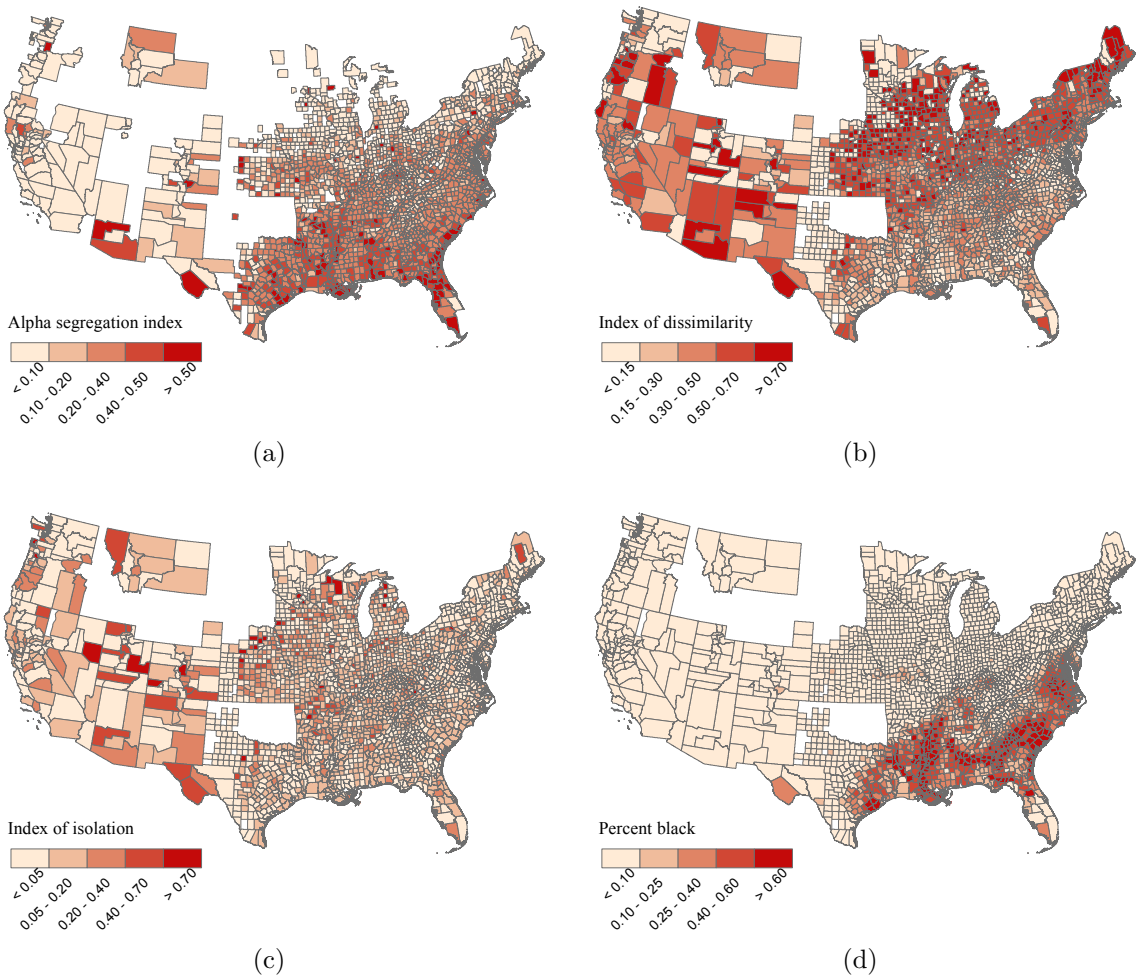

Figure 4: Segregation measures by county, 1880: (a) our α measure; (b) index of dissimilarity; (c) index of isolation; and, (d) percent black.

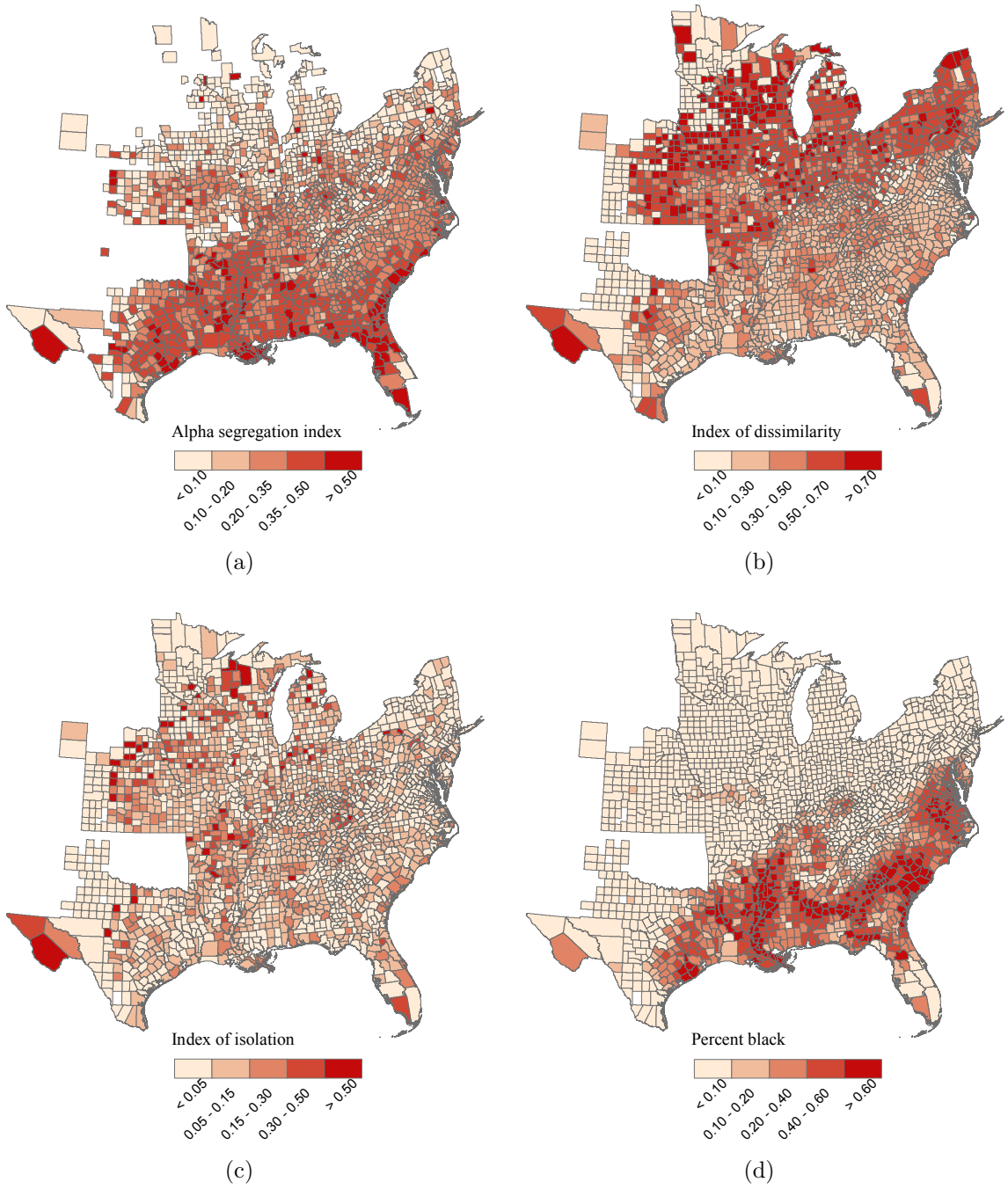

Figure 5: Segregation measures by county for regions with greater than 1% black population, 1880: (a) our α measure; (b) index of dissimilarity; (c) index of isolation; and, (d) percent black.

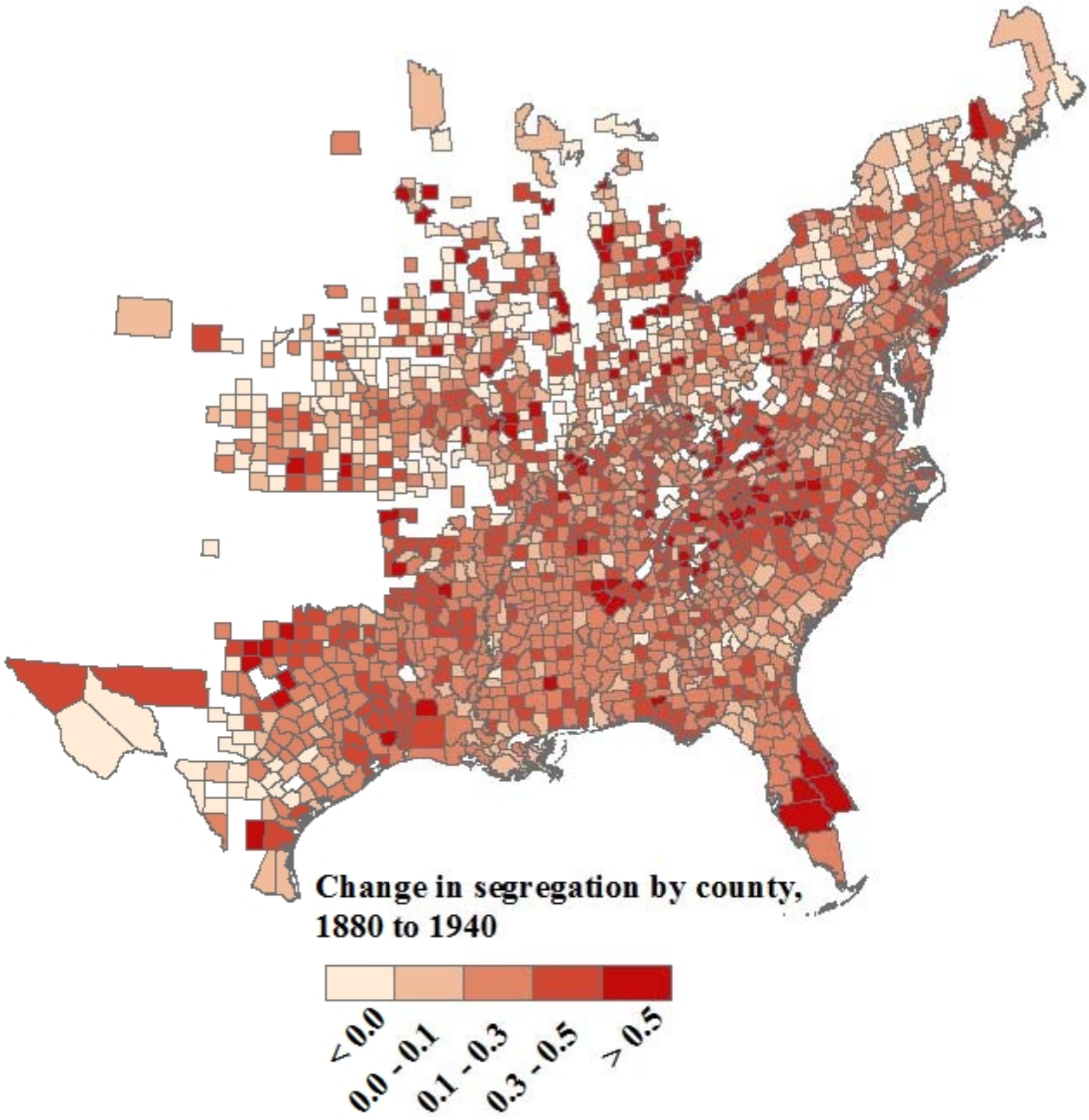

Figure 6: Change in the Neighbor-Based Measure of Segregation, 1880-1940. Source: Author's Calculations.

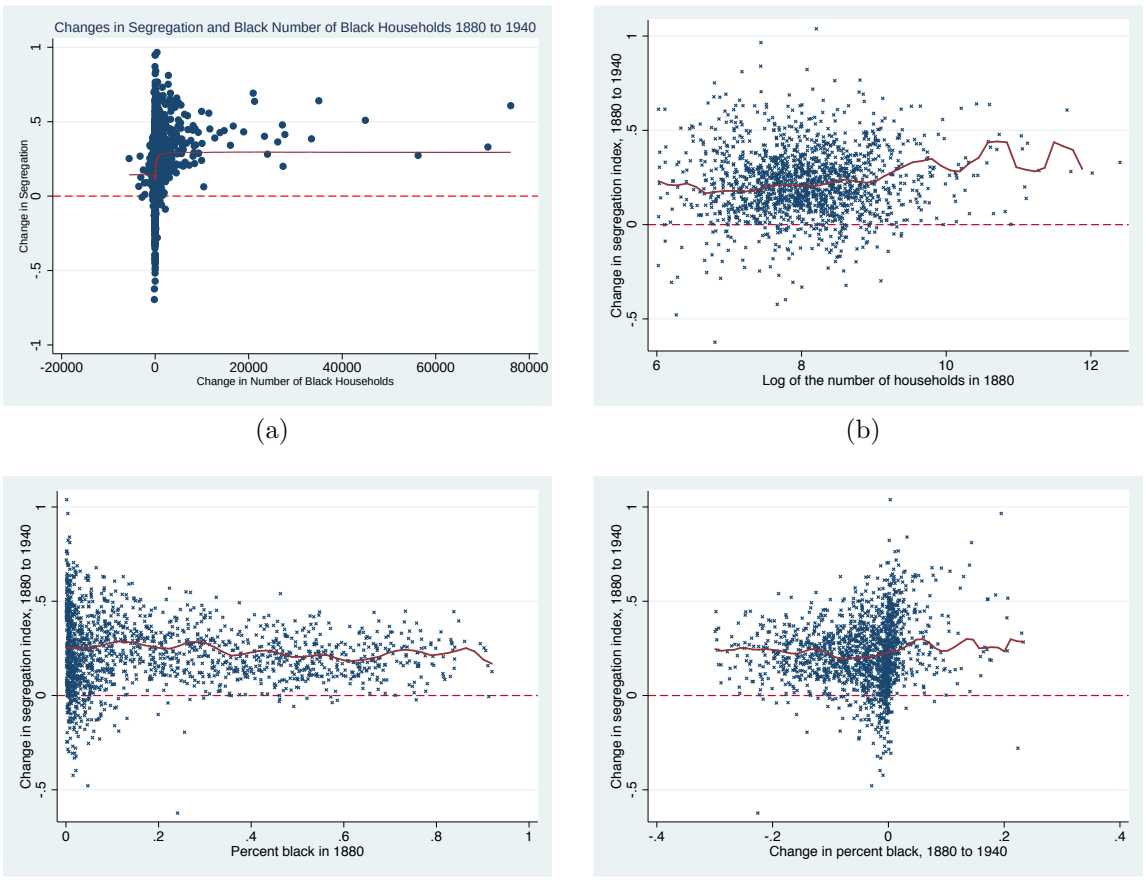

Figure 7: Changes in segregation by county, 1880-1940, by: (a) the change in the number of black households; (b) the change in the log number of households; (c) the percent black in 1880; and, (d) change in the percent black, 1880-1940.

A Deriving the Segregation Measure

Construction of the measure begins by identifying neighbors in the census. The complete set of household heads in the census are sorted by reel number, microfilm sequence number, page number and line number. This orders the household heads by the order in which they appear on the original census manuscript pages, meaning that adjacent households appear next to one another. There are two different methods for identifying each household head's next-door neighbors. The first is to simply define the next-door neighbors as the household head appearing before the individual on the census manuscript page and the household head appearing after the individual on the census manuscript page. An individual that is either the first or last household head on a particular census page will only have one next door neighbor identified using this method.

Naturally, one must be particularly careful to test the proposition that adjacency is a measure of neighbor status. To allow for the next door neighbor appearing on either the previous or next census page and to account for the possibility that two different streets are covered on the same census manuscript page, an alternative method for identifying neighbors is also used that relies on street name rather than census manuscript page. In this alternative measure next-door neighbors are now identified by looking at the observations directly before and after the household head in question and declaring them next-door neighbors *if and only if* the street name matches the street name of the individual of interest (and the street name must be given, two blank street names are not considered a match). This approach has the advantage of finding the last household head on the previous page if an individual is the first household head on his census manuscript page or the first household head on the next page if the individual was the last household head on a manuscript page. However, the number of observations is reduced substantially relative to the first method because many individuals have no street name given. Few roads had names in historical census records. This is particularly true in rural areas.

Once next door neighbors are identified, an indicator variable is constructed that equals one if the individual has a next door neighbor of a different race and zero if both next-door neighbors are of the same race as the household head.[34] Two versions of this indicator variable are constructed, one

[34]Based on the race assigned at enumeration. This is similar to the *racesing* coding of race constructed by IPUMS.

in which all observations are used and one in which only those observations for which both next-door neighbors are observed are used. This latter version reduces the sample size but, for the remaining individuals, gives a more accurate measure of the percentage of individuals with a neighbor of a different race.

Formally, we begin with the following:

- b_{all}: the total number of black household heads in the area
- $n_{b,B=1}$: the number of black household heads in the area with two observed neighbors
- $n_{b,B=0}$: the number of black household heads in the area with one observed neighbor
- x_b: the number of black household heads in the area with a neighbor of a different race

The equivalent variables for the set of white household heads are similarly defined. These components, by themselves, can be used to derive new measures of social interaction between races. For example, using the measures above one can calculate the share of households with an opposite race neighbor.

Given these measures, the basic measure of segregation is calculated as the distance the area is between the two extremes of complete segregation and the case where neighbor's race is entirely independent of an individual's own race. There are a total of four versions of the segregation measure. Each of these measures corresponds to one of the two different methods of defining next-door neighbors (whether the specific street of residence is identified on the census manuscript form) and whether all individuals with a neighbor present are included or only those individuals with both neighbors identified are used.

In the case of random neighbors, the number of black residents with at least one white neighbor will be a function of the fraction of black households relative to all households. In particular, the probability that any given neighbor of a black household will be black will be $\frac{b_{all}-1}{(b_{all}-1)+w_{all}}$.The probability that the second neighbor will be black if the first neighbor is black will then be $\frac{b_{all}-2}{b_{all}-2+w_{all}}$. The

One key feature of *racesing* for our purposes is places people with their race given as 'mulatto' in the same category as people with their race given as 'black'. So a black individual living next to two neighbors listed on the census as mulatto would be considered to be of the same race as his neighbors.

probability that a black household head will have at least one white neighbor can be written as a function of these probabilities by expressing it as:

$$p(\text{white neighbor}) = 1 - \left(\frac{b_{all} - 1}{b_{all} - 1 + w_{all}}\right)\left(\frac{b_{all} - 2}{b_{all} - 2 + w_{all}}\right) \tag{2}$$

where the second term comes from the assumption that the races of adjacent neighbors are uncorrelated, a reasonable assumption given that we are considering randomly located neighbors. The expected value of x_b under random assignment of neighbors would then be:

$$E(\overline{x_b}) = p(\text{white neighbor}) \cdot n_b \tag{3}$$

$$E(\overline{x_b}) = n_b\left(1 - \left(\frac{b_{all} - 1}{b_{all} - 1 + w_{all}}\right)\left(\frac{b_{all} - 2}{b_{all} - 2 + w_{all}}\right)\right) \tag{4}$$

The calculation of this upper bound on x_b must be modified slightly when including household heads for which only one neighbor is observed. In this case, the expected number of black household heads with a white neighbor under random assignment of neighbors will be composed of two different terms, the first corresponding to those household heads with both neighbors observed and the second corresponding to those household heads with only one neighbor observed. Letting B be an indicator variable equal to one if both neighbors are observed and equal to zero if only one neighbor is observed, the expected total number of black household heads with a white neighbor is then:

$$E(\overline{x_b}) = p(\text{white neighbor}|B = 1) \cdot n_{b,B=1} + p(\text{white neighbor}|B = 0) \cdot n_{b,B=0} \tag{5}$$

$$E(\overline{x_b}) = n_{b,B=1}\left(1 - \left(\frac{b_{all} - 1}{b_{all} - 1 + w_{all}}\right)\left(\frac{b_{all} - 2}{b_{all} - 2 + w_{all}}\right)\right) + n_{b,B=0}\left(1 - \frac{b_{all} - 1}{b_{all} - 1 + w_{all}}\right) \tag{6}$$

Under complete segregation, the number of black individuals living next to white neighbors would simply be two, the two individuals on either end of the neighborhood of black residents, giving a lower bound for the value of x_b. However, it is necessary to account for observing only a fraction of the household heads. The expected observed number of black household heads living next to a white

neighbor when sampling from an area with only two such residents will be:

$$E(\underline{x_b}) = p(\text{observe one of the two in } n_b \text{ draws}) \cdot 1 + p(\text{observe both in } n_b \text{ draws}) \cdot 2 \tag{7}$$

$$E(\underline{x_b}) = \frac{1}{\frac{1}{2}(n_b+1)} \left(1 - \prod_{i=0}^{n_b-1} \frac{b_{all}-i-2}{b_{all}-i}\right) + 2\left(1 - \frac{1}{\frac{1}{2}(n_b+1)}\right)\left(1 - \prod_{i=0}^{n_b-1} \frac{b_{all}-i-2}{b_{all}-i}\right) \tag{8}$$

The product in the expression above gives the probability of selecting neither of the two black household heads with white neighbors in n_b successive draws from the b_{all} black household heads. Thus one minus this product is the probability of drawing either one or both of the two household heads with white neighbors. Note that the product notation is used above because it makes it easier to see how the probability is being derived. In practice, the product reduces to $\frac{(b_{all}-n_b)(b_{all}-n_b-1)}{b_{all}(b_{all}-1)}$. The ratio $\frac{1}{\frac{1}{2}(n_b+1)}$ gives the fraction of these cases that correspond to drawing just one of the two household heads with white neighbors. This comes from noting that with n_b draws, that there are n_b ways to draw one of the two household heads while there are $\sum_{i=1}^{n_b-1}(n_b-i)$ or $n_b(n_b-1) - \frac{(n_b-1)n_b}{2}$ ways to draw both of the household heads.

Finally, in the case where household heads with only one observed neighbor are included, it is necessary to account for the probability that a black household head with a white neighbor will be drawn but that white neighbor is not the observed neighbor. The expected value of x_b accounting for the probability that the white neighbor is unobserved for a household head with only one observed neighbor is:

$$\begin{aligned} E(\underline{x_b}) &= \left(\frac{n_{b,B=1}}{n_b} + \frac{n_{b,B=0}}{n_b} \cdot \frac{1}{2}\right) && (9)\\ &\quad \cdot \left[\frac{1}{\frac{1}{2}(n_b+1)}\left(1 - \prod_{i=0}^{n_b-1} \frac{b_{all}-i-2}{b_{all}-i}\right) + \right. && (10)\\ &\quad \left. 2\left(1 - \frac{1}{\frac{1}{2}(n_b+1)}\right)\left(1 - \prod_{i=0}^{n_b-1} \frac{b_{all}-i-2}{b_{all}-i}\right)\right] && (11) \end{aligned}$$

In this equation, the fraction of black household heads with only one observed neighbor, $\frac{n_{b,B=0}}{n_b}$, has its expected value of x_b reduced by an additional factor of $\frac{1}{2}$ to account for the fact that if one of these individuals is one of the two black household heads living next to a white neighbor there is only

a 50 percent chance that the white neighbor is the observed neighbor.

The degree of segregation in an area, α, can then be defined as the distance between these two extremes, measured from the case of no segregation:

$$\alpha = \frac{E(\overline{x_b}) - x_b}{E(\overline{x_b}) - E(\underline{x_b})} \tag{12}$$

This segregation measure increases as black residents become more segregated within an area, equaling zero in the case of random assignment of neighbors (no segregation) and equalling one in the case of complete segregation.[35][36]

[35]Note that it is possible for this measure to be less than zero if the particular sample of household heads is actually more integrated than random assignment of neighbors. For example, suppose every other household head on the manuscript pages were black in an area that is 50 percent black. With random assignment of neighbors we would expect to observe at least some black household heads having black neighbors. In this case, x_b would be larger than $E(\overline{x_b})$ making α negative. The measure can also exceed one in the rare cases where only zero or one black household heads with a white neighbor are observed. In these cases x_b may actually be smaller than $E(\underline{x_b})$. We do not observe this for counties with more than ten black households.

[36]Given the evidence that population counts of the size of the African American community in census returns is biased, we are concerned about the problem of missing African Americans (Coale & Rives, 1973; Eblen, 1974; Preston et al., 1998). While it would appear that under-reporting of African Americans would be a concern, it would only bias estimates of the segregation measure if the missing African American households had white neighbors. To see how, note that $E(\underline{x_b})$ is invariant to the number of black and white households as it estimates the minimum number of households who would have opposite race neighbors, which itself is not a function of the size of either group. Since the measure of segregation is the ratio of the two differences ($E(\overline{x_b})$ - x_b and $E(\overline{x_b})$ - $E(\underline{x_b})$), only if the estimate of x_b is biased downward would missing black households have a material effect on the estimate of segregation. Given the reality of census enumeration, it is unlikely that enumerators deliberately skipped African American households in integrated communities as opposed to skipping entire groups of black households.