Ethnic Residential Segregation and Under-Age-5 Mortality:
A Spatial Analysis of 1880 Newark, NJ

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Abstract: Relying on administrative geographic units, previous research on residential segregation and mortality is susceptible to measurement errors, scale-sensitive results, and improper statistical inference due to ignoring inherent spatial features (e.g., scale, boundary, and proximity) and processes. Using household-level geocoded data of 1880 Newark (NJ), we adopt a spatial perspective with respect to neighborhood representation, segregation measures, and geostatistical modeling strategy to examine the association between ethnic segregation in egocentric neighborhood and child mortality. Preliminary results suggest that child mortality risk is not randomly distributed in space, but clustered in two hot zones. Also, ethnic residential segregation is greater at micro-scale than at macro-scale. Native-born Americans and Irish immigrants tend to be integrated with each other as the spatial scale increases, whereas German immigrants remained relatively distant from the others. On-going analyses will explore the link between residential segregation and child mortality, and the insights gained by recognizing spatial process and spatial autocorrelation.

INTRODUCTION

Research on the association between racial/ethnic residential segregation and health largely relies on administratively defined units, including but not limited to census geography (e.g., census blocks, tracts, and metropolitan statistical areas), electoral districts, and postal sectors and zip codes. Data aggregation based on administrative units may be unlikely to capture the neighborhood characteristics that affect individual health and behavior (Chaix 2009; Flowerdew et al. 2008; Guo and Bhat 2007; Lee et al. 2008; Sampson et al. 2002; Tatalovich et al. 2006). Previous studies of residential segregation and mortality rarely take into account any spatial dimensions in terms of measurement and analytical strategy, even though segregation itself is inherently spatial.

Aspatial measurement errors can occur when important spatial issues such as scale, boundary and proximity are ignored. Even though residential segregation can occur at both micro- and macro-scale, individual health is more likely to be affected by exposure to segregation at small rather than large geographies like city and metropolitan area (Chaix et al. 2005a, b; Chaix 2009; Guo and Bhat 2007). Smaller units like census blocks and tracts may approximate local environments in terms of area size. Nevertheless, the scale at which local segregation affects individual mortality does not necessarily coincide with that of a census block or tract. It is also possible that even within a block or tract, the effect of segregation on mortality occurs at multiple scales with its magnitude decaying as the measurement scale increases. In addition, the influence of residential segregation on mortality is rarely confined within the boundaries of administrative units. One's exposure to residential segregation is more likely to depend on his or her proximity to the nearby racial and ethnic population composition. A black person living on the boundary between a predominantly black census tract and a predominantly white tract is less racially isolated because of potentially stronger cross-racial interactions, compared to a black person living in the center of the black tract (Morrill 1991; Wong 1993 and 2003).

In terms of analytic strategy, inadequate treatment of potential intra-neighborhood correlations can result in biased regression estimate and inflated statistical significance. In one study, bootstrap methods are used to adjust for potential bias in calculating standard errors (Hearst et al. 2008). Nevertheless, aspatial multilevel models and other techniques that assume independent mortality risks across nearby neighborhoods remain susceptible to incorrect statistical inference and can only provide limited information on the spatial dimensions of risks (Chaix et al. 2005a, b).

Another limitation is related to a lack of clear conceptualization about why and how residential segregation can influence mortality. In many studies on mortality, the dissimilarity index is used as a measure of the degree of residential segregation (e.g., Fang et al. 1998; Hart et al. 1998; LaVeist 1989 and 1993; Peterson and Krivo 1993; Polednak 1991 and 1996), although it only captures one of the five dimensions of residential segregation, that is, unevenness in the population distribution of racial and ethnic groups (Massey and Denton 1988). However, other dimensions of residential segregation such as isolation and concentration may be theoretically more relevant in investigating mortality (Collins and Williams 1999; Guest et al. 1998; Hearst et al. 2008; Peterson and Krivo 1993).

Finally, it is known that neighborhood socioeconomic conditions serve not only as a confounder of the relationship between residential segregation and health, but more as part of the casual pathway that link segregation to individual outcomes (Collins and Williams 1999; Williams and Collins 2001). It remains inconclusive regarding whether residential segregation is an independent force or merely a proxy factor for mortality (Collins and Williams 1999; Fang et al. 1998; Guest et al. 1998; Hearst et al. 2008; Inagami et al. 2006; Polednak 1991 and 1996). Without an appropriate conceptualization of underlying mechanisms and processes, we may run the risk of treating residential segregation as a residual factor in addition to neighborhood socioeconomic conditions for individual mortality and other health outcomes (Macintyre et al. 2002).

In this ongoing project, we plan to address these challenges by adopting a spatial perspective to examine the relationship between residential segregation and under-age-5 mortality. Drawing from the household-level geocoded data of 1880 Newark, New Jersey, we will apply recently developed spatial approaches to analyze spatial aspects of segregation effects on child mortality. Specifically, we seek to: (1) determine the appropriate geographic level (the radius used to delimit neighborhood boundaries) and neighborhood representation (egocentric neighborhood that is concentric circular or depends on street network structures) for residential segregation to affect child mortality; (2) quantify both the magnitude and the geographic scale of spatial variations in child mortality, that is, at what geographic distance individual risks are spatially correlated across neighborhoods and how strong the correlation is; and (3) examine ethnic isolation and concentration as the specific theoretical mechanisms that link segregation to child mortality while controlling for neighborhood socioeconomic conditions.

In the following sections, we briefly discuss the theoretical background of the study, followed by an introduction of the data. We then present some preliminary results with respect to the spatial distribution of under-age-5 mortality risk and ethnic residential patterns in 1880 Newark. We finally introduce the next-step analysis that we plan to do.

THEORETICAL BACKGROUND

Pathways Linking Ethnic Segregation and Child Mortality

Residential segregation can affect residents' mortality risks through detrimental living environments. Segregated minority neighborhoods are characterized by concentrated poverty, overcrowded and dilapidated housing, social disorganization, and limited access to health care (Acevedo-Garcia 2000) in both the contemporary (e.g., Massey and Denton 1993) and the late 19th-century (e.g., Cunningham 1966; Galishoff 1988; Warner and Burke 1969) U.S. cities. Acevedo-Garcia and Lochner (2003) suggested that each dimension of segregation is conceptually associated with distinct pathways to the health outcome of interest. Isolation and concentration are the two dimensions that are most relevant to mortality in this study.

Isolation refers to the probability of interaction between two members of the same group (Massey and Denton 1988). The greater the probability is, the greater the group's isolation is, or in other words, the less inter-group contact. Residential segregation is likely to limit the contact between the segregated group and the rest of the population. Social isolation can deteriorate social support, reduce life opportunities and access to institutional resources, and tie the minority groups to the neighborhoods with multiple disadvantages (Collins and Williams 1999).

Concentration refers to the related concept of population density, or the relative amount of physical space occupied by a group in the urban environment. Members of a given group live at high densities if they occupy relatively small areas within an urban fabric and are residentially concentrated compared to those residing in low density areas (Johnston et al. 2007). Concentration of ethnic groups may lead to high population density in segregated neighborhoods which in turn results in: (1) overcrowded housing conditions that are related to risks of low birth weight (Roberts 1997) and later life mortality (Coggon et al. 1993), and (2) unsanitary living environments that increases post-neonatal mortality rates (Reid 2002).

In this study, the pathway between residential segregation and under-age-5 mortality is conceptualized to be routed through the influence of isolation and concentration of ethnic groups on transmissions of infectious diseases. Infectious diseases had become rampant in Newark since 1832 when the city was struck by a cholera epidemic with about sixty residents killed in less than two months (Cunningham 1966: 102). Throughout the 19th century, residents in Newark were vulnerable to the epidemics transmitted by fecalized water supplies such as cholera, typhoid fever, and dysentery and those transmitted by person-to-person contact such as influenza, smallpox and diphtheria (Galishoff 1988). Diseases like typhoid fever can also be spread through person-to-person contact as known in the story of Mary Mallon (also known as Typhoid Mary), an Irish immigrant who came to New York in 1884 and had 53 people infected over the course of her career as a cook (Bourdain 2001). The epidemic of cholera invaded Newark for several times and caught Newarkers' most fear in the 19th century, however, Galishoff (1988: 4) suggested that "it was the silent endemic diseases, notably tuberculosis, pneumonia, and the diarrheal diseases, that caused the greatest mortality."

Both isolation and concentration of ethnic groups may have direct impacts on the transmission of infectious diseases. The isolation of a group can confine the transmission of infectious diseases within ethnically segregated areas, regardless of neighborhood wealth or poverty, and prevent transmission to the members of other groups (Acevedo-Garcia 2000). Nevertheless, isolation may have the opposite effect to protect members of a group from transmissions of infectious diseases. In their simulation analysis, Poppel and colleagues (2002) suggest that the social isolation of a minority group can lower infant and child mortality by reducing transmission of infectious disease in an 1855-1912 Holland setting.

Spatial concentration of individuals from a given group in relatively small residential areas may accelerate and expand transmissions of infectious diseases because of physically intensified contacts. Minority groups are typically concentrated in inner cities in the U.S., resulting in high population density in segregated neighborhoods, which in turn may facilitate transmissions of infectious diseases (Acevedo-Garcia 2000). Therefore, the high concentration of immigrant minority groups in segregated neighborhoods may put them at greater risks of death due to increased exposure to disease transmissions.

Grady (2006) suggests that an infant's exposure to neighborhood hazard may occur during or even prior to the mother's pregnancy and the degree of exposure is related to the level of neighborhood segregation. Roberts (1997) also suggests how neighborhood social environments may impact infants' health status through affecting maternal health. Thus, the health consequence of living in an ethnic neighborhood can be substantial, even if an infant or child has only limited residential experience there.

Taken together, ethnic isolation in the 19th-century Newark could elevate the infection and mortality risks of communicable diseases if incidences occurred within the group due to frequent and close contacts. Spatial proximity in terms of residence serves a proxy to close social and physical contacts in this historical context. An incidence of child TB in, for example, the wealthy native-born American neighborhood near Washington and Military Parks could endanger other children living there because of their close day-to-day playing together. But this would have no effect at all on the German children living along Clinton Avenue. It may also be the case that in Down Neck where poor Irish and German immigrants coexisted, an Irish child infected with typhoid fever would put other Irish children living in the same multi-family tenement or the houses next door, but not the German children living in a different block at a greater mortality risk.

Egocentric Neighborhoods

For health outcomes, it is theoretically more relevant to consider individuals' proximity to each other in local space (Chaix et al. 2005a, b and 2009; Frank et al. 2004; Guo and Bhat 2007; Lee et al. 2008). In this study, we employ the idea of egocentric neighborhoods to measure residential segregation and neighborhood socioeconomic conditions. Under this framework, an individual's exposure to the local environment reflects a proximity-weighted average composition of each surrounding point within certain distance bandwidth centered at his or her residence. Local environment is particularly important for considering children's health as in this study because of their limited daily activity space around home and hence exposure to mortality risks at a small geographic scale (Lee et al. 2008; Sampson et al. 2002).

A simple way to define egocentric neighborhoods is to draw concentric circular buffers around individuals' residences at a certain or a range of different distances. An obvious limitation of this method is to ignore that every part of the circular area is not equivalently accessible because of the landscape barriers, in particular street networks in local areas (Chaix et al. 2009; Frank et al. 2004; Guo and Bhat 2007; Lee et al. 2008). The structure of local street networks has a significant effect on shaping the space where people interact with each other in daily life and hence develop their conceptions of the neighborhoods (Anderson 1992). Grannis (1998) demonstrated that pedestrian-oriented streets had a greater influence on connecting people and forming racially homogeneous communities than geographic proximity. Street networks may be particularly important for studying children's mortality risks because pedestrian-oriented streets are closely tied to patterns of interaction that involve children and families. Furthermore, street network-based neighborhood representation may also bear analytical advantages. In an analysis of residential location choice in the San Francisco Bay Area, Guo and Bhat (2007) found that the definition of egocentric neighborhoods based on network distance is statistically superior, in terms of model goodness-of-fit, to that based on circular buffers.

The geocoded street network data of 1880 Newark allows me to explore the issue of network-based neighborhood representation. Following the previous literature, we plan to construct and compare the results from circular buffering and network-based egocentric neighborhoods defined at a range of distance radii. We will further address the issue of fuzzy neighborhood delimitations by incorporating weights that follow a decreasing function of the distance from individual residence in computing segregation measures and neighborhood socioeconomic conditions (Chaix et al. 2005a and 2009).

DATA

Household-level Geocoded Data of 1880 Census

The household-level geocoded 1880 Newark data provide a unique opportunity to address the relative roles of ethnicity and SES in relation to residential segregation while taking into account spatial structures in the analysis. The data come from the Urban Transition Historical GIS Project directed by Professor John Logan at the Initiative in Spatial Structures in the Social Science (S4), Brown University[1]. This project uses historical census data to document the state of American cities from the end of the 19th Century into the early 20th Century. All the residents in 39 selected cities are or will be geocoded based on their household addresses from the full transcription of the 1880 Census of Population created by the Church of Jesus Christ of Latter-day Saints and made widely accessible through the North Atlantic Population Project (NAPP) at the Minnesota Population Center (MPC)[2].

The geocoded individual-level data provide a great opportunity to conduct a wide range of spatial analysis of residential segregation in historical American cities. Of the total population (136,508) in 1880 Newark, 133,554 persons (nearly 98%) from 28,489 households were successfully geocoded to their street addresses. In this project, we focus

[1] More detailed information regarding the Urban Transition Historical GIS Project and the data used in this study can be found at: http://www.s4.brown.edu/.

[2] More detailed information regarding the transcription of the 1880 Census of Population can be found at: http://www.nappdata.org/.

on three predominant ethnic groups, Irish, Germans and Yankees in 1880 Newark. Irish and Germans include both first- and second-generation immigrants, that is, those who were not born in the U.S., and those who were born in the U.S. but whose parents were not. Yankees are native born white and whose parents are also native born. By these definitions, there are about, 31,362 Irish (30,158 geocoded), 42,481 Germans (40,042 geocoded), and 37,967 Yankees (37,180 geocoded), together accounting for about 82 percent of the city's total population in 1880.

Figure 1 presents separate maps of the geocoded population distributions of the three ethnic groups under consideration in this project. All three ethnic groups spread out all over the city, though there appeared to be spatially distinct clusterings of each group. There were high concentrations of Irish population in the northwest, southeast and southern parts of the city. A large German population occupied the west, southwest and eastern parts of the city. The Yankee population spread in the south-north direction in the central part of the city.

[Figure 1 about here]

Death Records Data

The death records data are drawn from the database available at the Department of State of New Jersey. The death records between June 1878 and June 1885, including death certificates, burial, reburial, transit, and disinterment permits, are recorded by the New Jersey Department of Health. New Jersey is well known for its accurate and complete reporting of vital statistics in the late 19th century. Among all the 1880 U.S. Census death registration area, for example, New Jersey was one of the only two states that provided reasonably accurate and more than 90 percent complete registration of deaths (Galishoff 1988). Therefore, the death records between June 1878 and June 1885 in Newark would be fairly accurate and complete given the historical context.

We have identified a total number of 501 death records by June 1885 among 6,762 individuals who were infants (of age 0-1 year old) in 1880 Newark. These numbers translate into about 74 deaths per 1000 children during a roughly 5-year period, and crudely 15 deaths per 1000 on average in a single year. This number is quite close to the officially published death rate of Newark in 1880 (18.7 deaths per 1000 population; Galishoff 1988: 96). Therefore, there is a reasonable chance that the 6,261 infants whose death records were not identified here had not died by June 1885 in Newark.

In this analysis, we will focus on the 438 death records among 5,767 infants who were Irish, Germans or Yankees. These 5,767 cases resided along 1,380 street segments, and were from 5,558 households. In fact, only about 4% were clustered with each other within same households. In other words, there is likely to be a high intra-street segment, but low intra-household correlation in the data.

Measures

Ethnicity is determined by combining several variables, including race, place of birth, and parents' places of birth. For example, a white person who was born in Ireland (first-generation immigrant) or who was born in any state of the US but whose parents were born in Ireland (second-generation immigrant) is coded as an Irish immigrant. Other individual- and household-level control variables include infant's gender, number of siblings, and household header's age, ethnicity and SEI score. SES is measured by a socioeconomic index (SEI) score coded by MPC based on people's average education and earnings in each occupation as measured in 1950 and standardized to be a continuous value bounded between 0 and 100 with 0 indicating unemployed. Such a coding strategy is found to be robust with respect to the historical context (Sobek 1996). Number of siblings is derived from each household member's relationship to the header.

Egocentric neighborhoods are constructed by using Euclidean distance and street network distance separately at the radius of 50, 100, 150 and 200 meters to approximate the relatively small scales of children's limited activity space in 1880 Newark, a pedestrian city. Following Reardon and O'Sullivan (2004), we compute neighborhood measures based on proximity-weighted functions. Specifically, we use the classical kernel density estimation (KDE) for circular buffering neighborhoods (Diggle 1983; Gatrell et al. 1996), and a recently developed approach for network-based neighborhoods (Xie and Yan 2008). The KDE has the property of puttig greater weights on points that are at longer distance from the location of interest than on points that are nearby. A planar KDE reflects the proximity-weighted population count within an individual's local environment (i.e. spatially weighted number of people per unit area to one's egocentric neighborhood). A network KDE provides an estimate of population density over a linear unit and hence suits to constructing street network-based egocentric neighborhoods.

Ethnic isolation is measured by the proportion of own-group population (i.e. KDE for own-group population divided by KDE for total population) in one's egocentric neighborhood. Ethnic concentration is approximated by KDE for own-group population in one's egocentric neighborhood. We will explore ways to standardize these measures across different children's egocentric neighborhoods.

PRELIMINARY RESULTS AND FUTURE PLAN

Exploratory Spatial Data Analysis

We present preliminary results from exploratory spatial data analysis. Figure 2 simply depicts the household locations of the infants in 1880 Newark. The locations of those infants who died by 1885 are marked in black. At first glance, the locations of death occurrence are spread widely all over the city. A natural question is whether there is any pattern to the spatial distribution of child mortality. A common hypothesis tested in spatial analysis is the so-called complete spatial randomness (CSR), that is, given that N(A) events occur in a bounded region A, the events are uniformly and independently distributed over A. One way to test this hypothesis is to calculate the K-function (Gatrell et al. 1996) which measures the number of events around an arbitrary event as a function of distance for multiple different distances. Figure 3 plots the K-function for the observed occurrences of child mortality as well as the theoretical values under CSR. It is clear that at any given distance, the K-function of the observed data falls above the upper bound of the permutation envelope, suggesting the deaths are not random with respect to place.

[Figure 2 & 3 about here]

Given that the intensity of child mortality varies over space, Figure 4 portrays nonparametric estimation of mortality intensity together with the contour lines of the estimates. Overall, household locations of those who were infants in 1880 and died by 1885 are largely confined within the central region of Newark. There also seem to be two hot zones with relatively high intensity. The hot zone in the west roughly corresponds to an area populated by Irish and Germans, whereas the other one in the east was predominantly occupied by Irish and Yankees.

[Figure 4 about here]

We next explore the tendency of residential segregation by ethnicity in 1880 Newark. Figure 5 depicts average KDE values of own-group population by ethnicity for the infants in 1880, which is essentially an estimate of the mean distance-based weighted number of, for example, Irish people per unit area (i.e. square meter) within a certain radius of an Irish infant. It is not surprising that all the curves in Figure 5 drop very quickly as the distance radius increases from 50 to 100 meters and then continue to drop, but at a slower rate, since the weight of each counted person declines exponentially as the distance increases. This implies that the degree of residential segregation by ethnicity is greater at micro-scale than at macro-scale. More importantly, the relatively larger mean KDE values for Germans at any given distance suggest that Germans had a stronger tendency to live closer to others of the same ethnicity, whereas such tendency was weakest among Yankees. This result is further confirmed by the average percentages of own-group population calculated from KDE values as depicted in Figure 6. On average, over 50 percent of the total population within a 50-meter radius is of the same ethnicity for a German, whereas for Yankees the corresponding figure is nearly 40 percent. As the distance radius increases, the percentage of own-group population drops for all the three groups, suggesting more neighbors of different ethnicities are counted. Nevertheless, the curve for Germans lies almost parallel to that for Yankees, whereas the curve for Irish tends to converge with that for Yankees at large distances, indicating that Irish and Yankees were in closer proximity to each other at relatively large scale, whereas Germans remained relatively distant from the other two groups. These patterns are consistent with the historical accounts about native-born Americans' lower tolerance of the German community in 19th-century Newark (Cunningham 1966).

[Figure 5 & 6 about here]

Next Step

Next, we will conduct a step-wise analysis to examine associations between ethnic residential segregation and under-age-5 mortality. We will use both non-spatial and spatial methods to compare the results and illustrate the importance of space in statistical modeling. In the first step, we will fit a logit model in which all the responses are treated independent from each other. In this model, neither the non-spatial intra-neighborhood clustering nor the inter-neighborhood spatial correlation is assumed to exist.

In the second step, we will fit a two-level random-effects logit model in which children from the same territory neighborhoods are assumed more similar to one another than to other children due to shared exposure to the same environments. Street segments are used as the proxies of territory neighborhoods. We compare the regression estimates from this model and those from the simple model (in the first step), and test the significance of neighborhood-level variance to examine the presence of non-spatial intra-neighborhood correlation.

In the third step, we will fit a geostatistical logit model in which the potential inter-neighborhood spatial correlation is assumed to follow an isotropic stationary Gaussian process (i.e., spatial correlation does not depend on direction). The spatial correlation is modeled by a distance-based exponential function (Diggle and Ribeiro 2007). Essentially, the spatial correlation is assumed to decay as the distance between two neighborhoods increases. The distance beyond which the spatial correlation between different neighborhoods no longer exists can be explored by estimating the parameter of the spatial variance. We compare the results from the geostatistical model and those from the non-spatial multilevel model to show the additional insights gained by taking into account spatial dimensions.

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Figure 1. Distribution of Irish, German, and Yankee Population in 1880 Newark, NJ

Figure 2. Household Locations of Infants in 1880 Newark and Those Who Died by 1885

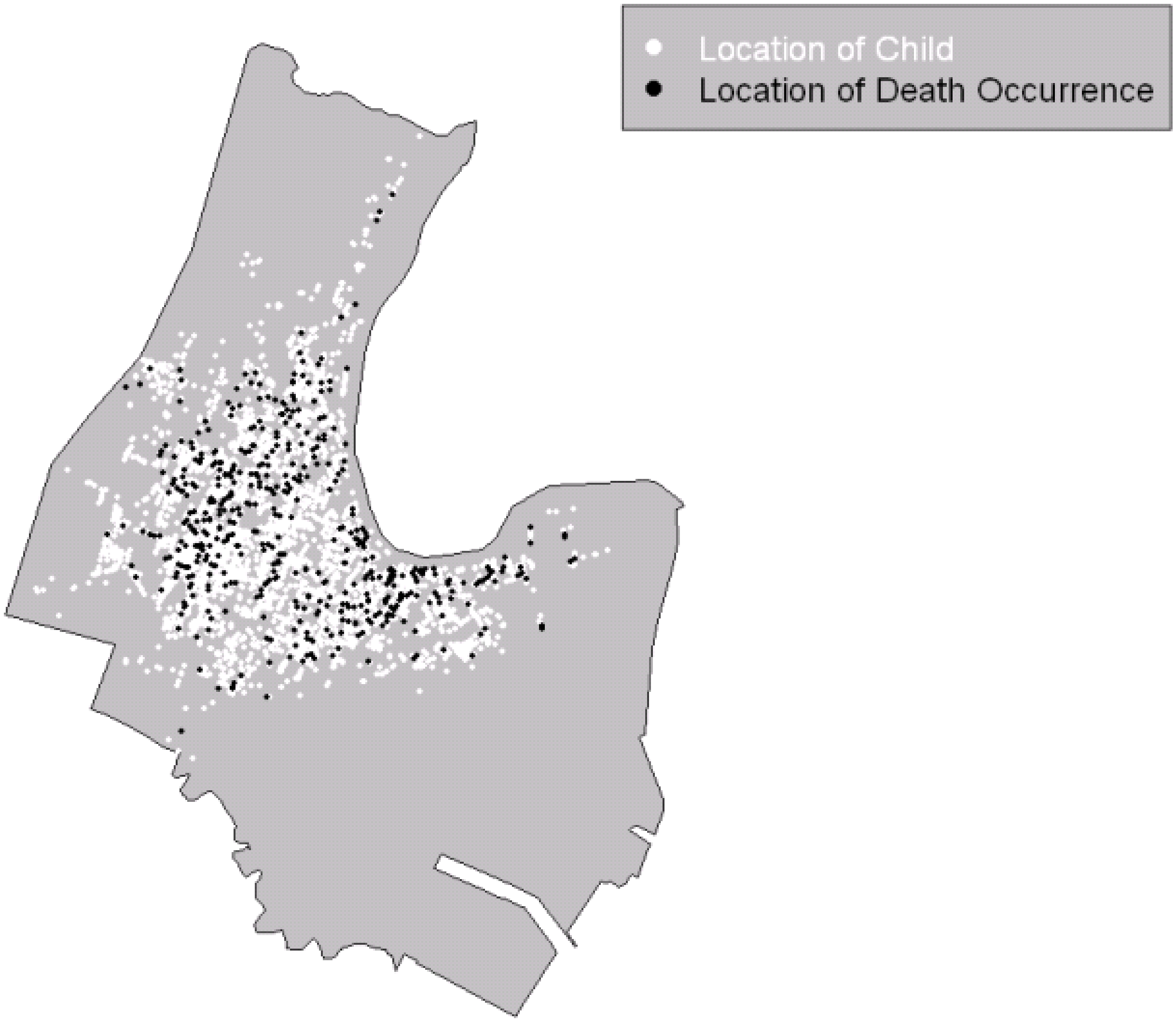

Figure 3. Estimated K-Function of Child Mortality

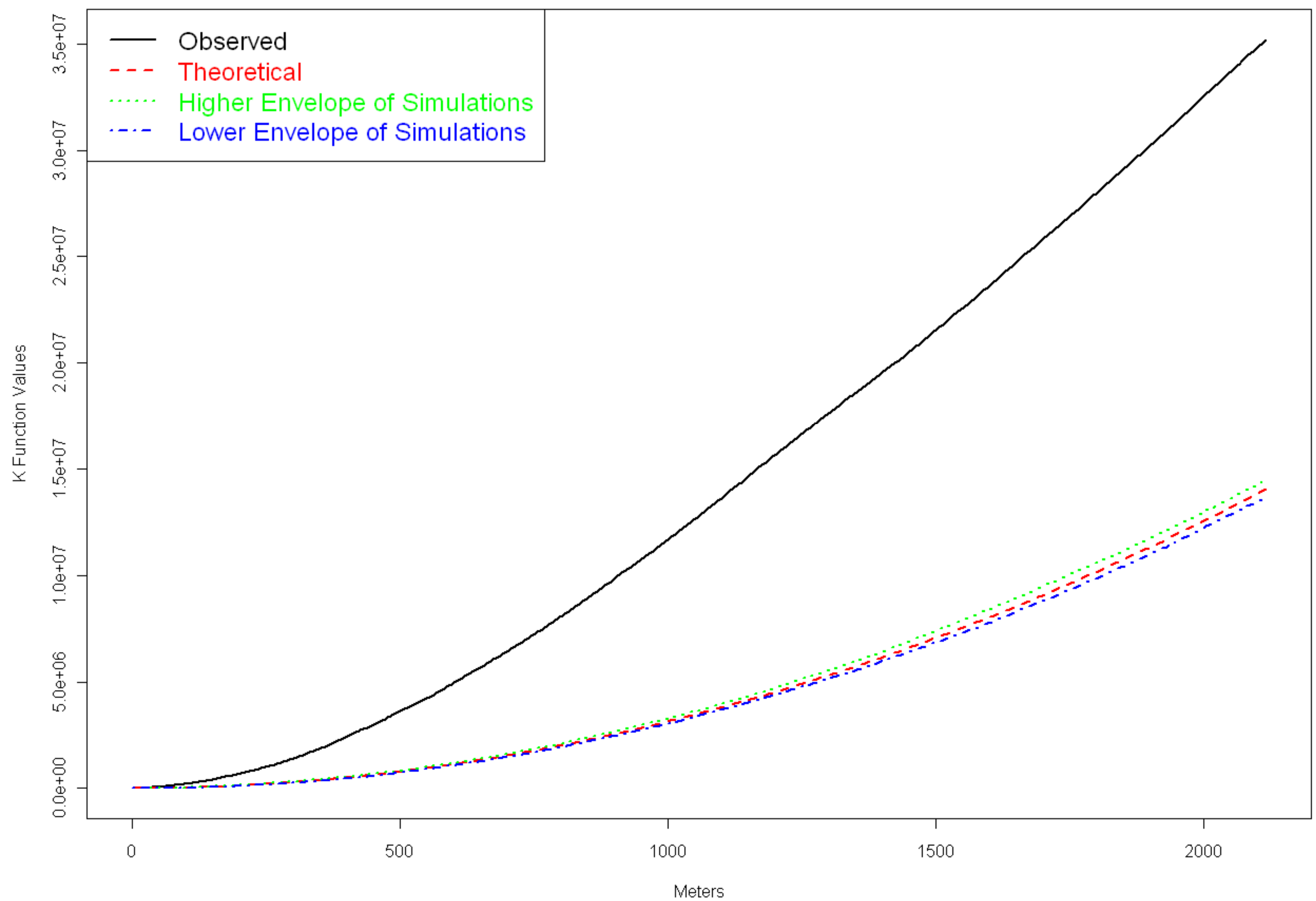

Figure 4. Nonparametric Intensity Estimation of Child Mortality

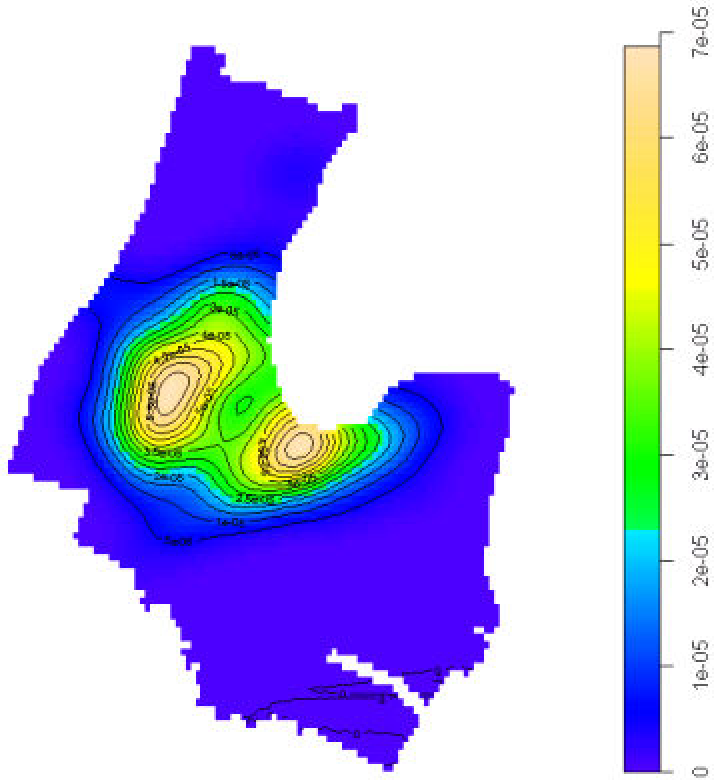

Figure 5. Average of Kernel Density Estimation of Own-Group Population

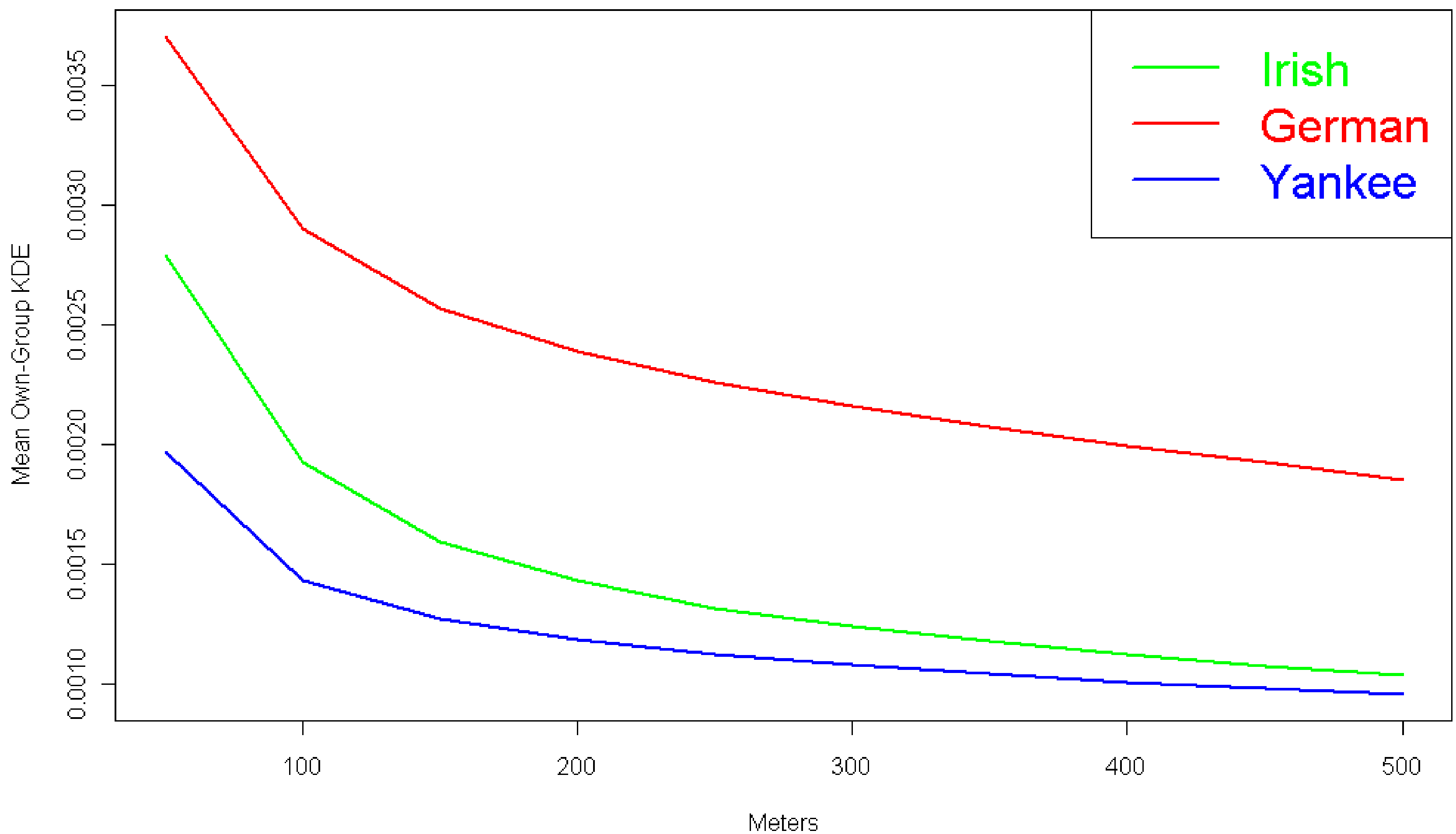

Figure 6. Average Percentage of Own-Group Population based on Kernel Density Estimation