Traffic Noise in Georgia: Sound Levels and Inequality

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Abstract: We examine whether Hispanics and blacks bear relatively larger noise burdens than other demographic groups, and whether there is spatial heterogeneity in these relationships. Using road and air traffic noise in Census tracts within the state of Georgia, we construct Lorenz-type curves, and estimate the relationships between noise and minority populations at the tract-level using OLS and locally weighted regressions (LWR). Excluding parts of Atlanta, average noise levels in Census tracts are not at levels that likely cause health problems. However, most tracts contain at least one area where noise meets or exceeds health-deteriorating levels. Lorenz-type curves for MSAs indicate that on average, the white population bears smaller shares of noise than the black population. Generally speaking, Hispanics bear noise level shares between whites and blacks. With noise as the dependent variable in OLS and fixed effects regressions controlling for many other factors, the coefficients on the percentages of both black and Hispanic populations are similar in magnitude and significant. Using LWR enables us to examine possible heterogeneity in the relationship between different demographic groups and noise. With LWR, we find substantial variation across tracts in Georgia in the coefficient estimates for the percent Hispanic variable and relatively little variation in the percent black variable. The noise LWR marginal effects for black populations across most tracts in the state are consistent with diminishing marginal noise from additional black population, while those in Atlanta exhibit diminishing marginal noise for Hispanics.

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Introduction

Much is unknown about the ultimate effects of traffic noise on nearby residents[1] and whether certain demographic groups may bear the burden of the noise more disproportionately than other groups. In this paper we focus on this latter issue. Specifically, we examine both general road noise and aircraft-related noise for MSAs located in Georgia.[2] Using traffic noise measures in conjunction with various data at the Census-tract level, we consider noise levels across MSAs in Georgia and generate numerous figures and statistical estimates, including Lorenz curves, to summarize the relationship between noise and the burdens borne by demographic groups. We also describe various relationships, including how some vary over space, more closely via regression analysis.

Since relatively loud noise can have detrimental impacts on health, in addition to mere annoyance, this highlights the potential interest in the question of whether some demographic groups are exposed to greater noise than others. Over the last two decades a substantial research effort has been undertaken to identify the effects of noise on health.[3]

Much research has also been produced on the health effects of airport-related noise. In a literature review published in 1997, Morrel, Taylor, and Lyle (1997) concluded that high-quality studies on these various health issues related to airport noise were lacking and, thus, definitive conclusions about adverse effects were not possible. However, more recent literature reviews reach somewhat stronger conclusions. Ising and Kruppa (2004) highlight that even during sleep the noise from aircraft may lead to the release of stress hormones and may increase the risk of heart attacks. Moreover, if daytime noise levels exceed 65 dB, a consistent trend toward increased cardiovascular risk is found. This conclusion is reinforced by Lefèvre et al. (2017) in their study of aircraft noise exposure in France.

The non-auditory effects of noise pollution are not limited to heart issues. Children are especially at risk for negative effects. Hygge et al. (2002) find a link between noise and cognitive performance. Stansfeld and Matheson (2003) note that children exposed to chronic noise suffer detrimental effects on reading comprehension and long-term memory. Based on additional studies reported in Clark et al. (2006) and Stansfeld et al. (2005), this conclusion has been found for children in the Netherlands, United Kingdom, and Spain. A recent paper by

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[1] In addition to hearing impairment, traffic noise can affect individuals via number of channels, such as affecting sleep patterns and elevating blood pressure.

[2] Kopsch (2016) found in a meta-analysis of housing prices and noise that the cost of an additional decibel of aircraft noise was more than an additional decibel of road noise.

[3] A review of the traffic noise and health literature as part of a larger paper by Swoboda, Nega, and Timm (2015) identified the following effects and many of the following references: 1) simple annoyance – Miedema and Oudshoorn (2001); Ouis (2001); Ohrstrom et al. (2007); de Kluizenaar et al. (2013); and Weinhold (2013); 2) sleep disturbance – Ouis (1999); Jakovljević et al. (2006); and Kim et al. (2012); 3) increasing risk for stroke – Sørensen et al. (2011); 4) hypertension – Jarup et al. (2008); and Bodin et al. (2009); 5) myocardial infarction – Babisch et al. (2005); and 6) overall quality of life – Shepherd et al. (2013).

Makles and Schneider (2016) highlights that noise may impair early childhood development that may ultimately have permanent effects on academic achievement and health. They find that preschool children exposed to relatively more noise (e.g., 10 dB(A)) are less ready for kindergarten.

These potential health effects have generated increased attention in recent years. While a statistical analysis of environmental justice is beyond the scope of our research in this paper, some of the increased attention in this literature has occurred because environmental justice issues have become more prominent.[4] Three airport-noise studies are related directly to the current study – Ogneva-Himmelberger and Cooperman (2010), Sobotta et al. (2007), and Cohen and Coughlin (2012). Ogneva-Himmelberger and Cooperman (2010), using Boston's Logan International Airport, find that minority and lower-income populations are subjected to relatively higher noise levels than their counterparts. Sobotta et al. (2007) regress airport noise in Phoenix, expressed as a qualitative dependent variable, on various independent variables, including the percentage of neighborhood population that is Hispanic. They find that households in neighborhoods with greater Hispanic population were subjected to higher noise levels than households in other neighborhoods. Following McMillen and McDonald (2004), Cohen and Coughlin (2012) estimate ordered probit locally weighted regressions (OPLWR) to explore the issue of spatial heterogeneity in the context of the determinants of airport noise in Atlanta.

Cohen and Coughlin (2012) find notable differences in parameter estimates for different houses in their sample with the OPLWR estimates. In particular, the sign on the coefficient for each explanatory variable contains some positive and some negative values. Also, compared to an ordered probit model, the mean of the magnitudes of the coefficients for some of the other explanatory variables is larger with the OPLWR model, while for other coefficients the mean is smaller. These differences between the OPLWR and ordered probit results imply that focusing exclusively on an ordered probit model for the determinants of noise can lead to biased estimates in our context due to ignored heterogeneity among individual houses in our sample. Overall, the heterogeneity over the relatively small area examined precluded any environmental-justice generalizations with respect to either the black or Hispanic populations.

Focusing on transportation noise in general, few studies have examined differences in exposure across demographic groups. Among these studies, more evidence has been produced on the association of noise and income differences than on the association of noise and ethnic differences.

Brainard et al. (2004) explored exposure to noise in Birmingham, UK. The connection between noise and various socioeconomic indicators was examined. No relationship was found between noise exposure and age. At most, only weak evidence was found for a relationship between noise exposure and ethnicity. Indian and Pakistani sub-groups tended to have lower exposure than the city average, while blacks tended to have higher exposure. Finally, evidence

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[4] The U.S. Environmental Protection Agency defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies". See https://www.epa.gov/environmentaljustice.

of a weak relationship between noise exposure and economic deprivation was found. Because of the strong association between ethnicity and deprivation, the authors could not identify the independent effects of these variables.

As part of a study examining various environmental indicators in the greater Rotterdam region known as the Rijnmond, Kruize et al. (2007a) examined exposure to traffic noise. They found that increased noise exposure for those with lower incomes, but these differences across income categories were quite small. Somewhat surprisingly, they found higher air traffic noise exposure to be associated with higher incomes.

In a related study, Kruize et al. (2007b) examined equity in an area surrounding the Amsterdam Airport (Schiphol). Similar to Kruize et al. (2007a), various environmental indicators were used, but we restrict our focus to noise. Also, because of a lack of data on race, income was the key socioeconomic indicator. In addition to the distribution of environmental quality, the authors explored the interaction of market forces and government policy that produced equity. A key finding was that exposure to higher levels of traffic noise was similarly distributed across income categories; however, those with lower incomes tended to be exposed to relatively more traffic noise. This finding resulted from a combination of historical process and market forces that have produced changes in the relative power of government regulation and market forces.

Finally, Havard et al. (2018) found that in Paris higher levels of noise in a neighborhood were associated with higher educational attainment and higher property values. In addition, more noise was associated with higher proportions on non-French citizens; however, when citizens were connected to their origin countries, they found that more noise was associated with higher proportions of citizens from advantaged countries.

A standard issue in this literature can be phrased as follows: Were a disproportionate percentage of minority residents already present at the time the environmental hazard was sited or did the disproportionate percentage occur as a result of location decisions after the hazard was sited? This question cannot be adequately answered in most cases without panel data.[5]

In the case of traffic noise throughout the state of Georgia, this issue is not of major concern. The vast majority of the locations of roads were determined many years ago. Of course, this issue is of importance for the construction of new roads and airport expansions/modifications.

Turning to our paper, first and foremost, using Lorenz curves and statistical analyses, we examine a number of simple relationships between traffic noise and economic/demographic variables. Next, our additional analysis provides insights on the relationships between road noise and economic/demographic variables.

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[5] Depro et al. (2015) stress this challenge in an examination of air toxics in Los Angeles County. They find differences across groups in their willingness to pay for cleaner air.

Data

In the context of our problem, we leverage the fact that we have some data covering multiple time periods. Our data come from two different sources; we merge the road/airport noise data with the Census data to create a dataset lending itself to analysis of how demographics are correlated with noise. We describe more details of our data below.

Specifically, we have obtained noise data for 2016-17 from the Bureau of Transportation Statistics (BTS). This dataset contains information on noise levels (measured in A-weighted 24-hour equivalent sound levels (LAEQ)) from both road and air traffic sources, and therefore it is quite comprehensive. The data are very close to being a continuous estimate of noise, therefore at virtually any point in geographic space (such as a centroid of a Census tract), it is generally possible to assign a noise level to this point. However, locations with noise levels below 35 dBA (A-weighed decibels) are not assigned noise values. While most of the other noise studies described above consider only road noise or airport noise, but not both, this dataset enables us to more accurately attribute sources of variation that are correlated with all types of noise.

Figure 1 shows these noise data aggregated to the average for Census tracts. For areas of Georgia below the 35 dBA reporting threshold, values of 0 were assigned. Thus, the average noise levels for most Census tracts are biased downward. Not surprisingly, the highest levels of traffic noise occur in the Atlanta area and in portions of other MSAs throughout the state. Traffic noise levels throughout most of the state are low.

Much of the remaining data we use come from the Census Bureau's American Community Survey data files, for 2016 and for 2011 – specifically the 2012-2016 and 2007-2011 5-year estimates. These data include tract-level variables on average house value, average rental rates, average house age, average number of rooms, average number of housing units, vacancy rates, population, and demographic information such as percent Hispanic, percent black, and average income. Note that we have chosen to ignore the percent Caucasian variable because black and white populations can include the Hispanic population, due to the fact that Hispanic is an ethnic group. That gives us reason for excluding the white percentage from our regressions, because the sum of the white percentage, the Hispanic percentage, and the black percentage could technically surpass 100%.

Table 1 - Descriptive Statistics, Census Tract-Level Data for Georgia, USA

Variables	Mean	Standard Deviation	Min	Max
Average Noise (2016-17)	12.6	14.6	0	65
2011 Median House Value	158836	93489.9	20500	992100
2011 Median Gross Rent*	840	266.4	249	1917
2011 Median HH Income	49192	21814.6	5426	188870
2011 Average House Age	28.9	12.4	6	71
2011 Number of Housing Units	2095.1	931.2	54	7092
2011 Median Rooms/Unit	5.7	1.0	3	9
2011 Population	4926	2420	117	19529
2011 Percent Black	32.6	28.4	0	100
2011 Percent Hispanic	8.1	11.2	0	90
2011 Vacancy Rate	11.4	7.3	0	77
2011 MSA Dummy	0.7	0.5	0	1
Number of Observations	1891			

Descriptive Statistics

The maximum levels of noise across Census tracts for each MSA revealed that only Atlanta had areas that could be characterized as excessively noisy. The Albany, Athens, and Gainesville MSAs had no Census tracts that exceed 50 dBA using the LAEQ metric. A reading of 50 is roughly equivalent to a quiet office or a quiet outdoor urban daytime setting. Atlanta, however, had areas with readings above 50 dBA. Readings in the 60s are indicative of heavy traffic noise at a distance of 300 feet. While average tract noise was relatively low for many areas, 94 percent of tracts in the state had at least one area with a noise level exceeding 60 dBA. We used ArcGIS to derive the "average" noise per Census tract based on the average values in each of the noise "grids" within the boundaries of the tract. This average noise level in 2016-17 was approximately 12 dBA, while the variation was large relative to the mean (i.e., the standard deviation was 14.6 dBA). Among all of the tracts in Georgia, the one with the highest amount of average noise in Atlanta had 65 dBA, while the quietest tract in the state had 0 dBA.

Table 1 presents the descriptive statistics for the Census tract-level data from the 1891 tracts in the state of Georgia for which we have values for all variables except median house value and median gross rent.[6] With the exception of the 2016-17 average noise data from BTS (described above), all of the data in our analyses are from the 2011 American Community Survey (ACS). The median house value is approximately $159,000, with a range of $20,500 to just under $1 million. The median gross rent is defined as the median dollar value of rent plus utilities paid by the renter. Gross rents range from $250 to over $1,900, with a median of $840. Median household income was slightly less than $50,000. The average house was about 29 years old, with 5.7 rooms, and the average number of housing units per tract was slightly less than 2100.

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[6] Median house value and median gross rent are interchanged in some regressions, so the descriptive statistics sample was chosen to capture all observations used in regression analyses.

The average total population per tract was just under 5,000, with a range of 117 to approximately 20,000. The percent black variable was defined as the percent of individuals in a tract whose race is black alone, including both Hispanics and non-Hispanics. The average tract was about one-third of its population comprised of individuals who are black, however the standard deviation was large (approximately 28 percent). The percent Hispanic variable was defined as the percent of individuals of any race who are Hispanic. The mean percentage Hispanic across all tracts was approximately 8 percent.

The vacancy rate was the percent of housing units that are vacant, excluding vacant migrant worker housing units, vacant vacation units, vacant rented units, and vacant sold units awaiting occupancy. The mean vacancy rate across tracts was 11.4 percent, with a standard deviation of approximately 7 percent. At least one tract had a vacancy rate that was as high as 77 percent, and some tracts had a 0 percent vacancy rate. Finally, the OLS regressions included an MSA dummy, which was a dummy variable equal to 1 if a tract is in an MSA and 0 if not.

Empirical Analysis

Background

We considered two different ways to examine how different demographic groups are related to the amounts of (air and road) noise exposure. First, we considered Lorenz type curves, to graphically demonstrate whether certain demographic groups were correlated with disproportional amounts of noise.[7] Then, we used locally weighted regressions (LWR), to consider the impacts that lagged demographics had on total noise exposure, and how they varied spatially, for all Census tracts in the state of Georgia. We describe the methodology for our regression analysis below. But first, our Lorenz curve analysis is presented.

Figures 2 through 5 present Lorenz-type curves for four MSAs in Georgia.[8] These curves were drawn as follows. First, we ordered all of the Census tracts in each MSA, from lowest noise to highest noise. We used the cumulative percentage of Census tracts as the horizontal (x) value. We used the corresponding cumulative percentage of a specific (white, black, or Hispanic) population in the MSA as the vertical (y) value. If the resulting curve was close to the 45-degree line, then the proportion of this population that was exposed to noise was relatively equal across noise levels. If the curve was below the 45-degree line, this implied that the population group bore a disproportionately large share of noise.

Lorenz-type curves for Atlanta are shown in Figure 2.[9] Apparently, Atlanta's white population bore a disproportionately smaller share of noise than Hispanics and, especially, blacks. Generally speaking, the Lorenz curve for Hispanics tends to be very close to the 45-degree line and, for the noisiest Census tracts, tends to be slightly above the 45-degree lines,

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[7] See Boyce et al. (2016) for the use of other measures in the context of environmental inequality.
[8] The appendix includes Lorenz-type curves for additional MSAs contained completely in Georgia.
[9] A health-related traffic noise study that is focused on Fulton County, Atlanta is Kim et al. (2012).

suggesting a less than proportionate share of noise. Meanwhile, Atlanta's black population bore a disproportionately larger share of noise.

A roughly similar pattern to Atlanta can be observed for the Albany MSA in Figure 3. Albany's white population and, to a lesser degree, Hispanic population bore a disproportionately smaller share of noise, while Albany's black population bore a disproportionately larger share of noise. However, an important difference, especially as it relates to health consequences, was that none of the Census tracts in Albany had average noise levels generally viewed as harmful.

Figure 4 also shows a roughly similar pattern for the Athens MSA that was observed for both Atlanta and Albany. A noteworthy difference, however, was that all three curves for Athens tended to be much closer to the 45-degree line than for Atlanta and Albany. Similar to Albany, none of the Census tracts in Athens had average noise levels that were generally viewed as harmful.

Figure 5 shows that the results for Gainesville's white population was similar to the previously discussed MSAs – a disproportionate share of noise. In contrast with the previous results, the relative positions of the Hispanic and black populations were reversed. For the noisier Census tracts, the Lorenz curve for blacks hugged the 45-degree line, while the Hispanic population tended to bear a disproportionately larger share of noise. However, none of the Census tracts in Gainesville had average noise levels generally viewed as harmful.

Overall, across all MSAs that we examined, whites bore smaller shares of noise than blacks. Generally speaking, but not without exception, Hispanics bore noise level shares between whites and blacks.

Methodology Underlying Regression Analysis

Fotheringham, et al. (1998) and Fotheringham, et al. (2002) provided general background on LWR. Consider a regression model that is estimated locally, around each point in the dataset, called a target point (in our case, a "target point" is a centroid of a particular Census tract). More specifically, LWR can be thought of as a version of weighted least squares, where such a regression is carried out at each target point. This allows for there to be different parameter estimates at each target point, which is a way to allow for nonlinearities in the relationships between the explanatory variables and the dependent variable. This technique is sometimes referred to as a kernel smoothing estimation approach. If in fact the true model is one where all parameter estimates are the same (i.e., if OLS is the true model), then the parameter estimates across all target points will be equal for a given explanatory variable, implying that OLS could be a special case of LWR.

Since LWR is a version of weighted least squares, an important consideration is how to define the weights. McMillen and Redfearn (2010) have noted that in general, the estimation results are quite robust to the choice of kernel weights. A common choice is the Gaussian kernel. The results are typically quite sensitive to the bandwidth selection, on the other hand. There are

some canned routines that select the optimal bandwidth, using a given kernel weights structure, as in the GWR routine in Stata (which is the approach we use in our estimations).

More formally, the LWR estimator for a given target point, i, can be written as follows:

$$\hat{\beta}_i = (X'PX)^{-1}X'PY,$$

$$\text{where } P \equiv w'_{ij}w_{ij},$$

$$w_{ij} = \left(\frac{1}{\sqrt{2\pi}}\right)e^{-(\frac{d_{ij}}{b})^2},$$

b is the bandwidth and d_{ij} is the Euclidean distance between points i and j.

We considered the following set of statistical models. We used LWR to regress 2017 total noise (i.e., airport and road noise, expressed as a continuous variable) in a Census tract, against 2011 Census tract house value, 2011 vacancy rates (to control for supply factors), 2011 average house age, 2011 average number of housing units, 2011 average number of rooms in housing units, 2011 population, and 2011 Census tract demographics (i.e., percent black, percent Hispanic, and income). Lagged independent variables partially mitigate endogeneity concerns. In order to assess whether there was a symmetric relationship between renters and noise as compared with owners and noise, we swapped 2011 Census tract house value with 2011 Census tract gross rent in our second specification. Our final specification included both house value and gross rent.[10] The results of these LWR estimations are presented in Table 3, and maps of the percent black and percent Hispanic coefficient estimates are in Figures 6 and 7.

OLS, Fixed Effects, and Locally Weighted Regressions Results

Our presentation of the results consists of the following. First, we describe the OLS and fixed effects regression estimates (based on the results in Table 2). Then, we discuss the results from LWR, based on Table 3 (descriptive statistics of the LWR coefficient estimates). Finally, we present our LWR results in several maps to glean insights regarding the spatial heterogeneity of the relationships between different demographic variables and the levels of noise.

In the OLS and fixed effects regressions in Table 2, we present results for 6 different specifications: Specifications 1-3 are identical to the three specifications discussed above for LWR, except that a dummy indicating whether or not a tract is within an MSA has been added. Similarly, specifications 4-6 are identical to the three specifications discussed above, except that MSA fixed effects have been added with a base group of tracts not in MSAs. Since the results are generally quite similar across specifications, we focus on the results for the fixed effects regressions with both the median sale price and median rental price included.

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[10] All variables not in percent form are transformed to logs for regressions.

Table 2 - Regression Results
Ordinary Least Squares & Fixed Effects

p-values in bold

DEPENDENT VBLE:

log(noise)	**OLS**	**OLS**	**OLS**	**FE**	**FE**	**FE**
log(median house price)	0.6904***	-	0.6367***	0.6538***	-	0.6358***
	(0.0000)	**-**	**(0.0000)**	**(0.0000)**	**-**	**(0.0000)**
log(median gross rent)	-	0.7728***	0.6363***	-	0.6719***	0.6385***
	-	**(0.0000)**	**(0.0000)**	**-**	**(0.0000)**	**(0.0000)**
log(household income)	0.1612	0.2821***	-0.0314	0.1602	0.2733**	-0.0009
	(0.1048)	**(0.0083)**	**(0.7533)**	**(0.1107)**	**(0.0117)**	**(0.9928)**
log(house age)	0.4495***	0.4394***	0.4968***	0.4530***	0.4574***	0.4875***
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**
log(housing units)	0.1431	0.5842***	0.2075*	0.1386	0.5740***	0.1842
	(0.2375)	**(0.0028)**	**(0.0979)**	**(0.2625)**	**(0.0019)**	**(0.1548)**
log(number of rooms)	-1.7004***	-1.8878***	-1.7466***	-1.6812***	-1.8560***	-1.7473***
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**
log(population)	0.0157	-0.3975**	-0.0467	0.0165	-0.4041**	-0.0244
	(0.8931)	**(0.0315)**	**(0.6929)**	**(0.8900)**	**(0.0248)**	**(0.8408)**
black percent	0.0165***	0.0139***	0.0154***	0.0164***	0.0143***	0.0159***
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**
Hispanic percent	0.0168***	0.0147***	0.0152***	0.0177***	0.0151***	0.0168***
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**
vacancy rate	-0.0030	-0.0100**	-0.0028	-0.0035	-0.0130***	-0.0018
	(0.4240)	**(0.0186)**	**(0.4497)**	**(0.3725)**	**(0.0071)**	**(0.6370)**
MSA dummy	1.1151***	1.1173***	0.9662***	-	-	-
	(0.0000)	**(0.0000)**	**(0.0000)**	**-**	**-**	**-**
Constant	**-9.1987***	**-6.8202***	**-10.6448***	**-8.7803***	**-6.0376***	**-10.9785***
	(0.0000)	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**	**(0.0000)**
R-squared	0.576	0.540	0.591	0.584	0.552	0.598
Log Likelihood	**-2259.6**	**-2353.9**	**-2186.3**	**-2169.8**	**-2330.4**	**-2169.8**
N	1870	1869	1848	1848	1869	1848

***(p<0.01); **(p<0.05); **(p<0.10)

Note: dependent variable is based on 2016-17 tract-level average noise, while independent variables are from 2011 American Community Survey.

The elasticities of noise with respect to price, for both the rental and sales variables, were in the range of 0.6 to 0.77, are highly statistically significant, and very close in magnitude across specifications. This result may seem surprising since it implies that higher priced residential real estate was in noisier areas. However, it was also likely that higher priced real estate was in more

urban areas (e.g., Atlanta), which were noisier. The elasticity of noise with respect to house age was approximately 0.5 and was highly significant, implying that older houses were in areas with more noise. The coefficient on the vacancy rate was insignificant. The household income elasticity was statistically insignificant in this specification. While the overall population size was generally uncorrelated with noise, the coefficients on the percentages of black or Hispanic population were significant, and quite similar to each other in magnitude. Minorities tended to live in Census tracts with more road and airport noise, and on average, the correlations between percentages of population that are minorities were quite similar across both blacks and Hispanics.

This similarity in the coefficient estimates for black and Hispanic populations, together with the fact that noise levels vary dramatically in Atlanta relative to other parts of Georgia, raises the possibility of heterogeneity in the marginal effects across geographic space. The LWR estimates in Table 3, along with the maps in Figures 6 and 7, enabled us to address this question. In all tracts, the LWR coefficient estimates for percent black and percent Hispanic were positive.

Interestingly, there was a substantial amount of variation in the coefficient estimates for the percent Hispanic variable, while relatively less variation in the percent black variable. Specifically, the mean of the LWR coefficient estimates for the black percentage and the Hispanic percentage variables were identical, and equal to 0.0217. But the range of the coefficient estimates for percentage Hispanic was between 0.0077 and 0.0232, with a standard deviation of 0.0025. On the other hand, the coefficient estimates for the black percentage was much more closely centered near the mean, with a range of 0.0179 and 0.0232 and a standard deviation of 0.0014. These descriptive statistics imply that the relationship between noise and the Hispanic population depends notably on the geographic location within Georgia, going from a coefficient very close to 0 to one indicating a 2 percent increase in noise for every percentage point increase in the percent Hispanic. Meanwhile, the relationship between noise and black population is relatively persistent across the state.

We can also observe some of this heterogeneity in Figures 6a, 6b, 7a, and 7b. These maps are based on the LWR coefficient estimates using the model results that included both gross rent and house value as explanatory variables. Figures 6a and 6b are maps of the percent black population and black LWR coefficients, respectively; and Figures 7a and 7b are maps of the percent Hispanic population and percent Hispanic LWR coefficients, respectively.

Table 3 – Locally Weighted Regressions Coefficients

DEPENDENT VARIABLE: log(noise)

N=1,967	mean	median	st dev	min	max	mean	median	st dev	min	max	mean	median	st dev	min	max
log(median house value)	1.1501	1.1614	0.1024	0.7522	1.3478	-	-	-	-	-	0.9389	0.9866	0.1204	0.4657	1.0283
log(median gross rent)	-	-	-	-	-	1.4779	1.3793	0.2334	0.9708	1.8632	1.1479	1.0491	0.2069	0.7746	1.5679
log(household income)	0.4037	0.3957	0.0459	0.3415	0.5951	0.6031	0.7351	0.2544	-0.1537	0.8699	0.0008	0.0245	0.0677	-0.1889	0.1340
log(house age)	0.5000	0.4861	0.0279	0.4794	0.6287	0.5284	0.5226	0.0173	0.4827	0.5878	0.5596	0.5429	0.0358	0.5273	0.7062
log(housing units)	-0.1219	-0.1207	0.0871	-0.3951	0.1836	0.4575	0.3739	0.2019	0.0610	0.9873	0.0170	0.0038	0.0854	-0.2439	0.3151
log(number of rooms)	-2.0940	-1.9227	0.4072	-3.7116	-1.7681	-2.5231	-2.5299	0.0833	-2.7395	-2.2707	-2.1080	-1.9836	0.2980	-3.2317	-1.8303
log(population)	0.2569	0.2407	0.0712	0.1222	0.4890	-0.3348	-0.2954	0.1362	-0.7404	-0.0091	0.0955	0.0943	0.0618	-0.0450	0.3241
black percent	0.0257	0.0259	0.0004	0.0243	0.0264	0.0206	0.0211	0.0011	0.0178	0.0225	0.0217	0.0225	0.0014	0.0179	0.0232
Hispanic percent	0.0267	0.0270	0.0016	0.0153	0.0291	0.0220	0.0229	0.0026	0.0070	0.0248	0.0217	0.0228	0.0025	0.0077	0.0232
vacancy rate	-0.0058	-0.0041	0.0041	-0.0232	-0.0039	-0.0135	-0.0116	0.0037	-0.0244	-0.0093	-0.0057	-0.0055	0.0008	-0.0087	-0.0044
constant	-16.3152	-16.3903	1.0430	-18.7127	-12.0953	-13.1826	-13.4310	1.1388	-14.8543	-8.3889	-16.8735	-17.0145	0.8559	-18.7402	-13.3034

Note: dependent variable is based on 2016-17 tract-level average noise, while independent variables are from 2011 American Community Survey.

In terms of general trends in Figures 6a, 6b, 7a, and 7b, with the exception of Atlanta, there was a fairly notable negative correlation between the percent black coefficients and the black population. The simple correlation between the tract-level percent black population and LWR coefficients on percent black was approximately -0.13 (p-value=0.0000). However, when we excluded tracts in Atlanta from this calculation, the simple correlation became -0.29 (p-value=0.0000). But for the Hispanic coefficients, the correlation between Hispanic population and Hispanic coefficients were positive throughout the state (0.10, with p-value=0.0000), although not as strong in magnitude as the correlation for the percent black coefficients. These varying correlations suggest there may have been diminishing marginal noise for black population but increasing marginal noise for Hispanic population.

In the Atlanta MSA, the eastern and western parts of the MSA appear to have had the greatest density of percentage black population. But in examining the LWR coefficient estimates in the Atlanta MSA, the largest LWR coefficients on the percent black variable appeared to be in the northern part of the Atlanta MSA, and somewhat smaller in the east and west sides of the Atlanta area with the highest percentages of black populations. There were similar trends in the entire state, in that the most northern parts of the state had the highest LWR coefficients on percent black, and they decrease in moving toward the south. Also similar to the state-wide result, the Atlanta results appear to be consistent with the notion of diminishing marginal noise with respect to black population.

In contrast to the entire state, the Atlanta MSA has some of the highest Hispanic population percentages in its lower Hispanic coefficient areas. Specifically, the northeast corner of the MSA had several of the highest Hispanic percentages in the state, and also had the lowest coefficients in the MSA. Thus, there were diminishing marginal effects of Hispanic population on noise in the noisiest region of Georgia.

Conclusion

The distribution of noise across demographic groups raises equity issues. Using road and air traffic noise in Georgia, we examined noise levels and whether certain demographic groups faced relatively larger noise burdens than other groups. We also investigated how these relationships varied spatially.

Combining traffic noise data from the Bureau of Transportation Statistics with various economic/demographic variables, we constructed Lorenz-type curves and estimated OLS and locally weighted regressions to provide basic information about the levels and distribution of noise. Excluding parts of Atlanta, noise levels in average Census tracts were not at levels that likely cause health problems. However, the vast majority of Census tracts contained an area with health-damaging noise levels. Lorenz-type curves for MSAs indicated that whites had borne smaller shares of noise than blacks. No straightforward generalization could be made for Hispanic populations. In some MSAs, the Hispanic population share of noise mirrored the share borne by whites, while in other locations, the Hispanic share was closer to the share borne by blacks. Then, there were times when it mirrored neither and could have been either less or more

than the shares borne by whites and blacks. As a general statement, Hispanics were exposed to noise level shares that fell between whites and blacks.

With noise as the dependent variables in OLS regressions controlling for many other factors, the coefficients on the percentages of both black and Hispanic populations were similar in magnitude and significant. Using LWR, we found substantial variation in the coefficient estimates for the percent Hispanic variable across the state and relatively little variation in the percent black variable. For tracts in the Atlanta MSA only, we found a negative correlation between Hispanic population and the LWR coefficient on Hispanic population, while for tracts throughout the state, we found a positive correlation between Hispanic population and the associated coefficients. The marginal effects for the black population percentages tended to decrease across geographic space as population increases. Such a negative relationship appears to be sensible because noise cannot increase indefinitely as population increases; usually, one would expect there to be upper bounds to noise, even in areas with extremely high minority population concentrations.

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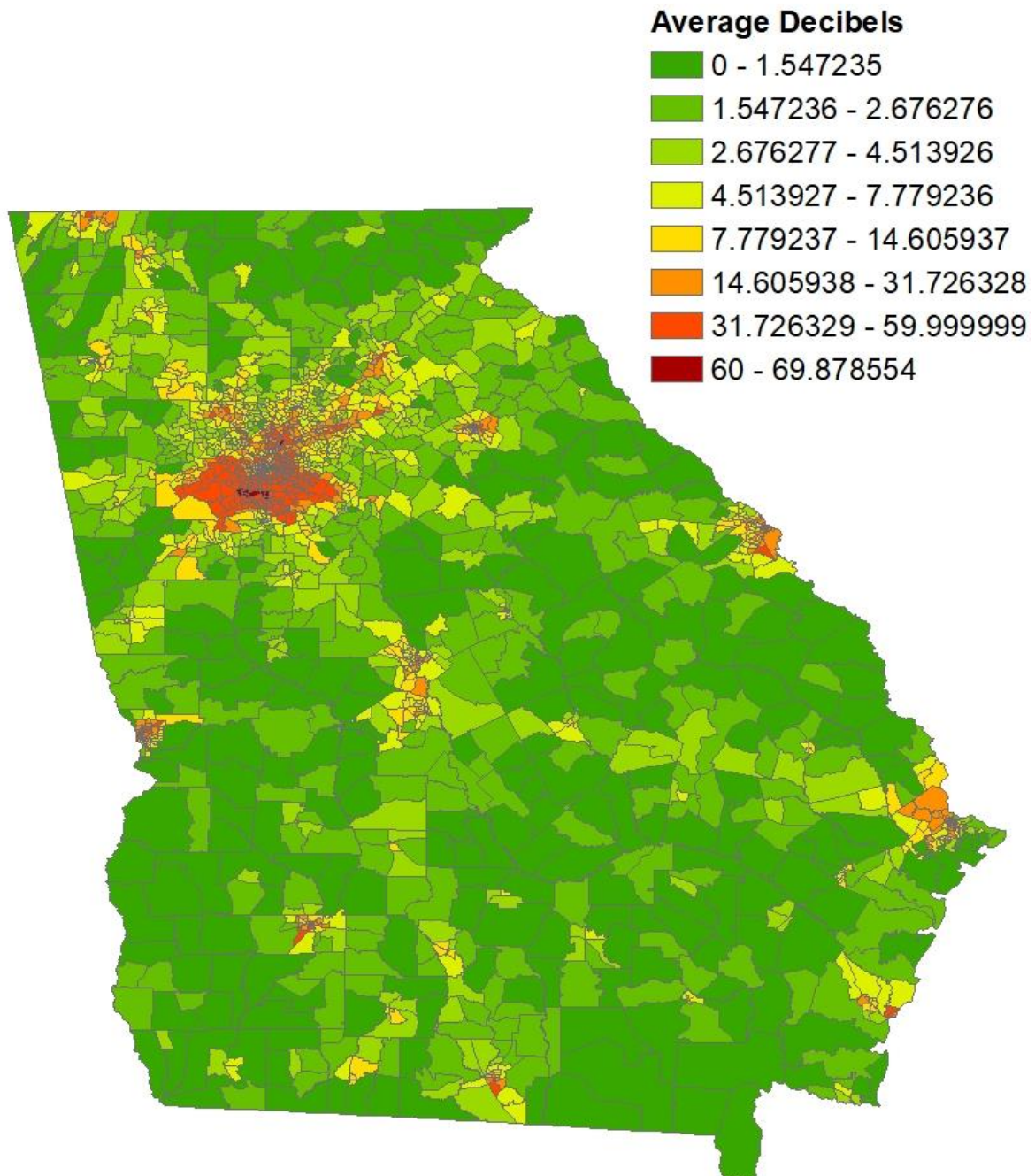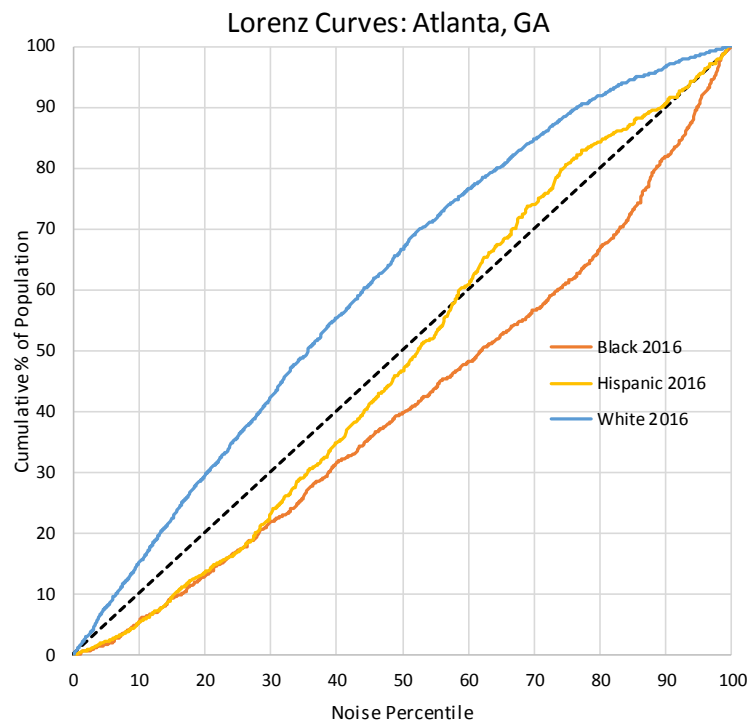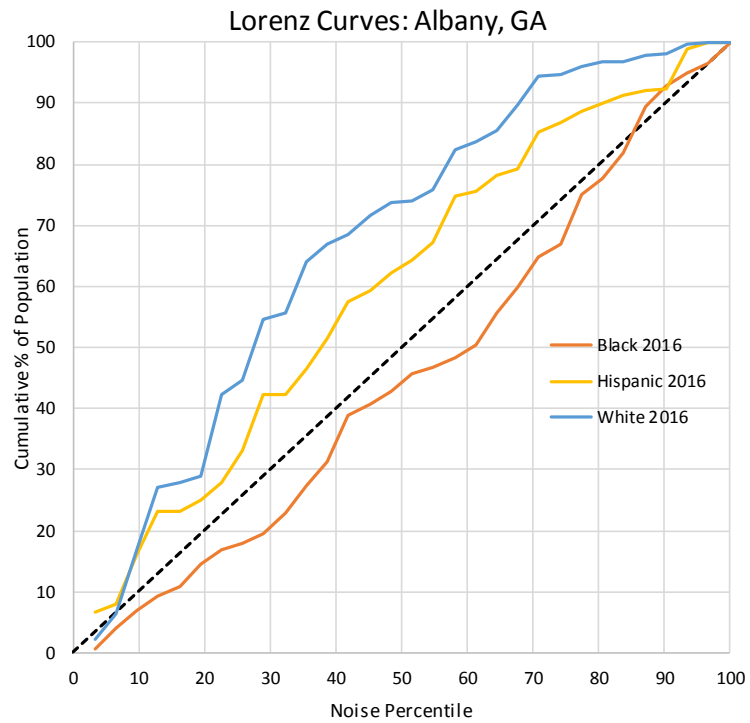# Figure 1

Census Tract Average Transportation Noise

Average Decibels
- 0 - 1.547235
- 1.547236 - 2.676276
- 2.676277 - 4.513926
- 4.513927 - 7.779236
- 7.779237 - 14.605937
- 14.605938 - 31.726328
- 31.726329 - 59.999999
- 60 - 69.878554

Figure 2

Lorenz Curves: Atlanta, GA

Figure 3

Lorenz Curves: Albany, GA

Figure 4

Lorenz Curves: Athens, GA

Figure 5

Lorenz Curves: Gainesville, GA
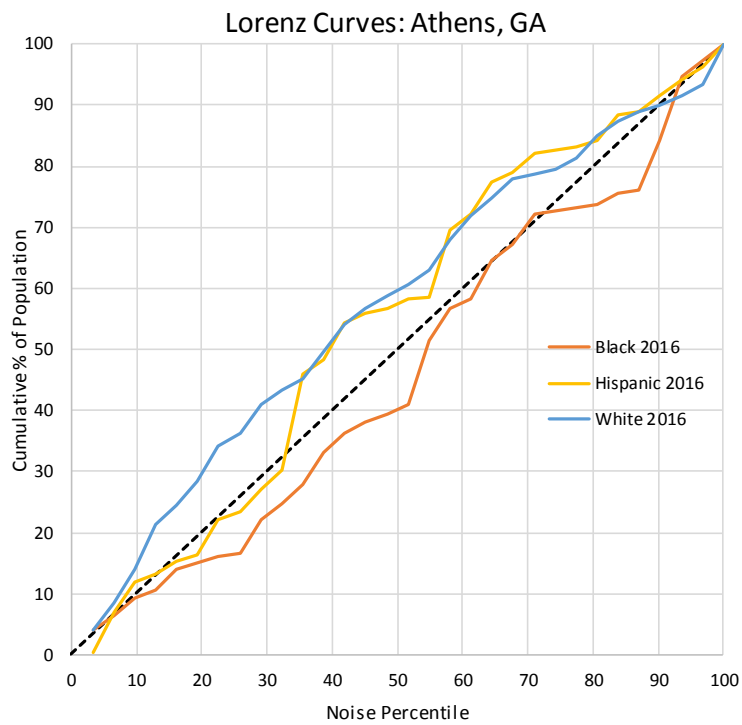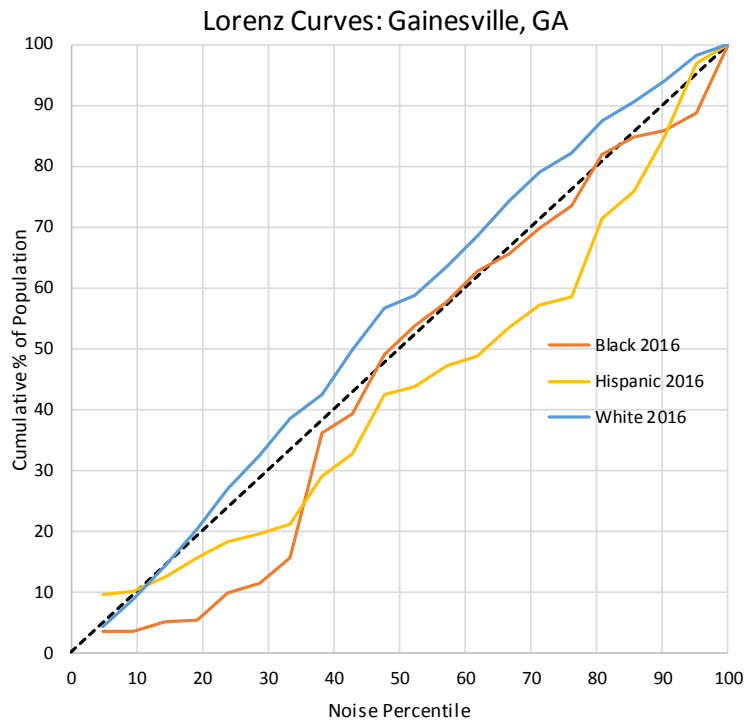
Figure 6a
Census Tract Percent Black

Percent
- 0 - 6.526488
- 6.526489 - 16.432039
- 16.432040 - 31.416878
- 31.416879 - 56.535125
- 56.535126 - 100
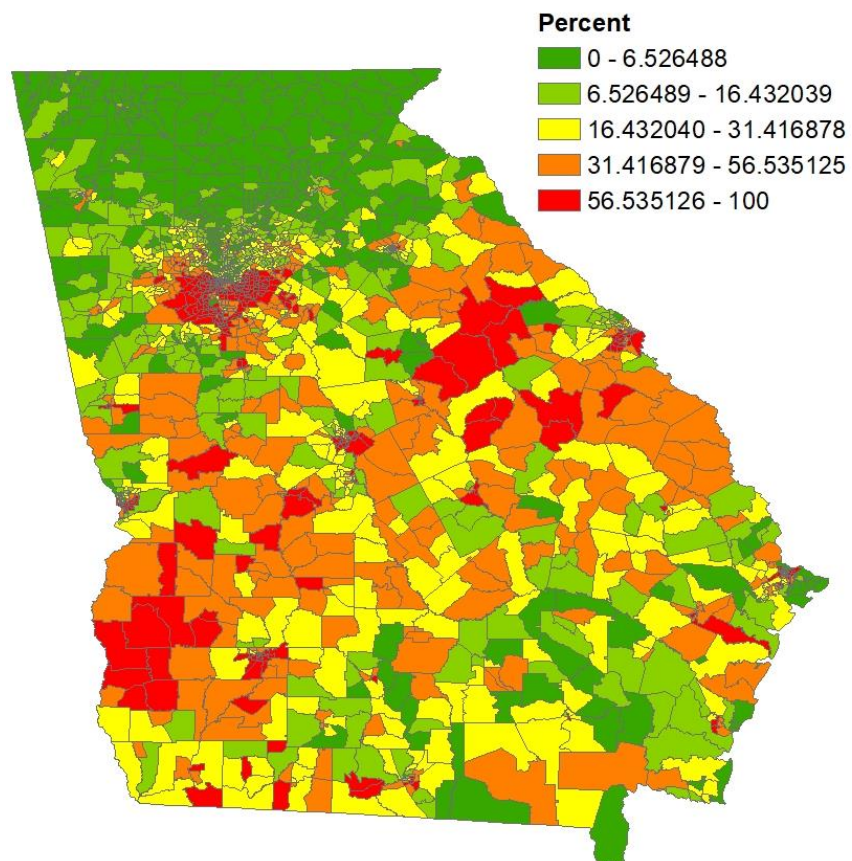
Figure 6b
LWR Coefficient on Census Tract Percent Black

Coefficient Value
- 0.017881 - 0.020601
- 0.020602 - 0.022229
- 0.022230 - 0.022603
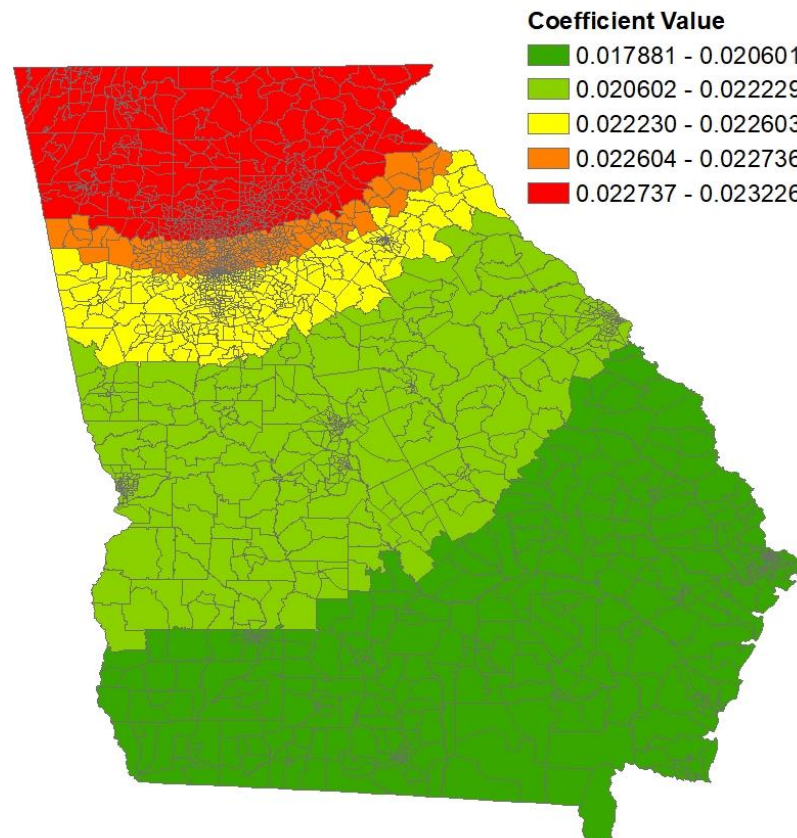- 0.022604 - 0.022736
- 0.022737 - 0.023226

Figure 7a
Census Tract Percent Hispanic

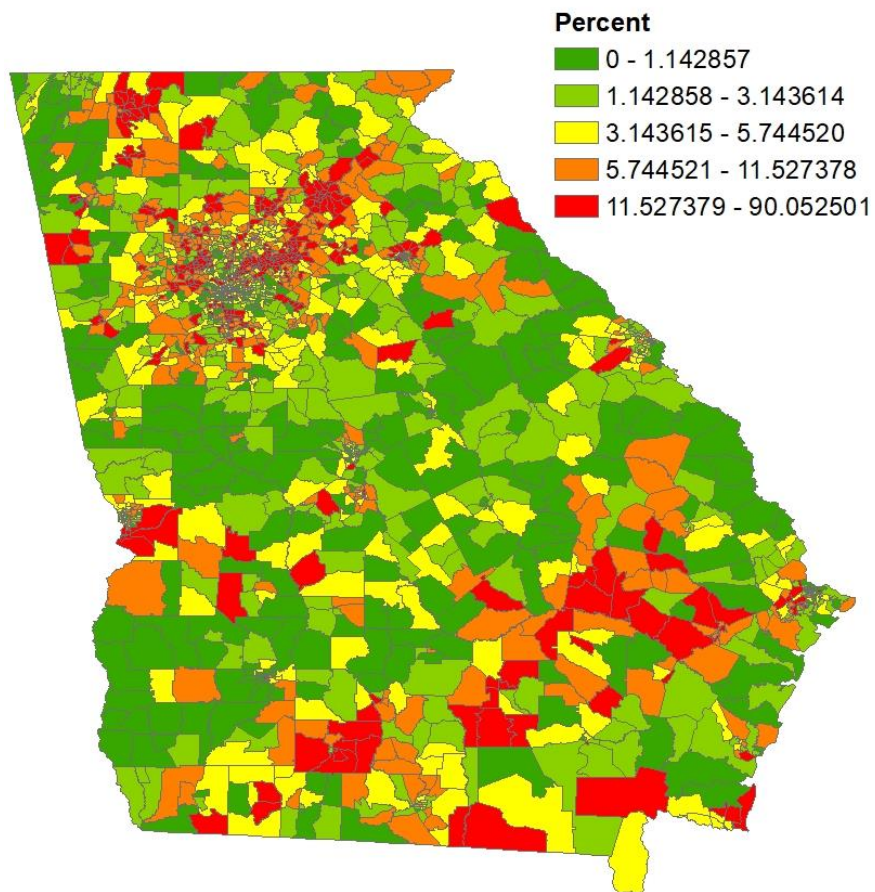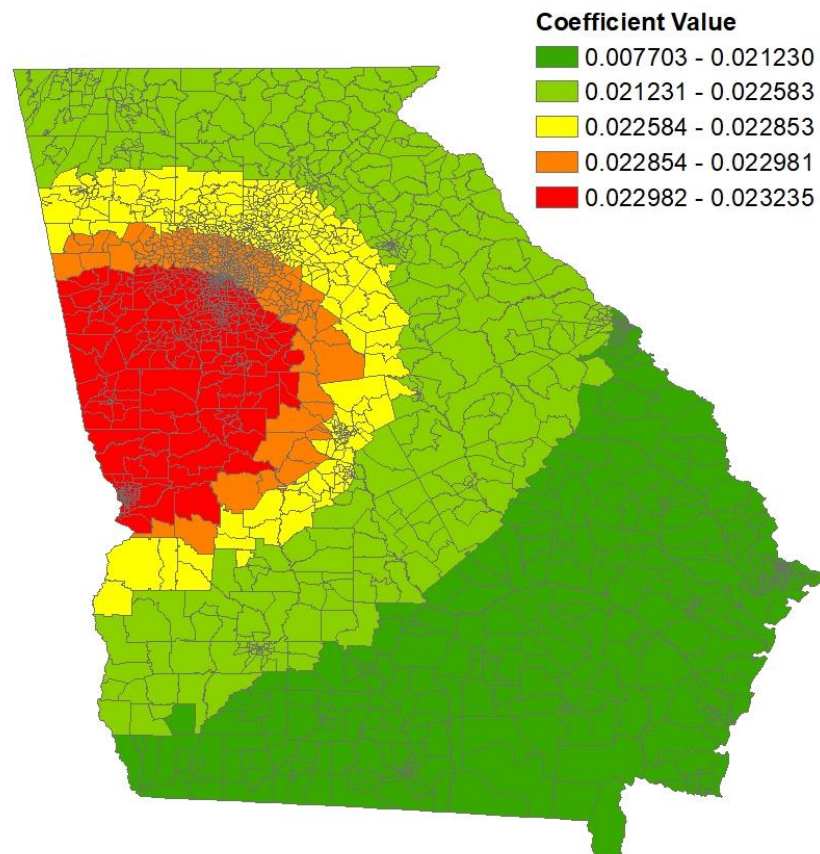## Figure 7b
LWR Coefficient on Census Tract Percent Hispanic

Percent
- 0 - 1.142857
- 1.142858 - 3.143614
- 3.143615 - 5.744520
- 5.744521 - 11.527378
- 11.527379 - 90.052501

Coefficient Value
- 0.007703 - 0.021230
- 0.021231 - 0.022583
- 0.022584 - 0.022853
- 0.022854 - 0.022981
- 0.022982 - 0.023235

Appendix

Lorenz Curves: Savannah, GA

Lorenz Curves: Valdosta, GA

Lorenz Curves: Rome, GA

Lorenz Curves: Brunswick, GA

Lorenz Curves: Dalton, GA

Lorenz Curves: Hinesville, GA

Lorenz Curves: Macon, GA

Lorenz Curves: Warner Robbins, GA