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SOCI 20253 1 - Introduction to Spatial Data Science - Final project

**Introduction:** The purpose of this investigation is to analyze the spatial distribution of the black population of Hennepin County, Minnesota (Minneapolis and its suburbs), and to gain a better understanding of why the county is so distinctly segregated. Though one potential explanation for this pattern is self-selection—that black people may prefer to live in areas with already existing black populations—I will analyze whether two structural variables, the locations of racially restrictive covenants and housing values (often determined by discriminatory zoning practices), may provide a significant part of the explanation for why black people in Hennepin County live where they do as well. It is important to investigate where barriers to desegregation remain in order to determine where integration efforts (eg. busing, housing loan programs) are most needed in order to promote equality.

Zoning and racial covenants were used extensively throughout the early and mid-20th century to exclude black populations (as well as other racial and ethnic groups, though to a lesser degree) from wealthy areas and suburbs in and around most American cities. While zoning is a government practice that determines the types of land use in each building lot (which can affect housing values), racial covenants were private agreements in housing deeds that required future homeowners not to sell to the specified racial groups under contract, which lasted even after they were deemed unenforceable by the Supreme Court in 1948. These were especially used in nearby suburban areas, which were largely developed during the times that these practices were in use. Due to both a lack of economic mobility and continuing racial prejudice and fear in areas with racial covenants, these patterns of segregation have largely persisted into the present day.

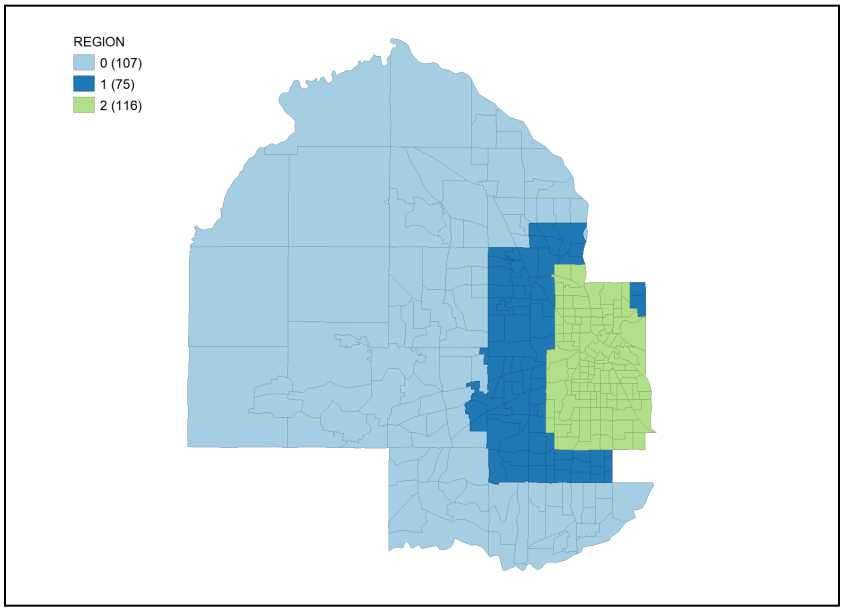


**Figure 1:** The division of Hennepin County into three regions. There are 107 outer suburban tracts, 75 inner suburban tracts, and 116 tracts in Minneapolis.

This study will separate Hennepin County into three subregions, the city of Minneapolis itself, the inner ring of suburbs, which was mostly developed by the mid-20th century,[1] and the outer ring of suburbs that was largely developed later. This division is presented in Figure 1. The inner ring mainly developed during the period of time in which racial covenants and discriminatory zoning practices were most regularly used, while the outer ring mainly developed later.

**Research question and hypotheses:** Can the distribution of the black population in Hennepin County today be partially explained by the spatial concentrations of racially restrictive covenants and housing values? Furthermore, where do each of these explanatory variables have the strongest impact on the distribution of the black population today? My hypotheses are as follows:

1. Black populations will be lower in areas with higher concentrations of racial covenants (measured in houses with racial covenants per capita within a given areal unit) and higher median housing values, as racial prejudice in areas with covenants and a lack of economic mobility have maintained patterns of segregation, not merely self-selection.
2. The concentration of racial covenants will have the greatest negative impact on the percent black population in the inner ring of suburbs, as fewer covenants were written by the time the outer suburbs developed, and because Minneapolis developed earlier (and thus its racial restrictions are likely older, allowing for a greater time period of racial diffusion). There will likewise be more multivariate high-high clusters of racial covenants and *non*black populations in the inner ring than in other areas proportionately.
3. The impact of housing values on the percent black population will be more evenly distributed between the three subregions, as they represent a contemporary economic barrier to poor black populations, regardless of where they are. However, there will likely be more high-high multivariate clusters between median house value and *non*black populations in the outer ring of suburbs than in other areas proportionately, because black populations tend to be lower and land values tend to be higher in the more distant suburbs.

**Data and variables (See Table 1 for descriptive statistics):** The following variable is from Mapping Prejudice,[2] a project that has mapped all racial covenants in Hennepin County:

- **"cov_pcap"** - number of houses with covenants per census tract per capita (continuous, independent variable). This was calculated by finding the centroids of each housing lot with a covenant, joining the centroids to the tracts using a spatial count, and dividing the count by "tot_pop" (see below).

[1] The selected suburbs were (in clockwise order from the south) Richfield, Edina, Hopkins, St. Louis Park, Golden Valley, Robbinsdale, Crystal, New Hope, Brooklyn Center, and St. Anthony, each of which were at least partially developed by 1950. Though with a few exceptions, most other suburbs were developed after.
[2] Ehrman-Solberg, K., Petersen, P., Mills, M., Delegard, K., & Mattke, R. (2020). *Racial Covenants in Hennepin County* [Data set]. Data Repository for the University of Minnesota. https://doi.org/10.13020/a88t-yb14.

The following variables are from 2019 5-year ACS estimates.[3] Variables and tract boundaries were extracted using the "tidycensus" R package.

- B25077_001 - **"med_hvalE"** - median value of owner-occupied housing units (continuous, independent variable)
- B02001_003 - **"blackP"** - percent black or African American population (continuous, dependent variable), calculated by dividing the original census variable by "tot_pop"
- B01003_001 - "**tot_pop**" - "total population" (continuous, used as a denominator to make "blackP" and "cov_pcap" spatially intensive)

| Variable | Min | Max | Mean | Std. Dev. |
|---|---|---|---|---|
| "med_hvalE" | $0.00 | $946200 | $287580.90 | $120366.10 |
| "cov_pcap" | 0.0 | 0.309 | 0.0232 | 0.0508 |
| "blackP" | 0.0 | 0.714 | 0.139 | 0.147 |
| "tot_pop" [denominator] | 1052 | 16206 | 4179.581 | 1975.673 |

**Table 1:** Descriptive statistics of each variable, divided by the total population in each tract.

**Areal units:** Census tracts in Hennepin County were used. There are 298 tracts,[4] averaging 2.03 $mi^2$ each. Tracts were chosen because they were the best level at which census data were available, allowing for a reasonable amount of internal variation (at the county level there would be no variation, and at the block group level there would be too much internal variation to be meaningful and an unmanageable amount of data). The extent is Hennepin County, where covenant data are available from Mapping Prejudice, which allows for the analysis of Minneapolis and its major suburbs. There are 116 tracts in Minneapolis, 75 in the inner suburban ring, and 107 in the outer ring (and thus the division is fairly even).

**Projection:** EPSG:26915, which projects Hennepin County in a flat plane, to allow for euclidean distance-based weights. The projection was obtained from the covenant data.[5]

**Basic EDA:** Univariate: Figures 2-4 are natural breaks maps (5 bins) of each variable. Just from analyzing these maps, it is clear that the black population in Hennepin County is most greatly concentrated in North Minneapolis and on the east side of the city, while also concentrated

[3] U.S. Census Bureau. (2019). *2015–2019 American Community Survey 5-year Estimates*.
[4] Excluding tract 9800 (Fort Snelling), as its population is only 322, its houses with racial covenants were all displaced by the construction of the airport, and its demographics are not reflective of the rest of the study area (military personnel and veteran housing).
[5] Projection information: "+proj=utm +zone=15 +datum=NAD83 +units=m +no_defs". From the .prj file: PROJCS["NAD_1983_UTM_Zone_15N",GEOGCS["GCS_North_American_1983",DATUM["D_North_American_1983",SPHEROID["GRS_1980",6378137.0,298.257222101]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-93.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0]]

somewhat in the northern suburbs. This appears to inversely follow the trends of the housing values map, which indicates higher housing values in the opposite areas. Meanwhile, racially restrictive covenants are most common in the nearby western and southern suburbs, where black populations are lower, but they are low in concentration both where there are high and low black populations. Figure 5-7 are conditional boxplots that compare each of these variables between the three subregions. While the percent black population increases stepwise closer to the city center (although the range also increases), house value similarly decreases, though the difference in the latter between the inner suburbs and the city is minimal. This could indicate that house value has a stronger effect on the percent black population between the two rings of suburbs than between the inner suburbs and the city, although on the macro, subregional scale. Meanwhile, the density of racial covenants is by far the highest in the inner ring of suburbs, while it is very low in the city (second lowest) and in the far suburbs (lowest). This could indicate that on this broad scale, there may be weaker correlation between covenant density and black population (especially given that the area with the fewest covenants has the lowest black population). However, a direct bivariate analysis between each of these variables would be needed to determine correlations among individual observations, rather than among entire subregions.

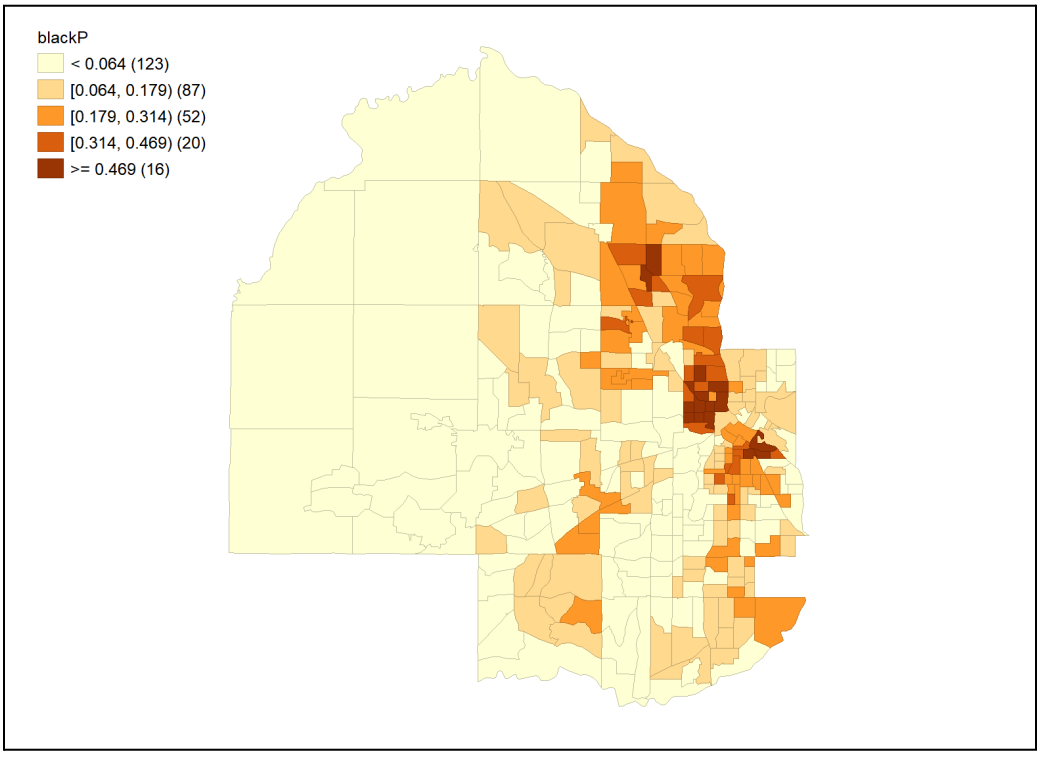


**Figure 2:** Percent black population in each census tract

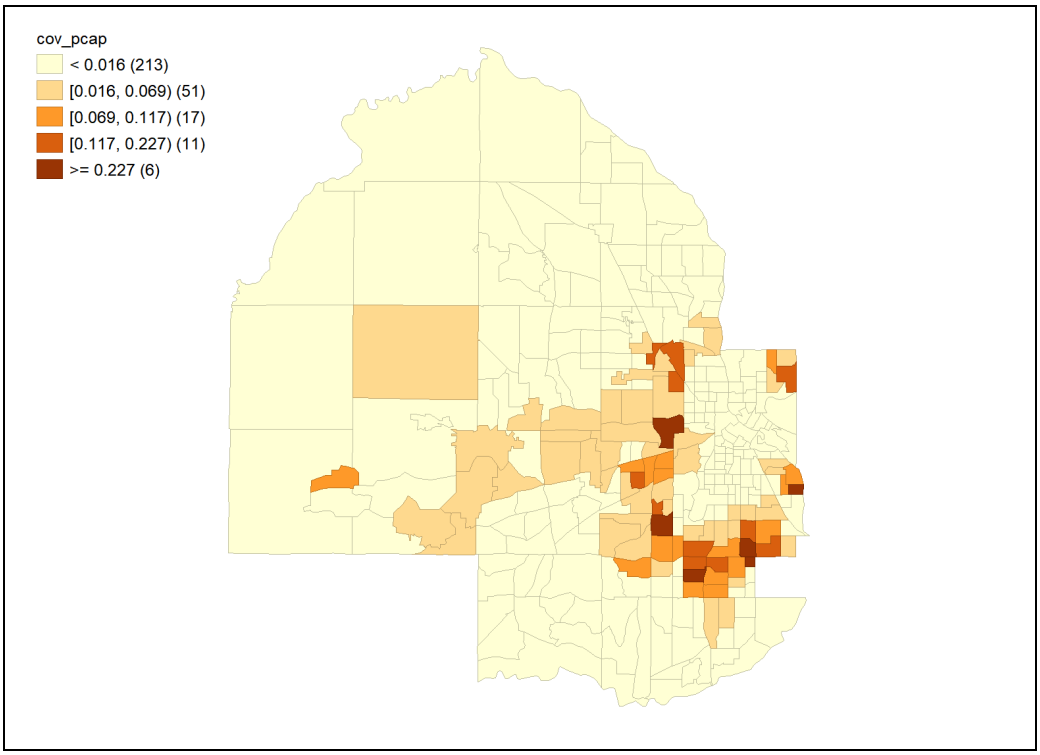


**Figure 3:** Number of houses with covenants per capita in each tract

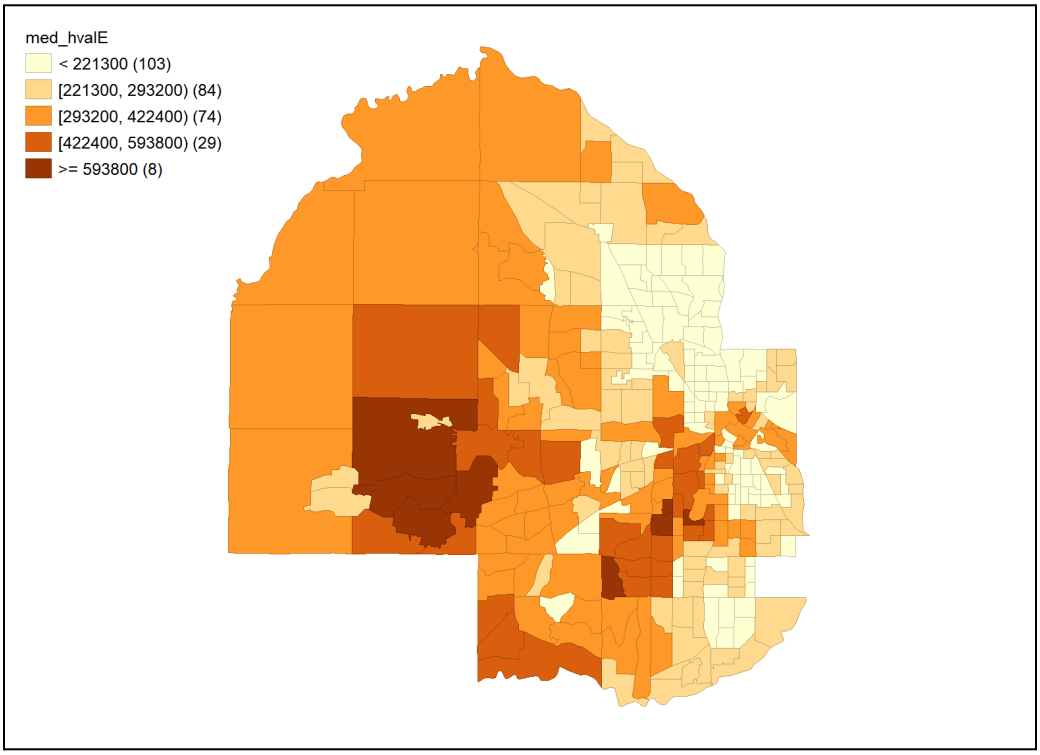


**Figure 4:** Median house value in each tract

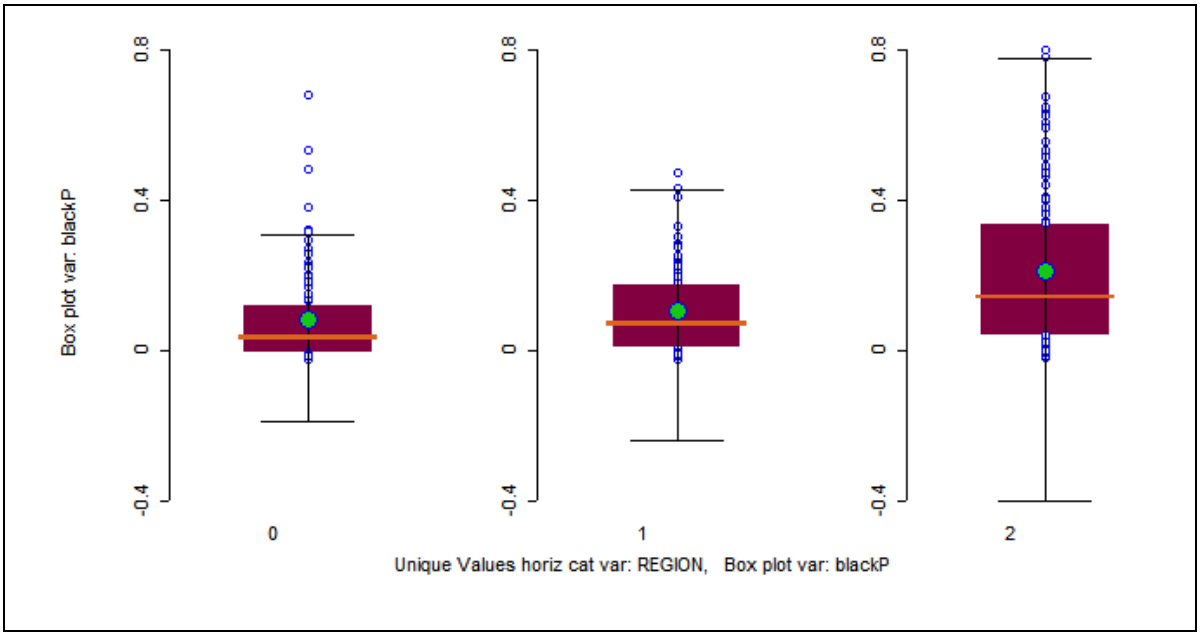


**Figure 5:** Conditional boxplot (hinge = 1.5) of the percent black population in each subregion (0 = far suburbs, 1 = near suburbs, 2 = Minneapolis)

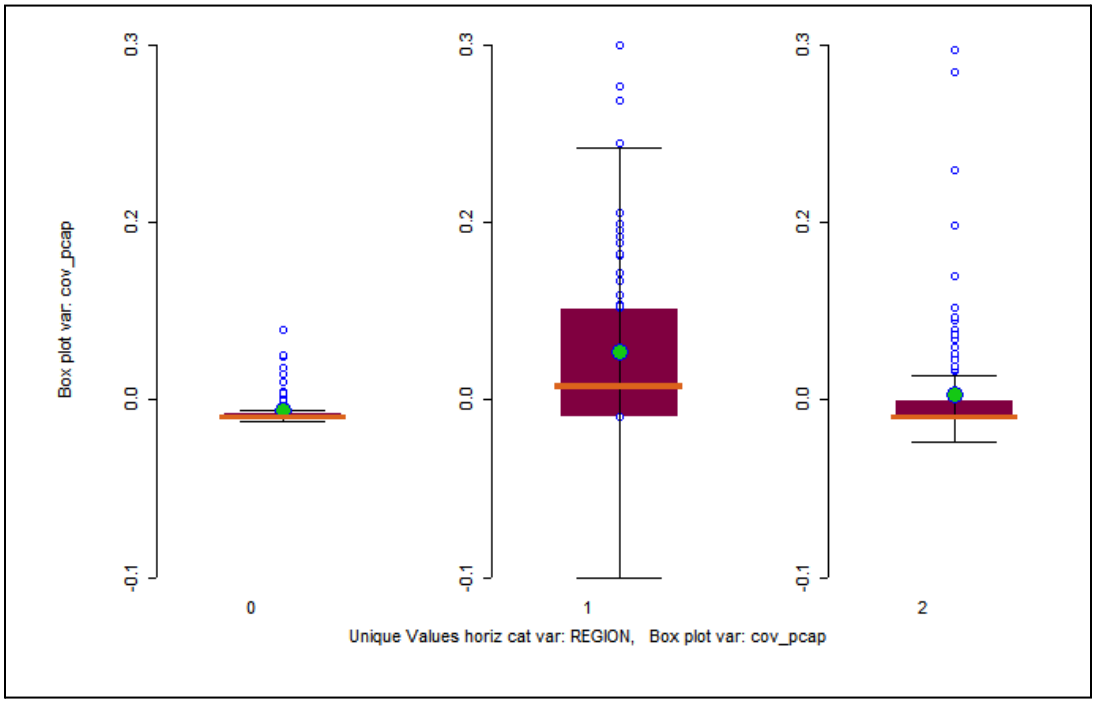


**Figure 6:** Conditional boxplot (hinge = 1.5) of the number of covenants per capita in each subregion

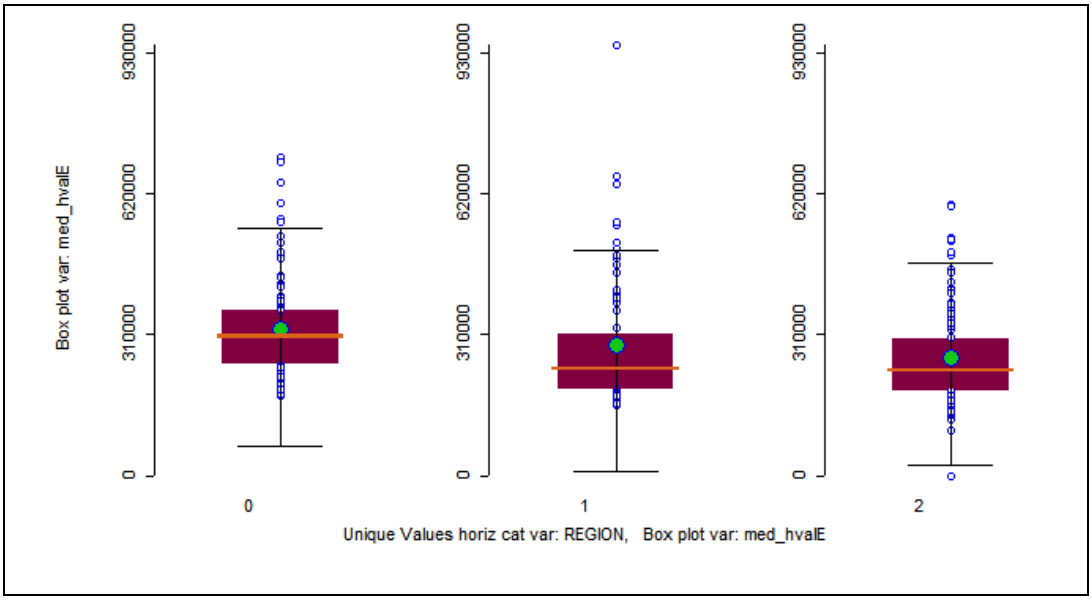


**Figure 7:** Conditional boxplot (hinge = 1.5) of the median house value in each subregion

Bivariate (Covenants and black population): Figure 8 is a scatterplot comparing covenant density to percent black population in all tracts. While there is a clear negative correlation between the two (supporting the first hypothesis), it is far from linear. This appears to be the case because, while census tracts with high concentrations of covenants tend to only have low black populations, census tracts with low concentrations of covenants tend to include both high and low black populations. Thus, while racially restrictive covenants can explain low black populations in the areas where they are, they cannot explain high or low black populations in the areas where they are not. However, the LOWESS smoother in Figure 8 also reveals another trend; an increase in racial covenants tends to decrease black population, but only up to a point (around the mean "cov_pcap" value, ~0.02, as indicated by the vertical dotted line). In fact, though black populations are very low in areas with a greater than average concentration of covenants, any further increase in covenant concentration hardly decreases the black population percentage at all (see Figure 9; the trendline for the selected tracts is almost flat). By viewing these tracts on the subregion map (Figure 10), it is revealed that they most profusely cover inner suburban tracts (52% of tracts in the inner suburban ring), though 19.8% of Minneapolis tracts and 0.065% of outer suburban tracts overlap as well. Sensitivity analysis was conducted to ensure that the ratios between these percentages were roughly the same using other cutoffs near the bend in the scatterplot. By selecting the inner ring (Figure 11), it is revealed that there is in fact a weaker effect of covenant density on the percent black population in the inner suburban region than in the other two regions (while the subregion has the highest density of covenants overall, as seen in Figure 6, and the second lowest black population, as seen in Figure 5), in direct contrast to the first part of my second hypothesis. However, the p-value of the Chow test, 0.578, indicates that the correlation is not significantly weaker in the inner suburban ring compared to the other subregions (though it is likely not stronger). Nevertheless, past a certain point (around 0.02 covenants per capita), a further increase in the concentration of covenants is

less likely to indicate a decrease in the percent black population, the possible reasons for which will be discussed in the "interpretation" section.

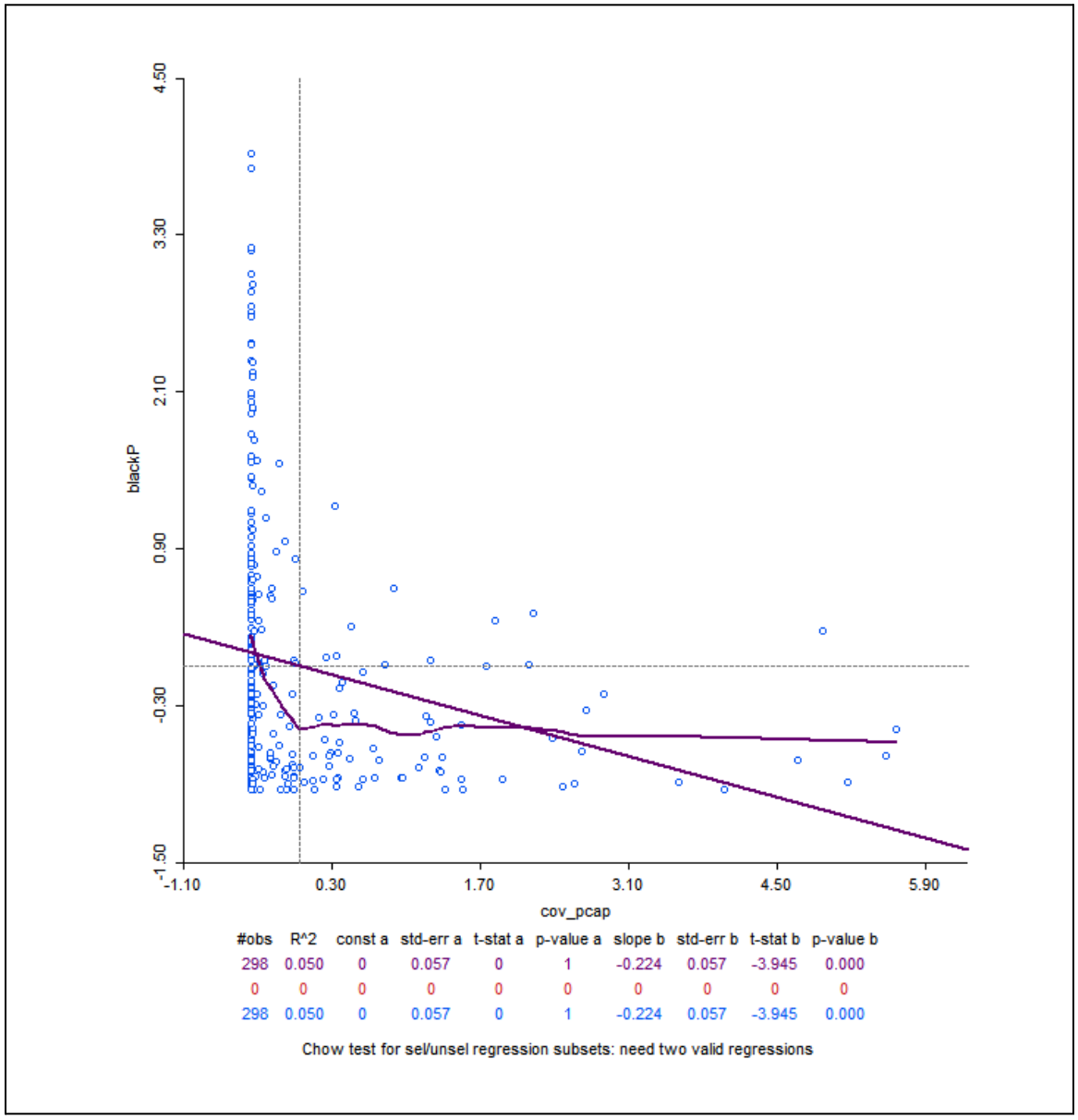


**Figure 8:** The effect of covenant density on the percent black population in each tract (data are standardized)

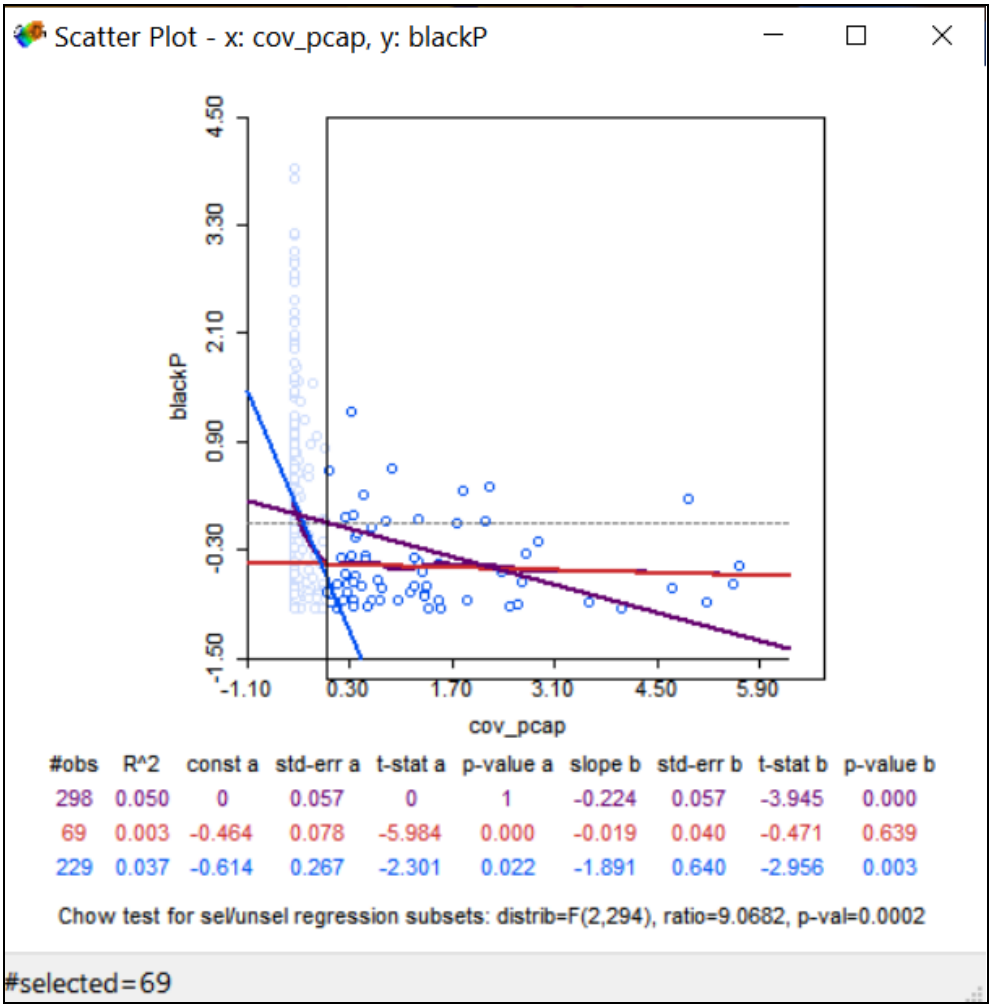


**Figure 9:** Same as Figure 8, but with areas past the bend in the LOWESS curve selected

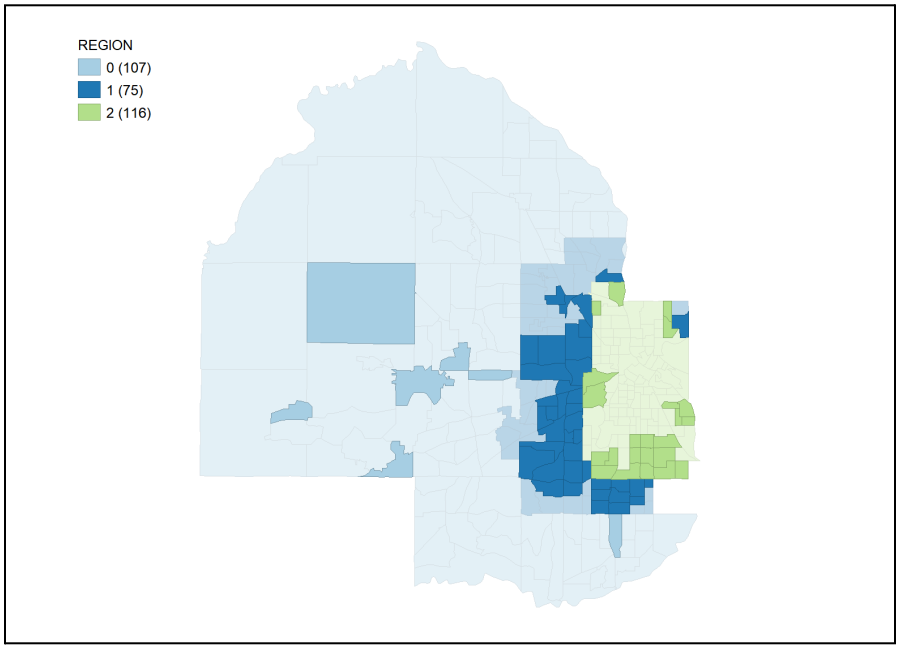

**Figure 10 (previous page):** The same selection, but overlaid on the subregion map. The inner suburban ring is most covered by tracts where increasing covenant concentrations do not further decrease the percent black populations (52% of tracts in the subregion), though 19.8% of Minneapolis tracts are covered as well (and only 0.065% of outer suburban tracts). Sensitivity analysis was conducted to ensure that these percentages were not merely an artifact of the exact cutoff chosen in Figure 9.

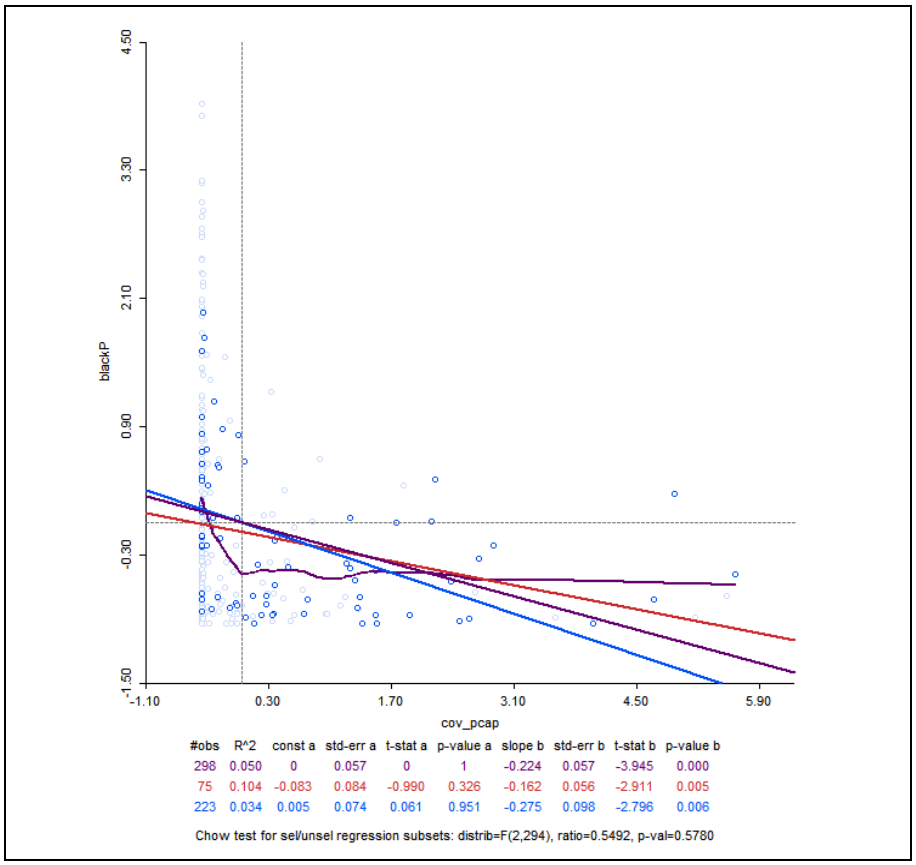


**Figure 11:** Same as Figure 8, but with the inner ring of suburbs selected. In the subregion, an increase in covenants actually is less of a predictor of low black population than in other subregions (though the high p-value of the Chow test should be noted - this is not a statistically significant difference).

Bivariate (Housing value and black population): Figure 12 compares median house value to percent black population in all tracts, which once again are negatively correlated (supporting the first hypothesis). Though it does not level off as dramatically, it once again appears that the association is nonlinear, with many tracts exhibiting both low levels of home value and percent black population. Thus, similarly to the association with covenants, high housing values can predict a lower percent black population, but low housing values do not necessarily predict a higher percent black population. Again, the LOWESS smoother in Figure 12 reveals another trend; after home values increase past a certain point, the percent black population declines to a far lesser degree, although by that point it is already fairly low. By selecting all observations after the curve most dramatically changes (Figure 13), it is revealed that beyond that point, higher housing value still leads to lower rates of black population, but far less than before (though the effect is less dramatic than that for covenant density in Figure 9). Viewing the selected area on

the subregion map (Figure 14), it is revealed that 73.8% of outer suburban tracts overlap with the selected region, while 41.3% of inner suburban and 41.4% of city tracts overlap. Sensitivity analysis was conducted, as before, to make sure that the ratio between these percentages was not highly dependent on the choice of cutoff point. There are therefore more tracts in the outer suburban ring where housing values are above the bend in the scatterplot, compared to other regions. Furthermore, by selecting the outer ring (Figure 15), it is likewise revealed that there is a weaker effect of house value on percentage black populations than in other subregions, even though the region has the highest house value and lowest percent black population (Figures 5 and 7). The difference in correlation, according to the Chow test, is also somewhat significant (given the p-value below 0.01). Therefore, like with covenants, an increase in housing value causes a decrease in black population, but less so once housing values pass a threshold (around $250K-$300K), and less so in the outer ring of suburbs, where housing values are greatest.

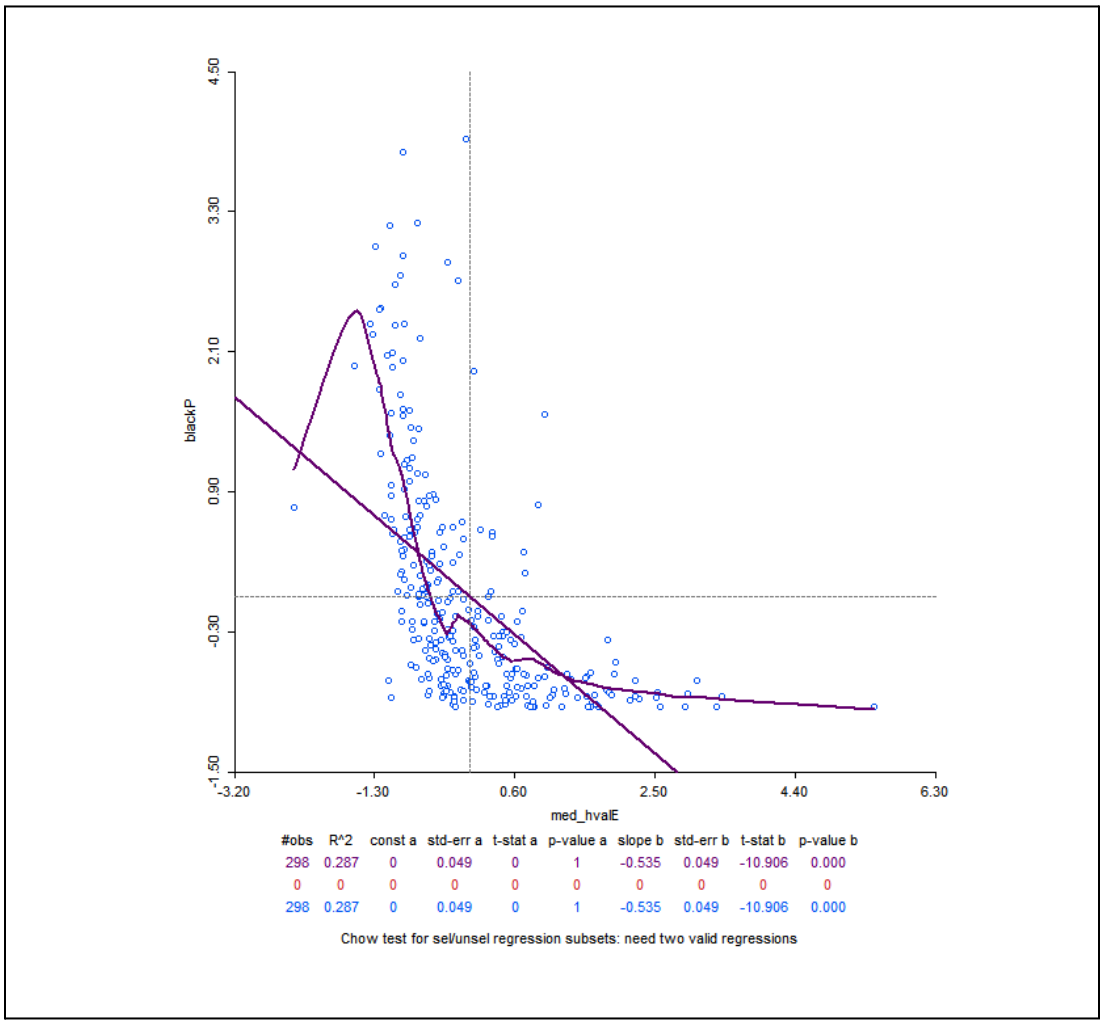


**Figure 12:** The effect of median house value on the percent black population per tract (data are standardized). The LOWESS smoother does show a positive trend on the far left, though this is likely due to the one tract that does not have any owner-occupied housing units, and thus "med_hvalE" is 0.

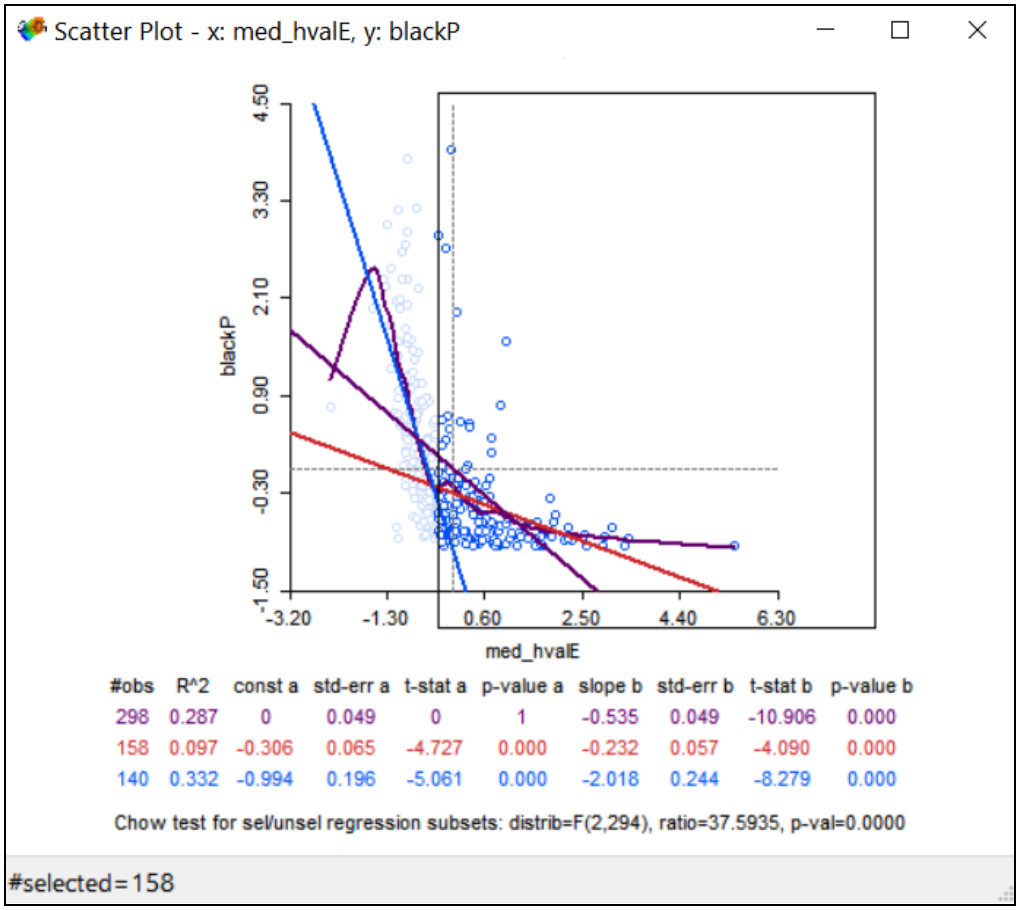


**Figure 13:** Same as Figure 12, but with areas past the bend in the LOWESS curve selected

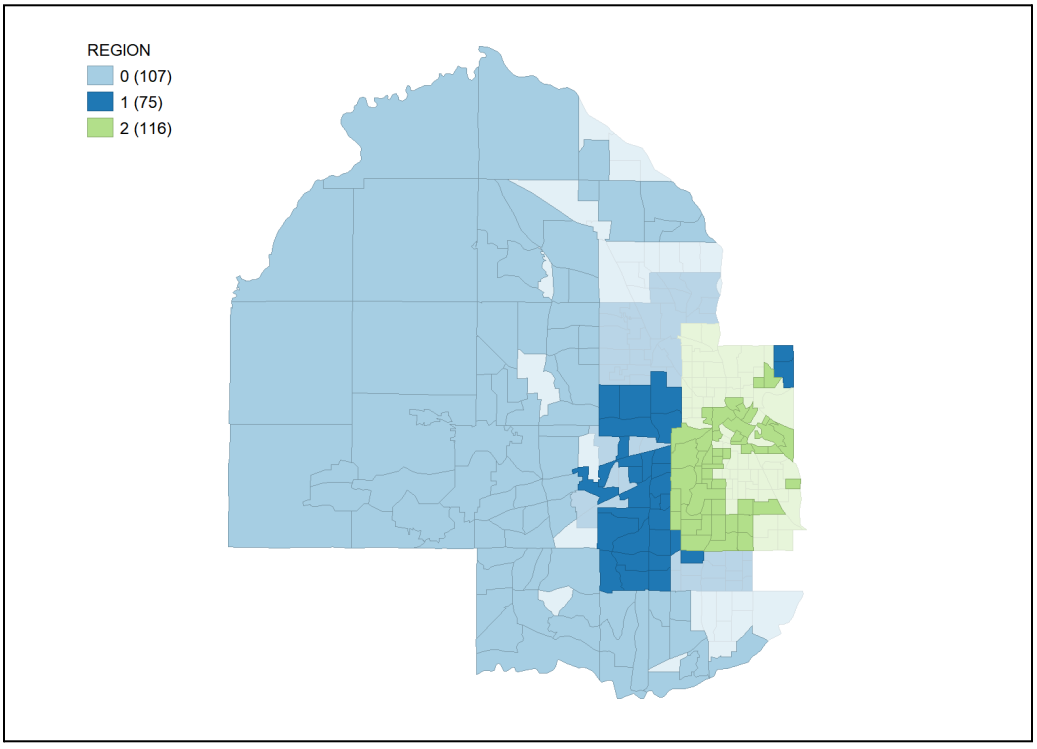

**Figure 14 (previous page):** The same selection, but overlaid on the subregion map. Outer suburban regions include the most areas where further increases in housing value did not reduce the percent black population (73.8% out of the outer suburban tracts), while such areas only covered 41.3% of inner suburban tracts and 41.4% of city tracts. Sensitivity analysis was conducted, as before, to make sure these figures were not highly dependent on the cutoff chosen in Figure 13.

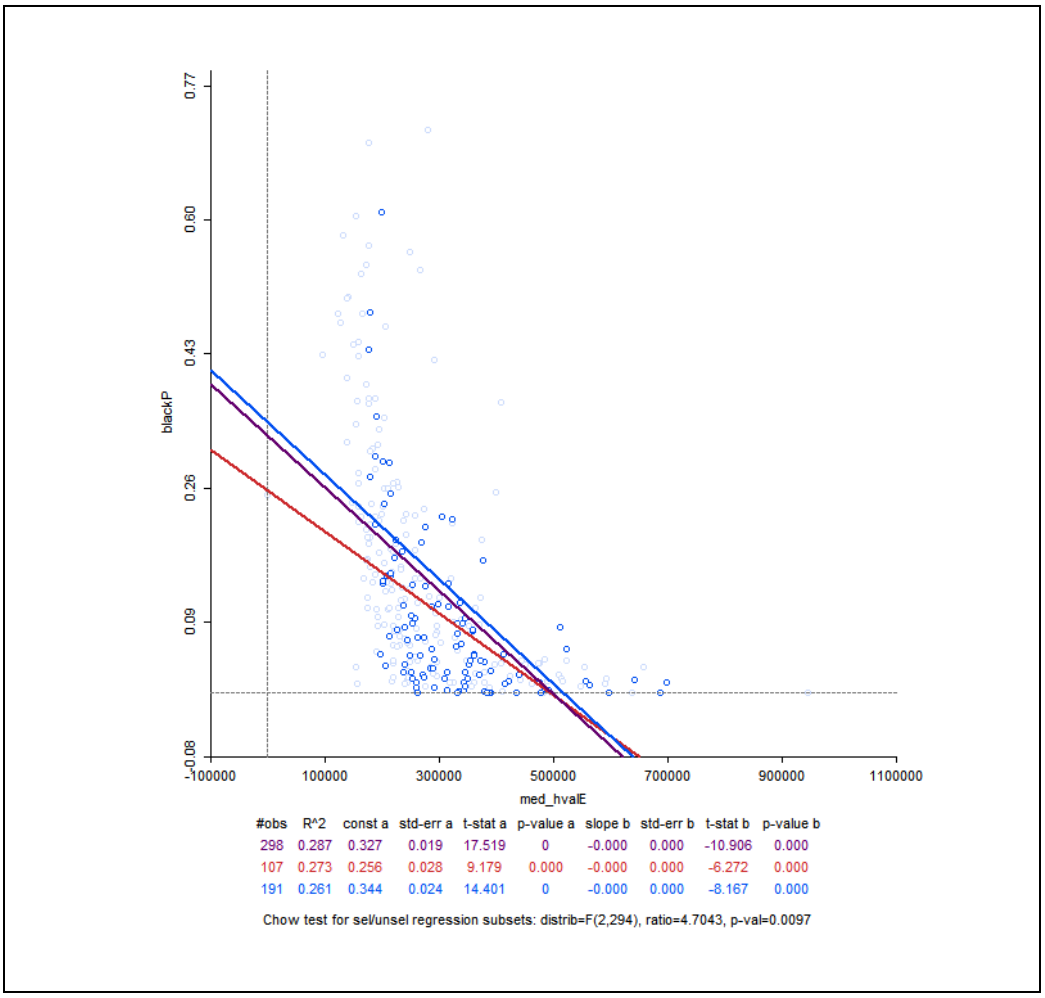


**Figure 15:** Same as Figure 12, but with the outer ring of suburbs selected. In the subregion, an increase in house value actually is less of a predictor of low black population than in other subregions. (Furthermore, the low p-value of the Chow test indicates that this is a somewhat significant difference).

**Sensitivity analysis and global SAC:** First of all, it was chosen to not include distance-based weights for SAC analysis, as the tracts vary in size, and thus more suburban tracts would have fewer neighbors, thus biasing the clustering results (it was found that a greater number of neighbors decreases Moran's I values and increases Z-scores). Furthermore, to avoid isolates, distance bands would be required to be far too large (almost 9 km), which would hide much internal variation within the city itself. The weights that were chosen for comparison were 1st and 2nd order (inclusive) queen contiguity weights (q1 and q2) and 6 and 19 nearest neighbor weights (6nn, 19nn) (the latter were chosen to roughly match the median/mean number of neighbors of the contiguity weights). Table 2 compares the Moran's I values (only to determine

the type of global SAC) and Z-scores for each weight. These Z-scores are also compared in Figure 16.

| Weight | Min/Max/Avg no. of neighbors | % Non-zero | Variable | Global Moran's I | Z-score (999 permutations)* |
|---|---|---|---|---|---|
| 1st order queen | Min: 1<br>Max: 11<br>Mean: 6.07 | 2.04% | blackP | 0.639 | 18.6489 |
| | | | cov_pcap | 0.391 | 12.0024 |
| | | | med_hvalE | 0.600 | 18.5981 |
| 6 nearest neighbors | Min: 6<br>Max: 6<br>Mean: 6 | 2.01% | blackP | 0.639 | 20.2276 |
| | | | cov_pcap | 0.374 | 12.3824 |
| | | | med_hvalE | 0.548 | 17.7878 |
| 2nd order queen (inclusive) | Min: 6<br>Max: 36<br>Mean: 19.05 | 6.39% | blackP | 0.454 | 24.4240 |
| | | | cov_pcap | 0.266 | 14.8327 |
| | | | med_hvalE | 0.451 | 24.2381 |
| 19 nearest neighbors | Min: 19<br>Max: 19<br>Mean: 19 | 6.38% | blackP | 0.499 | 28.4554 |
| | | | cov_pcap | 0.247 | 15.1189 |
| | | | med_hvalE | 0.438 | 24.7680 |

**Table 2:** Descriptions of spatial weights and global Moran's I values (and significance levels) for each variable and weight combination. *Permutations are limited to 999 due to computing power constraints. Pseudo p-values were all 0.001.

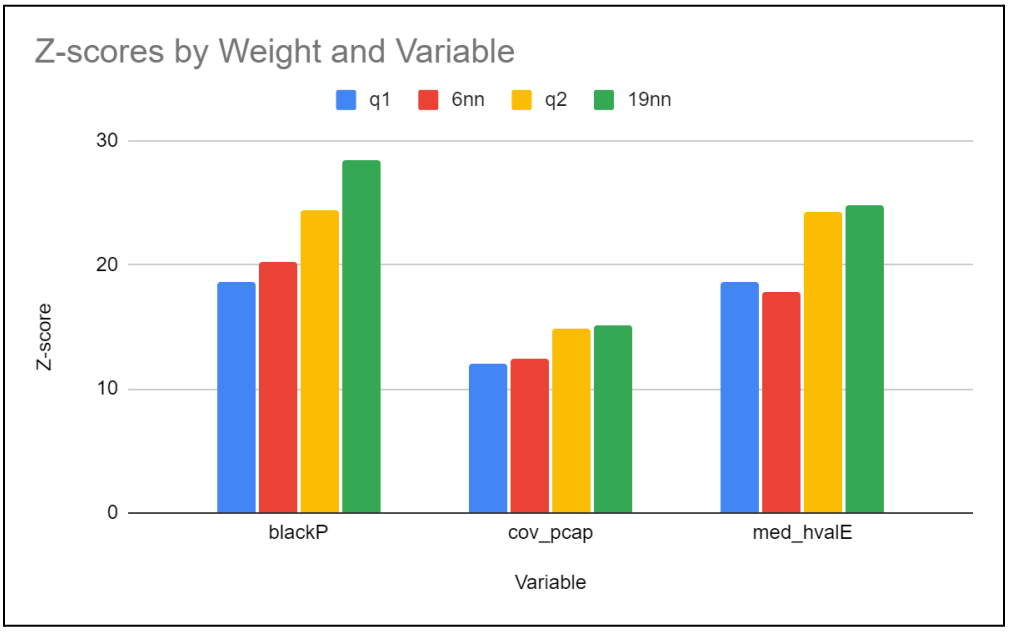

**Figure 16 (previous page):** Z-scores for each weight and variable

Though the average number of neighbors has a strong effect on the resulting Z-scores, the weight types themselves do not (except between q2 and 19nn for "blackP"). For this analysis, the 2nd order (inclusive) queen contiguity weight (q2) was chosen, as experimentation with local SAC (not shown here) revealed that lower order contiguity weights (eg. q1) tended to miss fairly obvious clusters (such as tracts with no covenants completely surrounded by other tracts with no covenants, simply because there were not enough neighbors to assess significance). Furthermore, higher order weights (eg. q3) were more similar to q2 in their local SAC findings, indicating that the q2 weight is less unique in comparison to other weights than q1. The weight was also chosen over 19nn, as the increase in the Z-score for percent black population between lower and higher order contiguity weights was more proportionate to the increase in Z-score for other variables, as opposed to lower and higher order k-nearest neighbor weights. Finally, as census tracts are generally rather small, using a lower order contiguity weight would likely only compare tracts to neighbors that are very similar, and thus not adequately capture spatial variation throughout. The significance filter cutoff chosen was 0.01 (with 999 permutations), as it is an intermediate value, below which very few clusters are shown, and above which clusters nearly dominate the entire map. Furthermore, Bonferroni Bounds and FDR were chosen against, as these did not reveal any clustering at all.

**Local SAC:** Figures 17-19 show both local Moran's I and Geary's C clusters of each variable, using the parameters specified above. The Local G statistic was chosen against, as the results were very similar to the Local Moran's I, except for the lack of outliers.

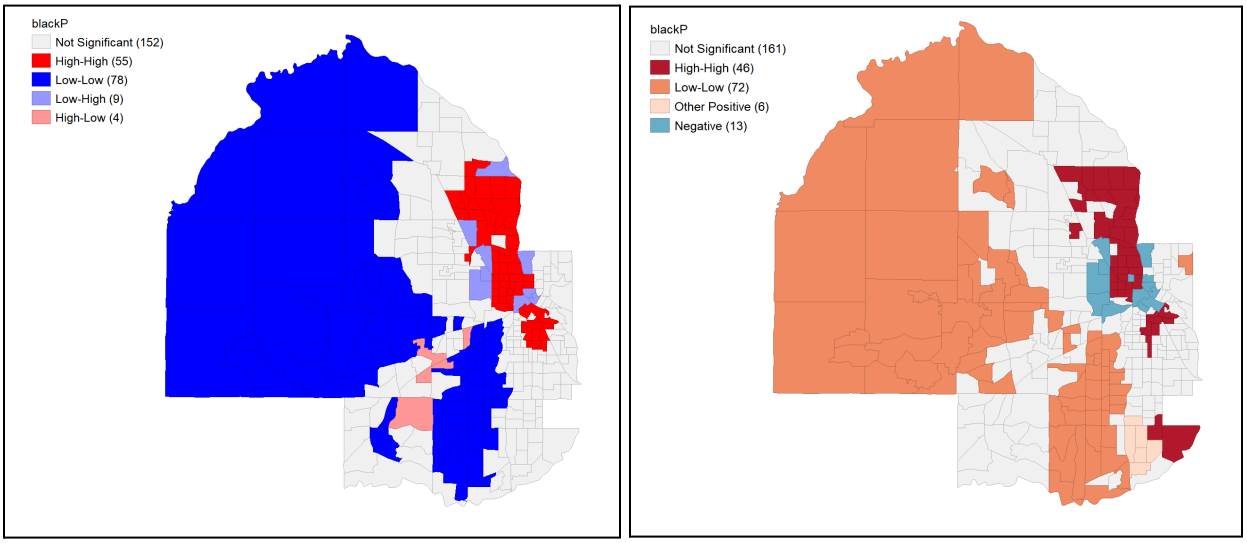


**Figure 17:** Local Moran's I and Local Geary's C for percent black population (q2 weight, 0.01 significance filter, 999 permutations)

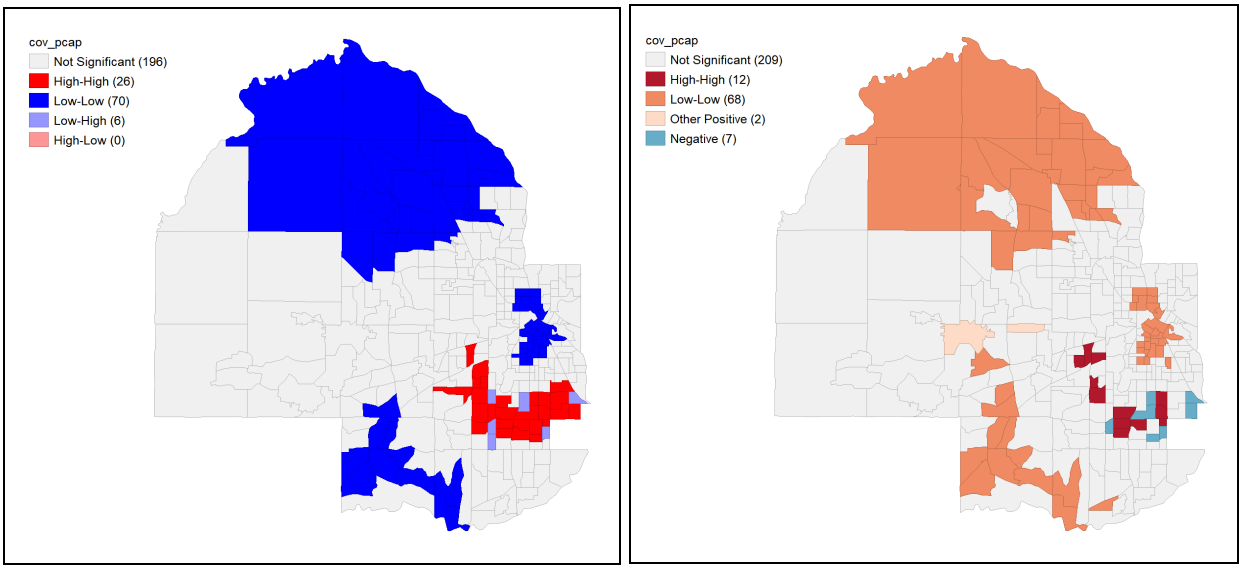


**Figure 18:** Local Moran's I and Local Geary's C for covenants per capita (q2 weight, 0.01 significance filter, 999 permutations)

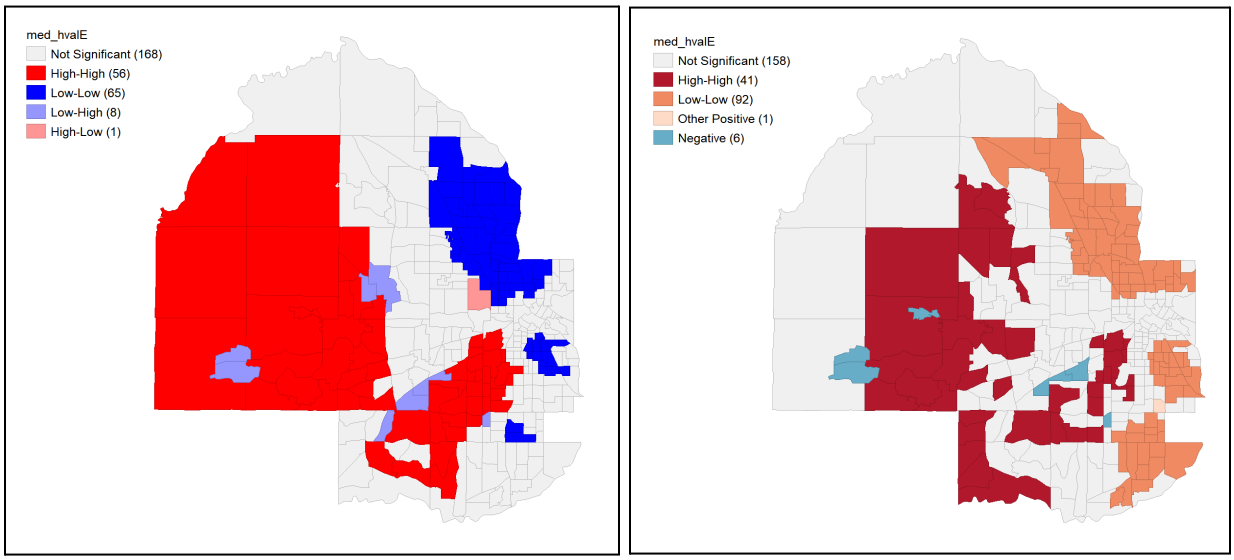


**Figure 19:** Local Moran's I and Local Geary's C for median house value (q2 weight, 0.01 significance filter, 999 permutations)

The results of the Local Geary's C and Moran's I are fairly similar for clusters of percent black population. However, for both covenants per capita and median house value, the high-high clusters are smaller in the Geary's C map compared to the Moran's I, while low-low clusters are slightly bigger for house value in the Geary's C map compared to Moran's I. The most interesting areas, those that are significant in both, are as follows:

- Percent black population: a high-high cluster can be seen stretching from North Minneapolis to the near north suburbs as well as in a small area southeast of downtown (much like in Figure 2). Two large low-low clusters can be found as well, one stretching

from the suburb of Edina (just southwest of Minneapolis) to the south, and one comprising most of the western half of the county. This finding indicates that there is more variation in clustering within the inner ring of suburbs (as it contains both the northern high-high cluster and the southern low-low cluster). Meanwhile, the outer ring of suburbs is mostly comprised of low-low clusters of black population.

- Covenants per capita: there is low-low clustering both in areas with high and low black populations (the center of Minneapolis, where there are higher black populations, as well as the far northern and southern edges of the outer ring of suburbs, where black populations are lower). This once again supports the finding that low densities of covenants do not entirely explain the presence or lack of black population, as opposed to high covenant densities. Meanwhile, high-high clusters seem to form to the immediate south and west of Minneapolis, around the same location as the southern low-low cluster of percent black population.
- Median house value: clusters of median house value tend to closely match those of percent black population. However, high-high clusters of housing value do not coincide with all the low-low clusters of percent black population, especially in the Geary's C map, once again indicating that low housing values do not entirely explain the concentration of the black population, which tends to cluster only in a subset of the areas with low housing values.

Bivariate local SAC: However, to formalize these findings and to directly prove or disprove the hypotheses, a multivariate analysis is needed. Quantile LISA (with co-location) was chosen in order to measure hot and cold spots between multiple variables, rather than merely finding attribute similarity or dissimilarity. A second order (inclusive) queen contiguity weight continued to be used, as well as 999 permutations in each trial. Figures 20 and 21 show the resulting quantile LISAs for the top of 3 quantiles of *non*black population and covenants per capita, and for the top of 3 quantiles of *non*black population and housing value, respectively (2 and 4 quantile LISAs were also conducted, of which the results will be used later). Both variable combinations show hotspots in Edina, the suburb immediately southwest of Minneapolis; however, while the *non*black population and covenants per capita combination forms a few other small hot spots to the north and west of this suburb, the *non*black population and housing value combination shows far more clustering to the west of the county, as well as in a few isolated census tracts in the city of Minneapolis itself.

To formally address the second and third hypotheses, whether these clusters concentrate most in one ring or another, the overlap of these cluster centers on each subregion was calculated in Tables 3 and 4 (and divided by the total area in the respective subregion). Then, the average coverage of each subregion was calculated (between 2, 3, and 4 quantile LISAs). These findings support my second hypothesis, but are more equivocal with respect to my third hypothesis; which will be discussed in the following section.

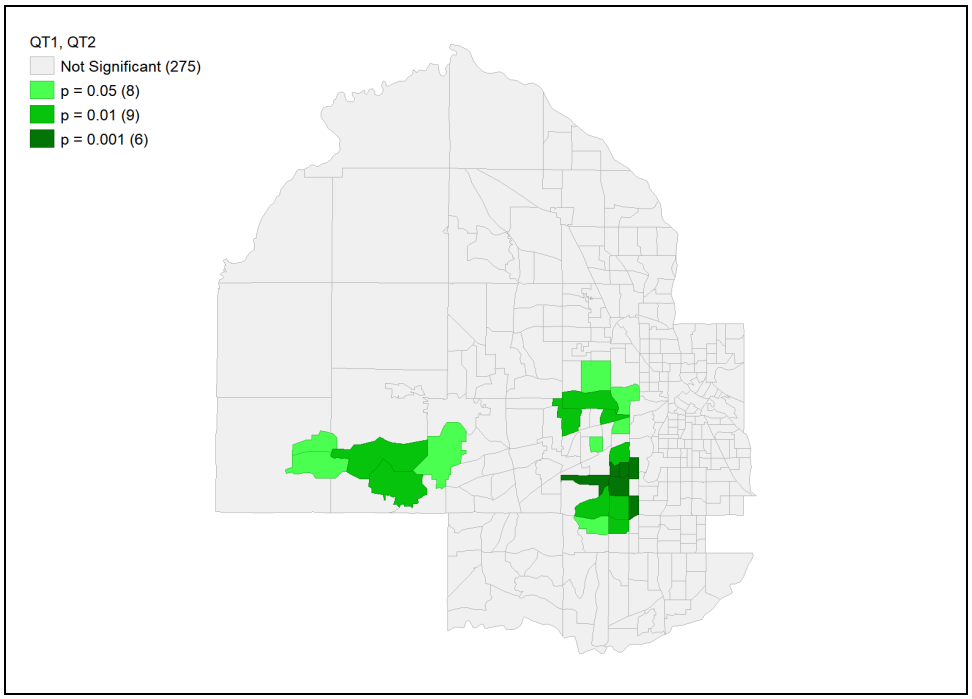


**Figure 20:** Multivariate quantile LISA for percent black population and covenants per capita (1st out of 3 quantiles for black population and 3rd of 3 quantiles for covenants, still using the q2 weight and 999 permutations). 2 and 4 quantile analyses were also conducted, the results of which, calculated as overlap in each subregion, are presented in Table 3.

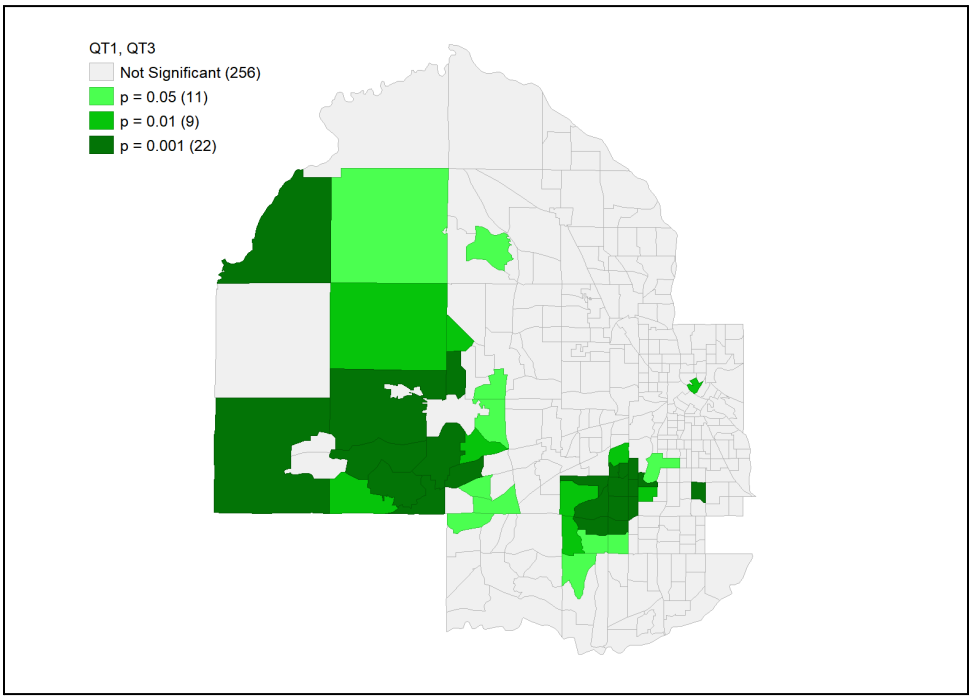


**Figure 21:** Multivariate quantile LISA for percent black population and median house value (1st out of 3 quantiles for black population and 3rd of 3 quantiles for house value, still using the q2 weight and 999 permutations). 2 and 4 quantile analyses were also conducted, the results of which, calculated as overlap in each subregion, are presented in Table 4.

| Number of Quantiles used | No. of "significant" (p=0.01) locations | % of city tracts covered | % of inner suburb tracts covered | % of outer suburb tracts covered |
|---|---|---|---|---|
| 2 | 36 | 2.59% | 21.3% | 15.9% |
| 3 | 15 | 0.862% | 16.0% | 1.87% |
| 4 | 6 | 0.00% | 8.00% | 0.00% |
| Average: | 19 | 1.15% | 15.1% | 5.92% |

**Table 3:** Results of multivariate Quantile LISA for covenants per capita and percent black population (0.01 significance filter)

| Number of Quantiles used | No. of "significant" (p=0.01) locations | % of city tracts covered | % of inner suburb tracts covered | % of outer suburb tracts covered |
|---|---|---|---|---|
| 2 | 53 | 7.76% | 18.7% | 28.0% |
| 3 | 31 | 5.17% | 16.0% | 12.1% |
| 4 | 21 | 2.59% | 10.7% | 9.35% |
| Average: | 35 | 5.17% | 15.1% | 16.5% |

**Table 4:** Results of multivariate Quantile LISA for median house value and percent black population (0.01 significance filter)

**Discussion:** First, I will discuss how these findings relate to each of my hypotheses:

1. (Negative correlation between covenant density and black population and between house value and black population) - This hypothesis is supported by the findings of my EDA analysis, which clearly show negative correlation in both cases. However, the relationship between each of these variables is more nuanced than a simple correlation; where the two independent variables are very low, the dependent variable (black population) may be high or low, indicating that the clustering of the black population, which is presented in Figure 17, is partially, but not fully explained by either of the two independent variables. In other words, covenants and house values likely prevent black people from moving into the areas where they are highly concentrated, but there seems to be another set of factors that cause black populations to concentrate further. Another finding is that an increase in housing values or covenants past a certain point (about 0.02 covenants per capita and about $250-300K house value, both around their respective means) does not decrease concentrations of black populations much further, especially in the case of covenants (as per Figures 9 and 13). Extremes in house value and covenant concentrations are therefore less important in predicting where black populations live.
2. (Negative correlation between covenants and black population will be the strongest in the inner ring, and more high-high clusters of *non*black and racial covenants will form in the inner ring than the other subregions, proportionately) - The first part of this hypothesis

was incorrect, as Figure 11 demonstrates. As I had not predicted, the concentration of racial covenants in the inner ring that was greater already means that a further increase in covenants per capita in fact has less of an effect on the percent black population (though the correlation is not *significantly* weaker, as per the high p-value on the Chow test, it is certainly not stronger). This does not mean that covenants themselves are less impactful in the inner ring, but that they are at such great densities that a further increase in their concentration is less meaningful (this phenomenon will be interpreted further below). However, the results from Table 3 strongly support the second part of the hypothesis—more of the inner ring is covered by high-high clusters than the other subregions proportionate to their number of tracts. This means that there is the strongest evidence for covenants forming a barrier to black populations within this subregion.

3. (Negative correlation between housing values and black population will be evenly distributed between the three subregions, and more high-high clusters of *non*black and housing value will form in the outer ring than the other subregions, proportionately) - Again, as I had not predicted, a further increase in housing values in the outer suburbs actually had a somewhat significantly weaker effect on percent black population, as per Figure 15 and the low p-value on the Chow test. This provides possible evidence that the impact of house value on percent black population is actually not evenly distributed, due to the phenomenon where rising house values can only diminish percent black population up to a point. The second part of the hypothesis is only weakly supported by the findings in Table 4; the outer ring of suburbs is only slightly more covered by high-high clusters than the inner ring, indicating that high housing values and low percent black populations cluster strongly in both regions. However, when only the 3rd out of 3 quantiles or 4th quantile out of 4 is used for both variables, coverage is actually greater in the inner suburbs, indicating that the clusters of the very highest values are actually more frequent closer to Minneapolis. This is very interesting, because the outer region tends to have higher house values and lower percent black populations than the inner region (see Figures 5 and 7), yet the high-high clusters of the highest quantiles of house value and nonblack population actually appear in the inner suburbs the most. Therefore, extreme values of these two variables coincide the most in the inner ring, despite the inner ring not having the highest house values or lowest percent black population overall.

Additionally, by looking at the locations of clusters from Figures 20 and 21, it appears that there is the most overlap between the two pairwise clusters in two locations - Edina (just southwest of Minneapolis), and around Lake Minnetonka, towards the south of the county's far western section. Figure 22 is a multivariate quantile LISA using the same parameters as the previous two, but combining all variables together in order to illustrate this phenomenon. These are the areas where there is the strongest evidence that racially restrictive covenants and high housing values are associated with lower black populations today, as opposed to other factors.[6] Notably, the

[6] As someone who is familiar with the culture of the suburbs of Minneapolis, this makes a lot of sense. These areas have a reputation for being wealthy and racially exclusive.

clusters in Figure 22 are almost entirely suburban (but existing in both rings). Though high housing values do correlate with low percent black population in a few isolated tracts in Minneapolis itself (Figure 21), the two factors together mainly coincide in areas with low black population in the suburbs.

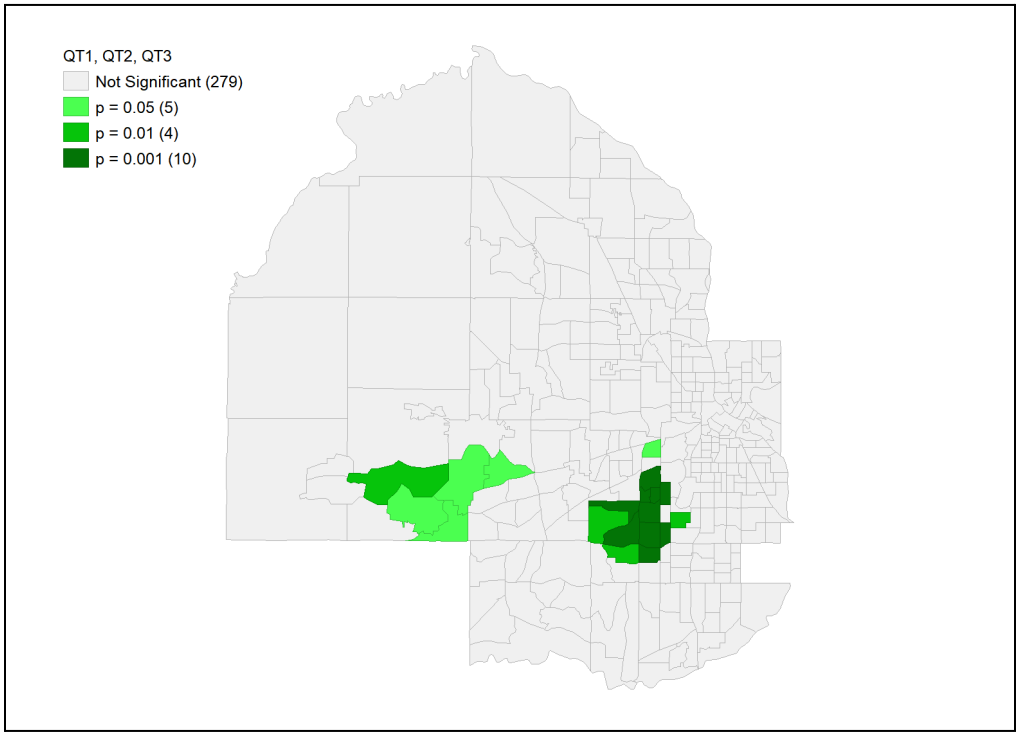


**Figure 22:** Multivariate quantile LISA for all three variables combined, using the same parameters as before (top ⅓ of each variable)

**Interpretation:** Of course, as strong as the correlations between the independent and dependent variables may be, they cannot prove causality. Though it would appear that high housing values and the lasting legacies of racial covenants have limited black populations in areas where they are present due to economic and prejudicial barriers, this may also be due to other related factors, such as self-selection (additionally, the large spread of percent black population that emerges when covenant concentrations and house values are low indicates that more factors are at play in determining where black populations live). Nevertheless, it does appear that there are several distinct locations where it is highly plausible that the two independent variables create barriers to black residence; especially in wealthy suburbs like Edina and the ones surrounding Lake Minnetonka (as discussed above). Results from comparing the overlap of these interesting regions on each of the three subdivisions reveal that the impact of racial covenants and house values on black populations is overwhelmingly a suburban phenomenon, especially so for inner suburbs (which has the most overlap of clusters with percent black and covenants, and the most overlap of clusters with percent black and house value if only the top ⅓ or ¼ of values are considered). Thus, the inner suburbs (likely because of Edina) have the greatest confluence of extreme values, where very high property values, high covenant concentrations, and low black

populations coincide, and thus would be an important point of focus for integration efforts, especially those that seek to help black populations overcome financial barriers and to reduce lingering prejudice in nonintegrated neighborhoods.

One result from the bivariate EDA should also be noted here—that in the tracts with higher than average house values and covenant concentrations (and very likely in the interesting locations of Edina and Lake Minnetonka), a further increase in the independent variables is less correlated with a decrease in black population. In the case of racially restrictive covenants, one possible reason for this phenomenon is due to spillover effects; as long as covenants existed nearby a house, it would be far less likely for black people to move in, regardless of whether or not the house itself had a covenant. Historical evidence (eg. case studies from the PBS documentary, *Jim Crow of the North*), seems to suggest that this was the case, as nearby covenants sent the signal that black people were not welcome, and often led to protests and violent confrontations when black families moved in nearby. Therefore, it likely only took a few covenants (around 0.02 per person) for an entire area to be considered off limits. Meanwhile, in the case of property values, the nonlinear correlation could be due to a general lack of wealth among the black population of Hennepin County—a $400K house is just as unaffordable as a $600K house for a person that can only afford a $200K house. This finding suggests that it is not only the areas with extreme covenant concentrations and house values, but all areas past the tipping points of these variables, where barriers to integration likely exist. This would suggest that, while Edina and Lake Minnetonka themselves are important to consider, that other, non-extreme areas (as displayed in Figure 23, a similar 3-variable quantile LISA as above, but including all values in the 2nd out of 2 quantiles), are important to consider too. Furthermore, given the less extreme house values in these areas, it may be more pragmatic to focus financial integration efforts, such as zero-interest home loans, in these locations.

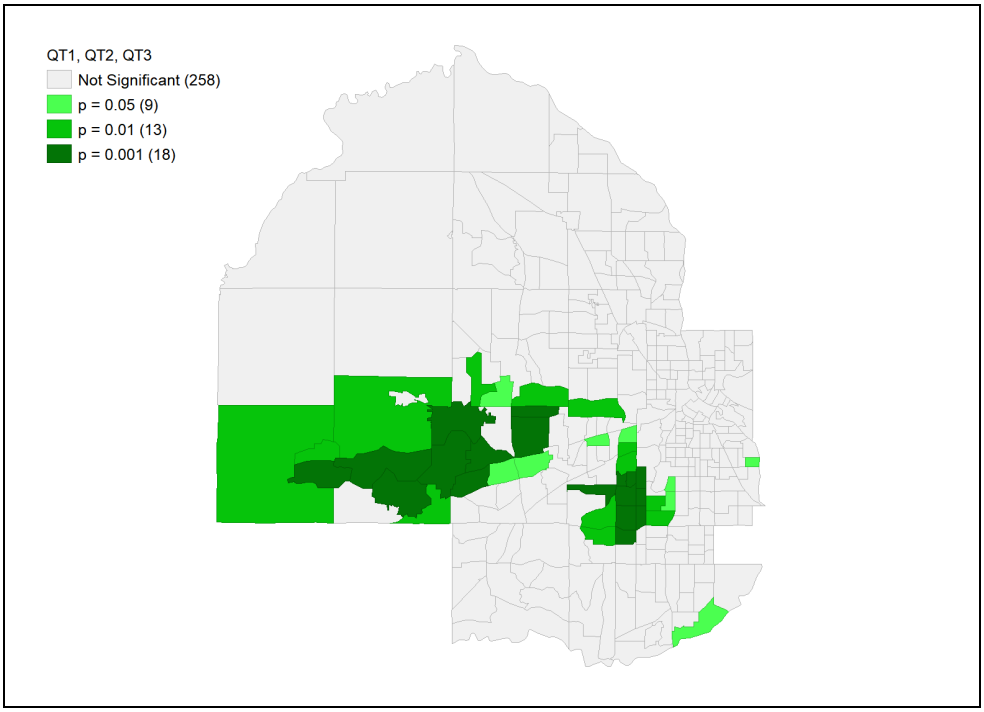


**Figure 23:** Same as Figure 22, but using the top ½ (all values above the median) of each variable