SCALE EFFECTS IN SEGREGATION PROCESSES[*]

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Abstract

A complex system is a social, physical, or biological system in which properties of the system emerge from interactions among lower level units. Scale effects showing the independent effect of population size on system dynamics have been well documented in sociology, economics, biology, and the physical sciences. Residential segregation is also a complex process, as neighborhoods emerge from the interdependent mobility decisions of individuals. However, we do not know what role absolute or relative group size plays in segregation dynamics. We use agent-based models to explore whether and how race/ethnic segregation processes are sensitive to city and neighborhood size, and also relative and absolute ethnic group size (e.g., critical mass) under alternative theoretical and empirical residential mobility behaviors. Preliminary evidence shows that the same level of tolerance may produce higher segregation in smaller cities. In the final paper we will provide a complete analysis of the relationship between group size, ethnic tolerance, and segregation dynamics.

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[*] We are grateful to Rick Riolo for his help and direction constructing the GPU-based agent-based model. This work was supported in part by the National Institute of Health and Google Corporation.

Motivation

There is a century of work in sociology and demography documenting patterns of residential segregation over time and across cities (Park 1952; Duncan and Duncan 1957; Taeuber and Taeuber 1967; Jargowsky 1996; Farley and Frey 1996; Massey et al. 2003). However, we are still discovering the processes through which these patterns arise and persist. Segregation is created and maintained through the interdependent actions of individuals (Schelling 1971, 1978; Zhang 2007; Bruch and Mare 2006, 2009). Any individual who moves in or out of a neighborhood affects the composition of both the neighborhood she leaves behind and the neighborhood she moves into, thus making residential choices of individuals dependent on the previous location decisions of others. When behavior is interdependent in this way, we observe feedback between features of the environment (i.e., neighborhoods) and the behavior of individuals. In the short run, individuals respond to their environment, but in the longer run their decisions change that environment. Under these circumstances, there is no simple or linear relationship between the intentions or behaviors of individuals and the collective implications of their actions (1971, 1972, 1978). Models that seek to explain the relationship between individual behavior and patterns of segregation must explicitly account for feedback between individuals' actions and neighborhood characteristics.[1]

Agent-based models are used to connect the preferences of individuals for neighborhoods (e.g., based on racial composition) and aggregate patterns of race-ethnic segregation. This method relies on artificial worlds in which synthetic people interact according to some specified rule of behavior. This work has revealed that even mild own-group preferences are consistent with high levels of segregation (Schelling 1971; Zhang 2007) and the shape of individuals' preference—not just their average level of tolerance—has significant implications for segregation dynamics (Bruch and Mare 2006, 2009a). The mechanisms that link individual action and aggregate segregation may work on multiple scales (Levin 1992). For example, although segregation can occur across rectangular neighborhoods of 20 blocks, individuals may be aware of 1 or 2 block areas, or their overall

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[1] We use agent-based modeling in this work, but other models used to capture dynamic interdependent behavior include interactive Markov models and general equilibrium models. The relative strengths and weaknesses of these dynamic models are discussed in Bruch and Mare (2009).

metropolitan environments, or social networks that are only loosely tied to geography. In addition, behavioral regularities may vary across geographical scales, and thus micro-level processes may not aggregate in a simple way. For example, Bruch and Mare (2006) show that, for a fixed neighborhood size and set of behaviors, changing the size of a population affects segregation. This suggests that we should be careful making comparisons in segregation levels across cities of varying size, as the size alone may introduce variation in levels even if the underlying process remains the same.

Scale effects in which the dynamics of a process change as the size of the population or organism increases are well documented in sociology, economics, biology, and the physical sciences. In biology, it is widely demonstrated that the physiology of organisms scales in a predictable way with size. For example, the metabolic rate of an organism decreases nonlinearly with body size, presumably due to economies of scale in energy consumption (West, Brown, and Enquist 1997). In population ecology, Couzin and colleagues (2005) show that among grazing animals the larger the herd the smaller the proportion of animals needed to lead the herd. In economics, both market thickness and economies of scale are widely used concepts implying that larger markets are more efficient.   In sociology, Oliver and Marwell (e.g., 1988a, 1988b, 1993) examine the relationship between the size of a group and the likelihood that group supports some social movement. They find that, when costs vary little with group size, larger groups are more likely to exhibit collective action than smaller ones. Mark Newman shows that social networks are often more homogeneous in more densely populated areas (which is consistent with ideas in economics about market efficiency). Overall, there is evidence to suggest that the dynamics associated with interdependent behaviors are affected by population size.

This paper uses agent-based models to examine the relationship between scaling and segregation processes. Note that scale has two different meanings. First, one can examine how the unit of observation (e.g., examining segregation among blocks, census tracks, or cities) influences descriptions of patterns and conclusions. Second, one can examine whether segregation dynamics change with the size of groups. Figure 1 illustrates these two meanings: one can analyze how segregation changes with the aggregation of geographic units across (e.g., looking at the segregation of people across blocks, Census tracts, or even cities) or exploring how the sheer numbers of people in blocks, Census tracts, or cities affects segregation dynamics. Reardon et al. (2008) does the first type of scaling work when they examine how segregation levels change at different *levels* of geographic aggregation. We focus on the second scaling question, investigating how the *size*s of groups affect dynamics in the context of race/ethnic segregation. For example, holding preferences or mobility behavior constant, what happens as we increase neighborhood size or total population size? How does the relative or absolute size of minority groups affect race/ethnic segregation dynamics under a given behavioral regime?

Understanding segregation requires elucidating the mechanisms that generate observed patterns. This entails the study of how segregation patterns and neighborhood variability change with the scale of description, and the development of laws of aggregation and scaling. When people act independently of others, for example pulling over to the side of the road for an ambulance or opening one's umbrella when it's wet outside, collective outcomes should scale linearly with population size. However---as is the case with neighborhood segregation, marriage markets, the formation and maintenance of social norms, and the composition of high school cliques and country clubs---when behavior is interactive and nonlinear because individuals are responding to the actions of those around them, it is likely that the collective results of these behaviors do not scale in a linear way. When we compare segregation levels across cities, we are implicitly comparing areas of very different size and urban geography. Understanding scale effects allows us to more critically evaluate these comparisons. (It also reveals the limits of generalization from agent-based models of segregation dynamics using small populations.)

Models and Methods

The paper will consist of two parts. In the first part, we briefly discuss the architecture of our agent-based model designed to simulate neighborhood dynamics in populations ranging from a handful to over 1 million agents.[2] Our models can simulate

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[2] Our agent-based model runs on a GPU rather than a conventional CPU. We are able to simulate more than 1 million agents on a two-dimensional grid topology or set of GIS maps, and our models run orders of magnitude faster than conventional CPU-based ABMs. We especially gain in situations involving large amounts of agent heterogeneity and varied choice functions. The framework is still under development, and

mobility using abstract populations (e.g., 200 agents who are 50% white and 50% black) or populations generated from Census data. They can run on abstracted space (e.g., a grid representing a highly stylized city) or in a space representing relationships among blocks or block groups in a specific city.

In the second part, we present results from our substantive experiments exploring the role of group size on segregation dynamics. In this paper, we assume a world of two race/ethnic groups, each of which has preferences for the race-ethnic composition of their neighborhoods. We assume a simple stylized city that is a grid, with neighborhoods represented by square subareas of that grid (e.g., blocks of 10x10 sets of cells). We explore scale effects under three alternative behavioral models: threshold, continuous, and empirical (as measured in the 1992 Detroit Area Study). These models are shown in Figure 2, and discussed in detail in Bruch and Mare (2006). Their implied segregation dynamics are discussed in Schelling (1978) and Bruch and Mare (2006, 2009). We examine how segregation dynamics change as we vary:

1. Neighborhood size (10-1000 households)
2. Total population size (100-1,000,000 households)
3. Minority group size (ranging from 5-50% of the total population)

Our goal is to get some basic sense of how the relationship between a given preference regime and segregation dynamics changes with population composition and size. We will, of course, have a full set of results for the presentation.

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we expect to continue to improve performance metrics, and the ABM scenarios where the framework is applicable.

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FIGURE 1. Different Types of Scaling, showing relationship between levels of analysis and group size

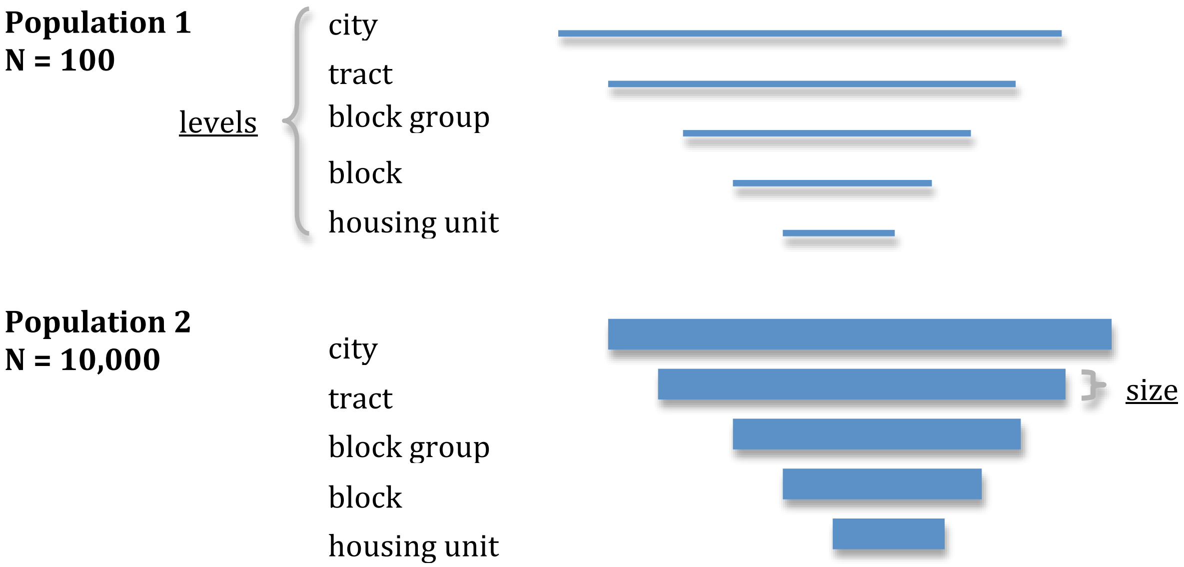

FIGURE 2A. Hypothetical Behavioral Functions used in the Analysis, Relationship between Neighborhood Proportion Own-Group and the Probability of Moving Into that Neighborhood

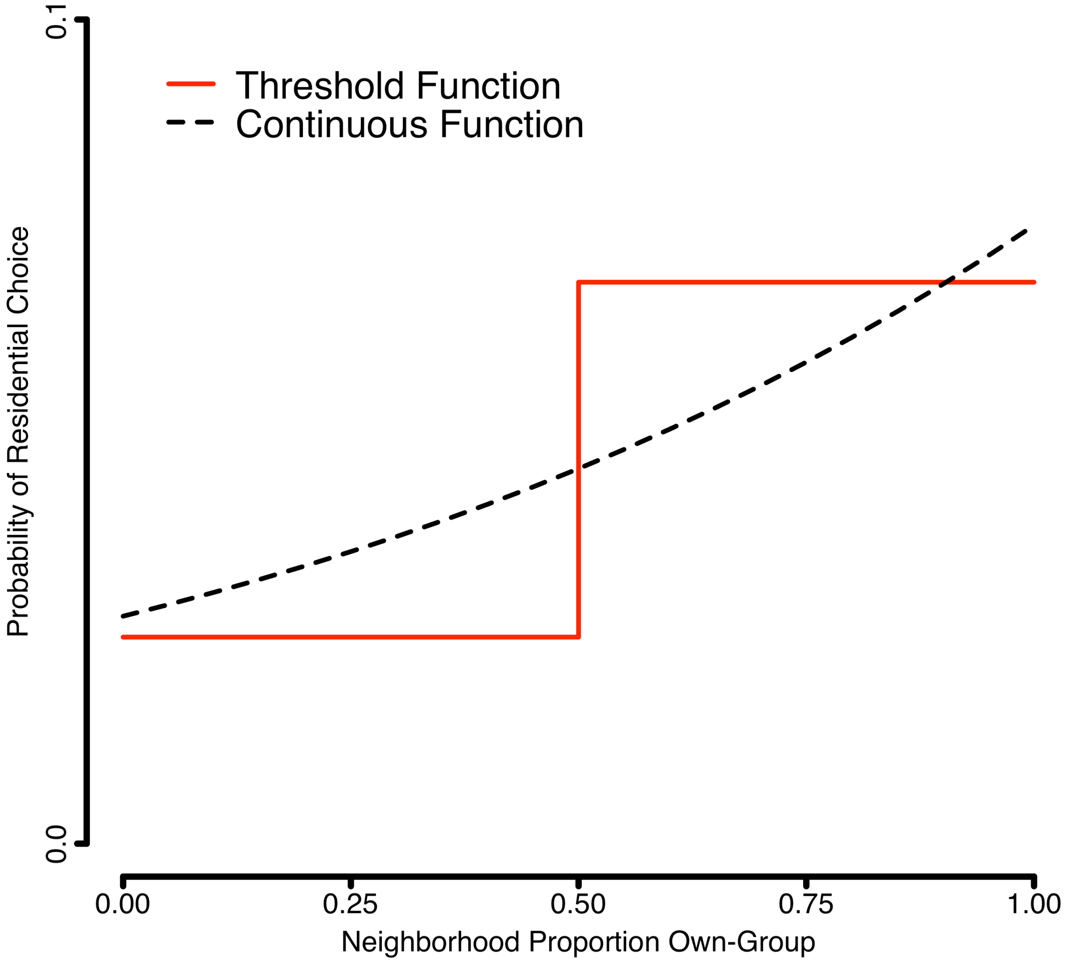

FIGURE 2B. Empirical Behavioral Functions used in the Analysis, Relationship between Neighborhood Proportion Own-Group and the Probability of Moving Into that Neighborhood, Detroit Area Study 1992

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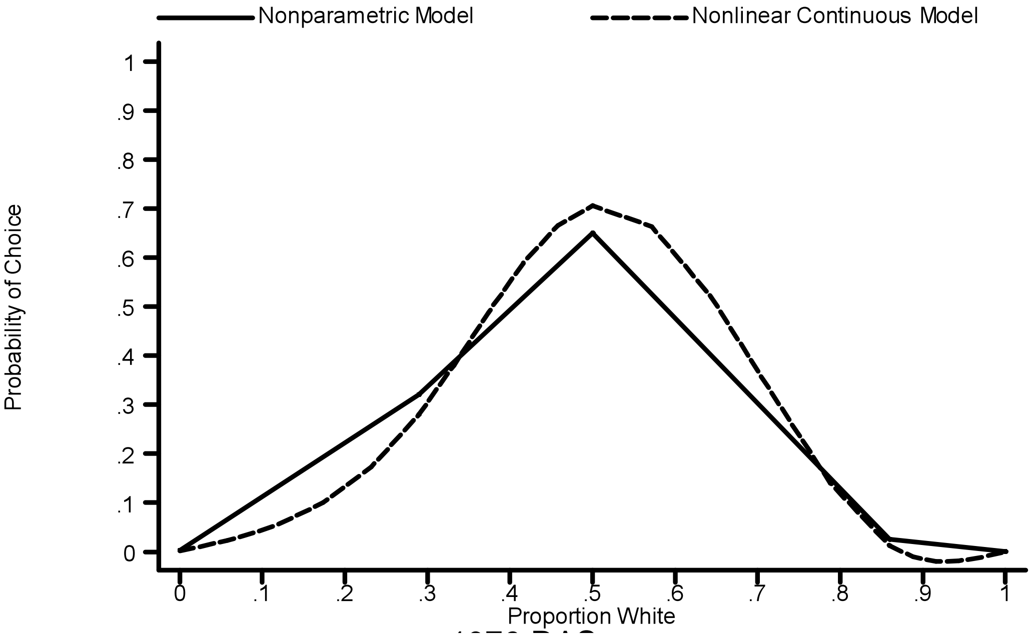

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