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A stop too far: How does public transportation concentration influence neighbourhood median household income?

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Abstract
Research on US cities has connected the concentration of public transit with various neighbourhood outcomes, but it remains unclear whether public transit was more attractive to lower or higher income households. Some research found neighbourhoods with public transportation were more attractive to lower income households, likely because such households could not afford private transportation. Closer examination suggested that the type of transit was important, as lower income households were more likely to use buses while higher income households were more likely to use rapid transit. A key limitation of existing research on transit and neighbourhood household income was that it did not adequately control for variation over time. The current study addresses this limitation by assessing how the concentration of subway and bus stops predicted variation in median household income in New York City during the 2000s. Results of cross-sectional regressions partially confirm the findings of previous research that lower income households corresponded to areas characterised by higher concentrations of bus stops. Longitudinal results, however, indicate that the concentration of different forms of transit was uniquely associated with changes in neighbourhood median household income, independent of other neighbourhood changes.

Keywords
exploratory spatial data analysis, income inequality, neighbourhood, New York City, public transit, random effects regression, transport

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Introduction

While the United States has begun to recover from the economic recession and

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housing bubble burst of the late 2000s, this recovery has not been felt equally. Many neighbourhoods have enjoyed recent economic growth, but concentrated poverty endured, and even expanded in some places (Kneeborn and Berube, 2011; McKenzie, 2014). Differing trajectories of income attainment during the time since the recession were especially visible in major cities like New York City, which featured higher income inequality than the United States overall. According to the 2005–2009 American Community Survey, New York City's Gini index topped the list of large cities, with a score of 0.502, representing high separation of low and high income residents (Weinberg, 2011: 7). While research has explored the growth of high-income neighbourhoods (Jargowsky, 2003; Reichl, 2007) or the endurance of poverty in cities (Kneebone and Berube, 2011; Sampson, 2012; Sharkey, 2013), little attention was paid to what influences both. One such factor was the presence of public transportation in a neighbourhood, which previous research found to be an important predictor of neighbourhood household income (Babalik-Sutcliffe, 2002; Bowes and Ihlanfeldt, 2001; Brueckner and Rosenthal, 2009; Glaeser et al., 2008; McKenzie, 2013). This study contributes to the discussion by assessing the influence of concentrations of different forms of public transit (rail and bus) on neighbourhood median household income over time.

Establishing whether the concentration of public transit was attractive to high income households is especially important given the longstanding interest in developing rail and bus transit systems to encourage development (Bowes and Ihlanfeldt, 2001; McKenzie, 2013; Sanchez, 2008). Further, while analyses conducted by Baum-Snow and Kahn (2005) indicated public transit use declined in most metropolitan areas between 1970 and 2000, more recent research by Pollack et al. (2010: 5) found transit ridership began to increase in 1995 and has grown steadily since. This was potentially due to the greater interest in living in transit-rich neighbourhoods (McKenzie, 2014; Pollack et al., 2010), which were concentrated in the United States' largest and most economically important metropolitan areas. In New York City, for example, the 2009–2011 American Community Survey 3-Year showed that about 55 percent of city residents used public transportation to commute to work (U.S. Census Bureau, 2013).

In spite of the growing importance of public transit for planners and riders alike (TransitCenter, 2014), existing research produced mixed results as to the association of bus and rapid transit stops with income distribution. The multi-city studies of Brueckner and Rosenthal (2009) and Glaeser et al. (2008) found that neighbourhoods, including those found in New York,[1] characterised by greater concentration of public transit were more likely to contain lower income households as public transportation was less expensive than car ownership. In contrast, other research found that poor neighbourhoods were characterised by a greater concentration of bus stops because the slower travel times associated with buses made their use less desirable to the wealthy (Giulano, 2005; Taylor and Ong, 1995). Still others found that neighbourhoods with a concentration of rapid transit system stops were associated with higher wealth because of their perceived speed and efficiency (Babalik-Sutcliffe, 2002; Bowes and Ihlanfeldt, 2001; McKenzie, 2013).

Several factors contributed to the lack of consensus among researchers. First existing work used cross-sectional research designs, or did not adequately control for time, making it unclear how changes in income and concentrations of different forms of public transit were related (Sanchez, 2002). Second, while much of the previous research focused

on overall access to transportation (Kawabata and Shen, 2007; McKenzie, 2013) or differences in transportation access across multiple cities (Brueckner and Rosenthal, 2009; Glaeser et al., 2008), few efforts assessed the role that different forms of transit had on neighbourhood trajectories, or accounted for the spatial structure of neighbourhood economics and transit (McKenzie, 2013).

This study contributes to previous literature by drawing upon elements of the locational attainment literature (Alba and Logan, 1991) to assess whether the concentration of bus or rapid transit (known colloquially as subway) stops in New York City neighbourhoods collectively or disparately influenced changes in median household income between 2000 and 2010. This period captures time points before and after one of the largest economic recessions since the great depression, characterised by a rapid increase in the economic divide of cities like New York (Weinberg, 2011). Cross-sectional results indicate that neighbourhoods that featured greater concentration of bus stops in 2010 and subway stops in 2000 and 2010 had significantly higher median household incomes. Results of the longitudinal analyses, however, indicate that variation in neighbourhood median household income was not directly associated with the concentration of either bus stops or subway stops, after controlling for changes in other characteristics of the neighbourhood. We believe this demonstrates the effect larger forces, as opposed to transit, have had on neighbourhood median household income over time. The bottom line is that there were notable income disparities for neighbourhoods surrounding transit concentration, with potentially dire implications for the poor who often depend on such modes of transportation (Chappel, 2009; Pollack et al., 2010).

Locational attainment and the role of transit

Social researchers have long recognised the neighbourhood as a key site of social integration. Sampson (2012) highlighted the role of neighbourhoods as containers of social mobility due to the social resources found within from which residents could benefit, what he termed 'neighbourhood effects'. The locational attainment literature in particular explored how residence in socially stable and resourceful neighbourhoods translated into superior socio-economic standing. A key question this literature sought to answer was who had access to higher quality neighbourhoods (Alba and Logan, 1991; Logan et al., 1996). In many cities, like New York, there has been a longstanding divide between neighbourhoods characterised by socio-economic advantages and those characterised by disadvantages (Reichl, 2007).

The socio-economic division of urban neighbourhoods in recent years was complicated by dueling fortunes of neighbourhoods in large cities. Many cities experienced precipitous declines during the 1950s and 1960s due to the mass migration of middle-class, predominantly white residents from cities to suburban areas in the wake of World War II, which exacerbated social problems such as unemployment and poverty in many inner-city neighbourhoods (Jackson, 1985). Beginning in the 1970s, however, many cities experienced revitalisation due to a shift in federal urban policy toward neoliberal redevelopment initiatives, especially those that encouraged public-private partnerships designed to deconcentrate poverty and increase tax revenues in cities (Hackworth, 2007). During the 1990s in particular, many cities enjoyed a decline in concentrated poverty (Jargowsky, 2003). For example, Kneeborn and Berube (2011: 5) found that the population living in extreme poverty

census tracts dropped by 31.4 percent during this period across the country.

In spite of these promising signs, many cities also experienced a re-concentration of poverty. Between 2000 and 2009, the number of highly impoverished neighbourhoods across the United States increased by one-third (Kneeborn and Berube, 2011: 5). The majority of growth in concentrated poverty took place in suburban areas, but cities were not spared a similar increase (Kneeborn and Berube, 2011; McKenzie, 2014) . For example, Wolf (2012) reported eight community districts in New York City that experienced a growth of concentrated poverty during the 2000s. The disadvantage of many impoverished urban communities was exacerbated by a history of poverty, contributing towards systematic generational disadvantage (Sharkey, 2013). What makes this return of concentrated poverty especially troubling was that there was not a notable decline in the number of highly affluent tracts in many cities. This suggests cities increasingly moved toward Dickensian extremes of high and low neighbourhood income.

One explanation for the recent simultaneous growth of income and poverty in city neighbourhoods is the 'dual city' paradigm (Dreier et al., 2004; Mollenkopf and Castells, 1992). The term 'dual city' suggests city neighbourhoods became increasingly segregated into high and low income neighbourhoods. This was not a new concept as city neighbourhoods have long been sites of stark income contrasts, but this concept came to the forefront of research due to the recognition of an increase in inequality of lower and higher income groups (Dreier et al., 2004; Reichl, 2007). For example, analyses conducted by Reichl (2007: 667) indicated that the average income in New York City increased by about US$8000 between 1979 and 1999, which suggested that a renewed attraction amongst middle-class residents to city living helped revitalise cities. Further analysis indicated that much of this increase was due to a dramatic growth of incomes in the Manhattan core while average incomes in many areas of The Bronx and Queens declined during the 1980s and experienced only modest increases during the 1990s.

Application of the 'dual city' paradigm to neighbourhoods suggested that specific socio-economic and physical features unique to each neighbourhood influenced their attractiveness to different economic groups. The 'locational attainment' model is especially useful in interpreting how individual socio-economic attributes of neighbourhood residents together affected the total collective median income of households in that neighbourhood (Alba and Logan, 1991; Logan et al., 1996). This framework argues that the ability of householders to access quality neighbourhoods was influenced by their acculturation, socioeconomic status and life cycle factors. In other words, upwardly mobile individuals had easier access to quality neighbourhoods, while those with fewer resources tended to live in lower-quality neighbourhoods. Massey and Denton (1985) labeled this form of residential attainment the 'spatial assimilation' model.

Various components of socio-economic status influenced the quality of neighbourhoods accessible to different groups. For example, married couples were characterised by greater socio-economic stability and a stronger desire for quality neighbourhoods (Rosenbaum and Friedman, 2007). Additionally, one's education was also positively correlated with median household income of neighbourhoods (Alba and Logan, 1991). Further, higher status neighbourhoods also often featured higher rates of homeowners who had a stronger interest in maintaining and improving their residences due to their importance as financial investments (Ellen and O'Regan, 2008: 859). While the majority of occupied housing in

cities continued to be renter-occupied during the second half of the 20th century, analyses conducted by Birch (2005: 8) showed homeownership rates in downtown areas of 44 large American cities increased by 141 percent between 1970 and 2000.

In contrast to the socio-economic measures of neighbourhood status, where most scholarship is in agreement on its collective effect, the role of race and ethnicity is contested. The dispute can be boiled down to disagreement as to whether socio-economic status alone affects residential attainment, as argued by the 'spatial assimilation' model, or whether racial characteristics biased residential attainment, regardless of socio-economic background, as argued by proponents of the 'place stratification' model (Alba and Logan, 1991; Alba et al., 1999). While a debated topic, there exists a large body of research which connects the growth and endurance of residential poverty to the continuation of residential segregation (Quillian, 2012). The systematic disadvantage minority residences faced due to constricted access to housing inhibited their ability to access better neighbourhoods, regardless of economic background (Friedman et al., 2014).

Features of the neighbourhood itself, such as housing age and location within the central business district, may have also influenced whether neighbourhoods were attractive to higher income households. Some argued the recent trend of increased representation of middle- and upper-class households in central city neighbourhoods was partly due to the availability of older housing stock. Traditional research on housing age supported the 'filtering' model, which argued that housing increasingly devalued as it aged because higher income households were more likely to be attracted to newer housing (Brueckner and Rosenthal, 2009). Research by Rosenthal (2008: 819) questioned this assumption as findings showed housing values declined until buildings reached 'middle-age,' which ranged from 10 to 39 years old. Upon reaching the age of 40, however, housing stock became increasingly valuable. This may explain the reversal of interest in suburban housing to housing in urban areas among the upper classes as housing in suburban areas began to reach middle-age status during the 1970s.

The location of neighbourhoods in reference to the central business district (CBD) was also an important predictor of neighbourhood economic status. While housing values in CBDs were found to be higher (Glaeser et al., 2008; Massey and Denton, 1985), there was some debate as to the value of homes outside of this area. Brueckner and Rosenthal (2009) found neighbourhood socioeconomic status declined in areas surrounding the CBD, but then increased with distance from the CBD until a distance of 20 miles from the city centre, at which point socioeconomic status declined. In contrast, Haider and Miller (2000) found that housing values in Toronto declined as the distance to the CBD increased. Bowes and Ihlanfeldt (2001) offered a potential explanation for these divergent findings as they reported homeowners were willing to pay a premium for properties within a mile of a rail station in areas further from the city centre.

Previous research offered mixed findings concerning whether public transportation played a role in locational attainment. Some studies found that neighbourhoods with greater concentration of public transit were more attractive to lower income households because such households were less able to afford private transportation to their place of employment (Brueckner and Rosenthal, 2009; Giulano, 2005; Glaeser et al., 2008; TransitCenter, 2014). Other research, however, found neighbourhoods with greater presence of public transit were more attractive to higher income households due to greater access to employment opportunities, which was similar to lower-class households,

but also because these neighbourhoods tended to feature amenities such as bars, restaurants and shops (Duncan, 2011; Kahn, 2007; Taylor and Ong, 1995). There is also potential racial bias in transit access, which may impact its role on locational attainment. Research by McKenzie (2013) showed that race stratified presence of either buses or rapid transit, demonstrating that black and Hispanic poor tended to live in areas with less concentration of transit.

Not all transit options were created equally, however, which may help to explain the contradictory findings of previous research. Public transit can take multiple forms, but the two most common were bus and rapid transit like subway. Each of these transit methods holds different perceptions on the economic status of their riders. For example, buses were typically associated with lower-class residents due to slower travel times (Giulano, 2005; Taylor and Ong, 1995), while rapid transit systems was associated with higher wealth (Babalik-Sutcliffe, 2002; Bowes and Ihlanfeldt, 2001; McKenzie, 2013). Given differences in travel time, it is expected that median household incomes will be positively associated with concentrations of subway stops and negatively associated with concentrations of bus stops.

Current study

This study assessed whether the economic status of New York City neighbourhoods during the 2000s was influenced by the concentration of different forms of public transit. Focusing exclusively on New York City neighbourhoods has advantages and disadvantages. Advantages include the fact that New York City had one of the most extensive public transit systems in the world while also being characterised by dramatic economic inequality between neighbourhoods (Weinberg, 2011). In addition, focusing on one city allows a closer examination of the spatial dynamics of transit as it relates to neighbourhoods (McKenzie, 2014). Disadvantages to focusing on New York City relate to its potential uniqueness as the city consists of five counties, each with unique population features, as well as being one of the most densely populated cities in the United States. Three sets of analyses were conducted to explore the association of neighbourhood socio-economic status with the location of public transit: exploratory spatial data analysis (ESDA), cross-sectional regression and longitudinal random effects regressions.

Analytical strategy

The first set of analyses consisted of ESDA analysis, including Local Indicators of Spatial Autocorrelation (LISA) analysis. Based on the Moran's I statistic, this analysis employed a spatial weights matrix to determine if a variable, like high levels of income in a census tract, was spatially dependent. This allowed for the identification of statistically significant clusters ($P >= 0.01$) of high median household income neighbourhoods (HH), low median household income neighbourhoods (LL), as well as HH bus stops, and HH subway stops in 2000 and 2010 (Anselin, 1995). These HH and LL clusters identified neighbourhoods where high or low concentrations of a variable like median household income were statistically significant due to the influence of other local spatial factors. As Sampson (2012) observed, the kind of spatial clustering identified through ESDA is an inflection of the neighbourhood effect – the tendency of certain variables of advantage or disadvantage to cluster in neighbourhoods. It is important to note that HH clusters, such as HH income, were not likely to be the only places characterised by high income or even to necessarily identify neighbourhoods with the highest

income levels. Instead, this method identifies neighbourhoods where high incomes were the product of local neighbourhood forces converging to produce bias in income across neighbourhoods.

Next, we assessed the relationship of bus and subway stops with median household income in census tracts with cross-sectional and longitudinal regressions for 2000 and 2010 to demonstrate how the results of the current study related to prior research. Hybrid fixed-effects and random effects regressions were assessed for the longitudinal models to control for unmeasurable factors that potentially influenced variation in median household income in neighbourhoods over time. Regression of hybrid fixed effects were assessed rather than conventional fixed effects, to account for lack of variation in subway stops per square mile during the study period (Allison, 2005). Results of the 'contrasts' test in SAS indicated that random effects regressions were preferable. Random effects regression models use multiple cross-sections of data to analyze variation within and between units of analysis over time. While not able to control for unmeasured variable bias in the way fixed effects regression would, random effects regression was an improvement over OLS regression because the standard error estimates adjust for the within-unit correlation that occurs with repeated measurements in longitudinal research (Allison, 2005; Bowes and Ihlanfeldt, 2001).

Data and units of analysis

Demographic data were collected from the Longitudinal Tract Database (LTDB), a repository of tract level Census and American Community Survey (ACS) data maintained by the US2010 Project (2013). The LTDB adjusted for tract boundary changes by standardising data from prior years to Census 2010 tract boundaries. The analyses in the current study drew primarily from the Census Summary File 1 (SF1) for 2000 and 2010, from which count information for racial characteristics and population per square mile were collected. Additional data from the Census 2000 Summary File 3 (SF3) and the 2006–2010 ACS were used to obtain information on neighbourhood socio-economic status.

Dependent variables

The primary question addressed in this study was whether differential concentrations of subway and bus lines, as measured by the number of stops per square mile, were associated with neighbourhood median household income. The dependent variable for the cross-sectional and random effects regressions was median household income per tract. This study builds upon Glaeser et al. (2008) by also exploring the relationship of transit with median household income in the densely populated borough of Manhattan and the more suburban borough of Staten Island[2] so that the entire population of New York City could be studied.

Location of transit variables

The location of subway entrances for the entire period and for bus stops for 2010 were downloaded from Spatiality, a blog maintained by the Director of Mapping Services at the Center for Urban Research at the CUNY Graduate Center (Romalewski, 2010).[3] Information on the location of bus stops for the year 2000 was unavailable, so the location of bus stops in 1998 was used as a proxy as was done by Rundle et al. (2007). This data was collected and shared by the staff of a civil engineering company, CH2MHill (2013).[4] Similar to Rundle et al. (2007: 326), who used tract level data from New York City to assess the relationship of the density of bus stops and subway stations

per kilometer to measure transit concentration, transit concentration measures were created by aggregating the number of stops in a census tract and dividing by the area of the tract to determine standardised measures of bus stops and subway stops per square mile. This was used instead of a distance to transit line measure such as that used by Glaeser et al. (2008) or Hess and Tangerine (2007) because the high population per square mile of New York City resulted in census tracts covering small geographic areas. Additionally, supplemental analyses indicated that the high percent of commuters who used public transit to commute to work made population-based measures of access such as that used by Brueckner and Rosenthal (2009) impractical. A key limitation of the measure used for this study was that it could not directly account for the accessibility of transit within a tract (McKenzie, 2014). Other forms of transit, such as regional rail, were not included in this study due to the low number of stops per tract.

Control variables

In addition to assessing the importance of the concentration of bus and subway stops, the analyses controlled for frequently used predictors of locational attainment including population per square mile, percent college educated,[5] percent married and percent renter (Friedman et al., 2014). Racial segregation was measured through the entropy index, a multi-group measure of segregation, and was used to determine how evenly whites, blacks, Latinos and Asians were distributed for each census year (Iceland, 2004). The entropy index was calculated, and spatially decompiled, with the Geo-Segregation Analyzer tool (Apparicio et al., 2013).[6] Analyses also controlled for the percent of occupied housing that was built 40 years or more prior to the start of the decennial census and a dichotomous measure of whether each tract was located within the CBD of Manhattan to capture the core high business areas of the city.[7] Location in the CBD was used instead of distance from the CBD (Brueckner and Rosenthal, 2009; Glaeser et al., 2008) because the density of New York City made a distance-based measure impractical.[8] A spatially lagged version of the dependent variable was included in the cross-sectional and longitudinal analysis to account for the spatial autocorrelation of the dependent variable (Ward and Gleditsch, 2008). Finally, this study included a dichotomy for the year 2010 (1 = 2010; 0 = 2000) to control for un-modeled changes in income between census years (Allison, 2005).

Results

Descriptive results

Table 1 provides descriptive statistics. The median household income for the average tract increased by about US$2400 between 2000 and 2010. The average tract contained about 50 bus stations per square mile in 2000 and experienced a small increase in the number of bus stations per square mile to about 56 in 2010. Subway entrances were not evenly distributed throughout the city as the standard deviation for the number of subway stops per square mile (7.585) was more than double the mean (3.047). The population per square mile in the average tract increased by about 750 people during the 2000s. The mean percent of college-educated residents increased by roughly four percent between 2000 and 2010. The majority of New Yorkers were renters, but the average tract experienced a decline of about five percent between 2000 and 2010. The Housing 40 Years or Older variable indicates that the average tract experienced an increase of about three percent in regards to the percent of buildings in this age range. The CBD of Manhattan consisted of a little

Table 1. Summary of transit and control variables.

Year	2000		2010
Median Household Income[9]	$52,571.90		$54,985.15
	(24,173.40)		(26,289.84)
Bus Stops Per Square Mile	49.771		56.175
	(37.654)		(43.860)
Sub Stops Per Square Mile		3.047	
		(7.585)	
Population Per Square Mile	49,980.472		50,730.151
	(35,432.197)		(34,857.336)
College Educated	17.370%		21.859%
	(15.136)		(16.262)
Married	35.335%		33.808%
	(9.584)		(10.801)
Renters	61.516%		56.591%
	(22.444)		23.733
Housing 40 Years or Older	83.295%		87.655%
	(16.436)		(14.766)
Entropy Index	0.571		0.607
	(0.213)		(0.193)
CBD Location		8.686%	
		(28.023)	

Notes: Standard deviation in parentheses.
N = 2073 Census Tracts.

more than eight percent of the city's census tracts. Finally, descriptive statistics for the entropy index identified a moderate amount of segregation at each time.

Exploratory Spatial Data Analysis

Exploratory Spatial Data Analysis in the form of LISA analysis was utilised to interpret the relation of transit to neighbourhood median household income. The LISA analysis allowed for the visual assessment of spatial patterns of transit stops, income and poverty. Comparison of the change of location for HH and LL tracts of income between 2000 (Figure 1) and 2010 (Figure 2) identified an economic divide among the neighbourhoods of New York City. Notably, HH income clusters became more consolidated in northwestern Brooklyn and southern Manhattan. Meanwhile, in 2010 the LL income tracts largely remained concentrated around preexisting LL income areas from 2000, including the South Bronx, Northern Manhattan and Brooklyn. These findings suggest not only an enduring bias between where wealthy and poor neighbourhoods could be found in New York, but also that their endurance was due to neighbourhood effects, like poverty concentration.

The ESDA results are less certain as to the relation of HH or LL clusters of income with clusters of bus stops and subway stops. First, it is important to note that the location of HH bus stop clusters only changed slightly between time points while the HH tracts of subway stops did not change at all. On the one hand, there were some instances of overlap with HH income and transit. This was most notable in lower Manhattan and northwestern Brooklyn, a correspondence that was stronger in 2010. This may indicate that affluence moved toward public transit areas, while poverty remained separated

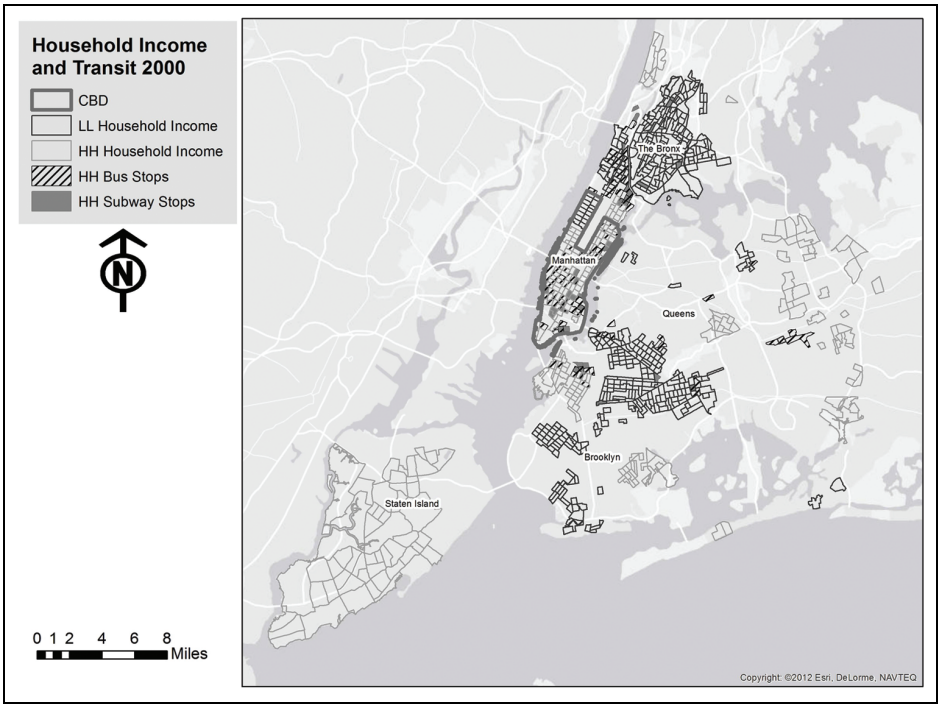

Figure 1. Household income and transit 2000

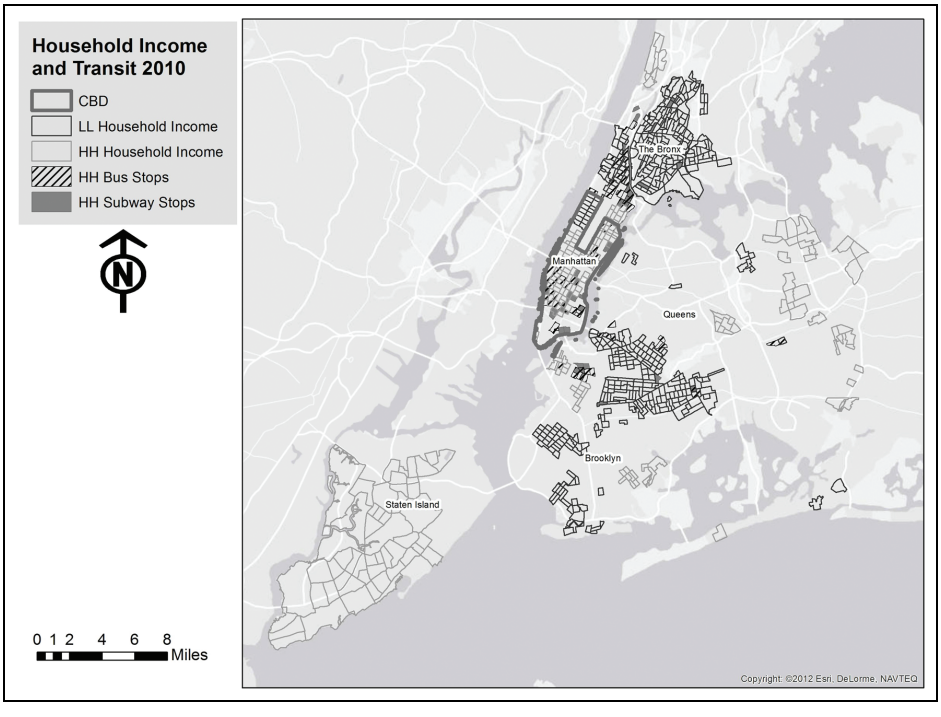

Figure 2. Household income and transit 2010

Table 2. Cross sectional spatial lag models of median household income.

	2000	2010
	1	2
Spatial Lag of Median Household Income	0.612**	0.525***
	(0.026)	(0.027)
Bus Stops Per Square Mile	3.423	22.695*
	(9.727)	(9.730)
Subway Stops Per Square Mile	205.039***	250.611***
	(47.666)	(54.959)
Population Per Square Mile	–0.061***	–0.064***
	(0.012)	(0.014)
College Educated	286.030***	369.938***
	(36.272)	(35.582)
Married	122.976*	48.765
	(47.662)	(45.974)
Renters	–170.203***	–221.340***
	(23.813)	(25.064)
Housing 40 Years or Older	18.187	–42.737
	(21.274)	(26.884)
Entropy Index	–4534.160*	–3034.931
	(1731.071)	(2108.377)
Central Business District	3486.776	2969.680
	(1878.115)	(2034.845)
Constant	24,660.377***	35,488.599***
	(3202.361)	(3632.235)
R2	0.589	0.555
N = 2073		

*p < 0.05; ** p < 0.01; ***p < 0.001, Standard Errors in parentheses.
Note: Income not adjusted for inflation.

from these places. These results do not, however, make it certain that there was a relationship between transit and high income in neighbourhoods. There were a few neighbourhoods where low income and transit overlapped, such as in northern Manhattan. In addition, these results do not directly account for the changing location of high and low income neighbourhoods, nor do they control for other relevant factors that may matter, such as educational attainment. These issues are explored further in the multivariate analyses.

Cross-sectional results

Results of the cross-sectional models for 2000 and 2010 are presented in Table 2. Overall, these results suggest a connection between both bus stops and subway stops and higher income in neighbourhoods. In both periods, the subway concentration measure featured a significant and positive relationship with neighbourhood median household income. For example, in Model 2 each unit increase of the rate of subway stops per square mile raised the median household income in a tract by US$205.03***. Meanwhile, the rate of bus stops per square mile is not significant in Model 1, but is significant in Model 2; each unit increase of bus stops was associated with an increase in neighbourhood median household income of a tract by US$22.69*. These results suggest that Glaser et al.'s (2008) finding that the poor were more likely to live in transit rich

neighbourhoods did not extend to all five boroughs of New York City. On the contrary, the cross-sectional evidence suggests that the transit bias favoring the wealthy grew over the past decade.

Turning to the socio-economic variables, results indicate similar patterns to those in the literature on locational attainment (Alba and Logan, 1991; Friedman et al., 2014; Logan et al., 1996). As identified in Model 1, each increase in the percent college-educated resulted in an increase of US$286.03*** and each increase in the percent married was associated within an increase in median household income of US$122.97*. Meanwhile, each increase in the percent renter was associated with a decline in median household income of US$170.20***. An unexpected finding was the lack of significance for percent married in Model 2. These changes may reflect larger developments that took place in New York City over the 2000s. The lack of significance of CBD location was also interesting, but likely a product of the uniquely dense concentration of New York City beyond its CBD. Regardless, the cross-sectional results show a clear relation between neighbourhood characteristics and neighbourhood median household income.

Longitudinal analyses

Random effects regressions were assessed to determine whether the overall association of transit concentration over time was an important predictor of neighbourhood median household incomes. The results presented in Table 3 emphasise how changes in

Table 3. Random effects regression of median household income.

	3	4	5
Year 2010 Dichotomy	2413.25***	2344.37***	–1111.58**
	(299.26)	(305.81)	(361.600)
Bus Stops Per Square Mile	-	10.75	12.87
		(9.873)	(7.685)
Subway Stops Per Square Mile	-	31.44	212.78***
		(71.808)	(46.717)
Population Per Square Mile	-	-	–0.06***
			(0.011)
College Educated	-	-	350.70***
			(28.072)
Married	-	-	129.57***
			(33.463)
Renter	-	-	–207.64***
			(19.004)
Housing 40 Years or Older	-	-	–10.02
			(17.013)
Entropy Index	-	-	–3022.48*
			(1527.440)
Central Business District	-	-	4865.59**
			(1674.960)
Spatial Lag of Income	-	-	0.49***
			(0.021)
Constant	52,572.00***	51,941.00***	32,524.00***
	(554.66)	(745.38)	(2611.410)

N = 4146 (2073 Census Tracts with two time points each).

***p > 0.001; **p > 0.01; *p > 0.05, Standard Errors in parentheses. *Note:* Income adjusted to 2010 dollars.

other measures of neighbourhood social status were associated with changes in median household income for neighbourhoods. To account for the influence of the economic recession on the distribution of household incomes during the second half of the decade, Model 3 assessed whether income levels in tracts for 2010 were significantly different from that of 2000. Contrary to expectations, the significant positive coefficient (2413.25***) indicates that the neighbourhood median household income in the average tract was significantly higher in 2010 than 2000. Given the significance of the Year 2010 dichotomy, the remaining models controlled for time to determine if changes in neighbourhood median household income were associated with the predictor variables or simply the result of an increase over time.

Results of the cross-sectional analyses contradicted previous research that found bus routes were more prevalent in neighbourhoods characterised by lower income levels (Giulano, 2005; Taylor and Ong, 1995), but supported research that found household incomes were higher in neighbourhoods characterised by concentrations of subway (Babalik-Sutcliffe, 2002; Bowes and Ihlanfeldt, 2001; McKenzie, 2013). In contrast, results in Model 4 indicate that concentration of bus and subway stops was not significantly associated with changes in neighbourhood median household income over time. This suggests that areas characterised by greater access to public transit were more likely to feature higher incomes at each time point, but that access to transit was not an important contributor for the growing economic divide in New York City highlighted by Reichl (2007) and Weinberg (2011).

Model 5 regressed neighbourhood median household income on the Year 2010 dichotomy, the measures of transit and the control variables for each time. The most striking result is the coefficient for the dichotomous measure of time, which was positive and significant in the previous models, but was negative and significant after the inclusion of the other variables. This indicates that the average tract experienced a decline in neighbourhood median household income between 2000 and 2010 after controlling for changes in other neighbourhood characteristics. The results in Model 5 also indicate that tracts that gained in population per square mile, the percent renters, and became more racially integrated were more likely to experience declines in neighbourhood median household income. Tracts were more likely to experience an increase in median household income if they saw gains in the percent college educated, percent married and were located in the CBD, shared a border with a tract that also experienced an increase in median household income and featured greater subway concentration. The significance of the subway measure in Model 5 was likely connected to larger changes which took place in these neighbourhoods over the 2000s.

Overall, results of the longitudinal analyses tell a different story from those of the cross-sectional results. While results of cross-sectional analyses supported the findings of previous research that found an association between concentration of transit and income levels in a neighbourhood, the longitudinal analyses conducted indicate that changes in neighbourhood median household income over time were largely the result of changes in neighbourhood characteristics other than concentration of public transit. The importance of the contradictory results is explored in the next section.

Discussion and conclusion

As noted by Berube and Kneebone (2011: 5), the number of impoverished neighbourhoods in the United States increased by about one-third during the 2000s. While the

majority of this growth in concentrated poverty took place in suburban areas (McKenzie, 2014), this trend was also visible in urban centres such as New York City, which became increasingly divided by high income or low income earning neighbourhoods (Reichl, 2007; Weinberg, 2011). While past locational attainment literature utilised various types of neighbourhood characteristics to understand the differences in neighbourhood attainment, including socio-economic status and race/ethnicity character of the residents (Alba and Logan, 1991; Friedman et al., 2014; Logan et al., 1996), there were comparatively few studies that sought to predict neighbourhood income more generally. To this end, transit was a highly useful measure as research demonstrated that different types of public transit appealed to different populations. Bussing, for example, was argued to attract lower income populations to neighbourhoods (Giulano, 2005; Taylor and Ong, 1995), while rapid transit, such as the subway, was argued to attract higher income peoples (Babalik-Sutcliffe, 2002; Bowes and Ihlanfeldt, 2001; McKenzie, 2013). Further, Glaeser et al. (2008) suggested that the poor were concentrated in cities because the greater availability of public transit allowed easier commutes to jobs without relying on cars. This study assessed whether median household income across New York City neighbourhoods was influenced by the concentration of different forms of public transit stops; it expands upon previous research by conducting random effects analyses and exploratory spatial data analysis to determine how the relation of transit and income in neighbourhoods varied over space and time.

The results indicate that public transit was differentially associated with variation in neighbourhood median household incomes, but not necessarily in the expected fashion. Results of cross-sectional analyses found that concentration of subway stops predicted higher income residents for both 2000 and 2010, while bus stop concentration predicted higher income residents in 2010. This suggests that the findings of previous research wherein the poor were more likely to be drawn to transit-rich areas are not generalisable to all places. The longitudinal results offer more subtext to the cross-sectional results, showing that when accounting for change over time, only subway stops predict higher income – but only after controlling for socio-economic status and un-modeled factor changes which took place between 2000 and 2010. This suggests the role of transit, either buses or subway, was likely secondary to other larger processes taking place in New York during this time, including the great recession.

Overall, these findings support the locational attainment literature's presumptions about neighbourhood conditions and socio-economic status (Alba and Logan, 1991; Friedman et al., 2014; Logan et al., 1996). In keeping with that literature, the results of the current study indicate that superior socio-economic status predicted the location of high-income neighbourhoods. While this study did not directly assess the influence of race, the association of racial heterogeneity with low-income communities suggests that racially mixed communities suffered from more income disadvantage. As far as public transit was concerned, these findings demonstrate that lower income households may have been pushed to neighbourhoods further from transit sources that would facilitate commuting to work. Similar to empirical research on the association of gentrification and displacement (Pollack et al., 2010: 3), this study did not find a direct relation between the placement of a new transit stop and the displacement of nonwhites. This issue should be explored further.

While this study makes important contributions, it has a few notable limitations.

First, the analytical strategy used did not allow for the determination of why median household incomes were more likely to increase in neighbourhoods that featured greater concentrations of subway stops. It might be that transit concentration was associated with employment opportunities or it may be that the recession during the second half of the 2000s encouraged upwardly mobile households to relocate to areas characterised by greater concentrations of low cost public transit, which potentially displaced lower-class households (Chappel, 2009; Pollack et al., 2010). This study did not, however, have sufficient data to confirm either speculation. Second, this study was unable to directly measure employment opportunities due to its focus on neighbourhoods within a city as opposed to metropolitan statistical areas, where such data would be available. Third, while these findings suggest the negative role racial segregation carries on transit location, future studies should more closely examine the role different racial and ethnic compositions carry on transit location over time. For instance, does the influence of transit on neighbourhoods over time differ significantly between neighbourhoods that are predominantly black compared to those which are predominantly white? Fourth, while the economic division and proliferation of transit in New York City made it an ideal case for this study, future research should examine the nuances in this association by borough or neighbourhood to determine the generalisability of these results. Further, while many consider Staten Island and Eastern Queens to be 'suburban' in character, future research should explore the association of transit and neighbourhood household income in suburban areas given that they have experienced greater increases in concentrated poverty (McKenzie, 2014).

Regardless of the limitations of this study, the results carry some notable implications to our understanding of urban economic inequality. It would appear that polarisation of incomes in New York City identified by Reichl (2007) during the 1990s continued and may have been fueled by efforts to rebound from the economic recession of the late 2000s. Public transit, which has been viewed by some as a means to help the poor (Glaeser et al., 2008; see also Brueckner and Rosenthal, 2009), may have ironically pushed them away, thus hindering the transit options of many poor households. This has reverberations to job access, as well as other resources. Future policy efforts should develop strategies to better accommodate transportation for neighbourhoods in need.

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Notes

1. Glaeser et al.'s (2008) study excluded Staten Island and Manhattan because they are potentially very different from the other boroughs.
2. While neighbourhoods in Staten Island do not have 'subway stops' in the way the other boroughs do, the Metropolitan Transit Authority recognised the Staten Island Railway as part of the New York City Subway system.
3. Stops were located within census tracts.
4. The file provided by CH2MHill counted stops on both sides of streets. To address this only one stop from each pair in the CH2MHill file was counted.
5. This measure includes those with a Bachelor's degree or greater.
6. Separate variables for each racial/ethnic group were considered, but the high levels of collinearity between some racial groups and socio-economic characteristics prevented their inclusion in the models.
7. The Manhattan CBD, also known as the 'Manhattan Core' is defined by the New

York City Department of Planning (available at: http://www.nyc.gov/html/dcp/html/zone/glossary.shtml, accessed 29 May 2015).
8. Unshown analyses indicated that distance from the CBD was not significant.
9. Not adjusted for inflation.

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