Residential integration by Income and Housing Market stability

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***Abstract*—The attractiveness of the City is a hard-fought victory, as for the first time in decades more people are moving to or staying in the City than leaving, said Mayor Bill De Blasio when introducing his inter agency plan Housing New York; A Five Borough, Ten Year Plan, an initiative has been launched in July 2014, aiming to address the escalating problem of New York Citys housing crisis. But is this urban victory successful to truly benefit the majority of New York Citys residents? This study focuses on neighborhoods Income Integration level and its relationship with housing market stability, represented by rent burden, at census tract level between 1990 and 2010. Furthermore, spatial autocorrelation analysis was performed to analyze the patterns of clustering and dispersing of the two criteria, income segregation and rent burden. Finally, a multivariate regression model had been developed to predict rent using income, income integration level and rental units number. We found that Income integration level is clustered among the city, so as rent burden.**

I. INTRODUCTION

New York City is well known for its unaffordable housing market. Today, the struggle to pay for housing has reached a breaking point, not only for the city's poorest households, but even for those that were once considered solidly middle-class (Office of the Mayor, 2014). For the last two decades, the rent burden for most New Yorkers has increased, and entire neighborhoods have lost their affordability (Office of the Mayor, 2014). In other words, these neighborhoods, pricing out their former residents, had been gentrified.

The Mayors Housing plan, within the ten-year time frame, aims to build or preserve nearly 200,000 affordable units, and help both tenants and small landlords preserve the quality and affordability of their homes (Office of the Mayor, 2014). In order to fulfill this goal the city has laid out five objectives, as follows: 1. Fostering diverse, livable neighborhoods. 2. Preserving the affordability and quality of the existing housing stock. 3. Building new affordable housing for all New Yorkers. 4. Promoting homeless, senior, supportive and accessible housing. 5. Refining City financing tools and expanding funding sources for affordable housing.

This study focuses on the first and second objectives, analyzing the past and existing dynamics of New York Citys housing market to help city departments to tailor a dynamic policy that uses free market forces and the characteristics of gentrification and leverage them to to broadly tackle the housing problem and to better meet the city and its residents goals.

This study focuses on neighborhoods Income Integration level and housing market stability, mostly represented by rent burden, at census tract level between 1990 and 2010. We tracked the changes of rent burden and income integration level and analyzed the correlation between the two. Furthermore, spatial autocorrelation analysis was performed to analyze the patterns of clustering and dispersing of the two criteria. Finally, a multivariate regression model had been developed to predict rent using income, income integration level and rental units percentage criteria.

II. LITERATURE REVIEW

A. Neighborhoods Change and Displacement

The phenomenon of gentrification is being discussed since it first emerged during the 1990s as a major force shaping urban neighborhoods [1]. Gentrification is a kind of neighborhood change driven by the migration of higher income households to a lower income neighborhood in urban cities [2], [3], shifting dramatically their demographic composition toward better educated and more affluent residency [1].

Gentrification has been viewed by some as a historic opportunity to reverse central city decline [1]. True, existing residents may benefit from the neighborhood change, considering factors such as better amenities, more services, and lower crime rate (Ng, E, 2016). On the other hand, a principle concern regarding gentrification is the displacement of the former lower income households, vulnerable to displacement resulting from redevelopment projects or rent inflation [1], [4]. Rents increased much faster in gentrifying neighborhoods compared to non gentrifying neighborhoods since 1990s [2], and in recent years, rent burdens are more severe compared to decades ago in both gentrifying and non gentrifying neighborhoods. In 2016, 72% of low income households (less than 30% of AMI) spent more than 50% of their income on rents (JCHS, 2016).

Although the ultimate effects remain unclear, researchers have used different methods to measure the impacts of gentrification on displacement. In 2000, Atkinson (2000) used census data and Longitudinal Study data to examine the displacement happening in central London, and analyzed the scale of displacement of vulnerable residents after gentrification began[5]. Vigdor [6] developed regression model to investigate the neighborhood stability using census data and American Housing Survey data. He examined displacement by comparing exits from gentrifying areas[6]. Freeman and Frank Braconi [1] used similar methods to analyze the exit rates of low income households in gentrifying neighborhoods based on dataset from the New York City Housing and Vacancy Survey (NYCHVS). Following that, Freeman [7] compared displacement by census tracts and found that the displacement rate in gentrifying area is around 1.3%[7]. McKinnish [8] compared the move in and out in gentrifying areas by census tracts using confidential census data from 1990 to 2000[8].

B. Residential Segregation by Income and Income integration

Economic segregation is strongly correlated to income inequality [9]. As segregation by income increases, it can

diminish the life chances of the poor, leading to disparities in crucial public good like schools, parks, libraries, and recreation[10]. Children would be the most vulnerable group to be affected from the above, raising the possibility that the negative effects will linger across generations [11], [12].

The level of residential economic integration across America experienced a downward trend between 1970 and 1990, then stabilized or rebound a bit between 1990 and 2000 [10]. During the period of 1970-2000, low income groups got more concentrated, especially in large metropolitan areas, with residential segregation of the rich [13], [14]. In 2000, the population of U.S metropolitan lived in segregated areas rose over 85% than thirty years ago [15]. In a recent research, Iceland and Hernandez [16] find that there is testified growth of poverty concentration between 1980s and 2000s, for both blacks and whites, while concentration level of poor black people was continuously higher than white. Sadly, policies and projects that were formed in the last decades to tackle this issue frequently face the rejection and avoidance of middle-high and high income populations [17]. At the same time, the natural, inevitable process of gentrification and neighborhood change succeed, neighborhood by neighborhood, to invade spatial segregation and poverty ghettos and to inform, for at least a period of time, economic heterogeneity [14].

C. Methods of measuring Income Integration of neighborhoods

Modeling housing stock and neighborhoods segregation (by race and/or income) has been researched and discussed a lot among the Urban Science field. The majority of the analyses uses Census tract, mostly of three decades, as the temporal variable of their data and models [18], [17], [19].

In order to describe residential integration by income one need to select or create a reasonable index to measure the extent of integration or segregation. Several approaches have been taken by scholars. The first is *the index of dissimilarity*, which has been extensively used in the study of social mobility due to its simple properties [13]. The index is built by first calculating the absolute value of the difference between the percentage of group As population of one area in total group population and the percentage of group Bs; then adding them together. The shortcoming of dissimilarity index is the oversimplification of the problems and would be not ideal if we need more income level groups included.

A popular measurement is a multi group approach named *entropy index*, a method that measures how evenly various income groups are distributed by calculating the portion of population in each group. The division is decided by the researcher. Kontokosta [17] and Galster [20] divide the population into 5 and 6 categories respectively, both following the Housing and Urban Development (HUD) guidelines, from poorest (less than 50% of the area median income (AMI)) to richest (greater than 120% or 150% AMI). The deficiency of entropy index is its dependency on researchers division [17], [20].

Another well known method is *Neighborhood Sorting Index (NSI)* developed by Jargowsky (1996). It is calculated based on the total income variance and deviation of neighborhoods mean income from total mean income. This method provides a clearer measure of integration / segregation by income, although calculating the total variance of income in a metropolitan area remains a challenge. One more interesting method introduced by Watson (2009) is the *Centile Gap Index (CGI)*. Its objective is to estimate how far the average family income deviates from the median income in one area in terms of percentile. Pangallo [21] focuses on price formation of the housing market in Paris by using a simple *Agent Based Model* that is spatially refined to residential integration by income. The simulation shows typical results of a housing market with demand and supply while new supply increased income integration [21].

Having the above methods reviewed, in order to balance the precision and feasibility of income integration, entropy index seems to be our best choice. Although different divisions of groups will affect the result of entropy index, this characteristic provides the flexibility about determining the scale of segregation and is easy to adjust in the process of study.

III. Data Inventory

A. Census Data

The Census data were collected from the Geolytics Neighborhood Change Database (NCDB)1. This dataset includes the Census data of 1970, 1980, 1990 and 2000 at the census tract level. Data of Population, Income levels and Rents were selected from the years 1990, 2000, 2010. The data of 1990 and 2000 have been recalculated and normalized according to the 2010 tract ID, in order to conduct comparisons of historic data by the exact same tract boundary definitions for different years. Since 2010, the Decennial Census stopped using long form survey and only includes some basic demographic and housing tenure information. Therefore, income, house value and rent data for this time period were collected from the American Community Survey (ACS) 2006-2010 instead. Data were cleaned and merged to overcome the different income levels for 1990 and 2000 census data.

B. Data Cleaning

From the NCDB, we get a whole dataset with 2168 observations for each year, which is the number of census tracts in NYC according to 2010 census. For regression analysis and spatial analysis, we do the data wrangling as below.

Firstly, use rent and income of each census tract to calculate the tract's rent burden, i.e. ratio of rent-to-income.

Secondly, use the number of families of different income groups to calculate the entropy index(see formula in the method part). Census data has divided families into 16 income groups since 2000, while having 19 groups in 1990. However, for entropy index calculation, we define 6 income groups based on the year's median income, respectively: less than 50%, 50-80%, 80-100%, 100-120%, 120-150%, and over 150% of median value of census tracts' median income. Hence, we need to harmonize two different divisions. We choose five census boundaries nearest to the defined boundaries as the actual boundaries.

Thirdly, for regression analysis, make four steps of preparation: select the variables we need, including rent, income, entropy index, and rent units for every year; drop observations

with 0 values; exclude the outliers, with the definition of larger than the mean plus triple standard deviation; last but also most importantly, normalize the dataset for every variable, to make the value between 0 to 1.

Fourthly, we standardize the dataset for spatial analysis, by subtracting mean and then dividing by the standard deviation.

Another preparation is for scatter visualization, by adding one column to label the income level of the census tract. It is grouped by the median income distribution of all tracts. Use 25%, 50%, 75% of all tracts' median income in the year to split the tracts as 'rich', 'high-middle', 'low-middle', 'poor'.

IV. Methods and Analysis

A. Entropy index calculation

Entropy index is a commonly used method for segregation measurement [20], [17]. In order to obtain the income integration level of each Census tract in each year we used the Entropy Index formula, returning a score of 0-1 range, when 0 is fully segregated (only one group of income is represented) and 1 is fully integrated. Census tracts income levels were first aggregated to six income groups, than entropy index was calculated according to them:

$$H_i = \sum_{m=1}^{M} Q_{im} ln(M)$$
$$if\ \pi_{im} > 0 : Q_{im} = -\pi_{im} * ln(\pi_{im});$$
$$else : Q_{im} = 0$$

where, π_{im} = the percentage of the number of tract i consisting of families from group m.

m = *1, 2, ..., M*.

M = Number of income level groups.

B. Descriptive statistics

The primarily variables were observed in order to assess their magnitude and trends over the decades analyzed and to detect possible trends or relationships. We observed the change over time of the main five variables: 1. Median Income; 2. Income Integration (Entropy index score); 3. Median Rent; 4. Rent Burden (median rent / median income); 5. Percentage of rental units.

Fig.1 and Fig.2 show change rate about above variables in NYC census tracts from 1990 to 2010, for 20 years and every 10 years respectively. We can see that among the variables, rent experienced the greatest growth during these twenty years, the only one doubled. Especially, the rents growth accelerated in the second 10 years, having a growth rate more than 50% since 2000. Due to 'only' 67% increase of income in the two decades, way slower than rent growth, in 2010 NYC has a median rent burden 25% higher than 1990. Its not desirable for the residents of NYC. The number of renter-occupied units went up slightly with 10% in 20 years, and notably the change of it nearly dropped to zero after 2000. The fact that supply for rent market was pretty stable may make it fall behind the increasing demand and drive the rocked up rent. And the entropy index, standing for the income integration level, although had a small decline in the first ten years, improved from 0.846 to 0.879 (see in Fig.3) between 2000 and 2010. It's encouraging, at least a good reverse trend.

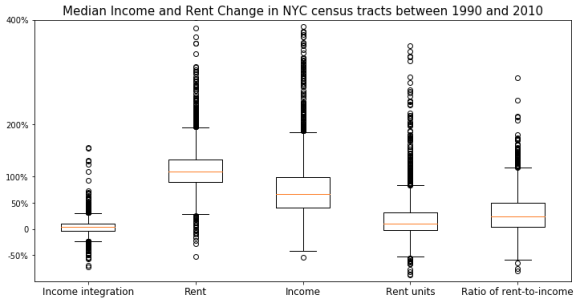

Fig. 1. The change of income integration, rent, income, rent units and rent burden between 1990 and 2010 for census tracts in NYC. The change rate is revealed in the form of boxplot, of which the central rectangle spanning the first quartile to the third quartile (the interquartile range, IQR), and outliers are either 1.5IQR or more above the third quartile or 1.5IQR or more below the first quartile.

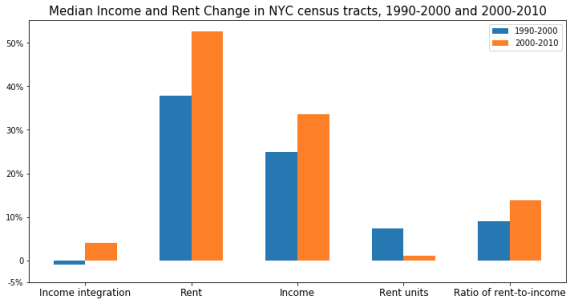

Fig. 2. The median change rate of income integration, rent, income, rent units and rent burden from 1990 to 2000, and from 2000 to 2010 for census tracts in NYC.

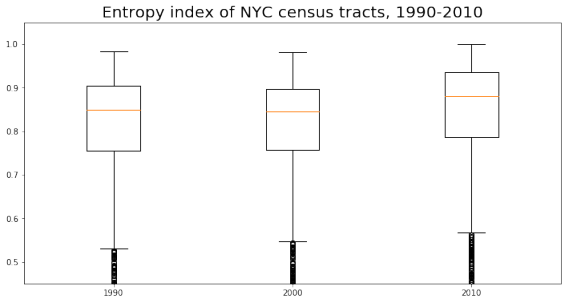

Fig. 3. The income entropy index of the census tracts in NYC in 1990, 2000, and 2010, revealed in the form of boxplot, of which the central rectangle spanning the first quartile to the third quartile (the interquartile range, IQR), and outliers are either 1.5IQR or more above the third quartile or 1.5IQR or more below the first quartile.

Given the trends to each variable, we focused on the Income Integration (entropy index) and viewed the distribution of rent burden for all three years accounted. The second box plot in Fig.3 is the Income Integration level (entropy index) information of the three years 1990, 2000, 2010.

The Spatial distribution of rent burden in the city is shown for each year in Fig.4.

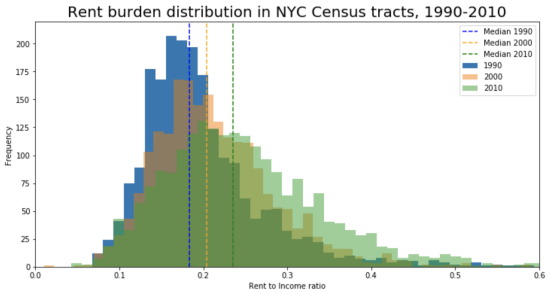

Fig. 4. Rent Burden distribution and median, year 1990, 2000, 2010

The rent burden distributions variance had increased over the years, as the median of the citys rent burden has consistently increased, too. Also, the distributions are not Gaussian and have longer tail as the years go by; which can inform of extreme rent burdened census tracts in New York City.

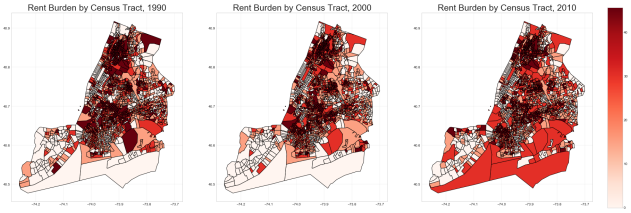

Fig. 5. New York City's Rent Burden by Census tracts, 1990-2010; The overall trend of rent burden over the two decades is not clear. Furthermore, rent burden clustering seems to increase, which will be further analyze in the spatial analytics section

In order to better view the trend of New York's entropy index over the two decades, we scattered 2010 entropy index level over 1990 entropy index level, as in Fig.6.

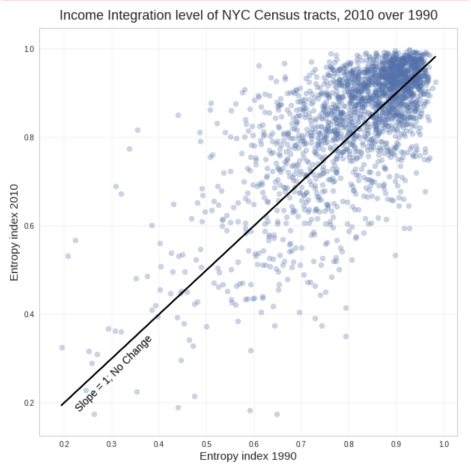

Fig. 6. Entropy index score of each of the 2,069 Census Tracts in 1990 and in 2010, when 1990 as the independent variable. The line with slope = 1 is the line dividing the Census Tracts that became more integrated by income (above the line) and those who became segregated over the 20 years period (below the line)

Fig.6 informs us the difference between NYC's integration by income trend and that of the the country. While in the US the trend shows economic segregation deepening [14], [19], in New York City more Census Tracts became more integrated by income than got segregated. The Spatial distribution of rent burden in the city is shown for each year in Fig.8.

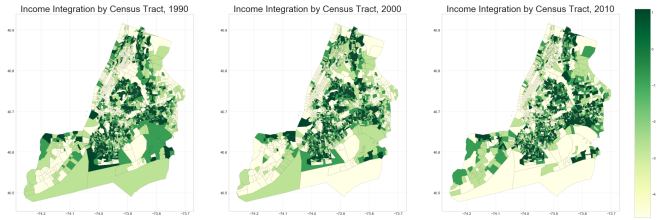

Fig. 7. NYC Income Entropy Index,1990-2010. Dark green colors revealing higher integration by income level

The entropy index maps depict the trend of the Income integration in the Census tracts level. Most of Manhattans tracts got less income integrated, so as Downtown Brooklyn and Dumbo, while Census tracts in Harlem area, which we know is facing gentrification in the last few years, indeed increases its income integration level.

Fig.8 is a description of Rent Burden over Income Integration (entropy index), for 1990, 2000, 2010.

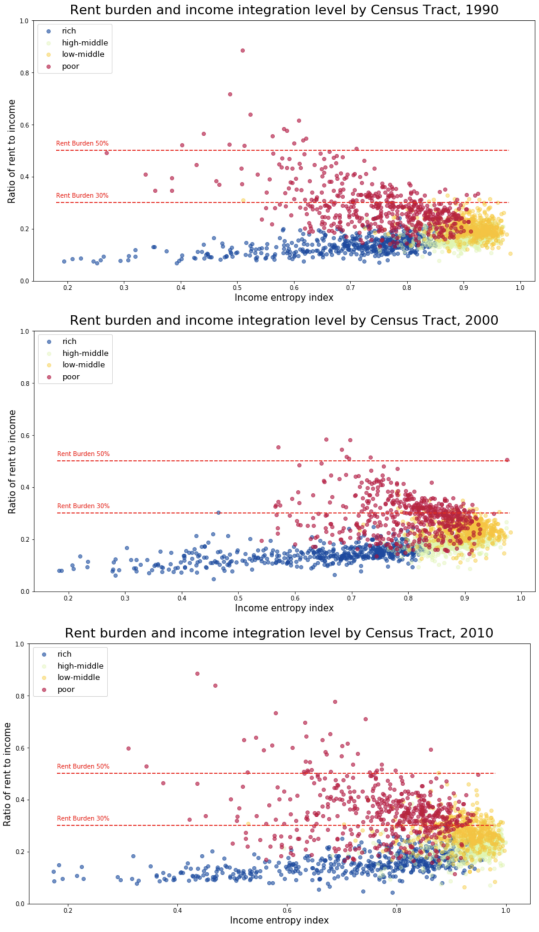

Fig. 8. Rent Burden and Income Entropy Index; 1990, 2000, 2010. Rend burden of 30% and severe rent burden of 50% are shown. Each observation is colored by its median income in comparison to the city's median income distribution: 'Poor' is the 25% of the distribution, 'Low-middle' is 25%-50%, 'High-middle' is 50%-75% and 'Rich' is the highest quarter of the median income distribution.

The graphs clearly reveal clustering by income, with middle income Census tracts concentrating in the highly-integrated and relatively middle rent burden side, as expected. Rich and poor census tracts are ranged over most of the entropy index range. Also, the change in the rent burden's trend is revealed; while decreasing between 1990 and 2000, it is dramatically increasing between 2000 and 2010, putting more and more Census tracts above the line of 30% rent burden, and more severely, above 50% rent burden.

Given the descriptive data it is obvious that Rent burden cannot be explained linearly solely by Income integration level. The next phase of the analysis was to build a multivariate regression.

C. Multivariate Linear Regression

Having rent burden calculated based on *rent* and *income* it would be wrong to try to predict it using income data. Thus, the dependent variable of this analysis is *rent*, while the independent variable that were included are *income, entropy index*, and *rental units*. The logic behind the independent variables choice was first to try and define the *demand* side of the housing market equation, and than to avoid multicollinearity. All variables were normalized and outliers were excluded, defined as observations that are larger than three standard deviations from the mean.

Initially, the whole dataset of two decades was used to develop the model. Then in order to further validate the model, observations of 1990 and 2000 were chosen to function as training dataset. The observations of 2010 were chosen for the test dataset and were compared with the predicted results of the model. The analysis results are shown in Table I,II.

TABLE I. MULTIVARIATE REGRESSION RESULTS

Variable	Coefficient
Intercept	0.0973064
Entropy index	0.232189
Income	0.668796
Rental units	-0.0881293
R2	0.505835

TABLE II. TRAIN AND TEST SET

1990-2000 R-squared	0.55822
2010 Test R-squared	0.384828

The multivariate regression results show that a relatively significant regression equation was developed with R-squared value equal to 0.5. All the three features of entropy index, income and rental units number are significant predictors of rent (P value < 0.05). According to the model, predicted rent equals to $0.669\times$ Income + $0.232\times$ Entropy index - $0.088\times$ Rental units + 0.097. Income has the biggest positive influence on rent. Rental units number has a small negative influence on rent which is reasonable because the rent will increase if the supply of rental units decreases. A positive relationship is found between entropy index and rent, which implies that if the income integration level in a neighborhood increases, the rent will increase.

D. Spatial Analysis

1) Global Moran's I: Patrick Alfred Pierce Moran claimed spatial correlation on his paper in 1950 and Hubert generalized Global Morans'I value[22], [23]. The equation is

TABLE III. GLOBAL MORAN'S I VALUE OF RENT BURDEN AND INCOME SEGREGATION, 1990 TO 2010

Global Moran's I	1990	2000	2010
Rent Burden	$-.39 \times 10^{-3}$**	.39*	.40*
Income Segregation	0.34*	0.42*	.31*

**P-value is .32 and *P-value is .001

$$\frac{n}{S_o}\frac{\sum_{i=1}\sum_{j=1} = z_i w_{i,j} z_j}{\sum_{i=1} = z_j z_j}$$

where S_0 is $\sum_{i=1}\sum_{j=1} = w_{i,j}$, $z_i = y_i - \bar{y}$, and $w_{i,j}$ is a spatial weight

Global Morans' I value is limited from -1 to 1 and 0 means the study area doesn't have spatial correlation, which the value is randomly distributed. -1 and 1 means strong negative and positive spatial correlation. Negative means the studied variable is distributed like a checker board. Positive means the variable is polarized. According to the table.III, 1990 year Global Moran's I value is almost 0, randomly distributed and the p-value is higher than 0.05 so the rent burden doesn't have spatial correlation. However, 2000 and 2010 Global Moran's I value is 0.39 and 0.40, which has 0.001 p-value.

2) Local Moran's I: In contrast, income segregation is always positive spatial correlation, from 0.31 to 0.42 with 0.001 p-value. The global Moran's I shows that rent burden and income segregation is polarized in NYC. Fig.4 and fig.1 shows clustering. However, it doesn't clearly show the polarization. Local Indicators of Spatial Association (LISAs) for Morans I is another way to show spatial clustering. The equation is

$$I_i = \frac{(n-1)z_i\sum_{j=1} = w_{i,j} z_j}{\sum_{j=1} = z_j^2}$$

Local Moran's I result is consist of High-High, High-Low, Low-Low, Low-High, and insignificant. High-High means higher value spatial area is clustered by high area. High-Low is high value spatial area is clustered by low area, etc.. The significant level is 0.005 and the 1990, 2000, and 2010 rent burden and income segregation results are correspond to Fig.9 and Fig.10.

E. Results

From the analysis using Census data in two decades, we found that the rent burden in New York City is increasing and most of the neighborhoods are becoming more integrated considering income level. The multivariate regression results reveal that income integration level has a positive influence on rent. By observing the results of spatial autocorrelation, the clustering patterns in space of rent burden and integration level are becoming more significant over the 20 years with the global Moran's I around 0.3-0.4 after 2000. Local Moran's I clustering figures of rent burden shows that High-High and Low-Low area doesn't change but Park Slope is stand out. Park slope area is changed from Low-High and High-Low area to High-High and end up High-Low, from 1990 to 2010. From the local Moran's I clustering figures of entropy index,

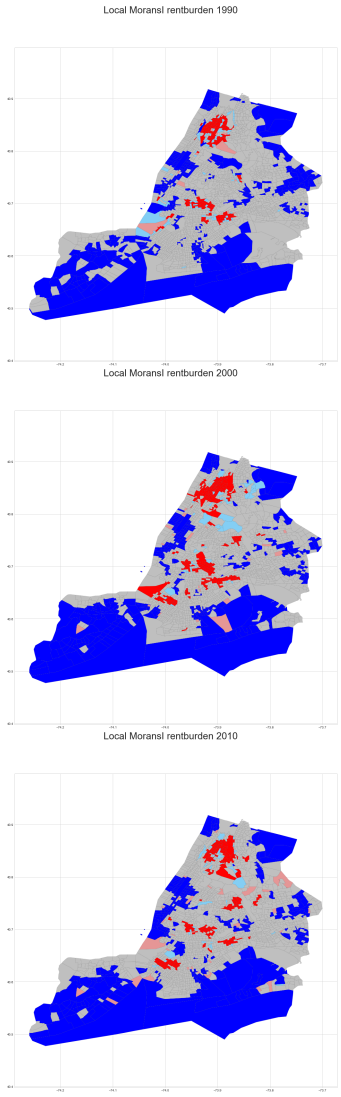

Fig. 9. Local Moran's I Rent Burden; 1990, 2000, 2010, Red area is high-high area, blue area is Low-Low, sky-blue is Low-High, and light-orange is High-low

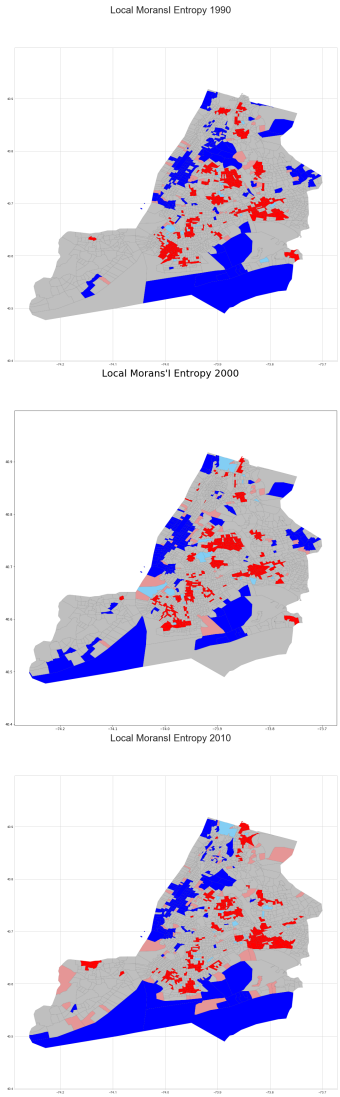

Fig. 10. Local Moran's I Income Segregation; 1990, 2000, 2010, Red area is high-high area, blue area is Low-Low, sky-blue is Low-High, and light-orange is High-low

a low-low cluster is observed in middle and lower Manhattan and a high-high cluster is observed in middle part of Queens and middle and south of Brooklyn, which implies that rich neighborhoods in Manhattan is becoming more segregated by income while neighborhoods with lower income in Queens and Brooklyn are becoming more diversity by income. The analysis are consistent with our statistical descriptive results. From 1990 to 2010, the high-high area is more toward to east Brooklyn and getting clustering each other.

V. CONCLUSIONS

Rent burden is a reasonable barometer to measure housing market stability because residents who are living in high rent burden area is threatened by financial stress and it would end up displacement from the area. Massey and Fischer claims rent burden is one of the important domains of people's mobility[13]. The rent is proportion to the rent burden, and the median rent price on census track level can be predicted with 0.38 R-squared value from the multivariate regression model, by income, income integration level and rental units. Moreover, as the city had a trend of heavier rent burden and higher income integration across 20 years, the local and global Moran's I test shows that rent burden and income integration is locally and globally clustered. Combining the spatial analysis and the rent predict model, characteristic of New Yorkers' mobility could be discovered and refined for future works.

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