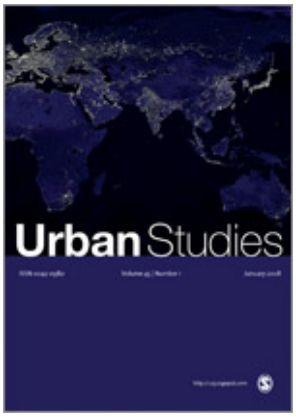
Mapping gentrification and displacement pressure: An exploration of four distinct methodologies



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Mapping Gentrification and Displacement Pressure: An Exploration of Four Distinct Methodologies

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Abstract

As housing costs continue to increase across many cities in North America and Europe, local governments face pressure to understand how housing's rising cost is changing neighborhoods and to ensure that everyone can access a home they can afford. To confront displacement concerns, cities are adapting models developed within academia to identify neighborhoods that may be susceptible to gentrification and displacement. We compare four gentrification and displacement risk models developed by and for the U.S. cities of Seattle, Washington; Los Angeles, California; Portland, Oregon; and Philadelphia, Pennsylvania and apply all four methodologies to one city, Boston. We identify the geographic areas of agreement and disagreement among the methods. The comparison reveals striking differences among the models, both in inputs and outputs. Of the 18 variables considered among the four models, only two variables appear in all four models. In the resulting maps, the four methods identified between 25 and 119 of the 180 Boston census tracts as at risk of gentrification and displacement, or as currently gentrifying. There are only seven tracts that all four models agreed were either gentrifying or at risk of gentrification and displacement. The findings indicate a need for cities to consider critically the assumptions of the models that are included in urban policy documents, as indicators and thresholds have major impacts on how neighborhoods in the liminal space of gentrification and displacement are characterized. This novel comparison of United States local government analyses of gentrification provides insight as modeling moves from theory to practice.

Keywords

gentrification, residential displacement, modeling, spatial analysis, vulnerability

Introduction

Rapid neighborhood socio-economic changes are an issue of pressing concern for many urban residents and local governments around the world. As a result, cities are using spatial analyses to understand where gentrification-induced displacement is occurring or may occur. Definitions, indicators, and methods of predicting gentrification, however, vary widely, and that variation has significant implications for urban policy. While scholars have debated differing definitions of gentrification used in the academic literature (e.g. Atkinson, 2003; Barton, 2016; Clark, 2005; Davidson and Lees, 2005; Freeman, 2009) there has been less examination of the ways in which city governments themselves are measuring gentrification. We fill that gap by identifying four leading governmental efforts in the United States to measure and map gentrification risk and then applying them all to one city in order to understand how the measures differ and what the significance of those differences are.

Over the past 50 years, numerous studies have sought to understand why gentrification happens, where it is occurring, and its effects (Edlund et al., 2015; Ellen and O'Regan, 2011; Freeman, 2005; Helbrecht, 2018; Lopez-Morales, 2011; Smith, 1979; Sýkora, 1993; Vigdor et al., 2002; Warde, 1991). Methods used by cities to map gentrification and displacement risk have operationalized this research in different ways leading to the emergence of different understandings of the leading causes and key outcomes. Regarding the causes of gentrification, many have identified the divergence between capitalized ground rents (rents captured by the current use) and potential ground rents (maximum rents that could be appropriated with a change of use or user) as a fundamental aspect of gentrification (Clark and Gullberg, 1997; Lees et al., 2008; Smith, 1979; Smith and DeFilippis, 1999). These rent gaps are shaped by legal structures, public policies, and the social and political dimensions of economic power, all of which have been affected by shifting patterns of transnational capital investment and urban governance (Lees, 2003; Lees et al., 2008). In the United States, these rent gaps and associated rent seeking are also expressed racially and socially, as a result of historic and continuing discrimination (Clark, 1995: 1496). Salient in recent decades has been the role of the state in producing gentrification in conscious or unwitting partnership with the private sector, through infrastructure investment, public or social housing redevelopment, economic development policy, and marketing (Chapple et al., 2017; Davidson and Lees, 2005; Goetz, 2003; Smith, 1996; Vale, 2013, 2019; Wyly and

Hammel, 1999). At the same time, economic restructuring has remade cities from centers of manufacturing to centers of business services and of knowledge and cultural production. High income households are increasingly opting to live in dense, walkable, urban centers (Zukin, 1982) previously home to low income residents, a consumptive choice (Warde, 1991) that may be driven by the desire for cultural, environmental, transportation, and recreational amenities (Anguelovski et al., 2018; Ley, 1986; Pratt, 2018; Zuk et al., 2018; Zukin, 1987) and may be related to decreases in leisure time for high-earning households (Edlund et al., 2015). In recent years, debates about the causes and *direct* effects of gentrification have often obscured how the phenomena has broadly transformed once accessible urban neighborhoods into havens for speculative profit seeking where severe housing cost burden or displacement are the only options for many longtime residents (Marcuse, 1985; Newman and Wyly, 2006; Slater, 2006, 2009).

Many have sought to identify where gentrification is occurring (Atkinson, 2000; Ellen and O'Regan, 2011; Freeman, 2005; Grodach et al., 2018; Holm and Schulz, 2018), including those who seek to profit from it (Chapple and Zuk, 2016: 125). Adverse impacts, such as displacement of longtime residents, local businesses, and cultural amenities; the disappearance of affordable housing and socioeconomic diversity; as well as increased real estate speculation and homelessness (Atkinson and Bridge, 2005) have prompted mapping analyses that aim to identify where to target harm mitigation efforts. These analyses, however, may obscure disagreements about what gentrification *is* and what factors characterize it.

Mapping efforts define gentrification differently, make varying decisions about how to operationalize components of gentrification, and consequently draw different conclusions from results. These operational differences are especially concerning in maps that are produced by governments, as they may then inform public policy through inclusion in comprehensive plans, such as in Seattle (Seattle Office of Planning & Community Development, 2016) and Portland (Bureau of Planning and Sustainability, 2018: GP5-8), or through consolidated housing plans, such as in Philadelphia (Division of Housing and Community Development, 2017: 97–98).

In this article, we explore these fault lines by comparing the outcomes of four distinct efforts to map gentrification from Philadelphia, Pennsylvania; Seattle, Washington; Los Angeles, California; and Portland, Oregon. In Seattle and Los Angeles, city agencies themselves mapped

gentrification and displacement risk for city residents. In Portland, the city commissioned a study, and in Philadelphia, analysts from the Federal Reserve Bank of Philadelphia mapped gentrification and mobility. While the stated motivations of these analyses were somewhat different, as discussed below, all claim to map gentrification in order to identify gentrification induced displacement.

By applying these four methods to the same city, we can identify how different approaches to operationalizing the concept of gentrification may influence how cities mobilize resources to address gentrification's negative effects. This paper aims to identify the relationships between theories of gentrification, measures of neighborhood change, mapping methodologies, and the neighborhoods that are ultimately identified as facing displacement pressure. To do so, we first identify the tracts pinpointed by each method. We then calculate descriptive statistics for the tracts identified by each model and conduct bivariate analyses to compare them. Significant disagreement among the four models points to the importance of choosing a model for mapping gentrification with awareness of the methodology's embedded assumptions about what constitutes gentrification and how neighborhood change should be measured. Though the origins of this paper are based in the United States, cities globally are confronting gentrification and displacement, and this research illuminates for advocates and policymakers that there is no 'one-size-fits-all' method for mapping gentrification and displacement risk; practitioners must ensure that the methodology they use fits the temporal, spatial, and socioeconomic context of the city at hand.

Mapping Gentrification and Displacement Risk

While early studies of gentrification were often qualitative analyses of specific neighborhoods (Hammel and Wyly, 1996), recent quantitative measures of gentrification have relied primarily on census data to measure changes in neighborhood composition by income, race, education, housing value and other factors (Clark, 2005; Davidson and Lees, 2005; Ding et al., 2016; Ellen and O'Regan, 2011; Freeman, 2005). Academic debate continues over the appropriate measures of gentrification (Barton, 2016; Bousquet, 2017; Ding et al., 2016; Freeman, 2009), with studies demonstrating the sensitivity of mapping measures to the variables included (Galster and Peacock, 1986; Mujahid et al., 2019). Previous gentrification mapping efforts have included various population and housing measures, including income, education, race, housing costs and

housing tenure (Bostic and Martin, 2003; Ding et al., 2016; Ellen and O'Regan, 2011; Freeman, 2005; McKinnish et al., 2008).

Beyond these demographic and economic measures, other studies also add proxies for potential causes of gentrification, including private real estate investment, state-led capital investment, and the role of creative industries (Davidson, 2007; Grodach et al., 2018; Hamnett, 1991; Newman and Wyly, 2006; Pollack, 2010; Smith, 1996; Zuk et al., 2018). Still others add measures of proximity to infrastructure and public amenities (Chapple, 2009), or use novel data analysis techniques, such as machine learning (Reades et al., 2018). Holm and Schulz (2018) developed a methodology for identifying gentrification that is meant to be transferrable to any city. Easton et al. (2019) reviewed challenges with quantitative assessment of gentrification, noting that novel data sources may ease some extant limitations.

Decreases in affordable housing, concerns over economic and racial segregation, anxiety about the role of public investment in accelerating gentrification, and public outcry over neighborhood change all make gentrification and displacement important to city administrators. Identifying neighborhoods vulnerable to the phenomenon may help guide response efforts and future public investments, as a growing body of research has found government investment in public infrastructure may trigger or exacerbate gentrification (Chapple, 2009; Chapple et al., 2017; Pollack, 2010).

As municipal concern over displacement increases, efforts to predict gentrification and displacement multiply. Chapple and Zuk (2016) examine the early warning systems that non-profit organizations, universities, and cities are developing, examine the format and goals of early warning toolkits, and assess the toolkits' policy influence. They argue that if the city is the creator or host of the early-warning system, the system is more likely to have policy influence. The increasing number of mapping efforts represent a concerted effort to understand where gentrification has happened, is happening, and may happen, in order to change internal city-government dialogue, assist efforts to organize against gentrification and displacement, or promote policy changes. These early warning systems and gentrification and displacement models, however, rely on a plethora of different variables and measures. While locally tailored data and

measures add value, this lack of consistency also may lead to "public confusion about the concept of gentrification" (Holm and Schulz, 2018: 255).

Data and Methods

We began by reviewing the seven leading mapping efforts in six major cities in the United States identified by Bousquet (2017), as well as identifying additional efforts conducted in the 30 largest cities by population in the United States.[1]

Following Chapple and Zuk (2016), we differentiate between mapping efforts conducted by academic research centers; non-profit organizations; and local governments or other public agencies. We limit our study to mapping efforts conducted by, or on behalf of, government institutions—thereby focusing on efforts that likely have the most direct policy influence. Governmental mapping would be expected to be particularly influential, yet these new efforts by municipalities are understudied.

We select four distinct methods developed by or for four different cities to measure gentrification related displacement pressure: the Los Angeles Innovation Team Index of Displacement Pressure; the Philadelphia Federal Reserve study of Gentrification and Residential Mobility; Seattle's Displacement Risk Index from the Seattle 2035 Comprehensive Plan; and Portland's Gentrification and Displacement Study.

As neither Seattle nor Los Angeles had initially planned their methods for reproduction, we worked with the city staff who had created them to recreate their methodologies, double-checking our methods against theirs.[2] We were also in contact with both the Philadelphia and Portland teams, and followed their published methodologies closely. We then applied all four methods to the same city, Boston. Variables and minimum thresholds used for each method are listed in Table 1.

[Table 1]

Seattle

The Displacement Risk Index was developed by Seattle's Office of Planning & Community Development for the Seattle 2035 Comprehensive Plan Equity Analysis (Seattle

Office of Planning & Community Development, 2016: 13–18, 36–51). It is distinct from, but follows, the Gentrification Susceptibility Index developed by Welch (2017: 87–89).

Using raster analysis, each variable (see Table 1) is given a score, typically ranging between 0 and 4. Data sources and definitions for the variables are outlined in the Seattle 2035 Comprehensive Plan and divergence is noted in the following paragraph for our adaptation. Each of the 14 variables are weighted approximately equally. At every point in the map, the given scores are added together, giving a composite Displacement Risk score. Thus, every point in Boston could receive a score between 0 (if it received a 0 for every variable) and 59 (if it received the maximum score for every variable).

Three major modifications were necessary to replicate the method for Boston. First, while the Seattle methodology used a city-defined model of development capacity, no analogous metric exists for Boston. In consultation with the Boston Department of Neighborhood Development, development capacity was approximated by parcels' land-use type. Second, rent data in Boston were scraped from the website PadMapper,[3] which differed from the proprietary data used in Seattle. Finally, although King County defines job and manufacturing centers, our model assesses distance to census tracts with high concentrations of industrial and office jobs, as defined by the EPA Smart Location Database.[4] In order to compare the final raster-analysis with the methods based on census tract boundaries, zonal statistics were taken in ArcGIS to calculate mean scores for each tract. The categories were then created using Jenks Natural Breaks, a clustering optimization method, though there were minimal differences as compared to using quantiles.

Los Angeles

The Los Angeles Index of Displacement Pressure was created by the Los Angeles Innovation Team to reduce displacement, promote revitalization, and inform the prioritization of pilot areas for their projects. It consists of two steps to arrive at a displacement pressure measure: first, the creation of a Los Angeles Index of Neighborhood Change (Pudlin, 2016) and second, its incorporation into the Los Angeles Index of Displacement Pressure (Pudlin, 2018).

The Los Angeles Index of Neighborhood Change (LAINC) incorporates six metrics, as indicated by Table 1. These indicators are normalized, weighted, and added to compare the relative

level of neighborhood change and create a corresponding change map, one of which is then used in the Los Angeles Index of Displacement Pressure (LAIDP). The Los Angeles Index of Displacement Pressure includes seven different measures, indicated in Table 1. Tracts in which less than 40 percent of households earned below the city median income were excluded. These values were normalized, weighted, and added to measure the displacement pressure for each census tract. Los Angeles created categories using quantiles for the tracts that were neither excluded nor had a negative normalized z-score, assessing relative risk.

In our replication of the model, we were able to incorporate much of the same data. We worked with the Boston Department of Neighborhood Development to acquire a dataset for subsidized housing in Boston, but the dataset was incomplete, requiring the judgement of the authors when incorporating this indicator.

The weighting of the indicators to calculate the Displacement Pressure Index was developed from past analyses and ground-truthing in Los Angeles. Since this was not possible for this study, we replicated the weights determined for Los Angeles for each variable when applying the method to Boston.

Portland

Portland's gentrification and displacement risk assessment was commissioned by the City of Portland and developed by Professor Lisa Bates (2013) as a basis for both understanding gentrification's impact on Portland and developing policies to address it. The assessment identifies risk of gentrification and displacement by census tract.

Risk typologies are determined by combining indicators across three dimensions: vulnerability to housing displacement, demographic changes, and housing market appreciation. Tracts are determined to be vulnerable to housing displacement if three of four indicators—accounting for race, higher education, rent, and income, as indicated in Table 1 — are above the city-wide average. Tracts are determined to have experienced demographic change indicative of gentrification if at least three of the vulnerability indicators have decreased more than the city-wide average, or if just the race and higher education variable decreased more than city-wide. Finally, housing prices are assessed and tracts are classified according to their housing value, level

of appreciation, or adjacency to high value tracts. Tracts that had not yet experienced a demographic shift indicative of gentrification but had populations vulnerable to displacement were classified as either *Susceptible* or *Early: Type 1* based on whether their housing market conditions were adjacent or accelerating, respectively. Tracts with demographic changes and vulnerable populations were classified as *Early: Type 2*, *Dynamic*, or *Late* based on whether their market conditions were adjacent, accelerating, or appreciated, respectively. Tracts not qualifying as vulnerable but that had increasing portions of white, college educated residents and an appreciated housing market were classified as *Continued Loss*.

Because all data used in the methodology are nationally available at the tract level, there were few challenges replicating it for Boston and no modifications were necessary.

Philadelphia

Ding et al. (2016) developed their categorical neighborhood gentrification measure for use in a study of gentrification's influence on residential mobility rates. While academically focused, the initial paper was followed by a "Practitioner's Summary," designed to assist city officials in understanding and addressing the issues of gentrification and displacement.

Following their method, our analysis utilized decennial census data from 1980, 1990, and 2000, harmonized to 2010 census tracts by Geolytics Neighborhood Change Database. Tracts are initially considered *gentrifiable* if their household income at the start of the period of analysis is below the citywide median; all others are considered *not gentrifiable*. Gentrifiable tracts were considered to be gentrifying over the period of analysis if they experienced an above citywide median rate of increase in their share of college educated residents *and* either median gross rent or median home value. Tracts that did not meet these criteria were categorized as *nongentrifying*.

While the main period of analysis was 2000 to present, the methodology also assessed whether gentrification occurred from 1980 to 2000. If tracts were gentrifying prior to 2000 and continued to gentrify from 2000 to present, they were categorized as *continued gentrification*. Tracts that were gentrifying before 2000 but did not qualify as gentrifying after were categorized as *stalled gentrification.* Tracts that only began to gentrify within the 2000-to-present time period

were classified as *weak gentrification*, *moderate gentrification*, or *intense gentrification* based on their quartile of median gross rent or median home value.

Similar to the Portland methodology, all data used for the Philadelphia method were available nationally at the tract level. Additionally, procedures for tract classification assignment allowed for straight-forward reproduction and application to Boston without modification.

[Figure 1]

Results

When applied to Boston, the four methodologies produce very different maps of gentrification-related displacement risk, as shown in Figure 1. In order to analyze agreement and disagreement between mapping methodologies, we first had to overcome inconsistencies among the ways the maps represented gentrification risk. Portland and Philadelphia both used categorical typologies, while Los Angeles and Seattle used continuous risk scores. To facilitate comparison, we converted the continuous scores into categorical variables, and further reduced them to a binary at-risk/not-at-risk variable when appropriate.[5]

Pairwise Statistical Analysis

Comparing the four methods, Table 2 presents the pairwise comparisons among the four models, showing greatest agreement between Portland and Philadelphia, while Seattle and Philadelphia diverge the most. The Portland and Philadelphia analyses take restrictive approaches to the census tracts that they consider to be eligible for gentrification. On the other hand, the Seattle and, to a lesser extent, the Los Angeles methodologies are more permissive, allowing for more of the city to be considered vulnerable. The way the methodologies determine tract eligibility for gentrification (see Table 1) and the distinct methods for determining severity of the risk together explain the large difference in number of tracts identified.

In order to compare agreement between methodologies, we followed Barton (2016) and calculated a chi-squared and Cramér's phi for each pairwise comparison (Table 2). Cramér's phi can be read similarly to a Pearson's correlation coefficient for association among bivariate categorical comparisons. Five of the six pairwise comparisons are statistically significant with p-

values below 0.001. The greatest association (indicated by phi) is between the Seattle and Los Angeles methods, meaning that there is relatively high correlation among those tracts considered at-risk and not-at-risk in both methods.

[Insert Table 2]

Map Matrix

Figure 2 shows a matrix of the four methods—along the diagonal—as well as the tracts that are excluded in the method listed along the horizontal axis and the tracts that are included in the method listed along the vertical axis, visualizing the findings from Table 2. The general disagreement among the maps is immediately apparent. The Portland, Los Angeles, and Philadelphia methods all have at least 40 percent of their at-risk tracts considered not-at-risk in another method; the average percentage of tracts retained in other models is 63 percent. This finding reveals significant heterogeneity in tracts identified by the different city models.

Figure 2 is helpful in understanding the significance of Table 2. Figure 2 reveals, for example, one tract in the Philadelphia model that is excluded from the other three. Philadelphia's unique exclusion of most of Dorchester—a neighborhood with a substantial African American population—is also illuminating. Portland's inclusion of a number of East Boston tracts—a neighborhood where over half of residents identify as Latino and that is undergoing intense residential development—is also evident, as is Seattle's uniqueness in identifying as at-risk most of Allston and Brighton, neighborhoods that are currently witnessing increased institutional investment with major rezoning and transit improvements planned, as well as the expansion of the Harvard University campus. In spite of the fact that anywhere between 25 tracts (in the Philadelphia method) and 119 tracts (in the Seattle method) are identified as at risk of gentrification and displacement, there are only seven tracts that all four models agree are at high risk of gentrification and displacement (Figure 3).

[Insert Figure 2]

[Insert Figure 3]

Differences in Population Covered

In order to compare the methods to expected outcomes, we describe the characteristics of the total population that each model identifies as at-risk. If gentrification occurs in neighborhoods with higher proportions of low-income individuals, people of color, those with lower educational attainment, and renter households, these populations would be expected to be disproportionately represented in the tracts that the models identify as at-risk. We developed Table 3 expecting to find roughly similar proportions among the four models, given that they purport to measure the same phenomenon.

Table 3 shows that Seattle, Portland, and Los Angeles, as expected, all have a much greater share of non-white residents at risk of gentrification or displacement than in the city overall. Surprisingly, in Philadelphia's model, renters and individuals in poverty are identified as at-risk only in equal proportion to the city-wide proportion. The Portland and Seattle models' results regarding Boston's black population are also striking, with Portland counting nearly twice the proportion of the black population as being at-risk than the proportion of the city-wide population, and Seattle's at-risk tracts encompassing over 90 percent of Boston's black population. Though no model included eviction data in their analysis, every model has a greater portion of the citywide evictions in their at-risk tracts than the portion of total households in those tracts.[6]

[Insert Table 3]

Discussion and Conclusion

The results of mapping all four methods onto Boston, and our subsequent analysis, show significant differences in the number and location of tracts identified as vulnerable to gentrification and gentrification-related displacement among the four methodologies. While each method aims to identify tracts experiencing, or at risk of, gentrification and related displacement, there are major differences in how each effort operationalizes the concept. From different variable choices to varying risk thresholds, the assumptions embedded within the methods have significant effects on what tracts are identified as vulnerable and, in turn, where city policy responses would be targeted if these methods were used.

The seven tracts identified as gentrifying or at-risk by all four methods (Figure 3) are consistent with anecdotal accounts of neighborhoods experiencing gentrification and displacement

in Boston. Two of the tracts lie in northern Dorchester, two in northern Roxbury, one in Jamaica Plain, one in Downtown/Chinatown, and one in East Boston. These are the five neighborhoods most often discussed as under threat of gentrification and displacement in Boston (see e.g. Acolin and Vitiello 2018). We do not suggest that identifying the intersection of all four methods will lead a practitioner to the "true" at-risk neighborhoods, but the findings suggest that the tracts on which these methods do agree represent some of the highest-risk areas of the city.

Other areas of agreement illustrate how similar choices of variables, even with different weighting (see Table 1) lead to similar outcomes. For instance, both Los Angeles's and Seattle's models identify tracts at risk along the route of the fixed-rail Orange line, because of their inclusion of transit as a predictor of risk. The inclusion of race as an indicator of risk in the Portland, Los Angeles, and Seattle models leads all three to have relatively large coverage of Dorchester, East Boston, and Mission Hill, all neighborhoods with a large share of residents of color. The variables included in or excluded from the different methods relate at the most fundamental level to their authors' decisions about the most salient causes and indicators of gentrification, highlighting the degree to which they understand gentrification to be driven by private investment, rent gaps, state-led public investment, or changing consumer preferences toward city living, to give a few examples.

Seattle's model, with its 14 variables across individual, property, and neighborhood characteristics, includes measures that reflect multiple theories regarding the causes of gentrification. By comparing rent prices and development potential, it incorporates the rent-gap theory directly. The numerous variables regarding income and race incorporate attention to social dimensions of household vulnerability to gentrification and displacement. By including amenities such as public transit, schools, community centers, restaurants, grocery stores, and location near job-centers, the Seattle method also reflects consideration of both state-led and consumption-based conceptions of gentrification.

The Los Angeles method similarly bridges the gap between conceptions of gentrification as driven by rent gaps, attention to the social-structural dimensions of household vulnerability to gentrification, and theories emphasizing the role of consumption of public and private goods in neighborhood change. The Neighborhood Change Index within the Displacement Risk Index uses

a base of household-level economic and social conditions that reflect the salience of rent-gaps and consideration of racial and other disparities in the ability to resist displacement. The inclusion of access to public transit as a risk factor and the unique measurement of affordable housing availability as a mitigating factor reflect the interplay between state-led and consumption based-models of gentrification. The inclusion of data on affordable housing illuminates where low-income populations may be protected through publicly subsidized housing; where low-income populations might be at risk, as affordability restrictions come to an end and subsidized units are eligible for conversion to market rates; and also where cities might consider investing in affordable housing preservation or new construction. Local housing authorities or other local government agencies could develop such databases to replicate this method in other cities.

The Portland method does not include data on neighborhood amenities such as public transit but focuses on housing tenure as well as housing market spillover effects from nearby neighborhoods, reflecting an emphasis on private investment-led gentrification. Portland, like Seattle and Los Angeles, also includes data on racial composition and other neighborhood demographic characteristics. People of color and renter households are more likely than whites and homeowners to live in neighborhoods where rent gaps (Smith, 1996) exist, as a result of historic discriminatory policies such as redlining, and therefore may be more vulnerable to gentrification driven by private investment today. The method also acknowledges that this type of private investment can have spillover effects as investors look for nearby areas in which real estate can generate high rates of return.

The Philadelphia method focuses almost exclusively on the rent gap theory of gentrification, excluding variables on race and housing tenure that all of the other methodologies include. Operationalizing gentrification in this way assumes that tenants and homeowners as well as people of color and whites are equally vulnerable to gentrification and that increases in income and housing costs alone are the clearest indicators of gentrification. The method lacks variables related to public investment in neighborhoods, which would be reflective of a state-led conception of gentrification, as well as amenities that would measure consumption-based theories of gentrification risk.

Simply stated, the four models represent the operationalization of multiple theories of gentrification and the adoption of varying methods developed within academia to map gentrification. Although cities are adapting these theories in their own methods, it is unclear the extent to which practitioners are consciously choosing among this combination of theories about the causes of gentrification in order to match their local context. Given that Denver has directly adopted Portland's method for mapping gentrification (Denver Office of Economic Development, 2016) and Boston was in the process of adopting the Seattle method when we began our project (Bousquet, 2017), this policy transfer leads to the inference that cities may not be carefully tailoring the methodologies to take into account local context when mapping gentrification.

The findings here show that cities that adopt one of the various different mapping methods will come to very different conclusions about the location and severity of gentrification based on the method they choose. To the extent that the causes of gentrification are informed by local historical and contextual factors, there is reason to question the wholesale adoption of models developed within academia or the adoption of a model used in one city for another city, without attempting to account for the particularities of gentrification experienced in each individual city, or at least consciously choosing among different methodologies and the theories that they operationalize.

It would serve practitioners well to consider the assumptions of the model they are adapting when they are adopting and modifying it. For instance, cities that are experiencing rapid demographic change and increasing housing costs may consider aspects of Portland's approach, while cities that are expecting significant public investment in the form of transit and other public amenities may wish to consider adopting some of the data sources used in the Los Angeles or Seattle methods.

The growing availability of novel sources of data means that future efforts to map gentrification may need to evolve beyond earlier academic models. Given our belief that gentrification is informed by local context, researchers and practitioners alike may wish to validate the models using ground-truthing of local conditions (see, e.g. Chapple et al., 2017 Appendix J), to see how the outputs relate to local understandings of gentrification and its impacts.

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Notes

[1] We limited our search to large cities for three reasons. First, the public and much of the academic focus on gentrification has been on its effects on inner-city neighborhoods. Second, most academic studies of gentrification have focused on major cities. Third, given the data intensive nature of creating these maps, we assumed that larger cities would have the resources and available data to devote to these maps' creation, while smaller cities may not.

[2] For specific guidance on the procedures for each methodology, please contact the corresponding author.

[3] Jeff Kaufman Boston Apartment Price Map. August 2015. Available at: https://www.jefftk.com/apartment_prices/details

[4] Environmental Protection Agency (EPA) Smart Location Database. July 2013. http://geodata.epa.gov/ArcGIS/rest/services/OA/SmartLocationDatabase/MapServer

[5] When creating the binary variable, the following categories were reduced to "Not-at-risk": Portland: Not at Risk, Susceptible; Philadelphia: Not gentrifiable, nongentrifying, stalled gentrification; Seattle: Very Low, Low Risk; Los Angeles: Over income, Low Risk. All other categories were considered "at-risk."

[6] This research uses data from The Eviction Lab at Princeton University, a project directed by Matthew Desmond and designed by Ashley Gromis, Lavar Edmonds, James Hendrickson, Katie Krywokulski, Lillian Leung, and Adam Porton. The Eviction Lab is funded by the JPB, Gates, and Ford Foundations as well as the Chan Zuckerberg Initiative. More information is found at evictionlab.org. While this data provides a new source of data on evictions, especially for areas where the data was not previously collected, it undercounts the extent of displacement in cities like Boston, as it excludes more common processes of informal eviction, in which rents are raised or a notice to quit is filed and the tenant moves out without the landlord ever going to court (Aiello et al., 2018).

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Table 1: Variables and thresholds included in each of the four mapping methods

	Indicators	Los Angeles	Portland	Seattle	Philadelphia
Individual	Percent (non-) white population	LAINC % change in white non-hispanic residents	> 47% of pop.*	> 20% of pop.	
	College education attainment	LAINC % change in residents ≥ 25 with Bachelor's degree	> 54.8% of pop. no college*	> 40% of pop. Over 25 without Bachelor degree	% change in college ed. pop. > 27.2%*
Household	Share of non-english speakers			> 15% of pop.	
	Rent Burdened population	LAIDP ≥ 50% household income in rent		> 15% of pop. under 80% AMI with cost burden or severe cost burden	
	Household income	LAINC % change in median household income LAIDP ≥ 60% of households earning under the median income	> 50% of pop. below 80% AMI*	> 25% of pop. under 200% of poverty level.	< $56374.99 *
	Household size	LAINC % change in household size			
	Share of renters	LAIDP % of renter ccupied units	> 65.7% of pop.*	> 40% of pop.	
	Rental cost	LAINC % change in median gross rent		< 125% city-wide average	% change in median gross rent > 15.6%*

	Housing price	LAIDP Change in housing price projections for tracts with housing prices < 80% median value and increasing at a higher rate than the citywide rate	Categorization of tracts as *Appreciated*, *Accelerating*, or *Adjacent* based on ratio of tract median price/median appreciation to city-wide median price/median appreciation		% change in median home value > 31.7%*
Neighborhood	Ratio of poor/wealthy households	LAINC % change in ratio of low income (≤ $25,000) to high income (≥ $75,000) tax filers			
	Presence and Expiration of Affordable housing	LAIDP Number of units weighted by year of expiry			
	Proximity to affluent neighborhoods	LAIDP < 1 mile to highly changed ZIP codes scaled by distance	Adjacent to tract with housing price categorized as either *Appreciated* or *Accelerating*	Tract with Median Household Income < 80% AMI adjact to tract with Median Household Income > 120% AMI	
	Proximity to transit - train	LAIDP < 0.50 miles to station scaled by distance		< .50 miles	
	Proximity to transit - buses			< .25 miles to station with > 100 daily bus destinations	
	Proximity to Jobs			< 20 minutes to job center	
	Attractive businesses			< .5 miles	
	Civic infrastructure			< .5 miles	
	Developable Properties			Binary at parcel level	

Table 2: Pairwise Comparisons of different mapping methods

		Philadelphia			
		At Risk	Not at Risk	Chi-squared	12.266***
Portland	At Risk	12	24	Phi	0.281
	Not at Risk	13	131		

		Seattle			
		At Risk	Not at Risk	Chi-squared	21.776***
Portland	At Risk	36	0	Phi	0.362
	Not at Risk	82	62		

		Los Angeles			
		At Risk	Not at Risk	Chi-squared	2.698
Portland	At Risk	16	20	Phi	0.137
	Not at Risk	41	103		

		Los Angeles			
		At Risk	Not at Risk	Chi-squared	9.304**
Philadelphia	At Risk	15	10	Phi	0.245
	Not at Risk	42	113		

		Seattle			
		At Risk	Not at Risk	Chi-squared	10.403**
Philadelphia	At Risk	24	1	Phi	0.257
	Not at Risk	94	61		

		Los Angeles			
		At Risk	Not at Risk	Chi-squared	29.595***
Seattle	At Risk	54	64	Phi	0.418
	Not at Risk	3	59		

Table 3: Differences in population covered by different mapping methods, and subpopulations

	% Total Population	% Non-Hispanic White Population	% Black Population	% Asian Population	% Hispanic Population
Philadelphia	16	14	14	21	19
Portland	22	10	40	11	36
Los Angeles	32	24	41	41	37
Seattle	73	55	91	81	87

	% Total Population	% Population less than Bachelor Degree	% Population under 200% of Poverty Line	% Renter Population
Philadelphia	16	15	17	15
Portland	22	30	28	25
Los Angeles	32	36	43	39
Seattle	73	79	86	80

	% Boston tracts at risk	% Total Households	% Evictions	% City Area
Philadelphia	14	13	16	11
Portland	20	20	32	16
Los Angeles	32	33	43	22
Seattle	66	69	88	48

Figure 1. Maps showing the four methodologies applied to Boston, MA

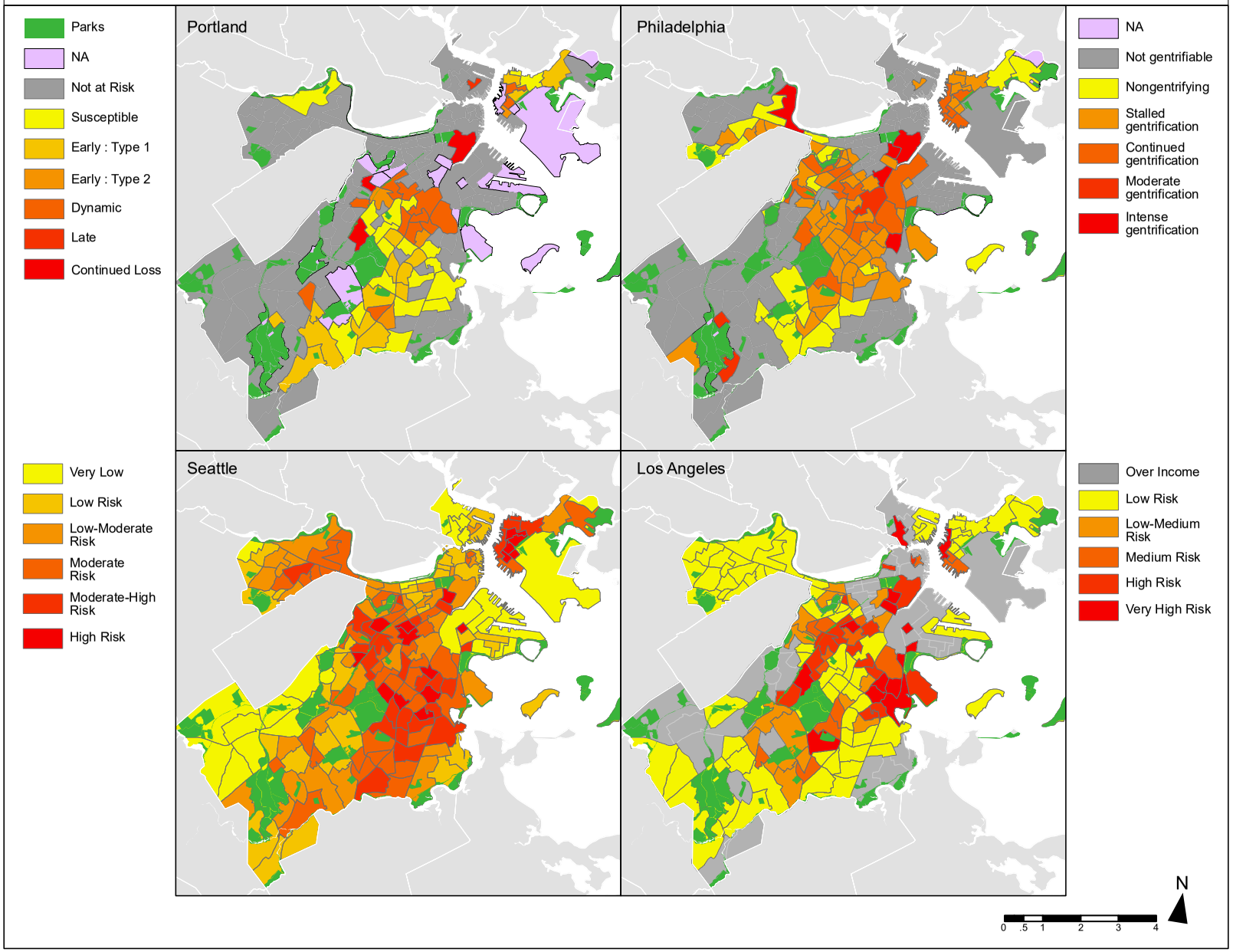
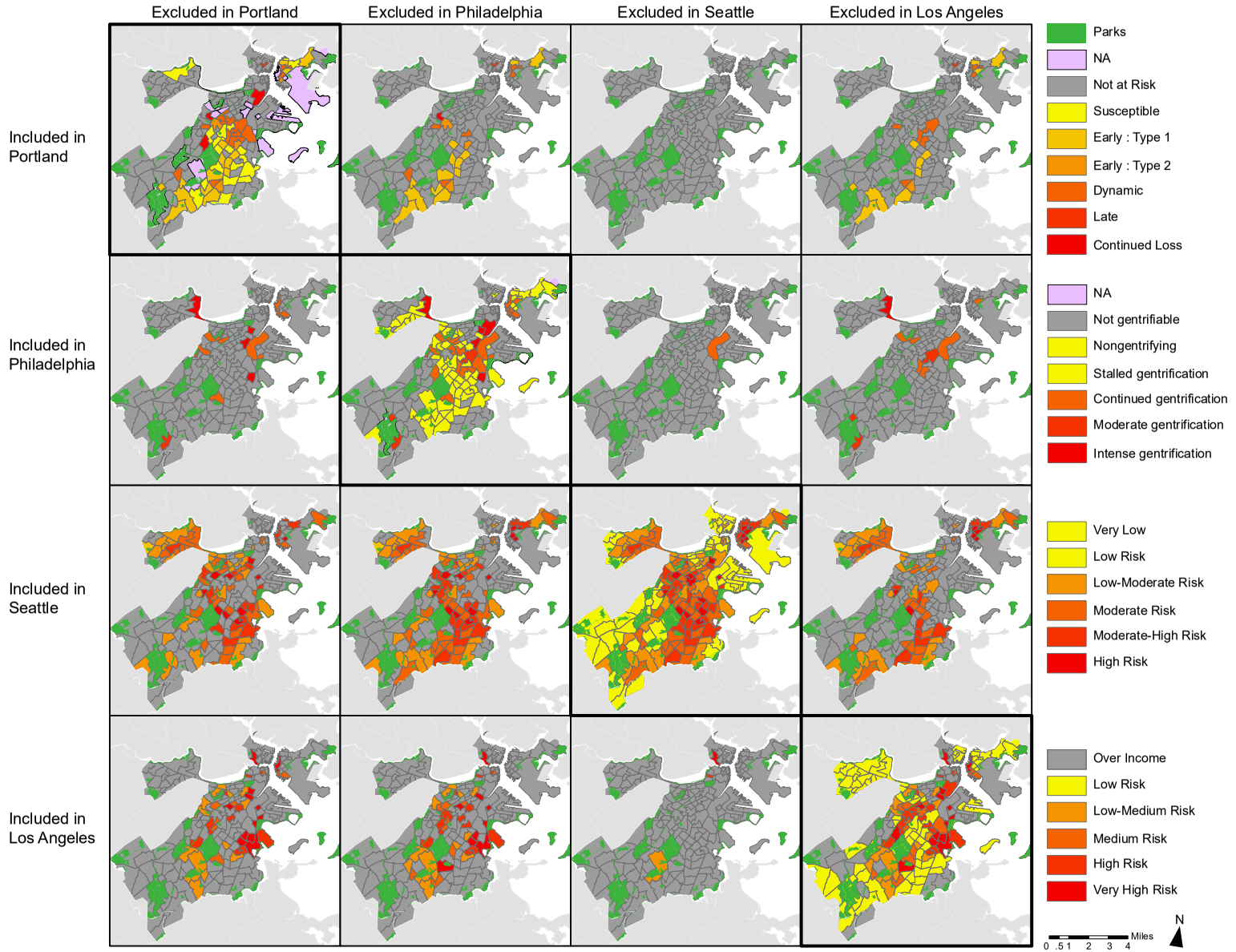


Figure 2. Map Matrix - Analysis of census tracts identified as at risk vs. not at risk by the four methodologies as applied to Boston, MA



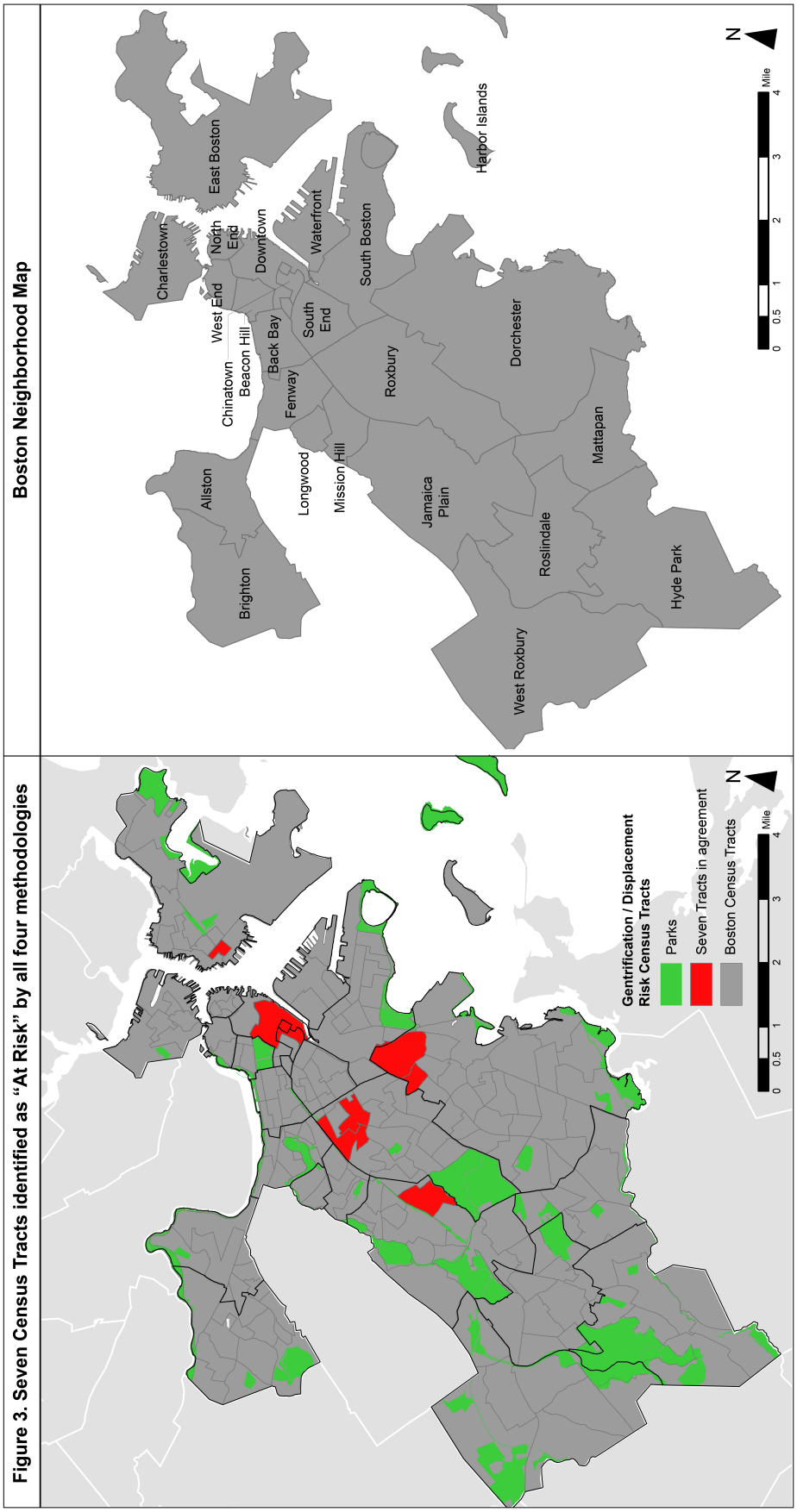


Figure 3. Seven Census Tracts identified as "At Risk" by all four methodologies