The Role of Natural Amenities in Gentrification

Abstract: The role of natural amenities (parks, hills, waterfronts) in appreciating the socioeconomic status of urban neighborhoods in five large U.S. cities from 1980-2010 is examined using statistical regression. The results indicate that natural amenities have no effect on urban socioeconomic upgrading, or gentrification. Nearness to the city center is found to be the strongest determinant of gentrification, suggesting that proximity to the urban core, jobs, and amenities such as restaurants surpasses proximity to environmental amenities as a key determinant of land value. The continued validity of the Chicago models of urban form, which predict high income located near natural amenities, is brought into question.

Key Words: gentrification, natural amenities, urban form

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Introduction

Natural amenities have been recognized as a strong determinant of human migration, both across vast regions and within urban centers. From a cross-regional perspective, natural amenities, such as climate, the ocean, and mountains, have been identified as a driver of migration to the American West and Sunbelt (Ullman 1954) and, more recently, as a cause of migration in present-day rural Australia (Argent et al. 2014).

Within the urban context, natural amenities are understood to attract wealthy households. Throughout the early to mid-20th century, a team of sociologists based at the University of Chicago and identified as the Chicago School of Urbanism observed that wealth in American cities anchors itself near natural amenities, including waterfronts and environs far from the city center and away from major roadways, because such areas provide superior recreation, beauty, and refuge from the dirt and grind of urban life (Burgess 1925, 1929; Hoyt 1939; Harris and Ullman 1945).

Gentrification, or the socioeconomic upgrading of urban neighborhoods in the developed world, is another form of migration, in which a population of greater wealth migrates back to the inner cities. Gentrification began as a mere “trickle” in the 1960s and 70s (Lipton 1977), but by 2001, at least 25% of all Canadian urban neighborhoods had experienced some form of gentrification between 1981-2001 (Meligrana and Skaburskis 2005); the related figures for the United States, although unavailable, are likely even greater because of the United States’ more flexible housing regulations.

Given the central role that amenities have been shown to play in intra-urban migration and regional migration patterns (Burgess 1925; Hoyt 1939; Harris 1945), as well as gentrification's growing magnitude, one may wonder if natural amenities influence urban gentrification patterns in the same way that these amenities impact regional and intra-urban migration. To the author's knowledge, the question of the role of natural amenities in instigating gentrification has never been systematically explored. This study seeks to fill this void in the research. Specifically, this study tests the role that natural amenities (parks, waterfronts, and hills) play in luring populations to migrate to newly discovered neighborhoods in the five densest American cities (Boston, Chicago, Philadelphia, New York City, and San Francisco) between 1980 and 2010 using statistical regression. The results find that natural amenities hold no significance in affecting gentrification patterns; rather, the strongest determinant of neighborhood gentrification is proximity to the city center, where natural amenities are particularly scarce but manmade amenities (commercial districts, jobs, cultural centers) are in abundance.

Academics, politicians, and the American public remain divided on whether or not gentrification is a positive development for cities. On one end, gentrification allows for increased efficiency in the use of land resources and capital, in which the highest-valued properties are awarded to the landlords and renters with the greatest willingness to pay. On the other, gentrification has been met with great resistance because it involves the displacement of vulnerable people with longstanding ties to the land. A wealth of literature focuses on the impact that gentrification has on the peoples it displaces, the conclusions of which are often alarming. One particularly militant researcher has gone so far as to identify and

support an instance in which local residents deliberately kept their neighborhood stigmatized as a Superfund area in order to ward off capital investment and gentrification (Pearsall 2013), suggesting that radical measures should be taken to "combat" this evil infiltrator.

While gentrification has its benefits and drawbacks, this paper does not engage in this debate. It rather focuses on the geographic distribution of gentrification, as explained by natural amenities. Regardless of whether one supports or opposes gentrification, it is pertinent for all those engaged with the issue to develop a deeper understanding of where gentrification occurs and what factors drive its development, and the results from this study can be used to by researchers on both ends of the spectrum.

This paper begins with a discussion of the Chicago models of urban form, which suggests why we would expect gentrification to congregate near natural amenities. It then shares a number of hypotheses for the broader-scale causes of gentrification and the cross-neighborhood gentrification literature. The focus then shifts to the study conducted here, including the theoretical and empirical models, followed by a presentation of the study's methodology results. The last section concludes. Tables of the results of the study are presented in the appendix (Tables 3–5).

The Chicago School

Theories of the importance of natural amenities in attracting residents date back at least to the 1920s with the work of the Chicago School of Urbanism, who proposed a series of

models in which natural amenities were leading factors in determining the spatial distribution of wealth in American cities. These 20th century models stipulated that wealth would concentrate in the amenity-rich suburbs, upon hills, near waterfronts, and near park space, avoiding the disamenities of urban areas, such as noisy and polluted freeways and factories (Burgess 1925, 1929; Hoyt 1939; Harris and Ullman 1945; Meyer and Esposito, under review).

The Chicago models accurately described American urban housing patterns for nearly a century. Shearmur and Charron (2004) found that modern Montreal also adheres to the concentric urban model, with wealth decreasing as commute times shorten. Meyer and Esposito (under review) show that even today, wealth continues to congregate in the urban periphery, atop hills, and near waterfronts in the metropolitan areas of Chicago and Los Angeles. But the Chicago models and the empirical studies performed by Shearmur and Charron (2004) and Meyer and Esposito (under review) do not expose some of the most recent transformations in American cities. Namely, gentrification (loosely defined as the socioeconomic upgrading of urban neighborhoods) has fundamentally altered the demographics of inner cities across the developed world. Within the Canadian context alone, gentrification has affected 25% of all urban neighborhoods in Canada from 1981-2001 (Meligrana and Skaburskis 2005).

Gentrification appears to be inconsistent with the historical pattern of partiality for natural amenities that wealthy Americans have displayed. For one, the movement of wealthy Americans back to inner cities, where natural amenities are relatively scarce, opposes the premise of the Chicago models from the outset. Furthermore, one would expect that when

gentrification does occur, it would concentrate near the same amenities that wealthy Americans have sought for at least the past 100 years. The results of this study, which found no relationship between natural amenities and gentrification, suggest that (1) the gentrifying class is defying historic American housing preferences, and (2) that if gentrification were to become a national trend, this would imply a near-complete reversal of the housing patterns postulated by the Chicago models.

Literature

A number of theories, including demographic, economic, and cultural explanations, have been proposed to explain why gentrification is occurring on a macro scale in recent years. Myers and Pitkin (2009), for instance, approach gentrification from a demographic standpoint, arguing that the United States currently has an atypically large number of young professionals (the second baby boom generation) that work jobs that are only available in cities. Lipton (1977) advances an industrial hypothesis, observing that gentrification is most likely to affect cities with a large percentage of service jobs. Because service-sector firms have fewer associated environmental externalities than industrial firms have, Lipton's findings suggest that deindustrialization may foster gentrification by reducing the severity of urban disamenities, such as pollution, in inner cities.

Gentrification may also occur as a result of newly built urban amenities. In a theoretical article, Brueckner et al. (1999) showed that cities rich in recreational amenities retain a large number of wealthy households near the urban core. Paris, which through central planning and

investment transformed itself from "a great manufactory of putrefaction in which poverty, plague, and disease labor in concert, and air and sunlight barely enter" (as cited in Shapiro 1985: 33) to the enclave of urban wealth it is today, is a striking historical example (Glaeser, Kahn, and Rappaport 2008). Centrally planned or facilitated investment in urban beautification and recreation, which occurred in U.S. cities in the latter part of the century in projects such as Baltimore's Inner Harbor, San Francisco's Fisherman's Wharf, Boston's Faneuil Hall, and Kansas City's Power and Light district, may have provided the initial surge that spurred private investment and housing demand in inner cities.

Other theories of gentrification include the housing price hypothesis, which argues that urban home prices became inflated in the late 20th century (Gale 1979) and Americans responded by opting for urban homes, and the housing age hypothesis (Brueckner and Rosenthal 2009), which argues that gentrification is a result of aging inner-city housing stock. Wealthy people seek to live in newly constructed homes, and given the expanse of America's exurbs, the most viable place to build new homes is now in the inner city, where structures are aging and readily demolished. Corollary observations also provide evidence as to why more wealthy people are living in American inner cities; Gaspar and Glaeser (1997), for example, find that technologically aided communication is a complement, rather than a substitute, to face-to-face contact.

Finally, Neil Smith's rent gap hypothesis (Smith 1979; Schaffer and Smith 1986; Smith 1996) deserves special attention because of its indirect but profound relevancy to natural amenities. The rent gap hypothesis asserts that the land values of gentrifying neighborhoods

exceed current rent prices. Malicious efforts by landlords to evict existing residents allow rents to climb, which leads to gentrification. The government and police are often accomplices in this effort (Smith 1987, 1996). The rent gap hypothesis may be deeply relevant to explain neighborhood gentrification patterns because housing markets are riddled with imperfect information. If imperfect information exists in the demand side of housing markets, landlords will be able to manipulate rents to spur gentrification. Natural amenities often serve as key identifying characteristics of urban neighborhoods and therefore render their vicinity to be particularly prone to imperfect information, if the capital holders are able to exert force (violent or otherwise) to alter the perceived value of natural amenities. Therefore, such amenities would likely be sought by landlords as "agents of change" in spurring gentrification. In turn, the results of this study will provide suggestive evidence of the validity of the rent gap hypothesis, depending on whether or not natural amenities are shown to help draw gentrification.

Neighborhood Level Gentrification

The macro-level causes of gentrification and its resulting micro-level distribution are two separate yet interrelated questions. Despite the large body of research on the topic, the literature has not yet formed a consensus on the cause of gentrification. Gentrification may well be a compositional result of the many factors that have been proposed to explain it. The youth demographic bulge, for instance, may be a driving force for gentrification, but regardless of how large this demographic population is, it will only result in gentrification if at least one of the other theories of gentrification is true as well, such as Lipton's jobs theory or Brueckner et

al.'s theory of urban entertainment, because the younger demographic will only flock to cities if they have a reason to do so.

The central question of this study, however, is not to look at gentrification's macro-level causes, but its micro-level spatial patterns (though its patterns will shed light on its larger causes). When gentrification does occur, it occurs unevenly across space. Residents on one side of a city may experience large influxes of wealthier newcomers to neighborhoods while other neighborhoods can remain unaffected. Investigating the role of natural amenities in building uneven geographies of gentrification will provide insights toward both the contemporary applicability of the Chicago models of urban form and the structural causes of gentrification.

Amenities have long been considered potential drivers of population migration across regions and across urban neighborhoods. Ullman (1954) pioneered regional-scale research on the role of amenities in driving migration; agreeable climates, mountains, and the oceanfront were among the determinants that led to a massive relocation of Americans from the East Coast and the Great Lakes region to the Pacific Coast and Sun Belt America during the early and mid-20th century. More recent research has reaffirmed Ullman's findings: Argent et al. *(*2014), for instance, found that amenities are strong predictors of recent Australian migration patterns in Australia; also published in the same special issue of the *Annals of the Association of American Geographers,* Shumway et al. (2014) purport the inverse argument, showing that environmental disamenities (in the form of environmental hazards) have caused Americans to relocate from "counties with high and very high impacts of environmental hazards to counties with lower impacts" of environmental hazards.

Ley (1986) pioneered research on the role of amenities in attracting migration within the urban context, finding positive correlations between gentrification and neighborhood quality, and the availability of art galleries, restaurants, environmental quality, school quality, resident satisfaction, and a social indicators index. He concluded that "economic and urban amenity variables together account most effectively for inner-city gentrification."

Amenities-based research on neighborhood migration and gentrification has progressed since Ley's (1986) early work. Lin (2002), for example, uses econometric analysis to study the relationship between access to mass transportation and gentrification. Applying distance buffers around the "El" train stations on the north side of Chicago, Lin finds that El stops have a *ceteris paribus* positive effect on gentrification patterns in their vicinity. Lin's approach has been utilized to study the relevancy of transportation amenities in explaining gentrification in related research, such as that by Grube-Cavers and Patterson (2014), which found similar gentrification patterns in two of three examined Canadian cities. The results of both studies may be explained by the findings of Wheaton (1977), which were confirmed by Glaeser, Kahn, and Rappaport (2008): within affluent households, the income elasticity of commuting exceeds the income elasticity for housing.

Helms (2003) expands his list of amenities beyond transportation amenities. Probit and tobit models show a positive and significant relationship between renovation expenditures and distance from the central business district, El train stations, highways, and proximity to Lake Michigan and neighborhood parks in Chicago using data from 1995-2000. Helms presents the first instance in which a series of natural variables were considered with respect to

gentrification, although the limited scope and scale of his study necessitates further research on the issue.

A longstanding difficulty in studying the effect of amenities on place-based gentrification is the tendency for amenities to change over time. Indeed, endogeneity remains a troublesome issue in the literature. It is very likely that gentrification builds local amenities, such as restaurants and stores; but Ley's (1986) explanatory variable, *art galleries per 10,000 people*, for example, is particularly concerning because it is well established that artists are some of the first people to move to a gentrifying neighborhood, blurring the causational relationship of Ley's correlation coefficients.

The issue of omitted variable bias should not be ignored in studies of the effect of amenities on gentrification. Generally, studies on gentrification have opted to control for, rather than measure, endogenous variables for this reason. Brueckner and Rosenthal (2009), for example, use school district fixed effects to this end.

Lee and Lin (working paper) take an inventive approach to endogenous variables by testing whether natural amenities cause neighborhoods to retain land values over time. Natural amenities are far more static over time than manmade amenities. Hills, waterfronts, suburbanness, and even human-shaped nature-like parks experience less change than do manmade amenities like restaurants and schools. Given nature's relative inertia, one might expect that neighborhoods located near natural amenities would retain their land value over time. Lee and Lin test this hypothesis using data spanning from 1880-2010 and find that neighborhoods located near natural, exogenous amenities were less likely to upgrade or

downgrade over time; nature serves as economic anchors within the constantly evolving urban system. But while nature rarely changes, the quality of a number of natural amenities, particularly parks and waterfronts, can. Parks, for example, can be either an asset or a liability, depending on whether they harbor natural beauty or crime. Likewise, waterfronts can be scenic or industrialized. Lee and Lin control for the quality of parks and waterfronts by interacting these amenities with time-lagged median household income. In doing so, the authors argue that well-maintained parks and waterfronts will have been surrounded by affluent households in previous years, thereby enabling the authors to study the effect of both high value parks and waterfronts on gentrification while avoiding the pitfall of endogeneity.

Data and Methods

This study focuses on gentrification in the five densest major U.S. cities as of the 2010 census: New York City, San Francisco, Boston, Chicago, and Philadelphia. These cities were chosen for two reasons. One, gentrification is most deeply a study of the renewed urbanization of America's middle and upper classes; America's densest cities provide the landscape for this re-densification to play out. Two, only in dense cities are some neighborhoods completely void of natural amenities, fostering a strong degree of cross-neighborhood variation in access to natural amenities. This variation makes statistical regression feasible.

Four dependent variables were used as measures of gentrification. Each variable served as a proxy measure of the socioeconomic upgrading of neighborhoods between 1980 and 2010. The study's sample included all neighborhoods located within the city limits of the five densest

U.S. cities, minus Staten Island in New York City and the few neighborhoods for which data were unavailable. A cross-definition correlation table of the measures of gentrification is given in Table 1. These variables include percent increase in tract median household income, percent increase in the percentage of tract population over the age of 25 with a 4-year college degree, percent increase in the percentage of working-age population with a census-defined professional occupation, and percent decline in the poverty rate. The increase in a tract's college-educated population was the preferred definition of gentrification because of its quantifiable nature and its robustness to external shocks, such as the Great Recession that began in 2008.

The unit of analysis used in this study was the 2010 U.S. Census-defined census tracts. Census tracts are the geographically smallest unit of measurement that the U.S. Census provides as public data. The borders of census tracts are redrawn regularly to keep census tract populations to an average of 4,000 residents, which results in the need to normalize census tracts to a common boundary; Logan, Xu, and Stults (2012) provide census tract data from 1980-2010, normalized to the 2010 census tract boundaries using population weights, including both the full-count demographic data and the economic sample data. Because the U.S. Census Bureau has eliminated the long form census, values from 2010 come from the Census-administered 5-year American Community Survey estimates.

Four forms of natural amenities were considered in the study: hills, parks, waterfronts, and privatized amenities such as larger backyards that are inferred from population density and distance from the city center. Data for the natural amenities were collected from a number of

sources and then processed in a Geographic Information System (GIS) to generate proximity variables. Elevation data were sourced from the United States Geological Survey's National Elevation Dataset at 1/3 arc-second accuracy, which corresponds to an area of about 8 square meters at the 40 degree latitude (Gesch 2007). From the elevation data, slope was calculated using GIS by computing the rise in elevation between the points immediately surrounding census tract centroids.

Waterfront data were collected by tracing the edge of the major bodies of water in the five respective cities. In San Francisco, the bodies of water were the San Francisco Bay and Pacific Ocean; in Chicago, Lake Michigan; in New York City, the Hudson River, East River, Atlantic Ocean, and New York Harbor; in Boston, the Charles River and Boston Harbor; in Philadelphia, the Delaware River.

400-meter buffers were applied to waterfronts to measure proximity to these amenities. 400 meters has been identified in the literature as the distance that most Americans are willing to walk to take advantage of an amenity in an urban landscape, which roughly corresponds to a five-minute walk (Boone et al. 2009).

Park GIS shapefiles were collected from each city's GIS repository. In order to normalize park definitions across cities, the average park size for each city was computed; parks smaller than the average city park size were dropped from the study. As with the waterfronts, buffers of 400 meters were applied to the parks to test for proximity. Park and waterfront buffers were interacted with 1980 median household income for each census tract in order to distinguish

between “good” and “bad” parks. This is a similar method as adopted by Lin and Lee (working paper).

City centers were defined as the active city hall in each city. In each instance, the city hall was located within the central business district. Density, another indicator of greater space and private natural amenities, was also computed by dividing total census tract population by the tract area. The summary statistics of all variables used in this study are given in Table 2.

Microclimate data were initially considered but later omitted. Microclimate is mostly a function of urbanness: “direct emission of waste heat, gases, and particulates into the urban atmosphere modifies…the surface receipt of solar and atmospheric radiation” and the area’s “thermal and radiative properties” (Geiger, Aroun, and Todhunter 1950: 448). Because of the risk of collinearity and the redundancy involved with microclimates, microclimate data were excluded from this study.

Model Specification

The question of where wealthy people choose to live is more deeply a question about the preferences of American homeowners. Quigley (1984) was among the first economic theoretical studies to acknowledge that most houses are heterogeneous. He developed the following estimatable model to show how house occupants sort across various houses:

$$V(i) = a_i X_i + b(y - R_i) \qquad (1)$$

in which utility (V) is derived from the vector X and disposable income remaining after paying rent ($y - R_i$). The parameters a_i and b measure a household's level of preference between paying more for better housing (b) and buying other goods (X).

Equation (1) assumes that homes are more or less homogeneous. Homes, in equation (1), do differ in quality and therefore rent rate (R_i), but the model does not address how these homes actually differ in quality. As Quigley later observes, it is necessary to partition the bundle of services associated with homes into at least two components: variables that vary across homes (e.g., home size) and components that vary across neighborhoods (e.g., school quality). Quigley writes this expanded model as follows:

$$P(i,n) = (e^{a[1]X[1i] + a[2]X[2n]}) / (E(e^{a[1]X[1j] + a[2]X[2k]}) \qquad (2)$$

in which the probability (P) of choosing a given home (i) in a given neighborhood (n) is a function of both variables that vary across homes (X[1i]) and variables that vary across neighborhoods (X[2n]).

Quigley's model (1984) has been used as the foundation of more recent research on gentrification. Brueckner and Rosenthal (2009), for example, begin with Quigley's first equation (1) to describe Americans' neighborhood choice using a standard Cobb-Douglas utility function in which homeowners spend their entire income on either housing or all other goods:

$$U = C^a * H^b \qquad (3)$$

in which U denotes utility, C is numeraire consumption, and H stands for housing. But as in Quigley's model, not all housing is of the same value. Better housing – either because of its size,

condition, or proximity to amenities – produces higher returns of utility. A perfectly rational agent will maximize their utility by outbidding other prospective homeowners for the best housing he or she can afford. In doing so, the agent makes a conscious decision of which amenities to live near. Like Quigley, Brueckner and Rosenthal expand their model to include variables that vary across both neighborhoods and houses:

$$Y_{i,j} = D\ (x_j, z_j, d_x, n) + w_{i,j} \qquad (4)$$

in which a degree of gentrification (Y) varies across time (i) and census tracts or neighborhoods (j) based on distance from the city center (x) and neighborhood amenities (z).

The model that is used in this study fundamentally resembles equation (4) as provided by Brueckner and Rosenthal. Moreover, homes near amenities are thought to derive higher levels of utility. Because of the limited availability of amenities-related data (there are, for example, no park boundary shapefiles archives for all cities in all years), the time component of equation (4) is omitted. Therefore, gentrification is studied here using cross-sectional data that vary across neighborhoods and cities; the dependent variable is computed by calculating the change in socioeconomic status of neighborhoods between 1980 and 2010.

This study also expands on the theoretical models discussed above by recognizing the issue of spatial autocorrelation. Spatial autocorrelation results from spatial observation points that are not independent of one another, violating Gauss-Markov assumptions (Kelejian and Prucha 1998). An inverse-distance weighting test for spatial autocorrelation using the eight nearest neighboring census tracts found spatial autocorrelation present in all but one of the cities in the study (San Francisco). Significant spatial autocorrelation was also found in the

global model using four nearest neighbor and twelve nearest neighbor spatial weights matrices (Table 5). Therefore, the spatial error model, as described in Anselin (2001), is used. The general spatial error model is given by

$$y = \beta X + u \qquad (5)$$

$$u = \rho M u + \varepsilon$$

in which the dependent variable y is regressed against a vector (X) of explanatory variables and the error term (u) is spatially reliant on nearby observation units contained in the spatial weights matrix (M); rho (ρ) measures the strength and sign of spatial autocorrelation in the error term.

Combining the motivation behind equations (4) and (5), the model used in this study is given by

$$\Delta \text{ socioeconomic status}_i = \beta_1 X_i + \beta_2 C_i + \beta_3 P_i + \beta_4 FE_i + u_i \qquad (6)$$

$$u_i = \rho M u_i + \varepsilon_i$$

where gentrification, defined as the change in socioeconomic status, varies across census tracts and is a function of geographical variables (X), an endogenous variable control (C), home price controls (P), and city fixed effects (FE). The error term (u) varies spatially according to the inverse-distance weighted 8-nearest neighbor spatial weights matrix (M); the error term's (u) residuals are conveyed by ε.

The above model (6) was run 10 times. It was first run on the entire dataset containing all five cities. Next, dropping the fixed effects, the model was run on each of the five cities

individually to test for city deviation from the general pattern. It was finally run on all the cities combined, using three alternative definitions of gentrification.

Results

The results from the statistical regression are shown in Tables 3–5 in the appendix. Bundling all five cities revealed the increase in tract percent college educated to be positively and significantly associated with 1980 vacancy rates and negatively associated with 1980 percent college educated, tract density, and centroid distance from city hall. Waterfronts, parks, slope (hills), and the control variables of 1980 median home value and 1980 median rent were all insignificant in the study; rho, the spatial autocorrelation coefficient, reported a Z-score of 5.85, suggesting that autocorrelation in the error term significantly increased the measured gentrification rates.

These results reveal much about the spatial and economic circumstances of neighborhoods that experience gentrification. Foremost, there is no evidence to suggest that natural amenities attract gentrification. Waterfronts, parks, and hills have no ceteris-paribus effect on gentrification patterns. Furthermore, a joint chi-squared test for the combined significance of parks and waterfronts was statistically insignificant (Table 3). However, gentrification was shown to be most likely to occur near city centers where natural amenities are particularly rare, holding amenities constant, as shown by the strongly significant negative coefficient on distance from the city center.

The coefficients on density and distance from the city center tell a particularly illustrative story when viewed together. While neighborhoods near the city center gentrified, the least dense neighborhoods (in terms of place-of-residence population density) also gentrified. In conjunction, these two findings show that less dense neighborhoods in the inner city gentrify the most, even after controlling for lagged (1980) neighborhood socioeconomic status by using the 1980 values of the dependent variable. In this sense, density is the only variable to suggest that the socioeconomic upgrading class still favors natural amenities. Low population density translates into more space for front lawns and larger backyards, what one might consider "private" amenities, as opposed to the public, free-access amenities such as parks, hills, and waterfronts. Therefore, one may infer that gentrification disregards all forms of public natural amenities but favors private amenities.

The findings from the Δ% college educated model mostly recurred under alternative definitions of gentrification. Defining gentrification as the increase in neighborhood median household income yielded the same sign direction and statistical significance (or lack thereof) for all of the primary explanatory variables (Table 3). Gentrification defined as a drop in the poverty rate or an increase in the professional occupational class had minimal changes on the results as well; the poverty rate definition rendered density statistically insignificant; parks were shown to be significantly associated with increased gentrification under the Δ% professional definition.

While the alternative definitions of gentrification produced occasionally divergent results, it is important to note that there is nonetheless a general pattern of gentrification in

the results. As Hackworth (2005) reminds us, we should expect disturbances in any empirical model, including those of urban form. Nonetheless, gentrification was shown to be completely unrelated to natural amenities under three of the four definitions used here.

Tests within individual cities for the consistency of the model confirm the robustness of the findings (Tables 3 and 4). The five cities have more in common than not; operating under the Δ% college educated gentrification definition, the endogenous variable control and distance from the city center revealed significant and negative coefficients while parks, waterfronts, and hills were insignificant in all cities, with the two exceptions of distance from the city center in Boston and waterfronts in New York.

The exceptions of center distance in Boston and waterfronts in New York can be explained by special circumstances that do not challenge the general patterns found in this study. The insignificance of center distance in Boston is almost certainly caused by the city's small geographic size. The city's land area is smaller than that of any of the other cities in the study, less than half the size of New York City and Chicago. Further, efficient rail transportation in Boston makes travel easier, reducing the time cost of transportation and minimizing the impact of distance on land values; in Glaeser, Kahn, and Rappaport's (2008) study of 16 U.S. cities, introducing access to rail transportation (such as the Boston subway) as a control variable removes two-thirds of the positive relationship between distance from the city center and income in neighborhoods within 10 miles of the city center. This finding is particularly relevant to Boston, where the entirety of the city limits rests within a 10-mile radius of city hall.

The waterfronts' significance in New York City should also not be interpreted as contradicting the broader patterns in the results. The significance of NYC's waterfronts is likely caused by the city's unusual terrain, where Manhattan is surrounded by water on all four sides. Much of the gentrification in New York City is occurring in neighborhoods of the boroughs of Queens and Brooklyn where commutes are convenient and housing is affordable. Waterfronts in New York City therefore coincide with gentrification only because the waterfronts are also the location of the some of the shortest commutes available. Likewise, density's lack of significance in Chicago and Philadelphia may be caused by the relatively low price of land in these cities, allowing gentrifiers to purchase larger properties in still dense neighborhoods. Too much should not be read into these stray results.

The failure of parks and hills to produce a single significant coefficient and waterfronts' lack of significance in four of the five studied cities are the most noteworthy findings of the investigation, particularly when considering that a strikingly similar study (Meyer and Esposito, under review) found positive and significant coefficients on parks, hills, and waterfronts when using static 2010 household income as the dependent variable in the metropolitan areas of Los Angeles and Chicago. Any relationship between gentrification and natural amenities rests in the implicit private amenities that are associated with low population densities. Indeed proximity to the city center was overwhelmingly the greatest predictor of socioeconomic upgrading in the five American inner cities.

Conclusion

The relationship between natural amenities and gentrification had not been systematically studied in the past. This paper shed light on the role that natural amenities play in drawing gentrification. Moreover, natural amenities have no impact on gentrification patterns; if anything, the strong push of gentrification near urban cores suggests that gentrification may have an inverse relationship with natural amenities.

Although the results from this study do not disprove the rent gap hypothesis (Smith 1979), the lack of significance of parks, hills, and waterfronts is sufficient evidence to view the rent gap hypothesis with greater skepticism—natural offerings are precisely the sort of amenity that landlords would exploit in order to appreciate rents. The lack of significance of natural amenities suggests that these amenities have not been utilized for this purpose. On the other hand, the concentration of gentrification in regions closest to the city centers supports Ley's (1986) argument that urban amenities, such as restaurants, museums, and bars, are primary drivers of gentrification.

This inverse relationship between gentrification and distance from the city center is the strongest and most persistent result from this study. It is likely that the opportunity cost of remoteness has risen, and therefore the cost of closeness has shrunk, due to rising gas prices. The U.S. Energy information Administration (EIA) reports that real gasoline prices jumped from $2.27 a gallon in 1978 to $3.56 just two years later, which may have ushered in an early stage of gentrification. More recent increases in real gasoline prices, from $1.49 a gallon in 1998 to $3.43 a gallon in 2014, may have provided a second shockwave that has caused urban land

values to appreciate. Further, as Gaspar and Glaeser (1997) argue, technologically aided communication has made face-to-face human contact more desirable, which makes living in close proximity to business and friends all the more relevant. Climbing gasoline prices, along with a heightened desire for face-to-face interaction, may have caused the initial "push" that made inner cities more desirable in the first place.

The past century of American urban history has been a story of deurbanization. The automobile enabled millions of Americans to live further and further from their workplaces and closer to nature, in areas void of traffic, congestion, pollution, and crime. Gentrification may reverse the patterns of the last hundred years; a recently released book (Ehrenhalt 2012) suggested that gentrification may now "invert" the predominant sprawling urban form, bringing wealth back into the cities centers. The results of this study suggest that gentrification may not just infuse wealth into inner cities; gentrification, if it continuous at a vigorous rate, could reduce or even eliminate the marriage between wealth and natural amenities that has persisted for so long. For gentrifiers, there is no better place to live than amongst the hustle and bustle in the urban core.

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Appendix

TABLE 1: Correlations Between Dependent Variables

	Δ% College educated	**Δ Household income**	**Δ% Professional**	**Δ% Poverty**
Δ% College educated	1	-	-	-
Δ Household income	0.3113	1	-	-
Δ% Professional	0.4830	0.2565	1	-
Δ% Poverty	-0.0763	-0.2759	-0.0537	1

TABLE 2: Summary Statistics

Variable	Mean	Std. Dev	Min	Max	Unit Type
Δ% College Educated	2.39	5.06	-1.00	135	Percent change
Δ Household income	0.113	0.0338	-0.0755	0.255	Percent change
Δ% Professional	1.09	2.29	-1.00	95.6	Percent change
Δ% Poverty	0.382	2.05	-1.00	67.3	Percent change
Distance from city center	10.4	5.39	0.204	25.9	Kilometers
Waterfronts	880	398	0	40000	400 meter buffer, interacted
Parks	3580	7180	0	52400	400 meter buffer, interacted
Hills	1.30	2.38	0	39.8	Slope in degrees
% Vacant, 1980	0.0640	0.0587	0.000511	0.721	Percent
Median home value, 1980	53200	38500	5000	225000	Dollars
Median Rent, 1980	214	36.7	43.0	519	Dollars
% College educated, 1980	0.149	0.143	0.00105	0.873	Percent
Median household income, 1980	14900	5640	3970	52400	Dollars
% Professional,1980	0.211	0.134	0.00752	0.739	Percent
Poverty rate, 1980	0.190	0.142	0.00109	0.767	Percent

Note: Five census tracts (out of the total of 3291) reported a -1.00 value for Δ% College educated, Δ% "Professional," and Δ% Poverty.

TABLE 3: Spatial Error Regression Results with Four Gentrification Definitions

	Dependent Variable			
	Δ% College educated	**Δ Household income**	**Δ% Professional**	**Δ% Poverty**
1980 Socioeconomic status	-11.4*** (1.00)	-2.33^{-6}*** ($1.90e^{-7}$)	-6.79*** (0.809)	-3.76*** (0.323)
Population density	-45.15*** (14.5)	-0.286** (0.122)	-24.37*** (8.709)	-0.480 (4.07)
Distance from city center	-0.210*** (0.0288)	-0.00103*** (0.000214)	-0.0925*** (0.0235)	0.0204** (0.00887)
Waterfronts	$1.30e^{-5}$ ($1.18e^{-5}$)	$-2.76e^{-8}$ ($1.15e^{-7}$)	$9.96e^{-6}$ ($1.06e^{-5}$)	$-9.32e^{-6}$ ($9.21e^{-6}$)
Parks	$8.81e^{-6}$ ($6.36e^{-6}$)	$-2.33e^{-9}$ ($6.18e^{-8}$)	$9.17e^{-6}$*** ($2.81e^{-6}$)	$1.49e^{-6}$ ($1.26e^{-6}$)
Hills	0.00949 (0.0253)	$-3.18e^{-5}$ ($1.93e^{-4}$)	0.0347 (0.0260)	-0.0107 (0.0105)
% Vacant, 1980	11.0*** (3.54)	0.0778*** (0.0172)	6.52*** (2.11)	-0.0682 (0.327)
Median home value, 1980	$1.19e^{-5}$ ($7.33e^{-6}$)	$1.36e^{-7}$*** ($2.42e^{-8}$)	$5.02e^{-6}$*** ($1.80e^{-6}$)	$-1.97e^{-6}$** (8.57^{-7})
Median rent, 1980	-0.00308 (0.00361)	$5.96e^{-5}$*** (1.77^{-5})	-0.00211* (0.00115)	-0.00125 (0.00137)
N	3291	3291	3291	3291

Note: There were 3291 observations in each regression. Robust standard errors are reported in parenthesis. *, **, and *** denote statistical significance at the 10%, 5%, and 1% confidence levels, respectively. Spatial autocorrelation in the error term is corrected for using 8-nearest neighbor inverse distant weighting spatial error lags. Parks and waterfronts are interacted with 1980 census tract median household income. Endogenous controls are *pcol80*, *hinc80*, *pprof80,* and *ppov80*, respectively. A joint chi-squared test on the parks and waterfronts was insignificant in the Δ% College educated regression.

TABLE 4: Spatial Error Regression Results in Five Studied Cities

	City				
	Boston	***Chicago***	***New York***	***Philadelphia***	***San Francisco***
1980 % College educated	-8.52** (3.79)	-17.3*** (5.94)	-11.3*** (1.07)	-8.20*** (1.32)	-6.91*** (2.28)
Population density	-164** (81.9)	-15.6 (16.9)	-35.5** (13.9)	-36.4 (32.5)	-66.1*** (16.5)
Distance from city center	-0.483 (0.359)	-0.272*** (0.0798)	-0.176*** (0.0297)	-0.0900*** (0.0323)	-0.235*** (0.0499)
Waterfronts	$-1.32e^{-4}$ ($8.98e^{-5}$)	$1.56e^{-6}$ ($4.20e^{-5}$)	$2.77e^{-5}$** ($1.24e^{-5}$)	$1.31e^{-4}$ ($1.16e^{-4}$)	$-3.43e^{-6}$ ($1.05e^{-5}$)
Parks	$2.12e^{-5}$ ($2.12e^{-5}$)	$9.75e^{-6}$ ($1.47e^{-6}$)	$1.47e^{-5}$ ($9.45e^{-6}$)	$1.27e^{-5}$ ($9.82e^{-6}$)	$9.24e^{-7}$ ($5.16e^{-6}$)
Hills	-0.00654 (0.0488)	-0.175 (0.112)	0.0211 (0.0621)	0.0117 (0.0459)	-0.0131 (0.0101)
% Vacant, 1980	14.7 (9.79)	1.38 (12.3)	16.1*** (5.15)	5.06** (2.62)	4.95* (2.67)
Median home value, 1980	$-1.00e^{-5}$ ($2.10e^{-5}$)	$5.77e^{-5}$ ($4.79e^{-5}$)	$7.15e^{-6}$** ($3.45e^{-6}$)	$1.88e^{-5}$*** ($6.46e^{-6}$)	$-8.48e^{-7}$ ($2.61e^{-6}$)
Median rent, 1980	-0.00507 (0.00841)	-0.0273 (0.0201)	-0.00288 (0.00225)	-0.00170 (0.00171)	0.00513** (0.00250)
N	167	766	1797	369	192

Note: Robust standard errors are reported in parenthesis. *, **, and *** denote statistical significance at the 10%, 5%, and 1% confidence levels, respectively. Spatial autocorrelation in the error term is corrected for using 8-nearest neighbor inverse distant weighting spatial error lags. Parks and waterfronts are interacted with 1980 census tract median household income.

TABLE 5: Checks of Robustness

	Regression Type		
	4 Nearest neighbors spatial weights	**12 Nearest neighbors spatial weights**	**Parks and waterfronts not interacted**
1980 % College educated	-10.7*** (0.922)	-11.9*** (1.06)	-11.4*** (0.1.01)
Population density	-44.6*** (13.2)	-46.1*** (15.8)	-45.2*** (14.3)
Distance from city center	-0.205*** (0.0261)	-0.212*** (0.0313)	-0.209*** (0.00284)
Waterfronts	$1.65e^{-5}$ ($1.06e^{-5}$)	$1.08e^{-5}$ ($1.27e^{-5}$)	0.325 (0.199)
Parks	$9.79e^{-6}$ ($6.44e^{-6}$)	$7.18e^{-6}$ ($6.33e^{-6}$)	0.105 (0.200)
Hills	0.0215 (0.0257)	0.00899 (0.0250)	0.00915 (0.0257)
% Vacant, 1980	11.7*** (3.54)	10.4*** (3.61)	11.0*** (3.53)
Median home value, 1980	$1.15e^{-5}$ ($7.26e^{-6}$)	$1.21e^{-5}$* ($7.18e^{-6}$)	$1.20e^{-5}$ ($7.34e^{-6}$)
Median rent, 1980	-0.00403 (0.00356)	-0.00260 (0.00365)	-0.00290 (0.00358)

Note: There were 3291 observations in each regression. Robust standard errors are reported in parenthesis. *, **, and *** denote statistical significance at the 10%, 5%, and 1% confidence levels, respectively. Parks and waterfronts are interacted with 1980 census tract median household income in the first and second regression but not in the third.