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Does demand lead supply? Gentrifiers and developers in the sequence of gentrification, New York City 2009–2016

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Abstract

Consumption-side theorists of gentrification examine the flow of middle-class White people into previously working-class neighbourhoods and argue that their demand for housing stimulates gentrification. In contrast, production-side theorists emphasise the movement of capital into previously disinvested neighbourhoods and contend that profit-seeking development increases property values and sparks gentrification. Hybrid theorists argue that consumption and production occur simultaneously. This article operationalises arguments made by each approach, and asks: Do gentrifiers precede rising home values or do rising home values precede gentrifiers? To answer this question of sequence, we build a dataset of census and property tax assessment data for 2192 New York City census tracts between 2009 and 2016. Using cross-lagged regression models with tract and year fixed effects, we find neighbourhoods that experienced an increase in White, middle-class residents had related housing price spikes in each of the subsequent two years. A 1% increase in gentrifiers was associated with a subsequent 2.7% increase in property values. However, housing market growth did not predict future increases in gentrifiers. This suggests that consumption leads production during neighbourhood gentrification, and that developers are reactive, not proactive, in their investment decisions. Focusing on the sequence of gentrification's subsidiary elements enables city officials, non-profits and social movements to better anticipate gentrification and develop more targeted policies.

Keywords

gentrification, housing, longitudinal methods, property tax assessment data, real estate investment

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摘要

关于绅士化的消费学派理论家考察中产阶级白人向以前的工人阶级街区的流动，认为他们对住房的需求刺激了绅士化。相比之下，生产学派的理论家强调资本向过往投资缩减的街区流动，并认为追求利润的开发增加了房地产价值，引发了绅士化。混合理论家认为消费和生产同时发生。本文对每种方法的论点进行了操作化，并提出了这样的问题：绅士化人群的出现先于房价上涨，还是房价上涨先于绅士化人群的出现？为了回答这个顺序问题，我们为2009年至2016年间的2192个纽约市人口普查区建立了一个人口普查和物业税征收数据集。我们使用具有区域和年份固定效应的交叉滞后回归模型，发现白人中产阶级居民增加的街区在随后的两年中每年都有相关的房价上涨。绅士化人群的1%增加与随之而来的房价2.7%上涨相关。然而，住房市场的增长并没有预测绅士化人群的未来增长。这表明，在街区的绅士化过程中，消费导致生产，开发商在投资决策中是反应性的，而不是主动的。关注绅士化的附属因素的顺序，使城市官员、非营利组织和社会运动能够更好地预测绅士化，并制定更有针对性的政策。

关键词

绅士化、住房、纵向方法、财产税征收数据、房地产投资

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Introduction

In the 1980s, gentrification scholars were divided into two schools of thought: one stressed gentrification's consumption dynamics, and one its production elements. The former emphasised the role of new middle-class residents in initiating gentrification with their retail and housing demands. By their account, wealthy, credentialed, usually White gentrifiers moved into previously poor and working-class neighbourhoods, thereby driving up housing prices (Ley, 1996: 19; Zukin, 1989). Production theorists emphasised how landlords and real estate developers initiate gentrification by changing the supply of housing. Investors seek profit in previously disinvested neighbourhoods by 'redeveloping' them. Real estate elites buy properties, evict long-term tenants, renovate old units and build new units to increase rents and attract wealthier tenants (Hackworth, 2002; Hammel, 1999; Smith, 1979).

Today, after several decades of gentrification research, the consumption–production dichotomy is often resolved by synthesising the two theories. A group we call 'hybridists' argue that 'gentrification involves both a change in the social composition of an area and its residents, and change in the nature of the housing stock' (Hamnett, 1991: 176). Exclusive supply-side or demand-side explanations describe different aspects of the same phenomenon the way the blind men in Aesop's fable each touched a different part of an elephant and failed to grasp its whole (Hamnett, 1991). Embodying this approach, Hwang and Sampson (2014: 728, emphasis added) argue that the 'social processes of neighbourhood selection interact with political and economic forces to *simultaneously* shape both the supply and demand for potential neighbourhood reinvestment'. Hybridists see consumption and production dynamics as conterminously shaping one another, and call for the integration of research on middle-class demand and developer investment.

This hybrid explanation is appealing. No one wants to describe a rope when they are holding an elephant's tail. What's more,

both demographic and economic changes are readily observable during gentrification. Yet, hybridists set aside an important question about the consumption and production of gentrification: which comes first? Do the gentry move into a neighbourhood and *then* housing investment spikes, or is the reverse true? The present study seeks to reveal gentrification's leading edge by sequencing its subsidiary elements. We collect data from New York City between 2009 and 2016 and model supply- and demand-side dynamics in longitudinal, cross-lagged regressions to gauge whether a neighbourhood's new residents predict future property value increases or vice versa, or whether they occur simultaneously.

Understanding the sequence of gentrification enables city officials, non-profits and social movements to anticipate gentrification and develop more targeted solutions to address housing unaffordability. Our project answers the Urban Institute's call to develop better early warning systems that can anticipate gentrification by providing a method with 'more current and frequently updated data that cover a broad range of indicators' (Greene and Pettit, 2016: 7). To this end, we use New York City property tax assessment data to capture housing market change at a more granular level and with more frequent measurement than the typical measures of home price that use census or sales data. New York City's active housing market, pronounced gentrification, demographic diversity and large sample of neighbourhoods make it a useful research site for developing this tool. Municipalities around the world can apply our flexible methodology to identify early signs of gentrification in their cities and develop more targeted policy and action.

Theories and research on the sequence of gentrification

Consumption-side explanations of gentrification emphasise how the flow of middle-class, often White professionals into previously working-class and poor neighbourhoods precipitates housing price growth. Ley (2003: 2541) argued that the cultural status of early gentrifiers 'brings followers richer in economic capital'. He emphasised how middle-class 'pioneers' lead reinvestment because their housing consumption represents a 'demand base for housing re-investment in the inner city' (Ley, 1986: 532). Increases in home value are then a *consequence* of the demands for housing by 'small middle-class households' (Ley, 1996: 23). Zukin (1989) traced a similar pattern in lower Manhattan in the 1970s, where gentrification was sparked by new residents with cultural capital. Middle-class professionals and artists presided over the early stages of gentrification, but then 'real estate development reassert[ed] its dominance over the arts economy' (Zukin, 1989: 121).

Empirical research supporting consumer-led explanations of gentrification has focused on the consumption patterns and the race of gentrifiers. Such research has not explicitly examined gentrification's sequence, but has instead assumed that demand leads supply (Cameron and Coaffee, 2005; Zukin, 2010). In one quantitative study, Galster and Tatian (2009) estimated models to predict when housing price appreciation starts in disadvantaged neighbourhoods. They found that an influx of better-off home buyers was a key predictor of rising housing prices (Galster and Tatian, 2009). However, they did not model the inverse: whether housing price appreciation predicts future gentrifiers.

This literature has not agreed on the role of race in gentrification (Brown-Saracino, 2017). Many quantitative scholars have found that in-moving gentrifiers are likely to be White (Baum-Snow and Hartley, 2017; Ellen et al., 2019; Freeman, 2005; McKinnish et al., 2010). Other researchers have noted that middle-class Black people also participate in gentrification (Bostic and

Martin, 2003; Pattillo, 2008). Yet other researchers have focused more exclusively on gentrifiers' class (Landis, 2015; Vigdor, 2002). Some studies have found that a neighbourhood's preexisting racial composition shapes the likelihood that it will gentrify (Hwang and Sampson, 2014; Timberlake and Johns-Wolfe, 2017). The demand-side literature is clear, however, that no matter the race of gentrifiers, they precede supply-side forces during gentrification.

Unsatisfied with 'consumer sovereignty' explanations of gentrification, production-side theorists have emphasised capital's role in producing gentrification (Smith, 1979: 538; 1996). Such theorists describe how landlords and developers reinvest in neighbourhoods with the highest potential rate of profit (Stein, 2019). As Smith (1979: 547; 1996) wrote, 'gentrification is a back-to-the-city movement all right, but of capital rather than people'. Lees and colleagues (2016: 87) echo this sentiment, writing that, 'planetary gentrification is a capital-led colonisation of urban space related to globalisation and neoliberalization'. Supply-side proponents see 'banks, real estate developers, small-scale and large-scale lenders, retail corporations, [and] the state, [as having] generally gone before' new residents (Smith, 1996: xvii). This includes state-led gentrification where 'government involvement signals to the market that it is safe to proceed' (Chapple and Loukaitou-Sideris, 2019: 47), and new-build gentrification that includes new construction led by large corporate developers. In short, production-side theorists expect developers to be active pioneers, not passive reactors to gentrifiers.

Empirical investigations into production-side explanations document how capital speculation spurs gentrification. Studying Swiss cities using mixed methods, Rérat et al. (2010b: 440) found that new housing construction best explained middle- and upper-class attraction to core cities, and argued that 'new-build gentrification in Switzerland is a process led by capital'. Qualitative research in this vein sometimes finds that state and private actors work together to push investment into neighbourhoods, upscale those areas and return profits to developers. For example, Schaffer and Smith (1986: 362) documented how private capital and city officials redeveloped and renovated dilapidated and abandoned buildings in Harlem, New York City, preceding a major influx of rich, White outsiders. Other research has shown that zoning policies, lending practices and targeted federal expenditures are often used to reinforce supply-side logic: rezone, invest and convert (Hackworth, 2002; Hackworth and Smith, 2001; Wyly and Hammel, 1999). Qualitative research has illuminated the profit seeking that has sometimes spurred gentrification. The present study aims to more quantitatively test those observations.

Hybrid theories of gentrification resolve the supply versus demand debate by either arguing that both occur simultaneously or by setting aside the debate to study other aspects. They do not try to resolve the debate, but rather argue that 'both production and consumption processes are important in explaining gentrification' (Hyra, 2017: 12). They contend that these explanations are 'complementary rather than competing' (Hamnett, 1991: 175), and that gentrification 'result[s] from both flows of capital and people' (Zuk et al., 2015: 13). Schlichtman and colleagues (2017: 27) think that any one-sided claims to resolve this debate belong in graduate student theory seminars because 'these phenomena are concomitant'. Other hybrid researchers like Ingrid Gould Ellen (2011: 3) are 'agnostic about underlying causes' and examine both elements. Similarly, Slater (2012: 575) sets aside the debate altogether, writing that it 'does not matter whether production or consumption is viewed as more important in

driving gentrification, so long as neither is completely ignored'.

Much of the hybridists' empirical research has assumed the simultaneity of consumption and production without modelling the question of sequence explicitly. For instance, Hwang and Sampson (2014) and Timberlake and Johns-Wolfe (2017) simultaneously measure the supply- and demand-side dynamics of gentrification, and make important contributions to our understanding of how gentrification can occur along racial lines, but they do not to identify whether it is property value increases or gentrifiers that spark the process. Lance Freeman (2005) developed a method for identifying gentrified neighbourhoods that uses both supply- and demand-side forces, though he does not speak to sequence. Using methods from computer science, Torrens and Nara (2007) run simulations that simultaneously model supply and demand to account for human behaviour in relocation dynamics. However, these hybridists do not examine which mechanism has stronger or prior predictive power. Our research tests which mechanism leads the other so as to better understand whose decisions (developers or gentrifiers) matter most in sparking gentrification.

The hybrid theory of gentrification expects that non-occupant landlords will invest in a neighbourhood as renting gentrifiers move in. It also anticipates a distinct case where a gentrifier buys a home in a new neighbourhood to live in, simultaneously changing the area's demographics and investing capital there (Hamnett, 2003; Schlichtman et al., 2017). These two scenarios might not co-occur, as rental and homeownership markets can move separately (Skaburskis and Moos, 2008). Supply-side theorists often focus on non-occupant property owners. Demand-side explanations generally consider both owner-occupants and renters to be potential gentrifiers. Regarding sequence, the hybrid theorists' approach most directly accounts for owner-occupant gentrifiers, as they simultaneously change supply *and* demand.

Research design: Data, methods and models

Our research site is New York City, measured annually between 2009 and 2016. The city had an active and tight housing market. It had strong rent regulations, 64% of its residents were renters and many of its residents lived in public housing (Gaumer and West, 2015; NYC Housing Authority, 2019). The population of New York at this time was diverse and included many immigrants. However, segregation remained high. During the Great Recession of 2007–2009, the federal government targeted the financial sector for relief, which stabilised New York City's large finance industry and economy and facilitated a quick recovery of the City's housing market. New York City is a useful place to study the sequence of gentrification because it provides a large sample of tracts, its housing market was uncommonly stable during this time and its status as a global city made it a prime destination for investment capital and gentrifiers alike. Gentrification trends are stark there (Hackworth, 2002; Zukin, 2010).

We use two samples of New York City census tracts to test gentrification's sequence. So as not to compare gentrifying neighbourhoods to those too wealthy or too recently developed to gentrify, the primary sample includes only tracts eligible for gentrification at the start of the period, 2009. Our tract eligibility criteria mirror those of Freeman (2005). Tracts were eligible for gentrification if in 2009 they had: (1) below-city-median household income and (2) below-city-median per cent of buildings constructed in the last 20 years, indicating disinvestment. The second sample includes tracts ineligible for gentrification based on the

same criteria, and while not the focus of this study, can help us understand the dynamics of super-gentrification during which capital and the very wealthy move into middle-class neighbourhoods (Lees, 2003). We exclude 12 tracts that had fewer than 1000 people in 2009. Models including tracts with fewer than 1000 people and models including a simpler elgibility criteria (using only income and not recent construction) found substantively identical results to those below.

Employing listwise deletion to omit tracts with two or more years of missing data excluded 66 tract years from the eligible sample (2.6%) and 180 from the ineligible sample (2.0%). We use the terms 'tracts' and 'neighbourhoods' interchangeably. Since tract boundaries changed in 2010, we harmonised data from 2009 into 2010 boundaries using the Longitudinal Tract Database (Logan et al., 2014).

Dependent and explanatory variables

We measure production-side dynamics of gentrification using *residential property value*, a measure of each tract's median home value, as reported in the New York City Department of Finance's (DOF) property tax assessment database. We obtained tax assessment data for fiscal years 2009 to 2017 from the DOF website, selecting the 'market value: current full value total' variable, which represents the total property value before tax exemptions or deductions have been applied (NYC Department of Finance, 2018). We remove utility and commercial properties from the dataset, leaving residential properties. The DOF's fiscal year ends on 30 June. So, we convert the data to calendar years by attributing half of a property's value to one year and half to the previous.

To aggregate property-level data to the census tract level, we merged them with the Primary Land Use Tax Lot Output file, a dataset with housing unit characteristic information (NYC Department of City Planning, 2018). We used the condominium identification number to label individual condominiums, and counted each as a unit. We then took the median property value in each tract and inflation-adjusted it to 2016 dollars using the all-items-less-shelter Consumer Price Index for New York City's MSA (US Bureau of Labor Statistics, 2019). We use the less-shelter measure to avoid controlling away variation in our variable of interest, housing prices. We then averaged the median property value over five years to mirror the census data, which, as described below, are five-year estimates. This averaging technique also 'improv[es] precision in noisy data' (Ellen et al., 2019: 5, fn. 16). While this averaging means we cannot say with one-year specificity when, for instance, a particular spike in housing prices occurred, we can be sure we are comparing the housing spike to the complementary five-year estimate of gentrifiers. Since the distribution of the variable is strongly right skewed, we take its natural logarithm to induce normality.

Our use of tax assessment data raises a concern that our models will be slow to capture changes in the market. While some studies use sale price data to represent price changes more contemporaneously, there are too few home sales in most tracts to generate accurate measures at the neighbourhood level. In 2016, the average New York City tract eligible for gentrification saw 13 of its properties sold, or 0.8% of its stock, and 7% of tracts had zero transactions. Further degrading its reliability, sales data can include 'non-arms-length' transactions between family members for below-market-rate prices. Tax assessors can use their expertise to purge such transactions. So, tax assessment data are both more comprehensive and more accurate than sales data at the tract level. Additionally, New York City DOF assesses all new construction with an in-person appraiser and annually updates all

previous properties with hedonic regression modelling, incorporating the sale prices of neighbouring properties (Robert Rolandi, 2017, personal communication). Our measure therefore incorporates sale price data, although they will not appear until the next assessment update. By averaging these data across five years, we further mitigate against concerns that our data lag the market. We expect state-led gentrification initatives like rezonings and redevelopment projects to be captured by residential property values, as the housing market reflects the increased value created by the regulatory changes.

While the American Community Survey (ACS) is another possible source of home price data, its property value questions are only asked if a unit's occupants own the unit, which excludes the 64% of New York's units that are renter-occupied (Gaumer and West, 2015; US Census Bureau, 2016: 7). Survey-generated home price data is further degraded because homeowners often overestimate the value of their properties (Benítez-Silva et al., 2015). Cities in which tax assessment data are not updated annually or not publicly available might use ACS data when applying this method to their neighborhoods, but we use tax assessment data because they cover all properties and are not subject to occupant overestimation.

We create an *index of gentrifiers* to capture the consumption-side dynamics of gentrification. We use a factor analysis of four measures of a tracts' White, middle-class residents: the per cent with a college degree, the per cent non-Hispanic White, the per cent of managers or professionals and the tract's median household income. The index scale loaded on one factor (eigenvalue = 2.84). The components' factor loading scores were: per cent with a college degree 0.95, per cent non-Hispanic White 0.69, per cent managers or professionals 0.94 and median household income 0.77.

As we noted above, there is no consensus in the literature about whether or when to include race in a measure of gentrifiers. Following research finding that gentrifiers are mostly White, we include per cent White in our models (Baum-Snow and Hartley, 2017; Ellen et al., 2019; Freeman, 2005; McKinnish et al., 2010). White people often serve as 'signals of neighbourhood change to potential residents and investors' (Schlichtman et al., 2017: 116). So, for our study of gentrifiers and developers, we expect whiteness to be an important mechanism linking the two elements. Further, as the loading scores indicate, per cent White is highly correlated with the three economic variables, suggesting it belongs in the index and that including it as a control variable outside the index could cause problems of multicollinearity. Finally, a definition of gentrifiers that includes White people aligns with popular conceptions of gentrification in New York City during our study period, as evidenced by the language of media accounts, community-based organisations, elected officials and researchers (Make the Road, 2007; Stringer, 2018; Yee, 2015; Zukin, 2010). As a robustness check, we ran a version of the models omitting per cent White (Appendix Table model pairs 1 and 2), and found very similar results.

Control variables

As basic demographic controls, we include tracts'*total population* and their *per cent male*. While gentrifiers are not homogenous (Rérat et al., 2010a), we control for the share of tracts' population *aged 18 to 34*, given the higher mobility of young professionals (McKinnish et al., 2010; Moos, 2016). We include the *vacancy rate* and the *number of housing units* to control for neighbourhoods with more capacity to accept in-movers because of empty properties or recent construction (Rérat et al., 2010b). We also control for the *per cent of residents who moved in the previous year*, a measure of residential

instability. As public housing is less susceptible to gentrification, we control for the *per cent of public housing units*. The *housing unit* and *public housing* controls come from the tax assessment data, while the other controls come from the ACS's five-year estimates. We take the natural logarithm of all skewed variables – *housing units, vacancy rate, per cent public housing* and *per cent moved in the previous year* – to induce normality. The *year* variable controls for macro, sample-wide shifts like the Great Recession or city-wide policy changes. Table 1 reports descriptive statistics for each variable included in our models for 2009 and 2016, as well as the percentage change between.

Models and estimation

Our research design adapts Granger causality theory, which posits that one variable 'Granger causes' another if prior values of the explanatory variable have a significant effect on the dependent variable's later values, controlling for past values of the dependent variable (Granger, 1980). We set aside the question of whether this technique indicates causation, instead using it to indicate sequence. One variable *leads* another if its past values are significantly related to future values of the second variable, and not vice versa. We apply this design to gentrification by testing whether lagged values of the *index of gentrifiers* are associated with future *residential property value*. We then flip the two variables and test whether previous *residential property value* relates to future increases in *gentrifiers*. If previous values of one are statistically significant predictors of the other and not vice versa, or if both are statistically significant but the coefficient of one direction is greater than the coefficient in the inverse estimation, that would suggest one dynamic leads the other. If, however, the coefficients of both are statistically significant and similar in magnitude, that would indicate a more simultaneous sequence, supporting hybrid theory. This analytic strategy is sometimes called a reciprocal effects design, and resembles a cross-lagged model (Allison, 2009).

We make no a priori assumptions about whether gentrifiers are owner-occupants or renters. When gentrifiers are owner-occupants, we expect both outcome variables to change in tandem, supporting hybrid theory. When gentrifiers are renters, our method will capture when they move relative to property value fluctuations.

This design requires our estimation procedures control for past values of the outcome variable because gentrification's production and consumption dynamics are likely endogenous. Residential property values and influxes of gentrifiers likely positively influence each other in a reciprocal feedback loop. Since we are trying to identify the sequence and directional strength of the elements in this loop, we have to separate the relationship of the lagged explanatory variable to the outcome variable at time t from the contemporaneous relationship between the two at time t–1. We do this by including a lagged dependent variable as a predictor. We use Arellano and Bond (1991) first-difference, generalized method of moments (GMM) models because they generate efficient and consistent parameter estimates when including lagged dependent variables in datasets with many panels and few periods like ours. Such dynamic panel models can introduce bias through second-order autocorrelation (Wooldridge, 2016). So, we use the standard Arellano-Bond test for autocorrelation and find no models exhibit second-order autocorrelation.

Using a first difference estimator allows us to measure change over time. This procedure subtracts each observations' values from their previous year's value and uses the difference to compute the regression estimates. For the index of gentrifiers, this method distinguishes

Table 1. Descriptive statistics.

	Tracts eligible to gentrify				
	2009		2016		2009–2016
Variables	Mean	S.D.	Mean	S.D.	% change
Population	4346	2313	4395	2368	1.13%
% moved in previous year	10.26%	5.24%	9.49%	4.84%	−7.54%
% public housing units	5.54%	18.25%	5.32%	17.49%	−4.10%
% male	47.63%	4.78%	47.89%	4.11%	0.55%
% age 18–34	25.60%	5.75%	27.08%	6.20%	5.78%
Housing units	415.25	298.42	414.94	297.69	−0.07%
Vacancy rate	7.15%	4.38%	7.43%	3.81%	3.81%
Index of gentrifiers	2.46	0.50	2.63	0.58	6.95%
% with a bachelor's degree or higher	21.05%	10.06%	25.27%	11.66%	20.05%
% professionals and managers	26.12%	10.91%	29.08%	11.58%	11.34%
% non-Hispanic White	26.17%	28.35%	24.10%	25.76%	−7.89%
Median household income	US$40,732	US$9850	US$44,099	US$13,739	8.27%
Index of gentrifiers (class only)	2.45	0.48	2.64	0.56	7.65%
Median residential property value	US$694,784	US$614,400	US$763,489	US$1,193,375	9.89%
Total observations	422		425		
	Tracts ineligible to gentrify				
	2009		2016		2009–2016
Variables	Mean	S.D.	Mean	S.D.	% change
Population	3808	2013	3887	2000	2.07%
% moved in previous year	10.60%	6.44%	9.60%	5.72%	−9.44%
% public housing units	2.61%	10.49%	2.46%	9.95%	−5.72%
% male	47.96%	4.40%	47.91%	3.86%	−0.08%
% age 18–34	25.38%	7.65%	26.41%	7.83%	4.05%
Housing units	602.39	486.77	613.45	496.03	1.84%
Vacancy rate	8.01%	5.61%	8.45%	5.15%	5.53%

(continued)

Table 1. Continued

	Tracts eligible to gentrify					
	2009		2016			2009–2016
Variables	Mean	S.D.	Mean	S.D.		% change
Index of gentrifiers	3.03	0.94	3.16		0.98	4.38%
% with a bachelor's degree or higher	31.30%	19.53%	34.83%		20.14%	11.28%
% professionals and managers	35.98%	16.81%	38.59%		17.47%	7.26%
% non-Hispanic White	37.29%	32.78%	34.25%		30.43%	−8.15%
Median household income	US$64,769	US$27,834	US$64,642		US$28,826	−0.20%
Index of gentrifiers (class only)	3.02	0.93	3.17		0.97	4.95%
Median residential property value	US$964,050	US$1,294,124	US$1,100,956		US$1,798,709	14.20%
Total observations	1495		1496			

new tract residents from incumbents. Another advantage of the Arellano-Bond GMM estimator is that it allows for tract fixed effects. Fixed effects models demean variable values using the within-tract average by removing the tract average from each value. This controls for all time-invariant neighbourhood characteristics like land area size, unique history, transportation infrastructure and proximity to the centre city, assuming that they did not change during the study period (Allison, 2009).

Our dynamic panel models take the following forms:

$$y_{it} = \mu_t + \beta_1 y_{it-1} + \beta_2 x_{it-1} + z_{it-1} + \alpha_i + \varepsilon_{it}$$

$$x_{it} = \tau_t + \delta_1 x_{it-1} + \delta_2 y_{it-1} + z_{it-1} + \eta_i + \varepsilon_{it}$$

Where y_{it} is the first dependent variable (the logged *median residential property value* in tract i at time t), y_{it-1} is the lagged dependent variable in the first equation and the lagged explanatory variable in the second, x_{it} is the second outcome variable (the logged *index of gentrifiers*), x_{it-1} is the lagged dependent variable in the second equation and the lagged explanatory variable in the first, z_{it-1} represents the vector of lagged control variables, α_i and η_i are the tract-specific fixed effects and ε_{it} is the error term. We generate robust standard errors using a Huber/Whites/sandwich estimator.

Results

Figure 1 maps changes in median residential property values for eligible tracts. Tracts coloured white indicate missing data or areas ineligible to gentrify because of high income, recent housing construction or too few residents. The map shows in black where, between 2009 and 2016, home prices increased. Growth was concentrated in upper and lower Manhattan, large sections of Brooklyn and the west of Queens, while large

Figure 1. Change in median residential property values for eligible tracts, New York City 2009–2016.

sections of the Bronx, east Brooklyn and east Queens saw declines, indicated in grey.

Figure 2 maps changes in the index of gentrifiers for eligible tracts. As before, black indicates increase and grey decrease. Comparing Figures 1 and 2, we see that some of the tracts experiencing increases in home prices – much of northern and central Brooklyn and upper and lower Manhattan – also saw an influx of high-income, credentialed, White professionals. However, the trends are hardly identical. Some parts of south Brooklyn that saw increases in home prices saw a departure of gentrifiers, while large parts of the Bronx and eastern Brooklyn and Queens saw increases in gentrifiers but decreases in home prices.

With each map portraying the same time period, no strong conclusions can be drawn about whether demographics precede development or vice versa, but the varying spatial patterns raise doubts about the hybridists' claims that the two are mutually constitutive. Of course, we need to include co-

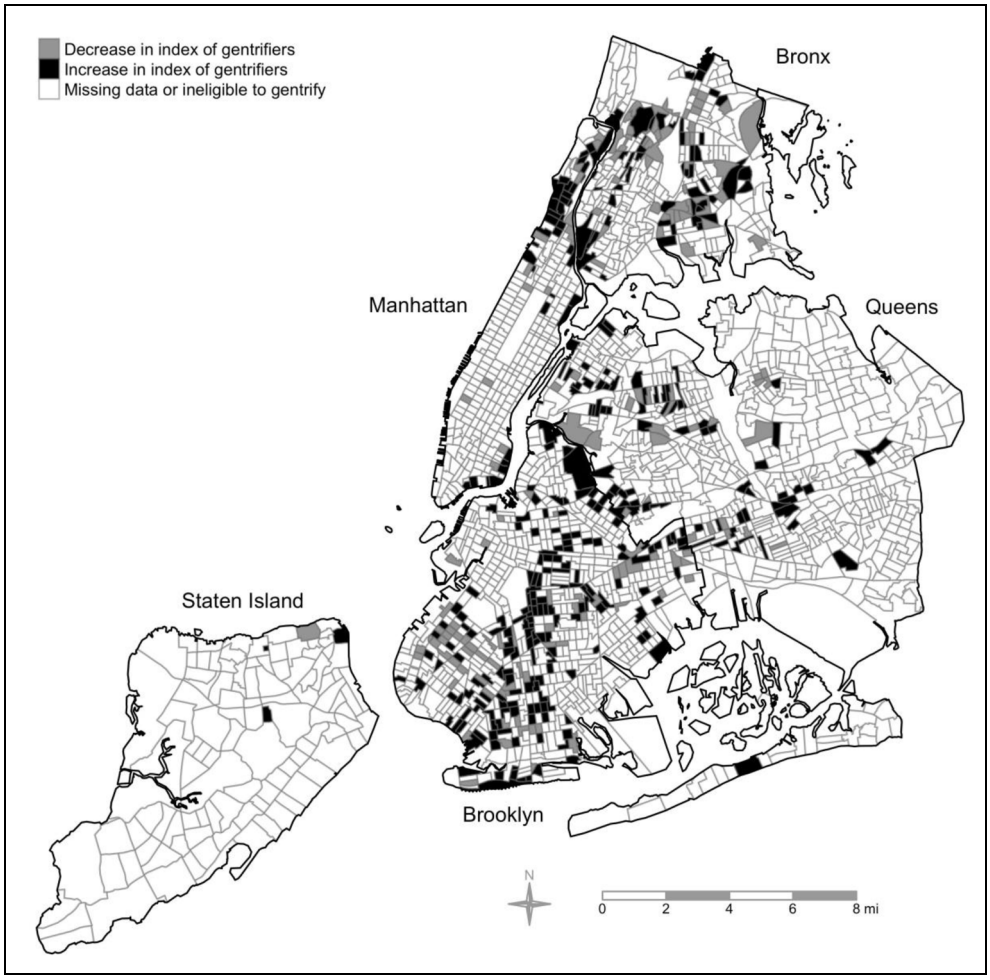

Figure 2. Change in index of gentrifiers, New York City 2009–2016.

variates and estimate the temporal sequence to know more. For that, we use multivariable modelling.

Table 2 presents the coefficients for our regression models. The reciprocal effects design is represented in the table by each model appearing in a pair. The first model in each pair regresses property values on the index of gentrifiers, on the lagged property value measure (the endogeneity control) and on the control variables. The second model in the pair then flips property values to be an explanatory variable and the index of gentrifiers to be the dependent variable and runs the same regression.

Model pair 1 finds that the average tract's gentrifier index score had a statistically significant relationship with its median property value in the following year, but property values were not related to subsequent demographic shifts. Model 1A expects a 1% increase in the index of gentrifiers in an eligible-to-gentrify neighbourhood to be followed by a 2.7% increase in the

Table 2. Unstandardised coefficients, Arellano-Bond GMM regressions with tract and year fixed effects.

	Tracts eligible to gentrify				Tracts ineligible to gentrify			
	1-year lag		2-year lag		1-year lag		2-year lag	
	Model pair 1		Model pair 2		Model pair 3		Model pair 4	
	1A: Residential property value†	1B: Index of gentrifiers	2A: Residential property value†	2B: Index of gentrifiers	3A: Residential property value†	3B: Index of gentrifiers	4A: Residential property value†	4B: Index of gentrifiers
Index of gentrifiers	0.027***		0.009***		0.009***		0.005***	
	(0.00)		(0.00)		(0.00)		(0.00)	
Residential property value		0.095		0.012		0.062*		−0.036
		(0.06)		(0.86)		(0.04)		(0.30)
Lagged dependent variable	0.795***	0.491***	1.561***	0.416***	0.869***	0.748***	1.565***	0.837***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Twice-lagged dependent variable			−0.724***	0.018			−0.678***	0.041**
			(0.00)	(0.46)			(0.00)	(0.00)
Population	0.000***	0.000*	0.000*	−0.000	0.000***	0.000***	0.000***	−0.000
	(0.00)	(0.01)	(0.02)	(0.18)	(0.00)	(0.00)	(0.00)	(0.22)
% male	−0.001	0.003	0.000	−0.000	0.001***	0.004***	0.000	−0.001
	(0.23)	(0.06)	(0.33)	(0.87)	(0.00)	(0.00)	(0.46)	(0.53)
% age 18–34	−0.003***	0.002	−0.000	−0.002	−0.002***	−0.001	−0.000**	−0.001
	(0.00)	(0.24)	(0.21)	(0.24)	(0.00)	(0.15)	(0.00)	(0.25)
Vacancy rate†	−0.004	0.012	0.002	−0.013	−0.002**	0.001	0.000	−0.006
	(0.07)	(0.26)	(0.24)	(0.19)	(0.01)	(0.85)	(0.99)	(0.43)
Housing units†	−0.208*	−0.105	−0.027	0.089	−0.211**	0.100	−0.015	−0.104
	(0.04)	(0.44)	(0.38)	(0.42)	(0.01)	(0.14)	(0.61)	(0.19)
% public housing units†	0.016	−0.012	0.001	0.014	0.021*	0.002	0.002	0.055
	(0.08)	(0.23)	(0.41)	(0.33)	(0.01)	(0.96)	(0.75)	(0.29)
% moved in previous year†	0.004	−0.017	0.000	−0.017	−0.001	0.002	0.000	−0.001
	(0.15)	(0.24)	(0.93)	(0.22)	(0.59)	(0.84)	(0.72)	(0.92)
Year	0.007***	0.015***	0.012***	0.018***	0.008***	0.007***	0.012***	0.008***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

(continued)

Table 2. Continued

	Tracts eligible to gentrify				Tracts ineligible to gentrify			
	1-year lag		2-year lag		1-year lag		2-year lag	
	Model pair 1		Model pair 2		Model pair 3		Model pair 4	
	1A: Residential property value†	1B: Index of gentrifiers	2A: Residential property value†	2B: Index of gentrifiers	3A: Residential property value†	3B: Index of gentrifiers	4A: Residential property value†	4B: Index of gentrifiers
Constant	3.689*** (0.00)	0.126 (0.90)	2.114*** (0.00)	0.741 (0.48)	2.802*** (0.00)	−1.054* (0.04)	1.420*** (0.00)	1.480* (0.01)
N	2534		2110		8966		7470	

Notes: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. † Variable logged to normalise.

neighbourhood's median property value. Because property values are logged, we transform the coefficient using the base of the logarithm, *e*, to interpret it as a percentage change ($((e^{0.027}–1) \times 100 = 2.7\%$). The average neighbourhood in our sample experienced a 6.9% increase in the index of gentrifiers between 2009 and 2016 (see Table 1), a change the model expects to be associated with an 18.7% growth in the neighbourhood's property values (6.9 × 2.7). Model 1B, however, shows no such statistically significant association between property values in one year and the index of gentrifiers in the next. In model pair 1, gentrifiers predict property value increases, but these increases do not predict future gentrifiers.

Model pair 2, which lags the independent variables two years, exhibits the same pattern, though with smaller coefficients. A 1% increase in a tract's gentrifier index is associated with a 0.9% increase in its property values two years later ($((e^{0.009}–1) \times 100 = 0.90\%$). As with the one-year lag, changes in a neighbourhood's property values are not related to its gentrifiers two years later.

The pattern is somewhat similar in tracts ineligible for gentrification. Model pairs 3 and 4 display results for neighbourhoods too wealthy or recently developed to be eligible for gentrification. In such neighbourhoods, a 1% increase in the gentrifier index was related to property value growth of 0.9% the next year ($((e^{0.009}–1) \times 100 = 0.9\%$) and 0.5% two years later ($((e^{0.005}–1) \times 100 = 0.50\%$). This mimicked eligible tracts. One difference from the eligible tracts was that the one-year lag of property values was related to future increases in gentrifiers, though the magnitude was small. A 1% increase in property value was related to a 0.0006% increase in White, middle-class gentrifiers ($((e^{0.062}–1)/100 = 0.0006$). While the demographics-lead-development trend is observable in both eligible and ineligible neighbourhoods throughout New York City

Appendix Table. Unstandardised coefficients, Arellano-Bond GMM regressions with tract and year fixed effects, for tracts eligible to gentrify.

	1-year lag		2-year lag		1-year lag		2-year lag	
	Model pair 1		Model pair 2		Model pair 3‡		Model pair 4‡	
	1A: Residential property value†	1B: Index of gentrifiers (class only)	2A: Residential property value†	2B: Index of gentrifiers (class only)	3A: Residential property value†	3B: Index of gentrifiers	4A: Residential property value†	4B: Index of gentrifiers
Index of gentrifiers (class only)	0.026***		0.009***					
	(0.00)		(0.00)					
Index of gentrifiers					0.037***		0.011**	
					(0.00)		(0.01)	
Residential property value		0.092		0.016		0.066		−0.021
		(0.07)		(0.81)		(0.21)		(0.72)
Lagged dependent variable	0.795***	0.505***	1.561***	0.439***	0.773***	0.568***	1.544***	0.478***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Twice-lagged dependent variable			−0.724***	0.016			−0.731***	0.024
			(0.00)	(0.49)			(0.00)	(0.44)
Population	0.000***	0.000*	0.000*	−0.000	0.000***	0.000	0.000	−0.000
	(0.00)	(0.01)	(0.02)	(0.19)	(0.00)	(0.09)	(0.15)	(0.27)
% male	−0.001	0.003*	0.000	−0.000	−0.000	0.003	0.001	−0.003
	(0.23)	(0.05)	(0.33)	(0.79)	(0.43)	(0.13)	(0.19)	(0.18)
% age 18–34	−0.003***	0.002	−0.000	−0.002	−0.002***	0.002	−0.000	−0.002
	(0.00)	(0.29)	(0.21)	(0.20)	(0.00)	(0.43)	(0.56)	(0.28)
Vacancy rate†	−0.004	0.013	0.002	−0.013	−0.005	0.009	0.004	−0.013
	(0.07)	(0.22)	(0.24)	(0.21)	(0.09)	(0.52)	(0.14)	(0.27)
Housing units†	−0.208*	−0.121	−0.027	0.076	−0.283	0.018	−0.037	−0.049
	(0.04)	(0.40)	(0.38)	(0.50)	(0.12)	(0.93)	(0.56)	(0.84)
% public housing units†	0.016	−0.012	0.001	0.015	0.026	−0.008	0.001	0.022*
	(0.08)	(0.18)	(0.42)	(0.19)	(0.12)	(0.40)	(0.23)	(0.05)
% moved in previous year†	0.004	−0.016	0.000	−0.018	0.000	−0.026	−0.001	−0.015
	(0.15)	(0.26)	(0.92)	(0.19)	(0.92)	(0.18)	(0.60)	(0.42)
Year	0.007***	0.016***	0.012***	0.019***	0.006***	0.014***	0.012***	0.019***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

(continued)

Appendix Table. Continued

	1-year lag		2-year lag		1-year lag		2-year lag	
	Model pair 1		Model pair 2		Model pair 3‡		Model pair 4‡	
	1A: Residential property value†	1B: Index of gentrifiers (class only)	2A: Residential property value†	2B: Index of gentrifiers (class only)	3A: Residential property value†	3B: Index of gentrifiers	4A: Residential property value†	4B: Index of gentrifiers
Constant	3.689*** (0.00)	0.196 (0.85)	2.113*** (0.00)	0.713 (0.49)	4.295*** (0.00)	−0.371 (0.77)	2.455*** (0.00)	1.821 (0.20)
N	2534		2110		1578		1315	

Notes: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. † Variable logged to normalise. ‡Model pairs 3 and 4 use the 40th percentile eligibility criterion

during this time, the trend is more consistent in tracts eligible to gentrify, suggesting that the sequence of supply and demand is different during super-gentrification, the movement of the very wealthy into middle-class areas (Lees, 2003).

As for control variables, in model pair 1, a tract's population was significantly associated with both future property values and future gentrifiers. Since tract boundaries remained static, population is a proxy for population density. Neighbourhoods getting denser saw increases in home prices and gentrifiers. The year variable was significant and positive, as we would expect with both dependent variables increasing city-wide during most study years. No other control variables were statistically significantly related to the outcomes at both time lags, though young people and residential units were negatively related to property value increases one year out.

Robustness checks

To account for different possible modelling choices, we ran alternative versions of the models. Some past research has measured gentrifiers' economic class and omitted measures of their race (Landis, 2015; Vigdor, 2002). In the Appendix Table, model pair 1 uses an alternative index of gentrifiers omitting the measure of racial change (per cent non-Hispanic White) and retaining the education, occupation and income measures. The results are substantively identical to our primary models. Another influential decision could have been the criteria we used for determining a tract's gentrification eligibility. A common alternative to the below-city-median threshold used above is a more conservative criterion including only tracts whose median income or recent housing construction were below the 40th percentile of the city median. Those results are presented in the Appendix Table as model pairs

3 and 4, and very closely resemble our primary models. Another researcher might choose a different lag structure. So, in addition to our one- and two-year lags presented above, we ran models with three-, four- and five-year lags. While neither supply nor demand predicted the other three years out, demand predicted supply – in line with our primary results – four and five years out.

Discussion and conclusion

To sequence the demand for and supply of housing during gentrification, we adapt Granger causality theory in longitudinal, cross-lagged regression models. While this approach cannot speak to causation, it provides strong support, robust to a battery of alternate specifications, that consumption-side dynamics led production-side ones, at least in New York City between 2009 and 2016. An increase in middle-class White people was a statistically significant predictor of an increase in residential property value, but the reverse was not true. Growth in a neighbourhood's residential property values was not associated with subsequent growth in its White, middle-class residents.

We take these results as evidence that the hybridists were too quick to synthesise production and consumption theories. At least during our study period in New York, consumption led production. This is not to say that supply-side actors and their development strategies are inconsequential. Production-side dynamics might not be the spark but rather the sustaining engine of gentrification, entering the picture later. Our results also raise the possibility that demand and supply are independent of one another. If this is the case, future research might test if gentrifiers move into some neighbourhoods absent housing price growth or if housing markets in disinvested neighbourhoods can tighten absent new in-movers.

Our results have a major take-away for urban theory: we must study time when we study place. We found that gentrification's subsidiary elements were not simultaneous. If we theorise all aspects of urban phenomena as occurring simultaneously, we might misunderstand the processes, and when we operationalise the theories we might inaccurately measure only the beginning or end of processes. In this way, our study underscores the importance of longitudinal, processional theories and analyses.

Our study suffers from some limitations. First, our tax property data might lag changes in market prices. As discussed above, we think this is less of a problem than with other tract-level measures of home price, and we guard against this lag by averaging the data across five years, adjusting fiscal year data to the previous calendar year and running our regressions with multiple-year lags. Further, New York City annually updates each property's assessed value using new sales data, making it more responsive to market changes than cities not doing so. A second limitation is that our study is just of one city and one time period. New York City is a global city and therefore our findings might be more applicable to London or Tokyo than to Little Rock or Toledo. Our methodology, however, can be used to test whether supply or demand leads in any city.

Some of this study's limitations suggest future research. Our strategy analyses middle-class professionals – a conservative marker of gentrification's beginnings – and does not model other possible stages of gentrification. Future research could more explicitly include artists, young people, childless couples or LGBTQ people in its measure of gentrifiers. Also, we do not adjust for spatial autocorrelation. Our tract fixed effects will control for any time-invariant spillover effects but not time-variant ones. When methods are developed

that account for both spatial and serial autocorrelation in a cross-lagged structure, future research might incorporate them. Finally, our models do not explicitly measure tracts' differing mixtures of regulatory statuses. Some research suggests that state-led actions like rezoning or social investment could spark gentrification (Hackworth and Smith, 2001). We think that such state action would appear as increases in our measure of housing prices, as investors react to the regulatory changes. Still, future research might directly account for government influence.

This project provides policymakers and social movements with a new and flexible methodology for analysing the sequence of supply and demand. Cities can reproduce our analysis as an early detection system to determine whether gentrifiers or residential property value increases are the leading edge of gentrification in their neighbourhoods. While New York City's frequently updated property tax data and numerous census tracts allow for analysis more easily there, smaller cities might consider using more years of data or third-party data like that from Zillow to perform their analyses. As scholarly disagreements about whether and when to define gentrifiers as White are ongoing, cities can customise the index of gentrifiers to include ethno-racial groups prevalent in their area or exclude race altogether. As discussed above, we found similar results whether we included per cent White in our index of gentrifiers or not. This suggests that gentrifiers spur landlord and property investment decisions both through the visible presence of new White residents, and through the less visible consumption decisions of middle-class residents like their willingness to pay higher rent and preference for upscale retail amenities.

Extant policy responses to gentrification and housing unaffordability have largely encouraged developers to supply new housing (Angotti and Morse, 2016). Our findings suggest that policy should focus on demand in addition to supply. It is likely that other cities resemble New York's demand-first sequence, and that intervening to stop gentrification's negative outcomes will be difficult because regulating the real estate sector is easier than regulating thousands of people moving semi-independently. But, since our results suggest that developers lag in-movers, it will be these individual- and community-level interventions that are more likely to interrupt gentrification early. For instance, the federal government could expand subsidies to tenants. City governments could pass 'just cause' eviction ordinances to help tenants challenge eviction proceedings, they could implement 'right of return' policies to offer displaced residents the first choice of new units built in their neighbourhoods and they could pass 'right to purchase' policies to allow tenants the option to buy their building before it is sold to developers (Causa Justa, 2015; Schlichtman et al., 2017). Once cities determine the leading edge of gentrification, they can identify neighbourhoods most at risk of further gentrification and concentrate anti-displacement services there.

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