Longitudinal Cluster Analysis of Jobs-Housing Balance in Transit Neighborhoods

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The jobs-housing balance is a spatial problem. Fixed-guideway transit systems (FGT) are capturing jobs across many metropolitan areas. Planners and policymakers have multiple justifications for focusing on efforts towards balance. For example, agglomeration economies, in large part the basis of metropolitan growth, benefit from the alleviation of congestion. Additionally, urban resilience is enhanced as workers can reduce transportation costs and utilize multiple modes of transportation. Moreover, Location Efficiency (LE), the optimal configuration of the built environment, is enhanced through job-worker balance. Transit systems can aid in alleviating congestion and in balancing jobs and housing. This paper presents a longitudinal study of spatial association of jobs, housing, and transit systems in Chicago before, during, and after the Great Recession. As workforce-housing balance is more indicative of internal capture, workers and jobs are classified by income level and analyzed for degrees of global and local spatial autocorrelation over time. The results show that LE transit neighborhoods are populated in large part by high-income jobs and workers, and this trend has continued in Chicago since the recession and during the years of recovery. The overall change for all workers within a 2-mile band of both jobs and transit was a gain of 13% from 2002 to 2009, and a loss of -47.3% from 2009 to 2014, while high-income workers lost proximity from 2009 to 2014 at a rate of -4.7%. Policies are needed that aid workers of all income levels in enjoying the benefits of LE and the increasing development of FGT systems.

INTRODUCTION

Efforts toward a jobs-housing balance has multiple justifications for its policy implementation, such as lowering emissions, freeway traffic, commuting time, and vehicle miles traveled (VMT). Additionally, agglomeration economies, which reduce production costs, thrive on spatial proximity, but are greatly obstructed by congestion, which a balance of jobs and housing, along with greater accessibility through the presence of public transit systems, helps to relieve. Accessibility can be defined as "the ease with which people can reach services, activities, and other important destinations" (Smith & Gihring 2017). Ongoing research has concluded that fixed-guideway transit systems (FGT), such as heavy rail (HRT), commuter rail (CRT), light rail (LRT), and streetcar (SCT) help to facilitate agglomeration economies and enhance economic development through heightened accessibility (Nelson 2017). Moreover, it is clear that the spatial mismatch between the location of housing and jobs is of concern in efforts to increase housing affordability, as transportation costs are increasingly factored into affordability indices (Cervero 1989, 1996; Center for Neighborhood Technology 2015; Nelson and Ganning 2015). Agglomeration economies provide greater economic resilience to a region, making its economy more resilient to shocks to the system, and transit and jobs-housing balance are key factors in those economies (Nelson et al. 2015).

Cervero (1989) identified five major forces behind the spatial mismatch between jobs and housing: 1) fiscal and exclusionary zoning, 2) growth moratoria, 3) worker earnings/housing cost mismatches, 4) two wage-earner households, and 5) jobs turnover. The first three underscore the ad-hoc and spatially scattered nature of municipal policy creation, which often divides regions that would otherwise function as whole units, just as ecosystems, watersheds, and transportation systems often function (Calthorpe & Fulton 2001). The last two are due to social dynamics, reminding policymakers of the constantly changing nature of demographics. The worker earning/housing cost mismatch continues to grow in some areas, as gentrification processes price low and even moderate-income workers out of the neighborhoods where they work. The effects of policies aiming at creating a greater balance in jobs and housing have been under studied, but travel demand research has shown that areas with a high accessibility to employment (i.e., that jobs are relatively near to housing) also tend to have shorter work trips (Stoker & Ewing 2014). As the ratio between jobs and housing evens out, research has shown that within-community commutes significantly increase (Cervero 1996). Transit systems are a key to a region's or neighborhood's degree of accessibility, as they reduce travel time compared with other alternative travel modes (Nelson 2017).

The effects of density, in population or in employment, differ depending on the type of density. Density in commercial land uses typifies the CBD, with the likelihood of congestion resulting from the concentration of commuting workers. Density in industrial uses can have congestion effects, due to cross-commuting, or signify a good level of internal (i.e., local) job travel from workers who live nearby, referred to as internal capture. One study hypothesized that the spatial distributions for industrial and commercial land uses take different forms, and therefore have different commuting patterns, and found empirically that 1) polycentric metropolitan areas aid in shorter commute times, and that 2) density effects differ between density types (Gordon, Kumar, and Richardson 1989).

The jobs-housing balance consists of more than just a one-for-one ratio of jobs per housing in a given area. A proper match between the kinds of housing, such as first-time buyer homes, apartments, condominiums, etc., and the wage and skill level of jobs in an area is a key to a proper balance. Some have termed this the "workforce housing balance," or "jobs-housing fit," as it denotes whether housing is affordable for workers to live near where they work, such as teachers or first-responders working in higher-value areas (Nelson et al. 2015; Cervero 1989; Calthorpe & Fulton 2001; Benner & Karner 2016). Moreover, as one study demonstrated, a balance of income between residents and workers is more indicative of internal capture, which refers to whether people can work in the same neighborhood in which they live, than is jobs-worker balance, as income balance allows workers to afford the housing close to their workplace (Stoker & Ewing 2014, 2016).

This study will analyze the spatial clustering (autocorrelation) of jobs and workers over time both at the regional scale, and within 0.5-mile, 1-mile, 1.5-mile, and 2-mile distance bands around key transit corridors, and determine how much change in clustering has occurred. The study will review change across three years, before, during, and after the recession in terms of clustering of jobs and housing across the Chicago metropolitan region, and then compare that change to the change that occurs in the neighborhoods around a given transit stop. FGT lines operating in Chicago included commuter rail transit (CRT), or heavy rail transit (HRT) subway-metro systems. Do the neighborhoods around a transit line exhibit increases in clustering? The study will use the Moran's *I* and the Getis & Ord Gi* statistics for worker and job location and compare z scores over time, first for the whole study area, and then for neighborhoods within a set of distance bands from transit stations. Environmental justice literature calls attention to the need for all demographic segments of society to be at optimal health to buttress a region’s resilience to shocks (Island Press & Kresge Foundation 2016). Accessibility is a key element to urban resilience. Real estate markets may favor transit-accessible locations during and after a recession, for example (Nelson & Stoker 2016). Taking this into account, the study will compare z scores for jobs by salary level with workers by salary level, both within transit neighborhoods and across the entirety of Chicago. Nelson & Stoker (2016) identified a gap in the resilience literature, which concerned the relation between public transit and economic resilience. This study proposes to provide further empirical study of transit-related economic resilience in terms of the jobs-housing balance around transit stops in Chicago. It will ask the following questions:

- What impact did the presence of FGT have upon the jobs-housing balance before, during, and after the Great Recession?
- Did the degree of clustering among jobs and housing change in transit neighborhoods across these time periods?

LOCATION EFFICIENCY

One key to accessibility is Location Efficiency (LE), which is described by the EPA and HUD as increasing accessibility in a location/site/neighborhood to a mix of everyday destinations, in a compact configuration close to transit stations, thus providing a mixture of transportation and destination options. People can bike, walk, drive, or take transit across or between these destinations to get to a high diversity of land uses, such as jobs, housing, entertainment, offices, retail, parks, and so on (HUD 2017.; EPA 2011; Adkins et al. 2017). Calthorpe (2011) highlighted the multiple resiliency benefits of LE sites, all of which will aid in cities’ response to climate change and other sustainability issues, from housing affordability to water infrastructure efficiency. The American Planning Association (APA), the Congress for the New Urbanism (CNU), Smart Growth America (SMA), and many others have taken up LE as one key solution to many sustainability issues facing the U.S. at present.

Sprawl, the antithesis of LE, is growing with suburbanization and having a negative impact upon the jobs-housing balance. As the third wave of suburbanization of the 1980s, when offices moved to the suburbs to match the earlier first wave (residents) and the second wave (retail), many expected the result to be a better jobs-housing balance, but in fact commutes have lengthened in general since then (Cervero 1989).

SPATIAL AUTOCORRELATION ANALYSES

Spillover or adjacency effects are evident in economic processes, such as the location of jobs and housing, and the value of real estate (Can 1992). Spatial autocorrelation, or spatial dependency, is one of the factors that cause these spillover effects. Many studies measure this phenomenon in order to remove it from spatial analysis models, as it has been shown to cause major errors in those models (Getis & Ord 1992; Anselin and Griffith 1988; Arbia 1989; Stoker & Ewing 2014). Others, however, utilize spatial dependency through various measures to capture spatial association, the tendency of phenomena to cluster spatially (Getis & Ord 1992). Can (1992) asked whether neighborhood effects directly determine housing prices, or is there a variation of marginal attribute prices across neighborhoods? Rosen (1974) offers a hedonic price regression model, the hedonic price function (HPF), which analyzes housing as a commodity consisting of a bundle of attributes, and determines whether neighborhood effects detail a uniform or segmented housing market. The key is whether neighborhood differentials produce varying or uniform prices for a given neighborhood characteristic; the former indicates a single price schedule for the region, while the latter indicates a segmented market, with schedules lying within the supply structures of submarkets in the metropolitan area. Typically, HPF has utilized submarket delineations, running the HPF within each submarket separately, which approach Can (1992) deemed arbitrary (Can 1992). Submarket delineation may be seen as partly due to spatial dependency. Can (1990) offered an extension of Rosen's earlier HPF model by including a spatially lagged dependent variable that captured adjacency effects from the price of nearby market counterparts. Geographically-weighted regression likewise modifies the HPF by allowing the covariates' parameters to vary across space, thus capturing variation due to spatial dependency (Yao & Fotheringham 2017). Moran's *I* tests evaluate the presence and magnitude of spatial autocorrelation or spatial dependency, which is a measure of how close things are more related to each other than far things, per Tobler's First Law of Geography (TFL) (Tobler 1970).

JOB-WORKER BALANCE METHODS REVIEW

Multiple studies have produced sophisticated measures of job-worker balance, using such methods as the transportation problem, linear regression, spatial regression, or multilevel analysis (Stoker & Ewing 2014; Horner et al. 2015; Schleith et al. 2016; Cervero 1989). Cervero (1989) estimated a rule of thumb for jobs-housing matchup in a subregion, using a 3- to 5-mile radius from homes to workplaces as the standard. Multiple distances have been cited as rules of thumb in the literature. Nelson et al. (2015) recommend an alternative of travel time to work, following up with a review of the literature on public health-related issues of those who suffer from a commute in excess of ten minutes, including increases in obesity and losses of time to socialize or prepare meals. Their results indicate a social divide: the higher/lower the education level, the higher/lower the number of white non-Hispanics, the higher/lower the income, the higher/lower the percentage of workers with a commute or 10 minutes or less.

The literature also varies on what functions as an appropriate jobs/housing ratio. Two highly-cited studies suggest a range of 0.75 to 1.25 (Margolis 1973), or 1.5 (Cervero 1989). Distances from home to work provide the measure for many of these studies. Stoker & Ewing (2014), pointing out the somewhat arbitrary nature of these generalized ratios, recommend determining an appropriate jobs/housing ratio on the basis of local data on workers per household. Likewise, Nelson et al. (2015b) notes that due to the varying size of households, and the fluctuating number of workers per household, a job-worker balance is a preferred measure. Nelson et al. (2015a) found that rent premiums from proximity to transit stations in the Dallas extended nearly 2 miles from the stations. Stoker & Ewing (2014) based their analysis on a cluster of census tracts consisting of those tracts within a 3-mile buffer of a given census tract, thus creating commuter sheds that would be applicable to a majority of cities across the United States. Schleith et al. (2016) use the transportation problem to delineate the minimum and maximum optima for commute distance in a given metropolitan area as baselines for observed commutes, to determine the *excess commute* (EC) for each metropolitan area.

DATA

Transit systems for this study were derived from General Transit Feed Specification (GTFS) static files, which most transit authorities across the United States provide in accordance with the Google GTFS data standard. Transit authorities prepare their data about stops and routes along the various modes of public transportation available in their communities, including local, express, and rapid bus routes, commuter rail transit, light rail, streetcar rail, and heavy rail subway-metro systems. The stop times table is the lookup table that allows the user to join the other tables together. The GTFS standard tables were processed through ArcGIS Model Builder. The data tables for jobs and workers were gathered from the U.S. Census Bureau's Longitudinal Employment-Housing Database (LEHD) job data tables for census blocks were downloaded from the U.S. Census Bureau's On the Map website in shapefile format. The LEHD Origin-Destination Employment Statistics (LODES) tables provide full counts, rather than samples, of wage and salary jobs covered by unemployment insurance, with strict enforcement of privacy for individual respondents. These tables provided the variables for study about the location of jobs and their pay level, as well as workers and their pay scale. The former are found in the Work Area Characteristics (WAC) files, detailing the workplace location and other data for the employees that are enumerated in the file. Jobs totals are provided, along with a breakout of jobs by age of employee, by pay ranges, and by jobs according to the North American Industry Classification System (NAICS) job sector categorization. The Residence Area Characteristics (RAC) file provides data on the residence location of workers, including the same variables as the WAC file, but from the basis of the residence location of the enumerated workers, which may or may not include the residence census block. Job and worker earnings are classified into three categories: the number of jobs with earnings $1250/month or less, the number of jobs with earnings $1251/month to $3333/month, and the number of jobs with earnings greater than $3333/month. Benner & Karner (2016) point out the limitations of this earnings classification, including the lack of an index to inflation and the significant variation in the number of workers who fall into each category as one controls for metropolitan statistical area.

STUDY AREA

The Chicago metropolitan area is a good case study region for this study, as it has a sufficiently large population, and has one of the oldest systems of subway and elevated heavy-rail transit lines in the country, which means that the effects of the recession will be more readily apparent along the transit lines, in contrast with other metropolitan regions that since the recession have been rapidly increasing the presence of fixed guideway transit routes. Nelson et al. (2015) has noted that CRT routes have had an insignificant or slightly negative impact on real estate values in their vicinity in the past, which makes Chicago's heavier forms of rail an important study.

METHODS

The question for this study is whether transit's presence before, during, and after the Great Recession had any effect on spatial dependency, pulling resources toward the transit stops, and pooling them from across the region, thus restructuring the regional economy in terms of housing values and density, as well as job quality and density. This paper therefore analyzes the spatio-temporal changes in concentrations of jobs and workers at the census block level before, during, and after the Great Recession, using proven spatial dependency measures. The analysis requires an answer to the question of the degree to which workers and job clusters are near each other and transit stations, and what occurs at the same time in the regionwide scores. Will we see a difference in the trends between the transit neighborhoods and the region as a whole? The census block scale of data is a fine spatial scale at which to run the analyses of local spatial dependency trends. The LEHD data set is a complete census of the variables covered, and therefore do not suffer from small sample size issues often mentioned for data at the census block scale. The definition of the transit neighborhood used for this study is smaller than the typical commute shed of a 3-mile buffer; rather, it follows Nelson et al.'s (2015b) findings that indicate an appropriate distance of 2 miles. Therefore, the presence of clusters of workers and clusters of jobs within the transit neighborhood gives evidence of those clusters existing within a commute shed range of each other. This paper aims to capture change in spatial concentration over time, rather than the strict job-worker balance. Moreover, this study classifies workers and jobs by income level. Identification of clustering of both jobs and workers at a given income level within transit neighborhoods provides a more complete picture of job-worker balance than a general count of jobs and workers.

In order to reduce spatial variability due to the greater distances between census blocks outside the urbanized areas of Chicago, using a nearest neighbor analysis the study identified those blocks that lie above three z scores of the mean distance between blocks in the study. This resulted in the removal of a portion of the census blocks from the study, approximately in accordance with the boundaries of the Census Bureau's Urban Area boundary.

While many studies have shown that the difference between Manhattan and Euclidean distance has a negligible effect on spatial measures, Cervero (1989) used travel time rather than Euclidean distance as a stronger measure for impedance in a gravity model. Moreover, Schleith et al (2016) used network distance to improve measures of cost and the impact on various modes of travel. This study will use Euclidean distance as appropriate for its specific questions.

Moran's I, a global measure of spatial autocorrelation, a spatially-weighted version of the Pearson correlation coefficient (Jackson et al. 2010), is the most appropriate analysis to begin with, as it determines overall levels of spatial clustering in a given region or total study area. Then, if it identifies statistically significant clustering, this finding indicates that more neighborhood-level measures can be used (and at what distance band), such as the Getis & Ord Gi* statistic, which identifies neighborhood-level hot or cold spots of a given variable, assigning z scores and p values for quantification.

Moran's *I* (Moran 1950) is defined as

$$I = \left(\frac{1}{s_y^2}\right)\frac{\sum_i^N \sum_{\{j:i\neq j\}}^N w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_i^N \sum_{\{j:i\neq j\}}^N w_{ij}} \qquad (1)$$

Where $\bar{y} = \sum_i {y_i}/{N}$, $s_y^2 = \frac{1}{N}\sum_{i=1}^N (y_i - \bar{y})^2$. y_i are counts, although alternative versions of Moran's *I* utilize continuous values (Jackson et al. 2010). The metric provides a cross-product, as it sums the covariance between each point and each of its neighbors, providing the sum of covariance (deviation from the mean at y_i multiplied by the deviation from the mean at y_j for all sets of adjacent neighbors, and then it divides it by the global variance, s_y^2. The resulting index ranges between -1 and 1, from a spatially dispersed pattern, to a spatially clustered one. This metric can be used at various distance bands, defined in the equation by assigning all features within the desired distance band a value of 1 in the matrix, w_{ij}. When the index is iterated over a series of distance bands, one or more peak distances often occur in the data, distances at which the data are at a peak of autocorrelation. Each of these peaks can represent neighborhoods in which the underlying spatial associations are strongest, and it is not necessarily true that each phenomenon has only one peak (ESRI ArcGIS Desktop Help. "Incremental Spatial Autocorrelation."http://desktop.arcgis.com/en/arcmap/10.4/tools/spatial-statistics-toolbox/incremental-spatial-autocorrelation.htm.. The researcher may then choose the peak distance band at which the phenomenon being studied is operative (see figure 1 below).

The Getis & Ord Gi* metric measures the degree of association resulting from the concentration of weighted points or areas and the other weighted points or areas within a given neighborhood, which is defined by distance *d* from the origin *i*. The Gi* metric is defined as follows,

$$Gi^*(d) = \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij}(d) x_i x_j}{\sum_{i=1}^n \sum_{j=1}^n x_i x_j} \qquad (2)$$

Where w_{ij} is the matrix of weighted points within each neighborhood, $w_{ij}(d)$. The matrix is a set of binary values designating whether each location *j* is within distance *d* of the origin location *i*. Each weighted point has the attribute value, x_i or x_j. The metric has a null hypothesis of spatial independence (Getis and Ord 1992). Moran's *I* is a useful starting point for using local-scaled metrics of spatial association, by defining distance bands at which association may be strongest. This distance then becomes the definition for the neighborhoods in the Gi* statistic (distance *d* in equation 2 above).

The count of significant clusters of workers that are near significant clusters of jobs inside the transit neighborhoods (based on peak Moran's *I* distance bands) is compared to the counts for the rest of the region. The variables will include jobs at different wage levels and workers at different wage levels. The transit neighborhoods include both of Chicago's FGT modes, heavy rail transit (HRT) subway-metro or commuter rail (CRT). The count of census blocks with significant clustering is tallied for each transit station neighborhood, and the number of workers and jobs at each pay level is summed.

RESULTS AND DISCUSSION

The regionwide counts of jobs and workers within statistically significant clusters changed over time (see table 2 below), while that count changed in the transit station neighborhoods. Summary statistics on the whole region are compared to statistics for transit station neighborhoods, at 0.5, 1, 1.5, and 2 miles in distance from the station. We can provide the number of workers and the number of jobs, by earnings level, within the region as a whole, and then for each zone for all statistically-significant blocks, including hot and cold spots. We can then do a Near analysis to determine the distance to the nearest significant cluster, and run summary statistics to count the number of workers near jobs by case, each in significant clusters that are within a given distance from transit station buffered areas, our definition of a transit neighborhood.

Downtown Chicago has an interesting phenomenon, wherein a large area is served both by CRT and HRT stations. There will inevitably be some interaction effects between these transit modes, as should be evident in the clustering effects in this area. There is a section of the downtown that has 96 subway stations or clustered stops packed into an approximately 3-mile by 2-mile area wherein people are no farther than half a mile to the nearest stop. Combine that with CRT stops, of which there are 5 in the same 3-mile by 2-mile neighborhood, and there will inevitably be a draw to this part of the CBD. Whether it is a cause or effect of growth and density of jobs or workers is not as important as the positive feedback loop that inevitably results from this clustering of infrastructure. If one considers a 2-mile distance from a transit stop as a viable transit neighborhood, then there is an area of central Chicago 19 miles by 8 miles that is entirely serviced by both transit modes together.

Results for the Moran's *I* test, given in table 1 below, demonstrate a significant level of global spatial association in Chicago in all time periods for all income levels. There is a variety of spatial structure dynamics in the low-, mid- and high-income jobs and workers, as defined by the LEHD categories for job earnings levels. The residential area characteristics indicate that The workers' residence locations show statistically significant clustering in all time periods and all pay levels, each having a p value of 0.00, but they do not demonstrate a peak at any of the distance bands at which the metric tested them. The distance chosen then rests upon making a meaningful comparison with those data sets that do exhibit a peak distance. Most of the job year/pay level categories show at least one peak distance band per year and per pay level. Those that do not nevertheless demonstrate statistical significance at approximately the peak distance band of data sets from previous and subsequent time periods. One interesting trend is in the low-income jobs. They peak in z score in 1,163 meters in 2002, increase to 1,804 in 2009, and decrease again in 2014 to 1,178 meters. In all cases the Moran's *I* statistic is highest at very short distance bands, around 0.5 miles, and gradually decrease with distance. The mid-income jobs demonstrate peak distances for only one of the three years, and this distance band was used for the other years as inputs in Gi* analyses.

The high-income job locations exhibit a significant trend, having the highest of the Moran's *I* scores, much higher than the other income levels for jobs and workers. Moreover, they exhibit an important dynamic across the study period, going from a score of 0.25 at 1,120 meters in 2002, dropping to a 0.20 at 1,124 meters in 2009, and then increasing to 0.42 at a shorter distance of 1000 meters in 2014, all of which have the p-value of 0. High-income jobs in Chicago have become much more spatially clustered since before and during the Great Recession. Their change in proximity to transit stations is covered below.

TABLE 1. Moran's *I* for Workers & Jobs by Income Level

RAC 2002	Distance	Moran's *I*	**Wac 2002**	Distance	Moran's *I*
Low Income	1087	0.11		1163.21	0.11
Mid Income	1202.96	0.13		1120.21	0.19

High Income	1086.3	0.20	1120.21	0.25
RAC 2009			**WAC 2009**	
Low Income	1055.51	0.09	1804.8	0.07
Mid Income	1040.34	0.10	*1124.6*	0.14
High Income	1040.34	0.17	1124.6	0.20
RAC 2014			**WAC 2014**	
Low Income	1091.62	0.05	1178.62	0.07
Mid Income	1044.41	0.07	1000.62	0.17
High Income	1044.41	0.11	1000.62	0.42

*Note: distance is in meters; p-value is p = 0 for all scores

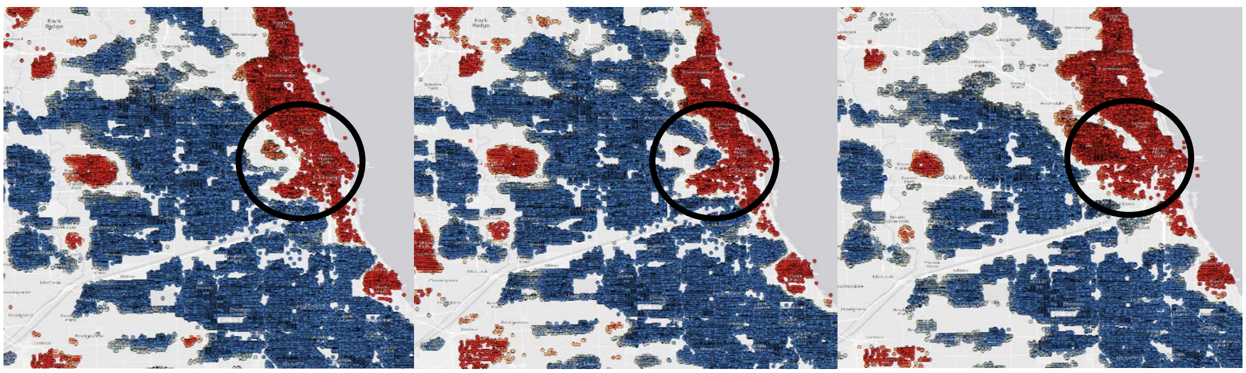

FIGURE 1. Map Series: Gi* for High-Income Housing in Chicago Before, During, and After Great Recession (years for images, left to right: 2002, 2009, 2014), with statistically-insignificant features removed. Downtown Chicago circled in black outline.

TABLE 2. Count of Workers or Jobs in Significant Gi* Hot Spots by Year by Income Level in Chicago MSA Urban Area

RAC	**2002**	**2009**	**% Change**	**2014**	**% Change**
Low Income	325,874	292,395	-10.3%	231,364	-20.9%
Mid Income	639,133	503,471	-21.2%	463,973	-7.8%
High Income	643,298	784,222	21.9%	747,049	-4.7%
Total	1,608,305	1,580,088	-1.8%	1,442,386	-8.7%

WAC	**2002**	**2009**	**% Change**	**2014**	**% Change**
Low Income	212,277	189,390	-10.8%	125,230	-33.9%
Mid Income	390,763	334,741	-14.3%	250,447	-25.2%
High Income	518,260	563,210	8.7%	713,663	26.7%
Total					

*Note: all scores are for clusters with 95% confidence level.

Census blocks with workers' residences with a 95% confidence level from the Gi* metric will be evaluated for proximity to transit *and* to worker residence. These numbers are broken out by 0.5, 1, 1.5, and 2- mile distance bands in table 3 below. Each distance represents a range, so the 0.5-mile band is from 0 miles to 0.5 mile, the 1-mile band is from 0.5 mile to 1 mile, and so on. One might expect the result of the longitudinal comparison of the figures for 2002 to be that the number of workers in these locations will have increased through the period approximately in accordance with population increase regionwide. The U.S. Census 2000 listed Chicago's population for that year at 9.09 million and 9.46 million in 2010, an increase of approximately 4%. However, the result is quite different from the population growth. In 2002 there were 120,313 low-income workers living in statistically-significant clusters within 2 miles of a significant workplace cluster and within 2 miles of a transit station. In 2009, the same area had 156,000 workers, but by 2014 that figure plummeted to 21,576. The results for all classifications show some substantial changes over time, shown in table 3 below. Between 2002 and 2009, all income groups within 2 miles of a transit station gained in proximity between the combination of housing, jobs, and transit. High-income workers gained this proximity at a rate of 7.8% for all distances up to 2 miles, while mid-income workers gained at a rate of 7.1%. The low-income group gained at a surprising rate of 29.7%. Perhaps in these highly positive figures is evidence of a lag in the effects of the recession. The next figures appear to represent the impacts of the recession, even while including Chicago's efforts toward recovery. They are astonishing. Between 2009 and 2014, high-income workers gained proximity to jobs and transit at a rate of 10.6% within the half-mile band, but lost proximity at a rate of -4.7%. Mid-income workers lost proximity at a rate of -53.0%, while low-income workers lost proximity at a rate of -86.2%. The overall change for all workers was a gain of 13% from 2002 to 2009, and a loss of -47.3% from 2009 to 2014.

TABLE 3. Workers by Income by Proximity to Transit & Jobs by Wage Over Time

Year	2002	2009	*% Change*	2014	*% Change*
High Income					
0.5-mile*	32,515	32,901	1.2%	36,380	**10.6%**
1-mile*	70,350	75,937	7.9%	72,410	-4.6%
1.5-mile*	110,251	116,966	6.1%	113,306	-3.1%
2-mile*	158,592	170,932	7.8%	162,813	-4.7%
Mid Income					
0.5-mile*	25,894	31,054	19.9%	9,537	-69.3%
1-mile*	70,565	84,995	20.4%	29,881	-64.8%
1.5-mile*	134,192	145,782	8.6%	59,531	-59.2%
2-mile*	200,418	214,653	7.1%	100,891	-53.0%
Low Income					
0.5-mile*	17,980	49,614	**175.9%**	3,583	**-92.8%**
1-mile*	46,179	89,185	93.1%	7,877	-91.2%

1.5-mile*	84,315	125,136	48.4%	13,152	-89.5%
2-mile*	120,313	156,000	29.7%	21,576	-86.2%
Total	268,787	419,935	56.2%	46,188	-89.0%

*distance to both transit and jobs for count of workers in statistically-significant worker clusters at the 95% confidence level.

Note: The distance bands are not precisely identical over time, but their range is very small, and the transit distance bands are identical over time.

CONCLUSION

The results of this study demonstrate the need for policy approaches that allow workers of all households to enjoy the benefits of LE and the rapidly increasing transit systems, especially FGT. There is clearly a high degree of loss in Chicago of the percentage of low- and moderate-income workers living near jobs and transit stations. Significant clusters of low-income workers exhibit the greatest loss of numbers of workers near jobs and transit. High-income workers are the only group, at a half-mile distance from transit and jobs of an appropriate wage level, that exhibit any degree of growth in numbers near those amenities. They suffered much less loss of proximity than moderate- or low-income groups.

Further study would include adding clustering effects of zoning, to ascertain how significant clustering of jobs or housing coincide with various zones. Additionally, the proximity of many CRT to HRT stops in downtown Chicago suggest plausibility of major interaction effects between transit modes. Further work on this phenomenon would be of great worth. This paper focuses on spatial association at the most statistically significant distances and then makes informal interpretations about these relationships based on summary statistics of jobs and workers within transit station neighborhoods, to determine whether the transit systems in Chicago attracted major relocations of workers or jobs in the periods during and after the Great Recession. Further work could place the transit stops at the center of commuter sheds based on commute time data to determine whether internal capture grew over time in those locations.

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