Velocity of Gentrification

Introduction

The desire for living in large urban cities has been increasing since the 1980s, "converting urban decay into the new chic"[1] and opposing the suburban life-style pull of the 1970s. As more middle-income people move to big cities, gentrification becomes a progressively alarming phenomenon, transforming "working-class or vacant area of the city to a middle class residential and/or commercial use"[2] and thus contributing to the displacement of low-income people.

Although it is easy for the human eye to look around a neighborhood and perceive whether it is going through gentrification, it would be interesting to quantify this phenomenon and analyze it in a more formal way. Having lived in Brooklyn for four years, I have seen this borough change drastically and seemingly go through gentrification, with substantial increases in rent and the emergence of expensive restaurants, bars and venues. It thus seems fitting to study the phenomenon of gentrification within the biggest city in the United States, and in the borough that has been most subject to gentrification in the past ten years.

My main question for this analysis is what the direction of gentrification is over time. In other words, how does gentrification spread? My hypothesis is that gentrification is spreading from North to South within the Brooklyn neighborhoods, starting from neighborhoods closer to Manhattan and moving further into Brooklyn. Secondly, I am asking whether the velocity of gentrification has a clear direction. My hypothesis is that gentrification velocity is higher in the Northern neighborhoods of Brooklyn. If both these hypotheses were verified, we could infer that in any given neighborhood gentrification accelerates at a faster rate over time.

If these results were verified, gentrification would prove to be even more of an alarming phenomenon, as it is a force that continues to gain velocity over time, contributing to the displacement of low income people at a faster rate over time. Faster displacement means less time to find adequate alternatives, both from an individual and a policies point of view.

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[1] Smith, Neil. *The New Urban Frontier: Gentrification and the Revanchist City*. New York: Routledge, 1996.
[2] Lees, Loretta, Tom Slater, and Elvin K. Wyly. *Gentrification*. New York: Routledge, 2008.

Data

To address these questions, I will analyze gentrification through the change in intensity of taxi drop-offs. Taxis are in fact an expensive transportation option. Moreover, the subway system in New York is efficient and offers a widespread coverage. Taxis are thus not taken out of necessity, but rather out of convenience. I thus assume that taking taxis is correlated with people's income. This assumption has been confirmed by Thomas Proctor's project "Do Rich People Take More Taxis," where the author finds a 0.65 coefficient of determination in comparing per-capita income and number of taxi drop-offs through a Poisson regression analysis.[3]

I will specifically analyze drop-offs in Brooklyn for which the pick-ups happened in Manhattan, with the goal of singling out rides taken by individuals who presumably live in one of these two boroughs and go to work or go out in the other one. Since one of the two boroughs is already extremely gentrified, the assumption is that I would be able to subset rides taken by individuals who contribute to the gentrification phenomenon. The main dataset I will use is the TLC Trip Record Data made available by NYC's Taxi & Limousine Commission.[4] This dataset provides date, time, latitude and longitude of all pick-ups and drop-offs of yellow taxis from January 2009. While the data is accessible all the way to June 2016, my study will focus in on data up to December 2013 to avoid market changes due to the rise of Uber and Lyft, which did not gain a considerable share of the market until later in 2014.[5]

While the TLC Trip Record Data provides the coordinates for each pick-up and drop-off, I will need datasets representing the different polygons of Manhattan and Brooklyn to provide a geospatial reference. To further study the gentrification phenomenon within Brooklyn, I will mark up the territory by its neighborhoods, following the Neighborhood Tabulation Areas (NTAs), which provide a regulated definition of "neighborhood." The boroughs dataset was provided by

[3] Proctor, Thomas. "Do Rich People Take More Taxis?" *Springboard*. Mar 16, 2016. https://www.springboard.com/blog/do-rich-people-take-more-taxis/.
[4] "TLC Trip Record Data." *NYC Taxi & Limousine Commission*. Accessed on Nov 19, 2016. http://www.nyc.gov/html/tlc/html/about/trip_record_data.shtml.
[5] Freier, Anne. "Uber Usage Statistics and Revenue." *Business of Apps*. Sep 14, 2015. http://www.businessofapps.com/uber-usage-statistics-and-revenue/.

Derek Willis through GitHub,[6] while the NTAs dataset was provided by NYC's Department of City Planning.[7]

To verify the results obtained through the taxi drop-offs analysis, I will also look at the change in median income between 2009 and 2013, the start and end years of my analysis. I will thus be able to confirm whether taking taxis is in fact correlated with people's income, and as a consequence give a more solid basis for using changes in intensity of taxi drop-offs as a proxy for gentrification. I will also look at changes in gross rent between 2009 and 2013; the increase in housing prices is in fact a clear indicator of gentrification. I will thus be able to confirm whether the taxi drop-off analysis is accurate thanks to two other measures that are more standard in investigating gentrification. The datasets I will be using to study median income and gross rent come from the American Community Survey (ACS) 5-Year Estimates. The first dataset is the "Median Income in the Past 12 Months," which is 2009 and 2013 inflation-adjusted and provided at the census tract level.[8,9] The second dataset is the "Gross Rent" for renter-occupied housing units, also at the census tract level.[10,11] Given the granularity of the data, ACS only provides multiyear estimates in order to increase the statistical reliability of the data. As a consequence, when analyzing these data, I will be referring to the years 2009 and 2013 for convenience, but I

[6] Willis, Derek. "nyc-maps/boroughs." *GitHub*. Accessed on Nov 24, 2016. https://github.com/dwillis/nyc-maps/blob/master/boroughs.geojson.

[7] "Neighborhood Tabulation Areas." *NYC Department of City Planning*. Accessed on Nov 24, 2016. https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-nynta.page.

[8] American Fact Finder. "Median Income in the Past 12 Months (in 2009 Inflation-Adjusted Dollars): 2005-2009 American Community Survey 5-Year Estimates." *United States Census Bureau*. Accessed on Dec 5, 2016. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_09_5YR_S1903&prodType=table.

[9] American Fact Finder. "Median Income in the Past 12 Months (in 2013 Inflation-Adjusted Dollars): 2009-2013 American Community Survey 5-Year Estimates." *United States Census Bureau*. Accessed on Dec 5, 2016. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_13_5YR_S1903&prodType=table.

[10] American Fact Finder. "Gross Rent: Renter-occupied Housing Units, 2005-2009 American Community Survey 5-Year Estimates." *United States Census Bureau*. Accessed on Dec 5, 2016. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_09_5YR_B25063&prodType=table.

[11] American Fact Finder. "Gross Rent: Renter-occupied Housing Units, 2009-2013 American Community Survey 5-Year Estimates." *United States Census Bureau*. Accessed on Dec 5, 2016. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_13_5YR_B25063&prodType=table.

will be in fact looking at the 5-year estimates 2005-2009 and 2009-2013. Since these datasets are at the census tract level, I will also be using an equivalence table to aggregate the data to the NTA level.[12]

Analysis

To address these questions regarding the direction of gentrification and its velocity, I plan to analyze the intensity of taxi drop-offs in Brooklyn through quadrats and uniform Kernel density estimation. First, I can determine whether for any given year, intensity is higher in neighborhoods closer to Manhattan. Second, I can look at the change in intensity, i.e. the average change in gentrification, and compare its results to those generated by looking at the change in gross rent and median income. Third, I can look at the change in change in intensity, i.e. the average velocity of gentrification, and determine whether gentrification increases at a faster rate over time.

The TLC Trip Record Data is provided monthly. Every csv file contains one row of data for every trip taken in New York City during the selected month. While the original idea was to run the Kernel density analysis on all months from January 2009 to December 2013, the size of the data did not allow me to do so. For any given month, there are about 14 million rides in NYC. Although I only need those rides starting in Manhattan and ending in Brooklyn, subsetting the data based on these conditions is very computationally intensive as it requires the computer to check for any ride whether the starting point and ending points are within the two polygons of Manhattan and Brooklyn. I thus randomly selected 1% of the data and used that as a sample from which to subset the rides starting in Manhattan and ending in Brooklyn. This sample is statistically significant for a confidence level higher than 99% and a margin of error lower than 1. I then filtered the relevant rides for 10 months in total, January and June of each year from 2009 to 2013. This process took four hours and resulted in 10 files containing about 4,500 rides each. Figures 1 and 2 show two examples of the rides data, June 2009 and June 2013, plotted over the Manhattan and Brooklyn boroughs.

[12] "2010 Census Tract to 2010 Neighborhood Tabulation Area Equivalency." *NYC Department of City Planning*. Accessed on Nov 24, 2016. https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-nynta.page.

Figure 1

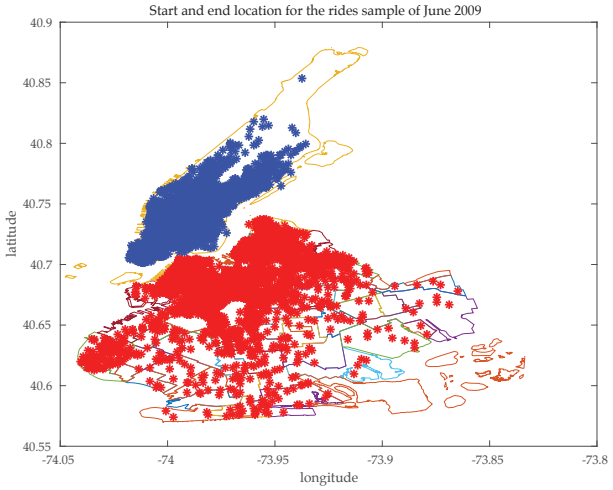
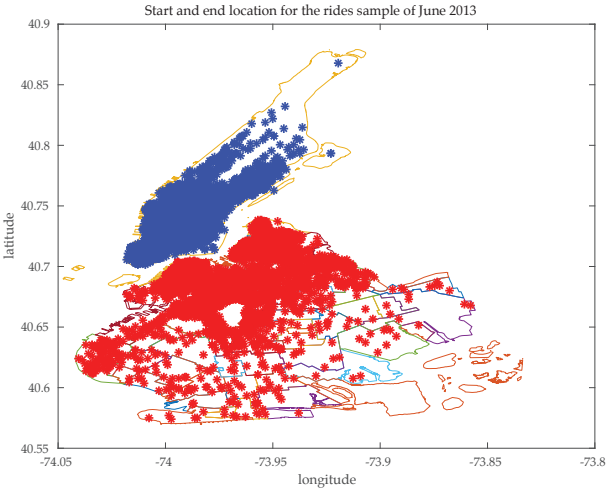


Figure 2



Once the sample was filtered, I proceeded to the calculate the intensities. First, I created a grid of 21 longitude points and 18 latitude points to be overlaid on the Brooklyn borough. Then I calculated the intensity for each of the 378 points on the grid by using uniform Kernel density estimation. The formula used to calculate the intensities is the following:

$$\hat{\lambda}(\vec{s}) = \frac{1}{\pi h^2} \times \sum_{j=1}^{N} 1[dist(\vec{s}, \vec{z_j}) < h]$$

where $\vec{s}$ is one of the 378 points on the grid, $\vec{z_j}$ is the drop-off location of a taxi ride, h is the cutoff distance, and $\sum j$ is the number of rides.[13] Based on this formula, I calculated the distance between the grid points and all the drop-off locations of the taxi rides and determined whether these distances were smaller than the cutoff value, h. For this analysis, I set h to be 0.05, which corresponds approximately to the median distance for all rides. For any of the distances smaller than h, I added a 1 to the grid point's weight. Once the final weight was determined, I divided it by the cut-off distance (squared and multiplied by π to account for the circular structure of the area being examined). Through this formula, I was able to calculate the intensity of taxi drop-offs throughout Brooklyn by month by year.

I then calculated the change in intensity between the same months of any two consecutive years and the start and end years of the analysis, by subtracting each lambda of one year from

[13] Formula as provided in: Hsiang, Solomon. "Lab 3: Point Processes." *PP275 Spatial Data and Analysis, Fall 2015*.

its corresponding lambda of the next year. A similar analysis was run to calculate the change between any two consecutive changes in intensities, i.e. the average velocity of gentrification.

To verify the results obtained through the taxi drop-offs analysis, I also looked at the change in median income and gross rent between the start and end years of the analysis. While the analysis itself was straightforward, the data processing was more complex. The data was in fact provided at the census tract level and did not contain coordinates. I thus aggregated the data to the NTA level by using an equivalence table between census tracts and NTAs, then merged the coordinates information, and finally calculated the differences between 2009 and 2013.

Results

Intensity is higher in neighborhoods closer to Manhattan

By plotting all the intensities for any given month and year combination on the grid overlaid on the Brooklyn borough, we can see that intensity is higher in neighborhoods closer to Manhattan. Figure 3 and 4 present the intensity for any of the grid points within the borough through red circles, where each circle represents one grid point and the size of the circle indicates the magnitude of the intensity. The figures clearly illustrate that intensity is higher in neighborhoods closer to Manhattan, and becomes progressively smaller moving from North to South. This is consistent throughout the analysis, i.e. for the other eight months of data not shown here.

Figure 3

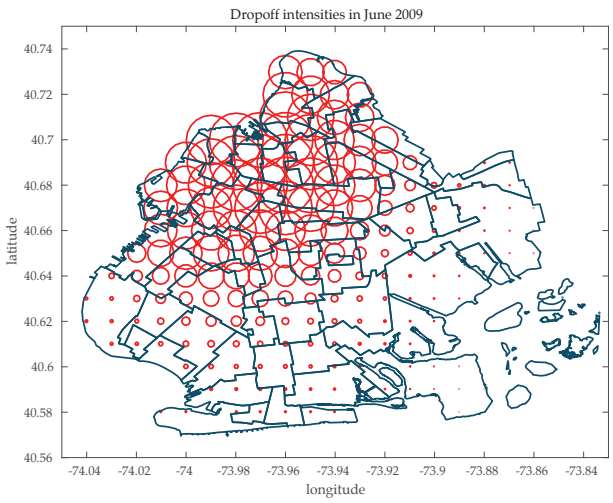
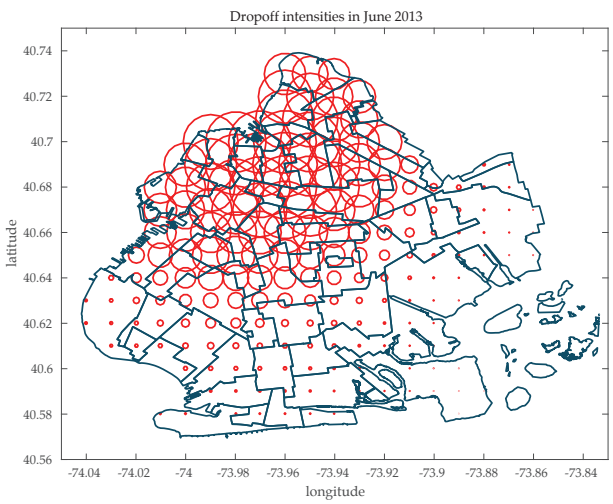


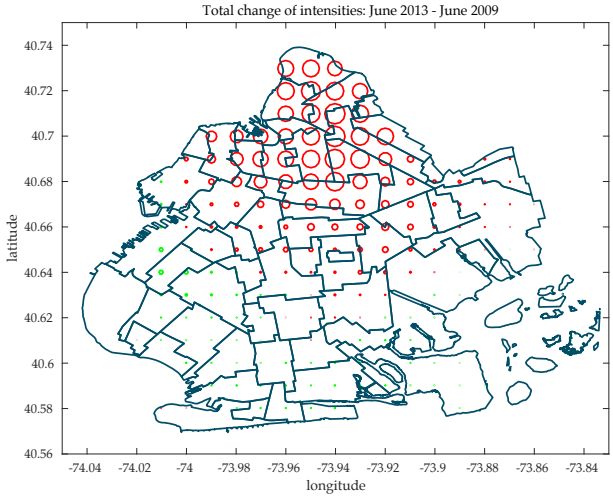
Figure 4



Change in gentrification is higher closer to Manhattan

Figure 5 shows the change in intensity between June 2009 and June 2013. The graph follows the same principles as the previous ones, whereby each circle represents one grid point and the size of the circle indicates the magnitude of the intensity. In this case however, when the circle is red, we see an increase in intensity over time, whereas when the circle is green, we see a decrease in intensity over time. Although there are some green circles, they are small, thus showing minimal decreases in intensity over time. Overall, we can see that the change in intensity is higher in neighborhoods closer to Manhattan, and becomes progressively smaller moving from North to South. This result is consistent when compared to the change in intensities between January 2009 and January 2013, not shown here.

Figure 5



This comparison can also be made between the same months of any two consecutive years. Figures 6 and 7 show the change in intensity between June 2009 and June 2010, and between June 2010 and June 2011. The year by year comparisons show more negative changes in intensity compared to the 5-year comparison between 2009 and 2013. Moreover, we can see that the magnitude of the change in intensity in Figure 7 is much higher than the one in Figure 6. This volatility is visible throughout all the year by year comparisons. A plausible reason for this volatility and the negative change could be that one year is not enough time to see change in a consistent manner.

Figure 6

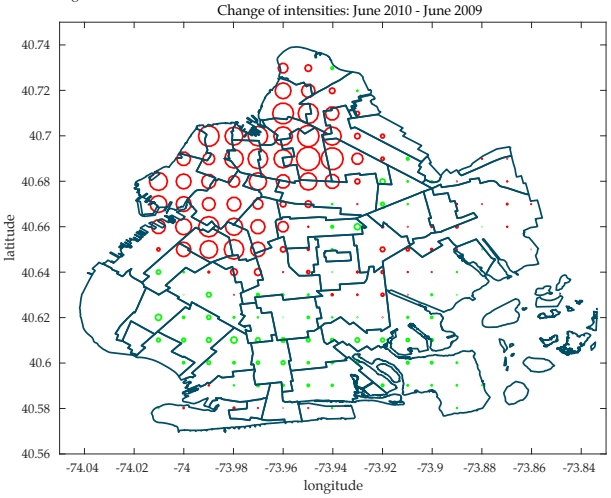
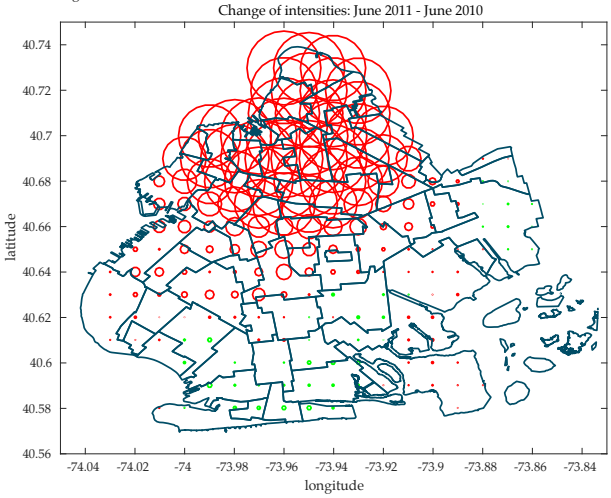


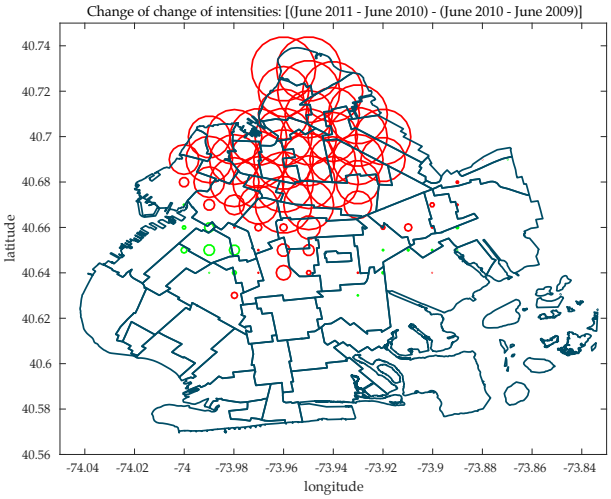
Figure 7



Velocity of gentrification does not show clear trends

Figure 8 shows the change in change in intensity, which I have previously defined to be the average velocity of gentrification. To avoid confusion that could rise from the negative changes of intensities of the previous analysis, to calculate the change of change of intensities I only considered those points for which the change in gentrification for both 2009-2010 and 2010-2011 was positive. As the graph shows, only the points in the North of Brooklyn pass this filter. We can see that the velocity of gentrification is higher closer to Manhattan, and becomes progressively smaller moving South. However, there are not enough points below -40.68 latitude to get a clear understanding of the trends. It is then not possible to conclude that gentrification increases at a faster rate over time.

Figure 8



Median income and gross rent

By plotting median income in 2009 and 2013, I can verify whether the income trends are similar to those of the intensity of taxi drop-offs. By looking at Figures 9 and 10, we can see that throughout the North there has been an increase in income, just as we can see that there has been an increase in the intensity of taxi drop-offs in Figure 5. We can also confirm that just as there has not been much change in the intensity of taxi drop-offs in the East of Brooklyn, there has not been much change in income. In the center of Brooklyn, we see some moderate increase in both income and intensity. In the Southeast however, we do not see much correspondence between the income analysis and the drop-off intensity analysis, as we see an increase in income (although moderate) and approximately zero change in intensity.

Figure 9

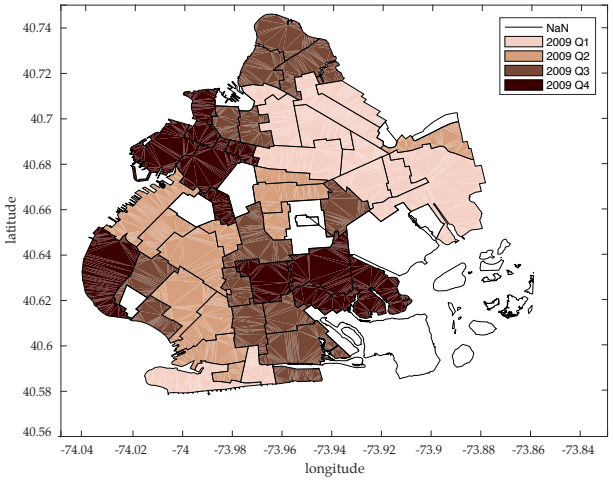
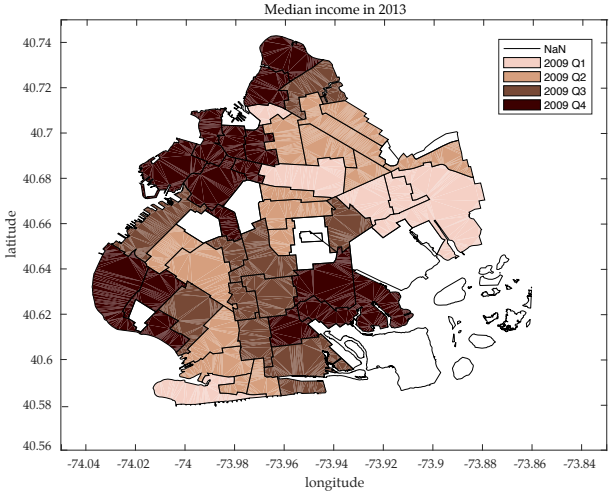


Figure 10



By plotting gross rent in 2009 and 2013, I can verify whether the gross rent trends are similar to those of the intensity of taxi drop-offs. By looking at Figures 11 and 12, we can see that rent changes split Brooklyn in half, whereby the North half shows a significant increase in rent, while the South half shows approximately constant rent. This is very much consistent with the drop-offs intensity analysis, whereby we see a positive change in intensities in the North of Brooklyn and not much change in the South of Brooklyn. As expected, the results obtained from the analysis of the change in taxi drop-off intensities seem to be mostly consistent with the results obtained from the analysis of the change in median income and gross rent.

Figure 11

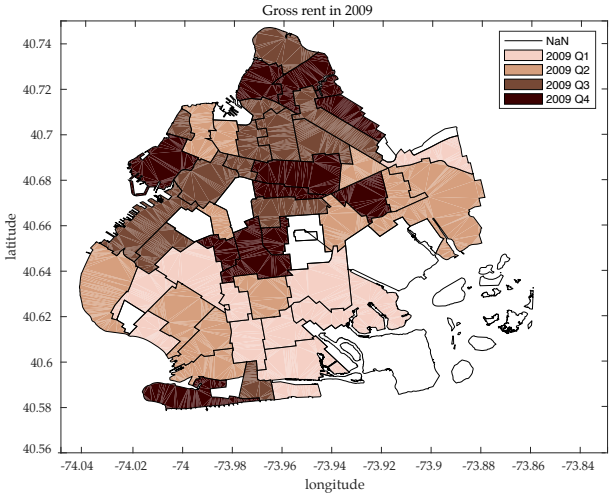
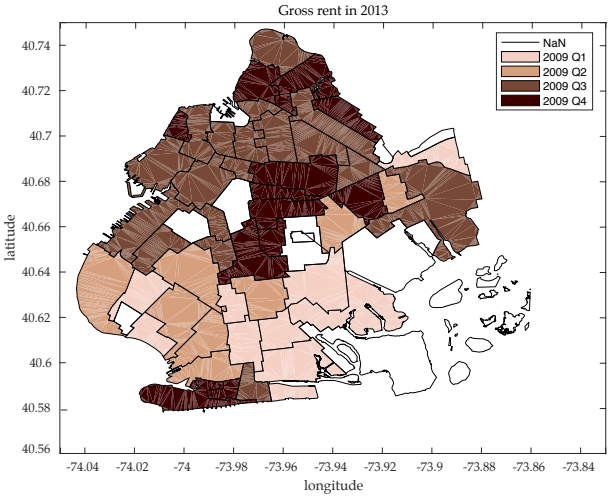


Figure 12



Conclusions

The primary purpose of this study is to understand the direction of gentrification and its velocity through the analysis of taxi drop-off intensity in Brooklyn. In agreement with my first hypothesis, taxi drop-off intensity and change in intensity (i.e. change in gentrification) are higher in neighborhoods closer to Manhattan and become progressively smaller moving from North to South. Supplementing the taxi drop-off analysis with an analysis on the change in median income and gross rent, I find that median income and gross rent have increased substantially between 2009 and 2013 in the Northern neighborhoods, showing consistency in results among all the measures used. The analysis put forward to verify my second hypothesis did not convey clear results. While velocity of gentrification is higher closer to Manhattan, and becomes progressively smaller moving South, there are not enough points below -40.68 latitude to get a clear understanding of the trends.

Although it is not possible to conclude that gentrification increases at a faster rate over time, this study was able to determine in a quantifiable way the direction of gentrification over time. Both at a 1-year and at a 5-year level, the study shows that gentrification and its change are higher in neighborhoods closer to Manhattan and become progressively smaller as they move from North to South.

Pursuing this project further, I would advance the study by analyzing data at the yearly level instead of the monthly level to make sure the analysis is providing a picture of the yearly

behavior, and is not picking up seasonal trends. I tried minimizing this possibility by looking at months that are very different from a weather perspective (January and June), and I found similar results across them, but for completeness I would like to aggregate the data and run the analysis at the yearly level. Moreover, it would be ideal to find a way to control for distance. As distance increases, taxis become more expensive. It could thus be possible that although there is gentrification far South or East, the area is too far from Manhattan for anyone to decide to take a taxi there. However, comparing my taxi drop-off analysis to the income and rent analysis, this does not seem to be the case. Nevertheless, controlling for distance would be advisable as it would make my analysis more robust.

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