

Quantifying the Welfare Effects of Neighborhood Change on Incumbent Low-Income Renters

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How does gentrification affect the incumbent residents of low-income neighborhoods? This paper investigates whether changes in neighborhood amenities and employment access accompanying gentrification are sufficient to compensate incumbent renters for increased housing costs. We link person-level administrative US Census data to construct an annual panel that tracks the earnings, workplaces, and residential addresses of over 1 million low-income urban renter households through 2000-2019. We use these data to estimate a dynamic structural model of residential and workplace choice. We identify our model with skill-specific labor demand shocks to potential commuting destinations constructed using geocoded data on the near universe of US business establishments from the Census Bureau's Longitudinal Business Database. Our estimates suggest that incumbent low-income renters benefited on average from gentrification relative to a hypothetical steady-state equilibrium formed using the observed spatial distribution of neighborhood rents, college graduates, and jobs in the year 2000. Most of the variation in welfare effects is between metro areas, indicating that where low-income renters lived within US metros mattered far less than which US metro they lived in.

Acknowledgments

1. Introduction

Gentrification is associated with simultaneous increases in housing costs and changes in both public (e.g. schools and public safety) and private (e.g. restaurants and bars) neighborhood amenities. Residents may benefit from gentrification if they value the change in amenities by more than the amount housing costs increase (Vigdor 2010). Conversely, residents may be harmed if changes in amenities are insufficient to compensate for rising housing costs. Residents with strong attachments to their home neighborhood are especially vulnerable to rising housing costs as they are less willing to relocate given any cost increase. This paper leverages extensive US Census Bureau data to quantify these tradeoffs for incumbent renters in gentrifying neighborhoods throughout 2000-2019.¹

Beginning in the 1990s and intensifying after the year 2000, gentrification transformed the socioeconomic composition of vast areas within American inner cities (Couture and Handbury 2023).² Between 2000 and 2017, Census tracts closest to their metros' central business districts (CBDs) increased their share of residents with a college degree by an average of 15-percentage points from a base of 24 percent. This contrasts with a 7-percentage point average increase in suburban neighborhoods' shares of college graduates, reflecting a secular increase in educational attainment.³ How this transformation of American inner cities affected the incumbent residents of gentrifying neighborhoods remains an open question.

The gentrification of inner-city America reversed postwar urban decline, wherein middle- and upper-class households left the inner city in favor of suburban life (Jackson (1987), Boustan (2010), Mieszkowski and Mills (1993)). This postwar suburbanization is considered a major contributor to concentrated inner-city disadvantage (Wilson (1987)). At the same time primarily white middle- and upper-class households were leaving to the suburbs, inner-city violent crime increased ten-fold (Cullen and Levitt (1999), Curci and Masera (2023)), city public finances declined (Derenoncourt 2022), and many employers relocated to the suburbs (Kain (1968),

¹We focus on low-income renter households because of their vulnerability to the financial costs of gentrification and the fact that in 2010, 64% of urban housing units occupied by households with incomes below \$50,000 were rented (Manson et al. 2022). Recent research does show the potential for homeowners to be harmed from gentrification due to rising property taxes (Ding and Hwang (2020), Berry (2021), Fu (2022)). Evaluating the welfare effects of gentrification on incumbent homeowners is an interesting question for future research.

²The economic forces causing demand for inner-city living to rise among college graduates were multifaceted. Rising top incomes increased the demand for local service amenities concentrated in downtown neighborhoods (Couture et al. 2023) and raised the time-cost of commuting (Edlund, Machado, and Sviatschi (2022), Su (2022)). Declining urban crime (Ellen and O'Regan (2010), Ellen, Horn, and Reed (2019)), shifting preferences for urban amenities (Brueckner, Thisse, and Zenou (1999), Glaeser, Kolko, and Saiz (2001), Baum-Snow and Hartley (2020), Couture and Handbury (2020)), evolving transportation infrastructure (LeRoy and Sonstelie (1983), Glaeser, Kahn, and Rappaport (2008)), and delayed child bearing (Moreno-Maldonado and Santamaria 2022) all likely contributed to the demand for downtown living. These forces were compounded by increases in the valuation of downtown amenities caused by the growing presence of college graduates (Berkes and Gaetani (2023), Diamond (2016), Guerrieri, Hartley, and Hurst (2013)).

³See Appendix A for more details on neighborhood change since the turn of the century.

Glaeser and Kahn (2001), Miller (2021)). If suburbanization was a significant factor behind these changes, its reversal over the past few decades might have caused environmental shifts favored by incumbent inner-city residents. Residents may have benefited from more local job opportunities, improved public amenities funded by rising land values, and greater access to private consumption amenities like grocery stores and restaurants.

Like any other good, though, improvements in neighborhood quality are invariably accompanied by rising prices. Incumbent residents could have been harmed by gentrification if housing costs increased by more than residents' willingness to pay for the accompanying amenity changes. That concerns over housing affordability are today ubiquitous in many large US cities makes this possibility salient (Glaeser (2020), Gabriel and Painter (2020)). High moving costs, neighborhood-specific accumulated capital, and sparse choice sets may also have exacerbated the potential harms of gentrification. By rendering incumbent residents less responsive to changing neighborhood characteristics, these moving frictions ensure incumbent residents bear the incidence of gentrification.⁴

To quantify the welfare effects of gentrification on incumbent residents, this paper estimates a dynamic model of residential and workplace choice that accounts for welfare-relevant neighborhood characteristics, a rich set of moving frictions, and changes in city-wide neighborhood choice sets. With our parameter estimates in hand, we then explore how incumbent residents were affected by gentrification between 2000 and 2019. Specifically, we ask whether incumbent renters of low-income neighborhoods benefited from gentrification relative to a hypothetical steady-state equilibrium formed using the observed spatial distribution of neighborhood rents, college graduates, and jobs in the year 2000. We finally conduct experiments to measure how various neighborhood and CBSA-level characteristics influenced the impact of gentrification on incumbent renters.

We conduct our analysis on de-identified person-level data from the US Census Bureau's Master Address File (MAF), which records the near universe of US adults' residential migration histories from 2000 onward. We link these data to persons' earnings and workplace locations from the employer-employee linked Longitudinal Employer-Household Dynamics (LEHD) database, which records the near universe of private sector, state, and local government workers' employment histories between 2000-2019. We finally link these data to person-level sociodemographic information from all American Community Survey (ACS) respondents (2005-2021), as well as property-level data from the Census Bureau's Master Address File Extract (MAF-X) and CoreLogic's residential property databases (2006-2019). Together, these data provide us with the distinct ability to observe the residential locations, earnings, and workplaces of over 1 million

⁴Incumbent residents may also be harmed if the supply of local amenities is skewed away from their preferences and toward those of the gentrifiers (Almagro and Domínguez-Lino 2022), or if gentrification alters neighborhoods' racial composition away from the preferences of incumbents (Davis, Gregory, and Hartley 2023).

low-income urban renter households across 50 large metros for up to 20 years during the most intense period of recent gentrification.

Our data yield three facts. First, low-income renter households are highly mobile. Only 54% of our sample resided in the same Census tract in 2013 as they did in 2010. However, the likelihood a renter household leaves its origin Census tract decreases significantly with longer tenure. Of renter households staying in their origin tract between 2010 and 2013, 77% remain there for the next three years. Second, gentrification is not associated with changes in the earnings, commutes, or residential tenures for our sample of incumbent renter households. This is true across a range of baseline neighborhood environments. Third, despite low-income renters being highly mobile, gentrification does affect the neighborhood characteristics incumbent renters experience. A one standard deviation increase in our measure of gentrification is associated with a 7.7% (5.4%) increase in the neighborhood rents and a 33.2% (36.6%) increase in the neighborhood college share incumbent Black (Non-Black) renters in poor neighborhoods experience between 2010 and 2019.⁵ These effect sizes suggest the potential for large welfare effects from gentrification among low-income incumbent renters.

In our dynamic residential and workplace choice model, heterogeneous agents choose their neighborhood and workplace locations each period to maximize their expected lifetime utility. Agents are subject to a rich set of moving costs, can accumulate neighborhood-specific capital, and are forward-looking. They obtain flow utilities comprised of expected housing and non-housing consumption, neighborhood amenities, and their accumulated neighborhood capital. Conditional on neighborhood rents, agents' expected consumption varies across neighborhoods because of differences in their commute-time-discounted proximity to jobs. This feature of our model captures the fact that neighborhoods farther from employment centers are less desirable due to the increased financial cost of commuting (Le Barbanchon, Rathelot, and Roulet 2021).

We model neighborhood amenities as a function of neighborhoods' shares of college graduates. This choice is motivated by a literature documenting a robust positive relationship between the provision of local public and private amenities and the local share of college graduates (Glaeser, Kolko, and Saiz (2001), Diamond (2016), Autor, Palmer, and Pathak (2017), Su (2022), Almagro and Domínguez-Lino (2022), Hoelzlein (2023)). We further allow neighborhood amenities to vary over time due to unobserved factors not caused by changes in the local share of college graduates. While the evolution of these unobserved exogenous neighborhood amenities is not caused by shifts in the local college share, they may nonetheless be correlated with households' residential location choices, presenting a challenge to identification.

We identify our model parameters by combining establishment-level employment data

⁵Changes in "experienced" neighborhood characteristics refer to the differences in the characteristics of the neighborhoods residents reside in during 2019 relative to the characteristics of the neighborhoods residents reside in during 2010.

from the Census Bureau’s Longitudinal Business Database (LBD) with advances in the quasi-experimental “shift-share” literature. Specifically, we construct two sets of instrumental variables to disentangle preferences for observed neighborhood characteristics and unobserved exogenous neighborhood amenities. The first set of instrumental variables aggregates skill-specific shocks to potential commuting destinations. The intuition behind these instruments is that as neighborhoods’ access to high-skill employment opportunities improve, they become more desirable for college graduates and thus are more likely to gentrify. These sets of instrumental variables build on recent work in [Baum-Snow, Hartley, and Lee \(2019\)](#) and [Baum-Snow and Han \(2023\)](#) that microfound measures of employment access with commuting data in a workplace choice model à la [Tsivanidis \(2022\)](#). Our establishment-level business data make identification from national industry shocks plausible, allowing the location of business establishments to be correlated with unobserved neighborhood characteristics ([Borusyak, Hull, and Jaravel 2022](#)).

Our second set of instrumental variables are motivated by the observation that gentrification tends to occur near neighborhoods with already high shares of college graduates ([Guerrieri, Hartley, and Hurst 2013](#)). For each census tract in our data, we construct distance-weighted measures of proximity to other neighborhoods’ shares of college graduates. We then exploit the fact that our analysis spans 50 metro areas, and interact our neighborhood-level proximity measures with CBSA-wide Bartik labor demand shocks. Identification then proceeds analogously to a difference-in-difference estimator: we compare differences in gentrification between neighborhoods near and far already gentrified tracts in CBSAs experiencing large labor demand shocks to differences in gentrification between neighborhoods near and far already gentrified tracts in CBSAs not experiencing large labor demand shocks.

Both Black and Non-Black low-income renter households in our sample have a positive valuation for the share of college graduates in a neighborhood, consistent with the existing literature. Black households, however, appear to place little weight on market access. This contrasts with Non-Black households who place a high value on market access. Black low-income renter households find it especially costly to leave their home neighborhood; our estimates suggest the fixed cost of moving within one’s own CBSA is over \$3,500 (\$1,600) for Black (Non-Black) households, and that this cost increases by around \$600 (\$250) with each additional year an incumbent renter remains in their home neighborhood.

What do our parameter estimates imply about the welfare effects of gentrification for low-income incumbent renters during 2000-2019? To answer this question, we run the following experiment. We calculate the expected welfare for hypothetical low-income renters initially residing in each urban low-income Census tract during the year 2000 under the assumption that the economy is in steady state. To do so, we find the continuation values and levels of exogenous neighborhood amenities that exactly rationalize a stationary equilibrium given the observed distribution neighborhood rents, college graduates, and jobs in the year 2000. We then

recompute expected welfare for each hypothetical renter household using observed changes in these equilibrium objects between 2000 and 2019. Comparisons between these expected utilities yield neighborhood-level estimates of changes to incumbent renters' welfare post-2000. We find that, on average, incumbent renters originally living in poor neighborhoods experienced an increase in expected welfare due to gentrification. We finally use our structural model to unpack these results.

Relation to Literature. Our paper contributes to three strands of literature. First, we contribute to the literature on the welfare implications of spatial sorting. Grounded in the canonical spatial equilibrium models stemming from [Rosen \(1974\)](#) and [Roback \(1982\)](#), an empirical literature has sought to quantify the implications of urban spatial sorting for households differentiated by their educational attainment. [Moretti \(2013\)](#) studied the implication of cross-metro sorting for real income inequality, while [Diamond \(2016\)](#) incorporated the endogenous supply of citywide amenities to study the implications of cross-metro sorting for welfare inequality. [Su \(2022\)](#) and [Couture et al. \(2023\)](#) similarly examine the welfare implications of spatial sorting, but focus on within-metro sorting.⁶ Other closely related papers focus on understanding the emergence of endogenously provided local amenities ([Couture and Handbury \(2020\)](#), [Almagro and Domínguez-Lino \(2022\)](#), [Hoelzlein \(2023\)](#), [Glaeser, Luca, and Moszkowski \(2023\)](#)). With few exceptions, the existing literature quantifies the effect of spatial sorting on the expected welfare of *prospective* city residents.⁷ Our paper instead exploits rich panel data to examine the impact of gentrification on the welfare of *incumbent* renters.⁸ To the best of our knowledge, we are the first to show how the welfare effects of gentrification vary across neighborhoods *within* cities.

Second, we contribute to the empirical residential choice literature that estimates households' willingness to pay for housing and neighborhood characteristics. Earlier static models of residential choice ([Brock and Durlauf \(2002\)](#), [Bayer, Ferreira, and McMillan \(2007\)](#), [Vigdor \(2010\)](#)) have given way to dynamic models that account for moving frictions and forward looking behavior ([Kennan and Walker \(2011\)](#), [Bishop \(2012\)](#), [Bayer et al. \(2016\)](#)). Researchers have used these dynamic neighborhood choice models to estimate preferences over the racial composition

⁶See [Kuminoff, Smith, and Timmins \(2013\)](#) and [Diamond and Gaubert \(2022\)](#) for a comprehensive review of these and other papers examining the implications of spatial sorting on inequality. This research in turn contributes more broadly to the quantitative spatial equilibrium literature summarized in [Redding and Rossi-Hansberg \(2017\)](#).

⁷[Balboni et al. \(2020\)](#) is a notable exception, which uses a repeated static commuting model coupled with the exact-hat algebra of [Dekle, Eaton, and Kortum \(2008\)](#) to estimate the welfare impacts of transit infrastructure investments and the resulting sorting of households on the welfare of incumbent residents in Dar es Salaam, Tanzania.

⁸Urban housing policies like rent control and eviction protections prioritize incumbent renters' welfare over landlords and residents unprotected by such policies ([Glaeser and Luttmer \(2003\)](#), [Diamond, McQuade, and Qian \(2018\)](#), [Collinson et al. \(2023\)](#), [Abramson \(2023\)](#)). Understanding the difference in welfare effects between prospective and incumbent residents is thus critical to discerning the appropriate set of policy responses to gentrification.

of neighborhoods (Davis, Gregory, and Hartley 2023), the insurance value of rent control (Diamond, McQuade, and Qian 2018), the willingness to pay to avoid violent crime and air pollution (Bishop and Murphy 2019), and horizontally differentiated consumption amenities (Almagro and Domínguez-Lino 2022), among others. We contribute to this literature by providing estimates on low-income renters’ preferences over welfare-relevant neighborhood characteristics, levels of neighborhood attachment, and a rich set of moving costs by combining our detailed Census data with findings from the recent quasi-experimental shift-share literature.⁹ We show how Black households appear to place less weight on access to employment opportunities relative to Non-Black households, but more weight on neighborhoods with higher shares of college graduates relative to Non-Black households. Our parameter estimates further show how the cost of moving across neighborhoods increases significantly with the length of households’ residential tenure.

Third, our paper contributes to empirical research documenting the effects of gentrification on observable outcomes for low-income residents. Much of this research has focused on gentrification’s impact on the propensity of incumbent residents to leave their home neighborhoods (Freeman and Braconi (2004), Freeman (2005), Ellen and O’Regan (2011), Ding, Hwang, and Divringi (2016), Dragan, Ellen, and Glied (2020)). This research has recently broadened to consider a wider range of outcomes. Baum-Snow, Hartley, and Lee (2019) examine the impact of neighborhood change on children’s long run outcomes. Brummet and Reed (2021) consider effects on employment and experienced neighborhood characteristics alongside effects on residential mobility. Lester and Hartley (2014) and Meltzer and Ghorbani (2017) focus on the employment impacts of neighborhood change on incumbent residents. This literature broadly finds economically insignificant *average* effects on incumbents’ household-level outcomes.¹⁰ Statistical power, however, limits these studies’ ability to examine heterogeneity across important dimensions like households’ origin neighborhood environments. We advance this literature by showing that these average results are robust to incumbent households’ origin neighborhood environments. This is a surprising finding as one might expect the impacts of gentrification to differ markedly based on local housing supply elasticities and the baseline level of neighborhood amenities.

Roadmap. This paper is structured as follows. Section 2 introduces our data and our sample of low-income households. Section 3 defines our measure of gentrification and presents reduced-

⁹Our instrumental variable construction builds on Baum-Snow, Hartley, and Lee (2019) and Baum-Snow and Han (2023), who are the first to construct and microfound shocks to employment access in a model of workplace choice à la Tsivanidis (2022). Brummet and Reed (2021) and Glaeser, Luca, and Moszkowski (2023) use proximity to already gentrified tracts as an instrument for gentrification.

¹⁰Baum-Snow, Hartley, and Lee (2019) find meaningful impacts on incumbent children’s future credit outcomes, consistent with the potential for neighborhood environments to effect children’s outcomes in adulthood (Chyn and Katz 2021).

form evidence on the effects of gentrification on low-income incumbent renters. Section 4 details our dynamic model of neighborhood and workplace choice. Section 6 presents our parameters estimates and welfare comparisons. Section 7 concludes.

2. Data and Sample Construction

We conduct our analyses using person- and establishment-level administrative micro data from the US Census Bureau spanning 2000-2019. Table 1 provides an overview of these data sources. We postpone a detailed discussion of the raw data and how we use it to construct our analysis samples to Appendix ??, presenting only a cursory discussion here.

TABLE 1. Data Overview

Source	Coverage	Description
A. Household Panel		
Master Address File - Auxiliary Reference File (MAF-ARF)	2000-19	Annual address-level residential locations
Longitudinal Employer-Household Dynamics database (LEHD)	2000-19	Annual earnings, workplace locations, basic sociodemographics
American Community Survey (ACS)	2005-19	Detailed sociodemographics
B. Housing Characteristics		
CoreLogic	2006-2017	Address-level housing transactions and multiple listing service entries
Master Address File Extract (MAF-X)	2019	Address-level unit characteristics
C. Business Data		
Longitudinal Business Database (LBD)	2000-19	Establishment-level employment and payroll aggregates

Notes: The 2019 MAF-X is a continuously updated inventory of all known living quarters in the US. Addresses verified in the past, but that are no longer known living quarters, remain in the MAF-X except in rare circumstances. The MAF-X 2019 therefore contains an inventory of all known addresses spanning our entire sample period.

We conduct our analyses on an annual panel that records the earnings, workplaces, and residential addresses of over 1 million low-income urban renter households through 2000-2019. To construct this panel, we first form an annual panel of persons' residential histories using the MAF-ARF. We then merge to these residential histories persons' annual earnings and workplace locations from the LEHD as well as additional sociodemographic characteristics from the ACS. These merges are facilitated by a unique person identifier called a protected identity key (PIK) which is assigned to individuals across data sets by the Census Bureau via probabilistic linking (Wagner and Layne 2014). We aggregate earnings by housing unit and designate the highest

earner of each unit as the household head for that year.¹¹ Our household panel is then restricted to persons who have been identified as a household head and who occupy a rental housing unit.¹²

We restrict our sample to household heads that are between 25 and 65 years of age. To focus our analysis on low-income households, we further restrict our sample to household heads earning in the bottom tercile of their respective core-based statistical area (CBSA) and decadal age band in the year they were first assigned household-head status.¹³ We finally limit our study to household heads living in the urban cores of the 50 largest CBSAs, located within the 28 states for which data is accessible in LEHD. We define urban cores using a similar method to [Hwang and Lin \(2016\)](#) and [Couture and Handbury \(2020\)](#). We denote as urban cores the set of census tracts associated with each CBSA that contain the 50% of the CBSA’s population that is closest to its central business district (CBD).¹⁴ Table 2 presents descriptive statistics from a 2010 cross-section of our panel.¹⁵

3. Exploratory Analyses

This section reports findings from reduced-form regressions of gentrification on an array of household-level outcomes. Our findings motivate a structural analysis and inform key features of our counterfactual welfare analyses. Before presenting our findings though, we first define our measure of gentrification and discuss our analysis period.

Gentrification. We follow the existing literature and define gentrification at the census tract level (e.g. [Ding and Hwang \(2020\)](#), [Dragan, Ellen, and Glied \(2020\)](#), [Brummet and Reed \(2021\)](#)).

¹¹We define housing units by their addresses in the MAF-X. Persons must have positive earnings in the given year to be considered as a household head.

¹²We describe how we impute rental unit status in Appendix ???. We also detail in Appendix ??? how we smooth residential histories and handle changes to household formations, out-of-sample migrations, and missing observations.

¹³CBSAs consist of counties associated with an urban core of at least 10,000 persons as well as adjacent counties that are deemed integrated through commuting ties. CBSAs are defined by the Office of Management and Budget (OMB).

¹⁴Our CBD definitions come from [Fee and Hartley \(2013\)](#). These CBD definitions are with respect to 2008 CBSA delineations. To keep consistent with these CBD definitions, we therefore use 2008 delineations of CBSAs throughout our analysis. Moreover, while each CBSA is associated with a primary urban center, some CBSAs additionally contain secondary urban centers called metropolitan divisions that have their own CBD. Although our low-income cutoff is constructed using the earnings distribution of the entire CBSA, our urban core cutoffs are particular to each urban center’s population, including metropolitan divisions. We believe these choices best capture our target population of low-income urban residents.

¹⁵The 2010 cross-section captures characteristics of the full sample we use to estimate our reduced-form regressions presented in section 3. We are postponing the release of sample statistics for the complete panel to help streamline the US Census Bureau disclosure review processes.

TABLE 2. Sample Characteristics: Household Heads in 2010

	Black Households	Non-Black Households
Panel A: Household Head Characteristics		
Household Income	21,250 (14,220)	21,660 (13,570)
Commute Distance	27.64 (12.43)	25.6 (12.82)
College Degree	0.11 (0.313)	0.165 (0.371)
Immigrant	0.212 (0.409)	0.45 (0.498)
Age	42.38 (10.64)	43.08 (10.8)
Female	0.611 (0.488)	0.519 (0.5)
Household Size	2.544 (1.549)	2.505 (1.578)
Parent	0.275 (0.447)	0.266 (0.442)
Panel B: Household Heads' Tract Characteristics		
Median Rents	834.4 (232.4)	934.7 (286.2)
Median Property Value	247,000 (205,100)	289,200 (214,600)
Share White	0.435 (0.264)	0.692 (0.208)
Share College-Educated	0.219 (0.147)	0.288 (0.183)
Share College-Educated and White	0.124 (0.137)	0.213 (0.169)
Distance to CBD	9.552 (5.172)	9.56 (5.33)
Unique Households	314,000	688,000

Notes: Table 2 reports mean characteristics for household heads with standard errors in parentheses. The sample comprising Table 2 consists of all household heads in the 2010 cross-section of the panel. Panel A reports household-level characteristics during 2010. Panel B reports characteristics of household heads' census tracts, also in 2010. Dollars are deflated to 2010 levels, and Census tracts are delineated by 2010 boundaries. The Parent variable is calculated only for household heads present in the ACS 2005-2021, and is inferred by the reported age of the child in the year they are survey respondents. The college degree variable is only computed for PIKs for whose education variables are not imputed in the LEHD or for whom we ascertain educational attainment through our ACS surveys. Details on the construction of tract aggregates are in Appendix B. Sources: ACS (2005-2021), LEHD (2010), CoreLogic (2006-2017), MAF-X (2019), and MAF-ARF (2010). Sample characteristics were disclosed by the US Census Bureau's Disclosure Review Board. Project Number 2358. Disclosure Clearance Number CBDRB-FY24-P2358-R10936.

Specifically, we define gentrification from period t_0 to t as the increase in the number of college graduates in a census tract, n , during those years. We then normalize this measure by tracts' total adult population in time t_0 :

$$\text{Gent}_{n,t_0,t} \equiv \frac{\text{College}_{n,t} - \text{College}_{n,t_0}}{\text{Adult Population}_{n,t_0}}$$

We follow the economics literature by normalizing the change in the number of college graduates by the total adult population in t_0 (Brummet and Reed (2021); Card, Mas, and Rothstein (2008); Böhlmarmark and Willén (2020)). One alternative definition is the change in the *share* of college graduates between periods t and t_0 . We nonetheless follow the literature's convention since this measure minimizes the mechanical relationship between gentrification and a primary outcome of interest: the out-migration rates of incumbent renters. This is because the out-migration rates of low-income incumbent renters have little influence on our measure of gentrification; only 11% and 16.5% of Black and non-Black households in our sample possess a college degree, and our sample comprises a small fraction of total households in each neighborhood.¹⁶ Our choice to define gentrification using educational attainment also follows convention in the economics literature (Diamond (2016), Brummet and Reed (2021), Su (2022)).¹⁷

Analysis Period. We choose to focus on the years 2010-2019 to establish our reduced form findings. We do so for two primary reasons. First, this choice mitigates the influence of potentially confounding factors resulting from the Great Recession, especially since we can control for changing neighborhood-level characteristics prior to 2010. Second, restricting our panel to 2010-2019 allows us to control for household characteristics throughout 2000-2009. Household characteristics like length of prior residential tenure are likely correlated with households' residential location choices.

3.1. Does Gentrification Impact Neighborhood Out-Migration Rates?

Gentrification does not meaningfully affect rates of neighborhood out-migration among incumbent renter households. We show that this result holds true across a range of baseline neighborhood environments, including census tracts that are already partially gentrified and that are highly developed.

¹⁶All the results we present below are quantitatively similar to specifications that exclude college-educated adults from our sample of low-income renters.

¹⁷Some research defines gentrification using changes in income (e.g. Dragan, Ellen, and Glied (2020), Ding and Hwang (2020)). Other research considers gentrification through the lens of changing racial compositions (Baum-Snow and Hartley 2020). We nonetheless believe that focusing on educational composition offers the clearest connection to the existing literature. We experimented with alternative definitions based on racial composition and income and found quantitatively similar results, and will disclose these results in due course.

To understand the impact of gentrification on incumbent renter households, we estimate a set of Cox-Proportional Hazard models. These models estimate the impact gentrification has on the probability an incumbent household leaves their origin neighborhood in any one year (i.e. on incumbents’ “hazard rates”).¹⁸ Our Cox-Proportional Hazards models take the following form:

$$(1) \quad \log(h(t|i)) = \alpha^{Cox} + \beta_{NC}^{Cox} \text{Gent}_{n(i),10,19} + \gamma^{Cox} X_i + \delta^{Cox} X_{n(i)} + \alpha_{CBSA}^{Cox} + \varepsilon_i^{Cox}$$

where $h(t|i)$ is the hazard in period t for household i . $n(i)$ denotes household i ’s origin neighborhood, X_i is a vector of household-level controls, $X_{n(i)}$ is a vector of controls characterizing the origin neighborhood of household i , and α_{CBSA}^{Cox} is a CBSA-level fixed effect. We detail and motivate our choice of controls in Appendix C. To mitigate concerns over sample selection, we often restrict our sample to longtime renters, defined as renter households who have lived in their origin tract for at least five years prior to 2010. We also postpone discussion of this choice and identification more broadly to Appendix C. Throughout our reduced-form analyses, we cluster standard errors at the Census tract level, which is our treatment unit (Abadie et al. 2023).

Estimates of β_{NC}^{Cox} from equation 1 are reported in Panel A of Table 3. Columns (1) and (2) of Panel A in Table 3 report estimates for our full sample of renter householders, separately for Black and Non-Black headed households. Columns (3) and (4) report the same estimates but restrict to longtime renters. Finally, columns (5) and (6) further restrict to census tracts with an initial share of college graduates below the sample-weighted median among all tracts our sample. For all subsets of our data, we document economically insignificant effects of gentrification on incumbent renters’ hazard rates.

Consider the effect of neighborhood change on Non-Black longtime incumbent renters’ hazard rates (column (4) in Panel A of Table 3). A 10 percentage point increase in gentrification corresponds to a 1.87 percent increase in the probability these renters leave their origin neighborhood in any given year between 2010 and 2019. Since the unconditional probability of leaving one’s origin neighborhood in any one year (i.e. baseline hazard) reaches at most 20 percent, these effect sizes are negligible.¹⁹ These results are consistent with the extant literature attributing neighborhood change to changes in in-migration patterns as opposed to increased

¹⁸Our choice to estimate Cox-Proportional Hazard models is motivated by incumbent renters’ short unconditional neighborhood tenures. Only 50.4 (51.7) percent of Black (non-Black) incumbent renter households remained in their 2010 origin census tract until at least 2015; these unconditional survival probabilities fall to 31.3 and 32.8 percent by 2019, respectively. Existing research that relies on intermittent sampling of residents loses potentially identifying variation from incumbent residents with short unconditional residential tenures. The Cox-Proportional Hazard model allows us to efficiently utilize our annual panel of residential histories to identify the effects of gentrification on incumbent renters’ neighborhood tenures.

¹⁹A ten percentage point increase in gentrification increases the probability an incumbent renter household leaves their origin neighborhood by at most $(20/100) \times 1.87 = 0.374$ percentage points in any one year.

out-migration among incumbent residents (e.g. [Ding, Hwang, and Divringi \(2016\)](#), [Dragan, Ellen, and Glied \(2020\)](#), [\(Brummet and Reed 2021\)](#))).

We advance our understanding of the impacts of gentrification on out-migration by using our expansive panel to show that these null results do not mask meaningful underlying heterogeneity. Column (5) shows that, if anything, out-migration rates *decrease* among Black low-income renters in neighborhoods with an initially low-share of college graduates. A 10 percentage point increase in gentrification corresponds to a 7.7 percent decrease in the probability a longtime incumbent Black renter leaves their origin neighborhood if it has an initially low share of college graduates. Again though, with a baseline hazard rate of at most 20%, these are economically small effect sizes. Table A2 in Appendix C explores additional sources of potential heterogeneity, including the density of urban development. We continue to find economically insignificant effect sizes. Finally, we test the robustness of our Cox proportional hazards models by estimating linear probability models where the dependent variable is an indicator equal to one if an incumbent renter remains in their origin census tract until at least 2019.²⁰ We again find economically insignificant results.

3.2. Does Gentrification Impact the Economic Outcomes of Incumbent Renters?

Gentrification does not meaningfully affect incumbent renters’ economic outcomes. This is true across most baseline neighborhood environments. We do, though, find that gentrification lowers average annual earnings for longtime Black renters living in tracts with an initially low share of college graduates.

To understand the impact of gentrification on incumbent renters’ economics outcomes, we estimate linear regression models regressing changes in incumbent residents’ annual earnings and commute distances on gentrification,

$$(2) \quad \Delta y_i = \alpha^{LP} + \beta_{NC}^{LP} \text{Gent}_{n(i),10,19} + \gamma^{LP} X_i + \delta^{LP} X_{n(i)} + \alpha_{CBSA}^{LP} + \epsilon_i^{LP}$$

where Δy_i denotes the change in either annual earnings or commute distances between 2010 and 2019. X_i , $X_{n(i)}$, and α_{CBSA}^{LP} are the same set of control variables and fixed effects used in equation 1. Estimates of β_{NC}^{LP} are reported in Panel B of Table 3. To interpret the magnitude of the coefficients in Panel B of Table 3, consider the effect of gentrification on Black incumbent renters’ annual earnings and commute **times**. A 10 percentage point increase in our measure of gentrification increases annual earnings by \$287 and reduces commute distances by **.2** minutes over 10 years, an economically small effect size. We do find some evidence, however, that

²⁰Cox proportional hazards models assume treatment effects are constant over time (i.e. proportion hazards). Our linear probability model specification mimics the existing literature which relies on intermittent sampling of residents (e.g. [Brummet and Reed \(2021\)](#))).

gentrification meaningfully reduces annual earnings for longtime Black incumbent renters in tracts with a low initial share of college graduates. Here, a 10 percentage point increase in gentrification reduces average annual earnings by \$914.

TABLE 3. Effect of Gentrification on Incumbent Renters

Outcome Variable	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Cox Proportional Hazards Model						
<i>Hazard Rate</i>	-0.0688 (0.0542)	-0.107* (0.0439)	-0.0793 (0.132)	0.187* (0.0781)	-0.777*** (0.286)	-0.264 (0.325)
Panel B: Linear Regression Model						
<i>Leave Tract</i>	-0.0176 (0.0223)	-0.0263 (0.0174)	-0.016 (0.0509)	0.07* (0.0278)	-0.305*** (0.106)	-0.0888 (0.0894)
<i>Annual Earnings</i>	2,872** (948.8)	2,268** (736.4)	-932 (2,170)	-86.05 (1,375)	-9,138* (3,854)	-551.8 (3,427)
<i>Commute Distance</i>	-0.2280 (0.776)	-1.905*** (0.531)	0.637 (1.609)	0.5900 (1.002)	-1.854 (3.132)	3.146 (2.775)
<i>Rent</i>	0.271*** (0.0472)	0.0960*** (0.0288)	0.389*** (0.0620)	0.222*** (0.0329)	0.863*** (0.145)	0.607*** (0.096)
<i>College Share</i>	0.726*** (0.204)	0.299*** (0.0598)	1.079*** (0.131)	0.567*** (0.0788)	3.726*** (0.250)	4.108*** (0.236)
Controls						
<i>Full Controls</i>	✓	✓	✓	✓	✓	✓
<i>CBSA Fixed Effects</i>	✓	✓	✓	✓	✓	✓
Sample Restrictions						
<i>Race</i>	Black	Non-Black	Black	Non-Black	Black	Non-Black
<i>Longtime Renters</i>			✓	✓	✓	✓
<i>Low Initial College Share</i>					✓	✓
N (1,000s)	314	688	56	156	35	67

Notes: We discuss how to interpret all coefficients in the main text. Leave Tract is an indicator equal to 1 if the household leaves their origin tract before 2019. Annual earnings is measured in 2010 dollars. Rent and college share are measured in percent changes. Commute **distances** are measured in miles. Every specification includes the full set of controls listed and detailed in Appendix C. Standard errors in parentheses are clustered at the census tract level. Longtime renters are renters who have lived in their origin census tract since at least 2005. Tables A3 and A2 in Appendix C report results for a wider range of baseline neighborhood environments. *Sources:* ACS (2005-2021), LEHD (2010), CoreLogic (2006-2017), MAF-X (2019), and MAF-ARF (2010). Estimates were disclosed by the US Census Bureau's Disclosure Review Board. Project Number 2358. Disclosure Clearance Number CBDRB-FY24-P2358-R10936.

3.3. Does Gentrification Impact Incumbent Residents' Neighborhood Conditions?

Gentrification meaningfully impacts the neighborhood conditions incumbent renters experience. That is, incumbent renters who initially live in gentrifying census tracts experience greater changes in their neighborhood conditions than similar residents in census tracts not gentrifying. This is not a mechanical result, as incumbent renters are free to move across tracts throughout our analysis period.

Panel A in Table 3 reports the effects of gentrification on changes in incumbent renters' neighborhood conditions. For example, a ten percentage point increase in gentrification led Black incumbent renters to live in tracts during 2019 that had on average 2.7 percent higher rents and 7.3 percent higher shares of college graduates. We see in columns (5) and (6) find that gentrification had particularly meaningful effects on the neighborhood conditions of incumbent renters initially residing in tracts with a low share of college graduates.

Our estimates on experienced neighborhood characteristics are indicative of moving frictions. For, without moving frictions, renters would simply re-optimize their location choice each period to ensure proximity to their ideal bundle of neighborhood characteristics, yielding economically insignificant estimates on incumbent renters' neighborhood conditions. Moving frictions in turn suggest the potential for differences in welfare effects from gentrification across tracts *within* CBSAs, motivating our paper's focus on incumbent renters. Moving frictions make incumbent renters averse to leaving their home census tract irrespective of changes in its characteristics. Whether incumbent renters then benefit from gentrification depends on their relative valuations of rents, job market access, and amenities vis-à-vis the actual change in these neighborhood characteristics.

It is worth noting here that there is limited correspondence between household residential mobility and welfare. Indeed, our estimates documenting no meaningful increase in neighborhood exit rates in response to gentrification are consistent with either positive or negative welfare effects from gentrification, depending on the aforementioned trade-off between rents, job market access, and amenities. Similarly, if we instead observed economically significant increases in neighborhood exit rates in response to gentrification, we would need to understand whether these estimates reflect insignificant moving frictions and dense choice sets, or declines in incumbents' relative valuations of their origin neighborhoods (Vigdor 2002).

4. A Dynamic Model of Neighborhood and Workplace Choice

To quantify the welfare impact of neighborhood change on low-income incumbent renters, we estimate a dynamic discrete neighborhood and workplace choice model (Bayer et al. (2016);

Diamond, McQuade, and Qian (2018); Davis et al. (2021); Davis, Gregory, and Hartley (2023); Almagro and Domínguez-Lino (2022)). We estimate our model to obtain parameter estimates of low-income households' preferences over neighborhood characteristics pertinent to understanding the welfare effects of gentrification. We use our estimated model parameters as well as observed changes in neighborhood rents, college shares, and employment access to compute the expected utility of incumbent renters separately for each low-income, urban census tract between 2000-2019. We finally difference these estimates with the expected utility renters would have obtained if the economy was in steady state during 2000, yielding tract-level estimates on the welfare effects of gentrification for incumbent renters. Note that while our expected utility calculations are constrained by our functional form assumptions, they never require us to compute counterfactual equilibria. We can therefore forego modeling the choices of agents beyond our sample population of low-income households.

Of papers in the dynamic discrete choice literature, our setup is most most similar to the neighborhood demand model in Almagro and Domínguez-Lino (2022), who analyze the endogenous formation of horizontally differentiated private consumption amenities in the context of Amsterdam's 2010-2019 tourism boom. One important departure from their demand model is that we incorporate differences in within-CBSA access to employment opportunities through a first-step workplace choice problem. We combine our LEHD and LBD data to compute micro-founded, time-varying, and neighborhood-level measures of employment access for our sample population. To the extent that gentrification affects access to non-tradable employment opportunities, this addition is necessary to capture the full welfare effects from gentrification. Moreover, coupled with our job market access instrument described in section XX, these measures help facilitate credible identification of households' preferences over neighborhood characteristics.

4.1. Households and Timing of Choices

Each period, t , household heads, i , must decide which neighborhood in the city, c , they should live.²¹ In addition to choosing their residential neighborhood, $n_{i,t}$, household heads must also decide which neighborhood to work in, $m_{i,t}$. Their workplace choice simply maximizes commute-time-discounted period income and is decided after neighborhood residence is known. Longer commute times reduce the time household heads spend working, effectively discounting the wage offered in workplace m . Finally, conditional upon deciding where to live and , households must then decide how much to spend on housing given the neighborhood-wide and period-specific rental rate.

Households differ ex-ante with respect to the household head's race, which we denote by $k \in \{\text{Black}, \text{Non-Black}\}$. Households can further differ due to their previous neighborhood

²¹Households take their city as given.

residences, which inform both their current neighborhood residence, $n_{i,t-1}$, as well as the how long they have lived there as of period $t - 1$, $\tau_{i,t-1}$. We collect these observable household-level state variables in $x_{i,t} \equiv (n_{i,t-1}, \tau_{i,t-1})$.

Just before households make their workplace and neighborhood choices each period, they receive idiosyncratic productivity and preference shocks, respectively. These preference shocks are unobserved by the econometrician but rationalize observed variation in households' choices within types conditional on $n_{i,t-1}$ and $\tau_{i,t-1}$. The remainder of this section presents the household head's problem in reverse chronological order, starting with their workplace choice problem.

4.2. Workplace Choice

Upon making their residential neighborhood and housing consumption choices in period t , households receive two independent productivity shocks. The first productivity shock is denoted by b_t^{kc} and is common across all type- k households in city c . The second productivity shock is household- and workplace tract-specific. This second productivity shock is denoted by $z_{m,t}^i$, where m denotes workplace tract. Conditional on living in neighborhood n , households choose their work location to maximize their commute-time-discounted income:

$$I_{n,t}^k \equiv b_t^{kc} \cdot \max_m \frac{z_{m,t}^i}{d_{n,m}} w_{m,t},$$

where $w_{m,t}$ is the wage offered in workplace m and period t measured in efficiency units and $d_{n,m} > 0$ is time it takes to commute between neighborhood n and m . We assume households spend a fixed amount of time each day working or commuting, so $d_{n,m}$ effectively discounts the total wage offered in m : $z_{m,t}^i \cdot w_{m,t}$. We assume that $z_{m,t}^i$ is drawn independently from a Frechet distribution with shape parameter $\epsilon^c \forall i \in c$. These shape parameters are specific to each city, which we make explicit with the superscript c . We further assume the Frechet shocks are independent across years, implying no cost to job switching. The expected income for a type- k household when living in tract n at time t is therefore,

$$\bar{I}_{n,t}^k = \Gamma \left(1 - \frac{1}{\epsilon^c} \right) \cdot b_t^{kc} \cdot RMA_n^{1/\epsilon^c},$$

where $\Gamma(\cdot)$ is the gamma function and $RMA_n \equiv \sum_{m \in \mathcal{N}^c} \left(\frac{w_m}{d_{n,m}} \right)^{\epsilon^c}$ is a summary measure of access to employment which we follow the literature in terming residential market access. We derive these equations and describe how we construct their empirical analogues in Appendix D.3.

4.3. Neighborhood Choice

Households' Neighborhood Choice Problem. Households choose their residential locations to maximize the sum of their expected discounted utilities,

$$(3) \quad \max_{\{n \in \mathcal{N}^c\}_t^\infty} \mathbb{E} \left[\sum_{t'=t}^{\infty} \delta^{t'-t} \cdot u_n^k(s_{i,t'}^c) \mid \mathcal{J}_{i,t} \right]$$

where δ is a known discount factor, $s_{i,t'}^c$ is a vector of state variables that determine household i 's flow utility u_n^k from choosing neighborhood n , and $\mathbb{E} [\cdot | \mathcal{J}_{i,t}]$ denotes the expectation operator conditioned on household i 's information set at time t . $\mathcal{N}^c \equiv \{OO^c, 1^c, \dots, N^c\}$ is the city-specific choice set, where OO^c denotes the outside option of leaving the city entirely. In each period, households observe the state variables s_{it}^c before choosing their residential location. Flow utilities are then realized and states evolve. Each household's information set \mathcal{J}_{it} therefore includes all current and past state variables which they may use to form expectations over the evolution of the state variables. We are precise about households' beliefs in section 5.1.

State Variables. Households' flow utilities depend on the vector of state variables $s_{it}^c \equiv (x_{it}, \varepsilon_{int}, \omega_t^c, \xi_t^{kc})$, where $(x_{it}, \varepsilon_{int})$ are household-level observable and unobservable state variables, respectively. By contrast, (ω_t^c, ξ_t^{kc}) are city-specific observable and unobservable state variables, respectively. The household-level observable state variables, x_{it} , are comprised of households' residential tenure and neighborhood choice in the previous period, $x_{it} = (n_{it-1}, \tau_{it-1})$. The evolution of these observable household-level state variables are determined by household i 's residential choices, as described in 4.1. ε_{int} is the household's unobservable state, which we assume is i.i.d. across households, neighborhoods, and time. We conceptualize ε_{int} as an unobserved-to-the-econometrician time-varying household and neighborhood-specific preference shock. As is common, we assume ε_{int} is distributed according to a Type I extreme value distribution.

Observable city-specific state variables are denoted by ω_t^c . The collection of city-specific state variables include vectors for each neighborhood's housing costs, r_{nt}^k , the share of college graduates in the neighborhood, $\frac{Coll_{nt}}{Pop_{nt}}$, each neighborhood's commute-time-discounted expected income, \bar{I}_{nt}^k , and an index for the time period t ,²²

$$\omega_t^c = \left(\{r_{nt}\}_{n \in \mathcal{N}^c}, \left\{ \frac{Coll_{nt}}{Pop_{nt}} \right\}_{n \in \mathcal{N}^c}, \left\{ \bar{I}_{nt}^k \right\}_{n \in \mathcal{N}^c}, t \right).$$

²²We include a time index in the set of observable neighborhood-level state variables to explicitly incorporate nonstationarity, so that the remaining observed state variables' evolutions can depend on time.

Expected commute-time-discounted income can vary across household types, hence the k superscript. Finally, ξ_t^{kc} is a city-specific vector of unobservable time-varying neighborhood-level amenity valuations among type k households. For example, ξ_t^{kc} could include time-varying valuations among type- k residents for suburban-life, independent of gentrification. To facilitate exposition, we define $\bar{\omega}_t^{kc} \equiv (\omega_t^c, \xi_t^{kc})$ as the vector containing both observable and unobservable city-specific state variables.

Flow Utility. Preferences over neighborhood characteristics net of moving costs for a type- k household can be represented by

$$A_{n,t}^k Q_{n,t}^k \tau_{it}^{\beta_\tau^k} \exp(\varepsilon_{int})$$

where $A_{n,t}^k$ is a type- k 's valuation of amenities in neighborhood n and $Q_{n,t}^k$ is consumption composite that is Cobb-Douglas over non-housing consumption, $C_{n,t}^k$, and housing consumption, $H_{n,t}^k$,

$$Q_{n,t}^k \equiv (C_{n,t}^k)^{\beta_C^k} (H_{n,t}^k)^{1-\beta_C^k}.$$

Households' expected period- and neighborhood-specific budget constraint is given by,

$$C_{n,t}^k \geq \bar{I}_{n,t}^k - r_{n,t} \cdot H_{n,t}^k.$$

Type-specific neighborhood amenities are,

$$A_{n,t}^k \equiv \left(\frac{Coll_{nt}}{Pop_{nt}} \right)^{\beta_A^k} \exp(\xi_{nt}^k).$$

We can additionally decompose unobserved neighborhood- and period-specific amenities into time-invariant neighborhood-specific components, time-varying city-level components, as well as neighborhood-specific time varying components:

$$\xi_{nt}^k \equiv \alpha_n^k + \alpha_t^{kc} + \tilde{\xi}_{nt}^k.$$

Taking logs, incorporating moving costs (defined below in 4.3), solving for expected optimal housing consumption, and substituting in the amenity specification yields the following expected flow-utility specification for a type- k household choosing neighborhood n with state s_{it}^c

that is consistent with households' preferences over neighborhood characteristics,²³

$$u_n^k(s_{it}^c) = \alpha_n^k + \alpha_t^{kc} + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \log(r_{n,t}) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Pop_{nt}}\right) \\ + \beta_\tau^k \ln(\tau_{it}) - MC_t^k(n_t, n_{it-1}) + \tilde{\xi}_{nt}^k + \varepsilon_{int}$$

Moving Costs. If a type- k household decides to leave their current neighborhood for another neighborhood in the same city they incur a non-monetary moving cost, $MC_t^k(n_{it}, n_{it-1})$, that is composed of a fixed disutility from moving, the physical straight-line distance between the household's origin and destination neighborhoods, as well as the social distance between these two neighborhoods. Conversely, if a type- k household decides to leave their city entirely, they obtain a single city-specific fixed cost. Specifically,

$$MC_t^k(n_t, n_{t-1}) = \begin{cases} 0 & \text{if } n_t = n_{t-1} \\ MC^k + \beta_d^{k'} \mathbf{d}(n_t, n_{t-1}) + \beta_s^{k'} \mathbf{s}(n_t, n_{t-1}) & \text{if } n_t \neq n_{t-1} \text{ and } n_t, n_{t-1} \neq OO^c \\ MC^{kc} & \text{if } n_{it} \neq n_{t-1} \text{ and } n_t \text{ or } n_{t-1} = OO^c. \end{cases}$$

where MC^k and MC^{kc} are the fixed intensive and extensive moving costs, respectively. $\mathbf{d}(n_t, n_{t-1})$ is a vector describing the distance between n_t, n_{t-1} and $\mathbf{s}(n_t, n_{t-1})$ is a vector describing the social distance between n_t, n_{t-1} in period t ,

$$\mathbf{d}(n_t, n_{t-1}) \equiv \begin{bmatrix} |Dist(n_t, n_{t-1})| \\ |Dist(n_t, n_{t-1})|^2 \end{bmatrix} \quad \mathbf{s}_t(n_t, n_{t-1}) \equiv \begin{bmatrix} |(S(n_t) - S(n_{t-1})) / (S(n_t) + S(n_{t-1}))| \\ |(S(n_t) - S(n_{t-1})) / (S(n_t) + S(n_{t-1}))|^2 \end{bmatrix}$$

where $Dist(n_t, n_{t-1})$ is the straight-line distance between the centroids of neighborhood n_t and n_{t-1} , and $S(n_t)$ is the share of college graduates in neighborhood n in time t .²⁴ Our measure of social distance captures the fact that while low-income renter households may value residing in neighborhoods with a high share of college graduates, it may be costly to assimilate to neighborhood environments different from one's own (Gans (1982), Jargowsky (2009)). Indeed, recent experimental research suggest low-income households' moving costs are poorly approximated by the physical distance of residents' potential moves, but strongly predicted by differences in the sociodemographic composition of households' origin and potential destination neighborhoods (Bergman et al. 2023).

²³Flow utility is expected in that it is the value households expect to obtain before their period-specific workplace tract productivity shocks are realized. It is this flow utility specification that is relevant for households' neighborhood choice and thus for our structural estimation.

²⁴We normalize our social distance measure by the sum of shares so the percentage changes are invariant to the direction of the residential move.

Value Functions, Choice Probabilities, and Expectational Errors. We denote $V^k(s_{it}^c)$ as the value function of the dynamic programming problem associated with equation 3. By Bellman's principle of optimality,²⁵

$$V^k(s_{it}^c) = \max_{n \in \{00^c, 1^c, \dots, N^c\}} \left\{ \mathbb{E}_{x'|x, n} \left[u_n^k(s_{it}^c) \right] + \delta \mathbb{E}_t \left[V^k(s_{it+1}^c) \mid n, s_{it}^c \right] \right\}$$

We define household i 's ex-ante continuation value function as the expectation of the value function with respect to ε_{int} ,

$$(4) \quad \bar{V}^k(x_{it}, \bar{\omega}_t^{kc}) \equiv \int V^k(s_{it}^c) dF^\varepsilon(\varepsilon_{int}),$$

and household i 's conditional value function as

$$(5) \quad \begin{aligned} v_n^k(x_{it}, \bar{\omega}_t^{kc}) &\equiv \mathbb{E}_{x'|x, n} \left[u_n^k(s_{it}^c) \right] - \varepsilon_{int} + \delta \mathbb{E}_t \left[\bar{V}^k(x_{it+1}, \bar{\omega}_{t+1}^{kc}) \mid n, x_{it}, \bar{\omega}_t^{kc} \right] \\ &\equiv \bar{u}_n^k(x_{it}, \bar{\omega}_t^{kc}) + \delta \mathbb{E}_t \left[\bar{V}^k(x_{it+1}, \bar{\omega}_{t+1}^{kc}) \mid n, x_{it}, \bar{\omega}_t^{kc} \right]. \end{aligned}$$

Then, given our assumption that ε_{int} are distributed i.i.d Type I extreme value, the probability a type- k household with state variables $(x_{it}, \bar{\omega}_t^{kc})$ chooses neighborhood n in period t is given by,

$$(6) \quad p_n^k(x_{it}, \bar{\omega}_t^{kc}) = \frac{\exp(v_n^k(x_{it}, \bar{\omega}_t^{kc}))}{\sum_{n' \in N^c} \exp(v_{n'}^k(x_{it}, \bar{\omega}_t^{kc}))},$$

and the ex-ante value function in 4 has the value

$$\bar{V}^k(x_{it}, \bar{\omega}_t^{kc}) = \ln \left(\sum_{n \in N^c} \exp(v_n^k(x_{it}, \bar{\omega}_t^{kc})) \right) + \gamma,$$

where γ is Euler's constant. Combining these two expressions yields the following well-known result which is critical to deriving our estimating equations (Hotz and Miller 1993),

$$(7) \quad \bar{V}^k(x_{it}, \bar{\omega}_t^{kc}) = v_n^k(x_{it}, \bar{\omega}_t^{kc}) - \ln(p_n^k(x_{it}, \bar{\omega}_t^{kc})) + \gamma.$$

Another critical element for deriving our estimating equations is the difference between

²⁵The expectation operator $\mathbb{E}_{x'|x, n}[\cdot]$ is with respect to the future value of households' observed household-level state variables, x' , conditional on households' current state and on their neighborhood choice. While the current deterministic setup yields this operator redundant, we include it here to be consistent with our empirical application that models the evolution of households' residential tenure stochastically conditional on their neighborhood choice.

households' expected ex-ante continuation values and their realized counterparts,

$$(8) \quad e^{\bar{V}}(x', \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) \equiv \underbrace{\bar{V}(x', \bar{\omega}_{t+1}^{kc})}_{\text{realized}} - \mathbb{E}_{\bar{\omega}' | \bar{\omega}_t^{kc}} [\bar{V}(x', \bar{\omega}') | \bar{\omega}_t^{kc}].$$

We follow [Kalouptsi, Scott, and Souza-Rodrigues \(2021\)](#) and term the differences *expectational errors*. These expectational errors allow us to discard households' actual expectations in estimation. Having to solve for households' expectations would be prohibitively costly given the high-dimensional nature of a household's state-space (some urban cores have over a thousand 2010-delineated census tracts).

Now that the function dependencies are clear, going forward we suppress their arguments and remove the city superscripts unless they are required for explicative purposes: $\bar{V}_{xnt}^k \equiv \bar{V}^k(x_{it}, \bar{\omega}_t^{kc})$, $V_{int}^k \equiv V^k(s_{it}^c)$, $\bar{u}_{xnt}^k \equiv \bar{u}_n^k(x_{it}, \bar{\omega}_t^{kc})$, $v_{xnt}^k \equiv v_n^k(x_{it}, \bar{\omega}_t^{kc})$, and $p_{xnt}^k \equiv p_n^k(x_{it}, \bar{\omega}_t^{kc})$.

5. Structural Estimation

We estimate our neighborhood demand parameters with what is termed in the dynamic discrete choice literature an Euler Equations in Conditional Choice Probabilities (ECCP) estimator.²⁶ Like other conditional choice probability estimators, ECCP estimation involves two steps. In the first step, we estimate households' conditional choice probabilities, the soon-to-be-introduced transition distributions for the household-level state variables, as well as households' variable moving costs β_d^k and β_s^k . We then estimate the remaining model parameters in a second step, conditional on our first-step estimates. Estimation in the second step is based off moment restrictions implied by the dynamic optimization of households, which we derive and explain in section 5.2. With flow utilities linear in the model's parameters, we can evaluate these moment restrictions in a standard linear GMM framework.²⁷

The ECCP estimator has many advantages in our setting. First, the ECCP estimator is computationally light. Since our analysis covers the residential history of low-income households for ten years in 50 large US metropolitan areas at the Census tract level, traditional dynamic discrete choice estimation procedures that explicitly solve for households' value functions are infeasible (e.g. [Rust \(1987\)](#)). Second, our focus on gentrification implies an inherently nonsta-

²⁶ECCP estimators are termed as such since they can be viewed as discrete choice analogues to Euler equations in models with continuous choice variables ([Aguirregabiria and Magesan \(2013\)](#), [Kalouptsi, Scott, and Souza-Rodrigues \(2021\)](#)).

²⁷ECCP estimation has been used in a variety of applied settings, from choices over agricultural land use, ([Scott 2013](#)), new technology adoption, ([Groote and Verboven 2019](#)), occupational choice ([Traiberman \(2019\)](#), [Gendron-Carrier \(2023\)](#)), and most relevant to our setting, residential neighborhoods ([Diamond, McQuade, and Qian \(2018\)](#), [Davis et al. \(2021\)](#), [Almagro and Domínguez-Lino \(2022\)](#)). See [Kalouptsi, Scott, and Souza-Rodrigues \(2021\)](#) for a comprehensive econometric treatment of linear regression techniques with ECCP estimators.

tionary environment, making modeling the evolution of neighborhood change conceptually and computationally challenging. As we demonstrate in the derivation of our moment restrictions, ECCP estimation does not require a complete specification of households' information sets and therefore neither the evolution of our city-specific state variables. Third, by providing moment conditions that we can evaluate in a linear GMM framework, we can exploit our instrumental variables detailed in section 6 to estimate our model parameters in a manner that is consistent with the recent literature on identification using Bartik shift-share instruments (Goldsmith-Pinkham, Sorkin, and Swift (2020), Borusyak, Hull, and Jaravel (2022)).

5.1. Estimation Assumptions

To identify our neighborhood demand parameters, we must make the following set of assumptions:

- (a) *State Transitions*: The state variables s_{it}^c evolve according to a controlled first-order Markov process with a transition distribution that factors as,²⁸

$$f(s_{it+1}^c | n_{it}, s_{it}^c) = f^x(x_{it+1} | n_{it}, x_{it}) \cdot f^{\bar{w}}(\bar{w}_{t+1}^{kc} | \bar{w}_t^{kc}) \cdot f^\varepsilon(\varepsilon_{int+1}).$$

- (b) *Utility Normalization*: The utility offered by the outside option in every city is normalized to α^{ck} for each time period,

$$\alpha_{OO^c}^k + \beta_w^k \ln(\bar{I}_{OO^c,t}) - \beta_r^k \ln(r_{OO^c,t}^k) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) + \tilde{\xi}_{OO^c,t}^k = \alpha^{ck} \quad \forall t.$$

- (c) *Rational Expectations*: Households' expectations over the evolution of the CBSA-level state variables conditional on their information set \mathcal{J}_{it} correspond to the conditional expectations of the true data generating process given \mathcal{J}_{it} ,

$$\mathbb{E} \left[e^{\bar{V}}(x', \bar{w}_t^{kc}, \bar{w}_{t+1}^{kc}) | \mathcal{J}_{it} \right] = 0,$$

where $e^{\bar{V}}(x', \bar{w}_t^{kc}, \bar{w}_{t+1}^{kc})$ are the expectational errors were defined in equation 8.

An important implication of assumption (a) is that the market-level state variables \bar{w}_t^{kc} are *perceived* as exogenous by individual households; a household cannot expect to individually

²⁸The evolution of the individual-level state variables, x_{it} , are “controlled” in that their evolution is influenced by the household's choices. While the current setup ensures the evolution of x_{it} is fully determined by the household's neighborhood choice, our empirical implementation assumes τ_{it} evolves stochastically conditional on the household's choice in order to reduce the dimensionality of our problem. Whether τ_{it} evolves stochastically or not, our discussion surrounding households' choice sets and moving costs in section 4.3 should make clear that x_{it+1} evolves independently of \bar{w}_t^{kc} conditional on n_{it} and x_{it} .

affect the evolution of $\bar{\omega}_t^{kc}$ with their own neighborhood choice (cf. assumption (1) in [Kalouptsi, Scott, and Souza-Rodrigues \(2021\)](#)). Given the typical 2010 US census tract houses around 4,000 residents, we believe this assumption is plausible.²⁹ Note that assumption (a) does not require the observed and unobserved city-specific state variables to evolve independently of one another. We highlight this to foreshadow the econometric challenge we face when attempting to identify preferences over functions of ω_t^c .

Assumption (b) says that residents who choose to reside outside of their respective CBSA's urban core obtain a time-invariant and CBSA-specific mean utility.³⁰ This assumption normalizes each CBSA's neighborhood mean utilities to a constant and time-invariant level, which is necessary to compare welfare across households within-CBSAs given logit models only identify differences in mean utilities. The assumption moreover facilitates exposition and, because each α^{ck} is unobserved, highlights the incommensurability of expected welfare both across different k -types and across CBSAs.

Lastly, assumption (c) says that, on average, households correctly anticipate the evolution of $\bar{\omega}_t^{kc}$. An important corollary of assumption (c) is that the contents of households' information sets in time t are mean independent of their expectational errors also at time t . The importance of this corollary will become clear in section 5.3 when we discuss choosing among our set of instrumental variables to estimate households' preferences.

5.2. Deriving our Estimating Equations

Our goal now is to take our model setup and show how one can derive estimating equations linear in households' demand parameters. With estimating equations linear in households' demand parameters, we may estimate our model with standard linear GMM techniques. To derive these equations, though, we must first introduce the concept of renewal actions.

Renewal Actions. To derive our estimating equations, we make use of what are termed in the dynamic discrete choice literature “renewal actions” ([Hotz and Miller \(1993\)](#), [Arcidiacono and Miller \(2011\)](#)). Renewal actions are actions that when taken in period t lead to the same distribution of states at the beginning of period $t + 1$, regardless of the household's state in period t . In our setting, simply moving to a new neighborhood is a renewal action; moving to a new neighborhood resets a household's residential tenure to 0 regardless of the household's

²⁹While our estimating equations are implied by households' dynamic optimization, they are not informed by any equilibrium conditions, allowing us to remain agnostic over how households' individual choices influence the evolution of the CBSA-wide state variables.

³⁰Recall that *all* residents of a given CBSA (i.e. including those outside the urban core) additionally receive a time-varying but neighborhood-invariant utility shock, α_t^k . The value of the outside option can therefore shift over time, but always in proportion to the mean utilities of inner-city neighborhoods.

origin neighborhood or their current residential tenure. Moreover, because the city-specific state variables, $\bar{\omega}_{t+1}^{kc}$, and unobserved idiosyncratic preference shocks, ε_{int} , are independent of the household's state in period t , *all* the remaining state variables are reset to a common value upon moving to a new neighborhood.³¹

We exploit such renewal actions when deriving our estimating equation. To see how, consider the residential choices of two hypothetical type- k households between periods $t-1$ and $t+1$. Assume that in period $t-1$ these households reside in the same neighborhood, n_{t-1} , but not in period t (i.e. at least one household chooses a new neighborhood in period t). Further, assume that in period $t+1$ both households move to the same neighborhood, n_{t+1} . Our estimation procedure involves relating the difference in the expected discounted utilities of the two households' neighborhood choices to the difference in the probability that these neighborhood choices are actually made. Critically, because moving to neighborhood n_{t+1} in period $t+1$ constitutes the same renewal action for both households, their state variables are reset to a common value which in turn equalizes their continuation values. Differences in the expected discounted utilities associated with the two sets of neighborhood choices are thus only a function of households' flow utilities. Relating such differences in expected discounted utilities to households' choice probabilities in this way therefore helps disentangle observed variation in households' flow utilities from households' unobserved continuation values.

To ease exposition, moving forward we term these consecutive residential location choices *residential paths*.

Our Estimating Equation. Consider the set of residential paths we just described for type- k households but with an additional requirement that one of the households chooses the outside option in period t :

- (a) In period $t-1$, both households reside in the same neighborhood, n_{t-1} .
- (b) In period t , one household chooses neighborhood n , while the other household chooses n' . n' also happens to be the outside option. While it must be the case that $n' \neq n$, it may be that $n_{t-1} = n$ or $n_{t-1} = n'$.
- (c) In period $t+1$, both households convene at \tilde{n} , where $\tilde{n} \neq n'$ and $\tilde{n} \neq n$.

Given these residential paths, we can derive equation 9 which is linear in households' preference parameters. It is this equation that we use to construct moment conditions that identify households' preferences. We derive it by equating the difference in the expected discounted utilities

³¹Note that renewal actions depend on our construction of households' neighborhood tenure in section 4.3. This construction assumes that the length of households' prior residential tenures has no impact on the value to future residential tenure. While this is a strong assumption, it is necessary to keep the dimension of the household-level state-space manageable.

associated with the two residential paths to the difference in the probability that households actually take these paths,

$$(9) \quad Y_{xnn'\tilde{n}t}^k = \tilde{\alpha}_n^k + \alpha_t^k + \beta_w^k \ln(\bar{I}_{OO^c,t}) - \beta_r^k \ln(r_{OO^c,t}^k) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) + \beta_\tau^k \tilde{\tau}_x - \widetilde{MC}_t^k + v_{xnn'\tilde{n}t}^k,$$

where

$$\begin{aligned} Y_{xnn'\tilde{n}t}^k &\equiv \ln\left(\frac{p_{xnt}^k}{p_{xnt}^k}\right) - \delta \left(\sum_{x'} \ln(p_{xnt}^k) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(p_{xnt}^k) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ \tilde{\alpha}_n^k &\equiv \alpha_n^k - \alpha^{ck} \\ \tilde{\tau}_x &\equiv \sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \\ \widetilde{MC}_t^k &\equiv MC_t^k(n, n_{xt-1}) - MC_t^k(n', n_{xt-1}) - \delta \left(MC_t^k(\tilde{n}, n) - MC_t^k(\tilde{n}, n') \right) \\ v_{xnn'\tilde{n}t}^k &\equiv \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) + \tilde{\xi}_{nt}^k. \end{aligned}$$

Since the full derivation of this estimating equation is becoming well known, we relegate it to Appendix D.1. With estimates of households' conditional choice probabilities, \hat{p}^k , and estimates of the household-level transition distributions, \hat{f}^x , we can estimate equation 9 using linear GMM. The next subsection details our two-step estimation procedure.

5.3. Two-Step Estimation Procedure

In the first step of the estimation procedure we estimate i) transition probabilities for the household-level state variables; ii) households' conditional choice probabilities; and iii) households' variable moving cost parameters. With these estimates in hand, we can estimate equation 9 using linear GMM.

Household Transition Distributions. To keep the dimension of the household state-space manageable, we follow the literature stemming from Rust (1987) and discretize our household-level residential tenure measure into two buckets.³² Specifically, we aggregate tenure into two buckets,

$$\bar{\tau} = \begin{cases} 1 & \text{if } \tau \leq 4 \\ 2 & \text{otherwise.} \end{cases}$$

³²The remaining household-level state variable is the household's residential location in the previous year. This state variable evolves deterministically depending upon the residential path under consideration. We therefore do not need to specify any transition probability for this component of x_t .

We assume that this aggregated location tenure variable evolves stochastically according to the following distribution function:³³

$$f^{\bar{\tau}}(\bar{\tau}_t = 1 | n_t, x(n_{t-1}, \bar{\tau}_{t-1}), \bar{\omega}^{kc}) = 1 \text{ if } n_t \neq n_{t-1}$$

$$f^{\bar{\tau}}(\bar{\tau}_t = 2 | n_t, x(n_{t-1}, \bar{\tau}_{t-1}), \bar{\omega}^{kc}) = \begin{cases} 1, & \text{if } n_t = n_{t-1} \text{ and } \bar{\tau}_{t-1} = 2 \\ g_{n_{t-1}}^k, & \text{if } n_t = n_{t-1}, \bar{\tau}_{t-1} = 1, \text{ and } i \in k. \end{cases}$$

where we estimate $g_{n_{t-1}}^k$ directly from the data,

$$\hat{g}_{n_{t-1}}^k = \frac{\sum_{i \in n_{t-1}, k} \mathbb{1}\{\tau_{xt} = 5\}}{\sum_{i \in n_{t-1}, k} \mathbb{1}\{\tau_{xt-1} \leq 4\}}.$$

Given that our analysis is at the Census tract level, estimated in this way $\hat{g}_{n_{t-1}}^k$ is a sparse measure of $g_{n_{t-1}}^k$. In practice we therefore take a weighted average of $\hat{g}_{n_{t-1}}^k$ across census tracts in each county and each year.

Conditional Choice Probabilities. Researchers typically face a trade-off between sparsity and flexibility when estimating first-step conditional choice probabilities, \hat{p}_{xnt}^k . Our setting is no different. On the one hand, we may estimate \hat{p}_{xnt}^k directly from the data by calculating the probability a type- k household with state x_{it} moves to each neighborhood $n_t \in \mathcal{N}^c$.³⁴ While this approach does not impose any restrictions on the implied data generating process, it leads to very sparse estimates of \hat{p}_{xnt}^k in our setting given the number of census tracts in our largest CBSAs. On the other hand, we may impose some structure on the implied data generating process to smooth \hat{p}_{xnt}^k . Given our particularly sparse empirical choice probabilities, we choose this latter option.

We model the count of type- k households in neighborhood $n \in \mathcal{N}^c$ choosing neighborhood $n' \in \mathcal{N}^c$ between periods t and $t + 1$ as being derived from a Poisson distribution.³⁵ We parameterize the mean of the Poisson distribution in a way that does not impose additional restrictions on the data generating process implied by our dynamic model.³⁶ Specifically, we estimate the

³³Our notation here corresponds to the marginal transition distribution of τ_{it} , taking n_{it} as given.

³⁴We could similarly employ any non-parametric methods to compute \hat{p}_{xnt}^k directly from the data.

³⁵We choose to model the data as a Poisson distribution because of its ability to account for sparse data and its computational efficiency (Correia, Guimarães, and Zylkin 2020).

³⁶Note that the independence of households' neighborhood moves in any one period implied by the Poisson distribution is embedded in assumption (a); f^x for household i is independent of all other households' actions. Appendix D.2 additionally shows how our Poisson regression specification does not impose additional restrictions on the neighborhood choice problem of households in our dynamic model.

following flexible Poisson regression separately for each type- k household,

$$(10) \quad \log \left(\mathbb{E} \left[\left| n_{t-1}^{k\bar{\tau}} \rightarrow n_t^{k\bar{\tau}} \right| \right] \right) = \gamma_{n't}^k + \mu_{\bar{\tau}} \cdot \mathbb{1}\{n' = n_{t-1}\} + \gamma_{n't}^k \cdot \lambda_{\bar{\tau}} \cdot \mathbb{1}\{n' = n_{t-1}\} - MC_t^k(n', n_{t-1}),$$

where $\left| n_{t-1}^{k\bar{\tau}} \rightarrow n_t^{k\bar{\tau}} \right|$ is the count of type- k households with aggregated tenure status $\bar{\tau}$ in neighborhood n that choose neighborhood n' between period $t - 1$ and t . $\gamma_{n't}^k$ is a fixed effect that captures the neighborhood- and period-specific component of utility associated with choosing neighborhood n' in period t , $\mu_{\bar{\tau}}$ is a fixed effect that captures the additional utility residents obtain from staying in their origin neighborhood given their tenure status, $\bar{\tau}$, and $\lambda_{\bar{\tau}}$ is a parameter capturing how the additional value one obtains from staying in their origin neighborhood varies with neighborhood mean utilities. $\mathbb{1}\{n' = n_{t-1}\}$ is an indicator variable that equals 1 if the household stays in their origin tract, and $MC_t^k(n', n_{t-1})$ are the same moving costs described in section 4.3. We use our estimates from the Poisson model to predict the probability a type- k household with aggregated tenure status $\bar{\tau}$ living in neighborhood n chooses neighborhood n' in each year: $\hat{p}_{xn't}^k$.³⁷ As expected, the predicted probabilities are strongly correlated with their empirical counterparts; the coefficients of correlation are 0.951 and 0.984 for Black and non-Black households, respectively.

Equation 10 additionally identifies our variable moving cost parameters, $\beta_d^{k'}$ and $\beta_s^{k'}$. Since the cost of moving to neighborhood n differs for each type- k household depending on their origin neighborhood, we can separately identify the parameters governing variable moving costs from γ_{nt}^k , $\mu_{\bar{\tau}}$, and $\lambda_{\bar{\tau}}$. How the cost of moving varies with the physical distance of the move, $\beta_d^{k'}$, is identified with variation in the distance households move within their urban core, conditional on moving. Similar variation but with respect to social distance identifies the cost of moving to neighborhoods socially different to one's origin neighborhood, $\beta_s^{k'}$.³⁸ We report our variable moving cost estimates with the rest of our parameter estimates in Table 4.

Step Two. Given our estimated variable moving cost parameters, our estimated conditional choice probabilities, and our estimated transition probabilities from step 1, we may now construct the empirical analogue of equation 9:

³⁷Many Census tracts lack type- k households or in-migrants in a given year. Consequently, we cannot compute their conditional choice probabilities and exclude them from type- k households' choice sets. These tracts tend to be suburban or affluent, and their removal is unlikely to affect our estimates.

³⁸Note that in this repeated cross-sectional framework, we are unable to separately identify the fixed cost of moving from the value of residential tenure. We must instead estimate households' fixed moving costs in a second step using equation 9. Note also that our assumption of a Poisson distribution in equation 10 does not impact the variable moving cost estimates we obtain here. This is because of the isomorphism between the score of the Poisson distribution and of the conditional logit for these continuous variables, yielding identical MLE estimates (Guimarães, Figueirido, and Woodward 2003).

$$(11) \quad \hat{Y}_{xnn'\tilde{n}t}^k = \tilde{\alpha}_n^k + \alpha_t^k + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \ln(r_{n,t}) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) + \beta_\tau^k \hat{\tau}_{xt} - \widehat{MC}_t^F + v_{xnn'\tilde{n}t}^k,$$

where

$$\begin{aligned} \hat{Y}_{xnn'\tilde{n}t}^k &\equiv \ln\left(\frac{\hat{P}_{xnt}^k}{\hat{P}_{xn't}^k}\right) - \delta\left(\sum_{x'} \ln\left(\hat{p}_{xnt}^k\right) \hat{f}^x\left(x'|n, x_t, \bar{\omega}_t^{kc}\right) \right. \\ &\quad \left. - \sum_{x'} \ln\left(\hat{p}_{xnt}^k\right) \hat{f}^x\left(x'|n', x_t, \bar{\omega}_t^{kc}\right)\right) + \widehat{MC}_t^V \\ \hat{\tau}_{xt} &\equiv \sum_{x'} \ln(\bar{\tau}_{xt}(x')) \hat{f}^x\left(x'|n, x_t, \bar{\omega}_t^{kc}\right) - \sum_{x'} \ln(\bar{\tau}_{xt}(x')) \hat{f}^x\left(x'|n', x_t, \bar{\omega}_t^{kc}\right) \\ \widehat{MC}_t^v &\equiv \widehat{MC}_t^v(n, n_{t-1}) - \widehat{MC}_t^v(n', n_{t-1}) - \delta\left(\widehat{MC}_t^v(\tilde{n}, n) - \widehat{MC}_t^v(\tilde{n}, n')\right) \\ v_{xnn'\tilde{n}t}^k &\equiv \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) + \tilde{\xi}_{nt}^k, \end{aligned}$$

and where $\hat{\cdot}$ represents estimates from the first step. \widehat{MC}_t^v is the difference in the fixed, $v = F$, or variable, $v = V$, portion of moving costs. We detail the difference in expectational errors, $\tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc})$, in Appendix D.1.

To be precise about identification, it is worth unpacking the error term, $v_{xnn'\tilde{n}t}^k$, in equation 11. $v_{xnn'\tilde{n}t}^k$ is comprised of both unobserved neighborhood-specific amenities, $\tilde{\xi}_{nt}^{kc}$, as well as expectational errors, $\tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc})$. We will consider each of these in turn starting with the unobserved neighborhood-specific amenities, $\tilde{\xi}_{nt}^{kc}$. Since we place no restriction on the relationship between $\tilde{\xi}_{nt}^{kc}$ and the remaining time-varying observable neighborhood characteristics, OLS estimates of 11 will be biased. Expected income, neighborhood-level housing costs, and the share of college graduates will invariably be correlated with many unobserved neighborhood-level factors like proximity to natural amenities that we do not observe as econometricians.

To distinguish between preferences for observed versus unobserved neighborhood amenities, we start by differencing equation 11 using residential paths starting in 2017 (i.e. $t - 1 = 2017$) and residential paths starting in 2010 (i.e. $t - 1 = 2010$), obtaining,

$$(12) \quad \Delta \hat{Y}_{xnn'\tilde{n}}^k = \Delta \alpha_t^k + \beta_w^k \Delta \ln(\bar{I}_{n,t}) - \beta_r^k \Delta \ln(r_{n,t}) + \beta_A^k \Delta \ln\left(\frac{Coll_n}{Po p_n}\right) + \Delta v_{xnn'\tilde{n}}^k,$$

where the Δ 's correspond to the difference in the associated variables between $t = 2011$ and $t = 2018$. Differencing equation 11 removes the time-invariant component of exogenous neighborhood amenities, $\tilde{\alpha}_n^k$, the measures of residential tenure, $\beta_\tau^k \tilde{\tau}_x$, and the time-invariant com-

ponents of the moving costs variables, MC^k , MC^{kc} , and $\beta_d^{kj} \mathbf{d}(n_t, n_{t-1})$.³⁹ Our main concern now is that *changes* in the observed components of households' flow utilities are correlated with *changes* in unobserved neighborhood amenities and household expectational errors. We must therefore construct neighborhood-level instruments, z_n , for our endogenous regressors that are orthogonal to both of these components:

$$\begin{aligned}
 (13) \quad 0 &= \mathbb{E} \left[z_n \Delta v_{xnn'\tilde{n}}^k \right] \\
 &= \mathbb{E} \left[z_n \left(\Delta \xi_n^k + \Delta \tilde{e}(x, \bar{\omega}_t^{kc}, \bar{\omega}_{t'}^{kc}) \right) \right] \\
 &= \mathbb{E} \left[z_n \left(\Delta \xi_n^k + \Delta \left(e^{\bar{V}}(n, x, \bar{\omega}_t^{kc}, \bar{\omega}_{t'}^{kc}) - e^{\bar{V}}(n', x, \bar{\omega}_t^{kc}, \bar{\omega}_{t'}^{kc}) \right) \right) \right],
 \end{aligned}$$

where, $e^{\bar{V}}(n, x, \bar{\omega}_t^{kc}, \bar{\omega}_{t'}^{kc})$ is the difference between the realized type- k ex-ante continuation value and type- k households' expectations of these continuation values, integrated over the potential realizations of the household-level states:

$$e^{\bar{V}}(n, x, \bar{\omega}_t^{kc}, \bar{\omega}_{t'}^{kc}) \equiv \sum_{x'} \left(\bar{V}(x', \bar{\omega}_{t'}^{kc}) - \mathbb{E}_{\bar{\omega}' | \bar{\omega}_t^{kc}} \left[\bar{V}(x', \bar{\omega}') | \bar{\omega}_t^{kc} \right] \right) f^x(x' | n, x_n, \bar{\omega}_t^{kc}).$$

In addition to being orthogonal to changes in unobserved neighborhood amenities, equation 13 shows our instruments must also be mean independent of changes in households' expectational errors. Recall assumption (c) which states that households have rational expectations over the evolution of the model's state variables. A corollary of this assumption is that the contents of households' information sets at time t are mean independent of their expectational errors (Kalouptsi, Scott, and Souza-Rodrigues 2021). Conversely, elements of households' future information sets that cannot be predicted from their period- t information sets will be correlated with their expectational errors. For this reason, our instruments must not predict future values of $\bar{\omega}_t^{kc}$ in a way that cannot simultaneously be predicted using information in households' period- t information sets. To see why, consider an instrument that shocks the neighborhood- n elements of $\omega_{t'}^{kc}$ for any $t \leq 2017$.⁴⁰ Assume this shock is uncorrelated with changes in unobserved neighborhood amenities but cannot be predicted with information in households' contemporaneous information sets, \mathcal{J}_{it} . If this instrument is relevant it will be mechanically correlated with the realized values of households' time- t ex-ante continuation values, $\bar{V}(x', \bar{\omega}_{t'}^{kc})$, but uncorrelated with households' time- t expectations, $\mathbb{E}_{\bar{\omega}' | \bar{\omega}_t^{kc}} \left[\bar{V}(x', \bar{\omega}') | \bar{\omega}_t^{kc} \right]$, violating the

³⁹We estimate the remaining time-invariant parameters in a final stage, estimating equation 11 conditional on the estimates from our differenced regressions and our first-step multinomial choice model. We assume that the effect of residential tenure on the likelihood of different residential paths is uncorrelated with unobserved neighborhood amenities.

⁴⁰If the instrument shocks elements of $\omega_{t'}^{kc}$ for $t' > 2017$, we must also consider how the instrument affects the difference in expectational errors over time. The current example is sufficient to show that z_n must be constructed using variation that can be predicted from households' 2010 information sets.

exclusion restriction embodied in 13. For this reason, the instruments we detail immediately below are designed to predict changes in the CBSA-level state variables through 2011-2018 using only variation that can be predicted from households' 2010 information sets.

6. Identification

We now present the instrumental variables we use to identify low-income renters' preferences for our three endogenous variables, β_w^k , β_r^k , and β_A^k . Our first set of instruments predict changes in neighborhood-level job market access for our target population of low-income renters, helping to identify their preference for job market access, β_w^k . Our second set of instruments are similar but predict changes in neighborhood-level job market access for college graduates. By predicting neighborhood demand among college graduates, these instruments help identify preferences for endogenous amenities, β_A^k . Our third set of instruments interact predicted changes in neighborhood-level job market access for college graduates with the intensity of neighborhoods' ex-ante urban development.⁴¹ Neighborhoods with an ex-ante high share of urban development are more likely to be on the inelastic portion of the local housing supply curve, making demand shocks more likely to translate into higher rents. These interaction terms are useful for identifying households' distaste for paying rent, β_r^k . To increase first stage power, we include a fourth set of instruments. These instruments use the proximity to other neighborhoods' shares of college graduates to help predict neighborhood demand among college graduates. These instruments are therefore particularly helpful in identifying households' preferences for endogenous amenities, β_A^k .

6.1. Job Market Access IV

Neighborhoods differ in their access to employment opportunities. Neighborhoods located near establishments with a high demand for skilled labor will be attractive to college graduates due to shorter expected commute times among this group, all else equal. A similar argument follows for low-income households and neighborhoods near establishments employing low-skill workers. Our job market access instruments predict changes in the desirability of neighborhoods based on changes to their expected commute times to employment opportunities. We construct these instruments in two steps. First, we define industry- and neighborhood-specific measures of job market access in a baseline year, separately for college graduates and low-income households. Second, we interact these baseline measures with national industry employment trends to

⁴¹Specifically, we interact changes in job market access with the share of land in the census tract that is covered by urban development in 2011. We obtain these measures from [Baum-Snow and Han \(2023\)](#) who in turn construct them using data from the National Land Cover Database.

predict changes in job market access that are plausibly uncorrelated with underlying trends in neighborhoods' exogenous amenities. We discuss how we construct these instruments as well as threats to identification below.

Instrument Construction. Our neighborhood-level measures of job market access can be formally defined in terms of each neighborhood n 's access to employment in industry d at time t :

$$(14) \quad JMA_{ndt} = \sum_{m \in \mathcal{N}^c \setminus n} e^{-\eta^c \tau_{nm}} l_{mdt},$$

where l_{mdt} is the number of jobs in workplace tract m and 6-digit NAICS industry d in time t , $\tau_{n,m}$ is the travel-time between tracts n and m , and η^c is a spatial decay parameter governing the importance of faraway jobs relative to closer jobs in determining a tract's employment access.

We obtain measures of $\tau_{n,m}$ for college graduates using reported commute destinations and times from our ACS data. However, since the number of neighborhood-pairs in each CBSA is large relative to the number of college graduates surveyed in the ACS, we follow [Baum-Snow, Hartley, and Lee \(2019\)](#) and estimate a simple forecasting model to predict $\tau_{n,m}$ for all neighborhood pairs in each CBSA. We obtain CBSA-specific measures of η^c by using our employer-employee linked data to estimate gravity equations derived from a workplace choice model á la [Tsivanidis \(2022\)](#). We detail both our forecasting model and workplace choice model with its resulting gravity equations in Appendix D.3.⁴²

We use these industry-specific measures of employment access to construct our job market access IVs:

$$(15) \quad \Delta \widetilde{JMA}_{n,t_0,t} = \sum_{d \in \mathcal{T}} \underbrace{\frac{JMA_{n,d,t_0} \theta_d^c}{\sum_{d'} JMA_{n,d',t_0} \theta_{d'}^c}}_{Share} \underbrace{\frac{L_{d,t}^c - L_{d,t_0}^c}{L_{d,t_0}^c}}_{Shift},$$

where $L_{d,t}^c$ is national employment in industry d less employment in industry d located in neighborhood n 's CBSA. \mathcal{T} denotes the set of tradable of industries we use to predict changes in job market access.⁴³ As we do not observe the educational level or race of workers in our establishment-level data, we scale our industry-level measures of job market access by the

⁴²Travel times and spatial decay parameters are defined separately for college graduates and low-income renters.

⁴³We define our set of tradable industries using trade costs for 6-digit NAICS manufacturing and service industries, as estimated in [Gervais and Jensen \(2019\)](#). We label an industry as tradable if its estimated trade costs are in the bottom three quartiles of the manufacturing and service industries analyzed by [Gervais and Jensen \(2019\)](#). We find this threshold ensures sufficient first-stage power while excluding industries whose establishment locations are likely endogenous to the spatial sorting within cities, such as local retailers. We discuss our choice to focus on tradable industries below.

share of workers employed in each industry and in each state that have a college degree, θ_d^c . Remember that analogous IVs are constructed for low-income renter households.

For all our job market access instruments, we select $t_0 = 2002$ and $t = 2007$. As our discussion around households' expectational errors in section 5.3 highlights, our instruments may not use information outside of households' information sets to shift the endogenous variables. If the instruments predict changes in the endogenous variables that households do not - on average - expect, then the instruments will be correlated with their expectational errors. By setting $t_0 = 2002$ and $t = 2007$, we rely on serial correlation in the endogenous variables to ensure our instruments remain relevant. Our choice of $t_0 = 2002$ is motivated by the fact that the US Census Bureau's Economic Census occurs on the years ending in 2 and 7 (Chow et al. 2021). The allocation of firm employment data across establishments is most accurate in these years, increasing the precision of our baseline shares.⁴⁴ We find that first-stage power for our job market access instruments are then maximized when we choose $t = 2007$; local labor demand shocks induced by the Great Recession don't appear to influence households' location choices throughout 2011-18.

Identifying Assumptions. Recent studies on shift-share instruments show how the exclusion restriction can hold with either conditionally exogenous shares (Goldsmith-Pinkham, Sorkin, and Swift 2020) or with conditionally exogenous shifts (Borusyak, Hull, and Jaravel 2022). The shares in equation 15 correspond to neighborhoods' baseline commute-time-discounted exposure to employment in each industry. The shifts correspond to the national employment growth rate in each industry. As it is less plausible that establishments' baseline neighborhood locations are unrelated to underlying trends in nearby neighborhoods' exogenous amenities, we argue that identification comes from the conditional exogeneity of national industry employment shifts.

Borusyak, Hull, and Jaravel (2022) show that three conditions are together sufficient to ensure our employment "shifts" are conditionally exogenous. First, establishments in industries with nationwide employment shocks (positive or negative) must not be concentrated near neighborhoods experiencing trends (positive or negative) in their unobserved exogenous amenities. Second, no small subset of industries may comprise a large portion of the baseline shares. Third, industries' national employment shifts must be mutually uncorrelated given trends in unobserved amenities and baseline shares.⁴⁵

⁴⁴We considered using 1997 as our baseline year, but this would have required manually geocoding establishments' addresses since the LBD had not started reporting establishments' census tracts at that time.

⁴⁵The first condition can be represented formally as $\mathbb{E}[g_d | \{\bar{\Delta}v_d\}_d, \{s_d\}_d] = \mu$, the second condition as $\mathbb{E}[\sum_d s_d^2] \rightarrow 0$, and the third condition as $\text{Cov}(g_d, g_{d'} | \{\bar{\Delta}v_d\}_d, \{s_d\}_d) = 0 \forall (d, d')$, where $s_d = \sum_n s_{n,d} = \sum_n \sum_{d'} \frac{JMA_{n,d,t_0} \theta_d^c}{JMA_{n,d',t_0} \theta_{d'}^c}$, $g_d = \frac{L_{d,t}^c - L_{d,t_0}^c}{L_{d,t_0}^c}$, and $\bar{\Delta}v_d = \frac{\sum_{nn' \bar{n}} s_{n,d} \Delta v_{nn' \bar{n}}}{s_d}$.

We consider a number of threats to identification. First, researchers have argued that throughout our analysis period there was a general trend toward suburbanization among low-income households irrespective of gentrification (Bartik and Mast 2023). If establishments concentrated near suburban neighborhoods that primarily employed low-skilled workers were overrepresented in industries experiencing negative nationwide employment shocks, then we may mistake a secular migration trend as a distaste for market access. To account for this possibility, we residualize $\Delta \widetilde{JMA}_{n,t_0,t}$ on measures of proximity to the metro division’s CBD. These measures include a quadratic in the physical distance between the CBD and neighborhood n ’s centroid, a quadratic in the population-weighted distance between the CBD and neighborhood n ’s centroid, and fixed effects for five equally-sized concentric rings that are centered at the CBD. The concentric rings are measured in population-weighted distance. Together, these measures ensure that our job market access instruments induce variation in the endogenous variables among neighborhoods that are equidistant from each metro division’s CBD.

A second threat to identification is that changing consumer preferences may jointly influence households’ location choices *and* industry employment trends. For example, changing preferences for different types of non-tradable services may simultaneously influence employment in those industries and households’ within-CBSA residential location decisions. To avoid this concern, we construct $\Delta \widetilde{JMA}_{n,t_0,t}$ using only employment shifts in *tradable* 6-digit NAICS industries.⁴⁶ This ensures employment trends are not caused by households’ residential location choices. We also construct our national employment shifters excluding employment in the CBSA for which we are predicting changes in job market access.

A third threat to identification relates to the secular decline in manufacturing (NAICS 31-33) employment throughout 2002-07 (Autor, Dorn, and Hanson 2013). Correlated employment shocks to 6-digit NAICS industries within the manufacturing sector threaten the consistency of our estimates. To account for correlated employment shocks within the manufacturing sector, we residualize $\Delta \widetilde{JMA}_{n,t_0,t}$ on neighborhoods’ baseline exposure to manufacturing employment. Identification then requires industry employment shifts *within* the manufacturing sector are mutually uncorrelated conditional on baseline shares and unobserved amenities, a significantly less stringent requirement (Borusyak, Hull, and Jaravel 2022).

6.2. Proximity IV

Guerrieri, Hartley, and Hurst (2013) show that during a positive city-wide employment demand

⁴⁶By restricting to tradable industries, the effective “shares” in $\Delta \widetilde{JMA}_{n,t_0,t}$ do not sum to 1 across industries and within neighborhoods. To control for the possibility that neighborhoods near high concentrations of tradable industry establishments are systematically exposed to increasing/decreasing exogenous neighborhood amenities, we additionally control for neighborhoods’ exposure to the total share of tradable employment (Borusyak, Hull, and Jaravel 2022).

shock, among low-income neighborhoods it is those closest to other high-income neighborhoods that experience the greatest home price appreciation - a proxy for gentrification. Motivated by these findings, we construct a neighborhood-level and distance-weighted measure of proximity to other neighborhoods' share of college graduates. We then interact this measure with CBSA-wide Bartik labor demand shocks constructed using initial CBSA-wide shares of college graduates in tradable 6-digit NAICS industries. Again, though our instrument construction is novel, we are not the first to use proximity to other high-income neighborhoods as an instrument for gentrification (Brummet and Reed (2021); Glaeser, Luca, and Moszkowski (2023)).

Instrument Construction. We first form neighborhood-level distance-weighted measures of proximity to other neighborhoods' shares of college graduates in the same CBSA. We then interact these neighborhood-level measures with shocks to CBSA-wide tradable industry employment:

$$\Delta \widetilde{\text{Prox}}_{n,t_0,t',t} = \sum_{d \in \mathcal{T}} \underbrace{\sum_{m \in \mathcal{N}^c \setminus n} e^{\rho \tau_{n,m}} \frac{\text{Coll}_{m,t_0}}{\text{Pop}_{m,t_0}}}_{\text{Proximity}} \cdot \underbrace{\frac{l_{d,t'} \cdot \theta_d^c}{\sum_{d'} l_{d',t'} \cdot \theta_{d'}^c}}_{\text{Share}} \underbrace{\frac{L_{d,t}^c - L_{d,t'}^c}{L_{d,t'}^c}}_{\text{Shift}},$$

where $\frac{\text{Coll}_{m,t_0}}{\text{Pop}_{m,t_0}}$ is the share of residents in neighborhood m who are college graduates, and where $l_{d,t'} = \sum_n l_{d,n,t'}$. The variables $l_{d,n,t'}$, $L_{d,t}^c$, and the parameters $\theta_{d'}^c$ are defined as before. ρ is a spatial decay parameter governing the importance of faraway neighborhood college graduate shares relative to closer neighborhood shares. As $\rho \rightarrow \infty$, only the neighborhoods immediately adjacent to neighborhood n matter for determining the value of $\Delta \widetilde{\text{Prox}}_{n,t_0,t}$. Conversely, as $\rho \rightarrow 0$ the instrument loses all relevance as every neighborhood matters equally in determining $\Delta \widetilde{\text{Prox}}_{n,t_0,t}$, ensuring $\Delta \widetilde{\text{Prox}}_{n,t_0,t}$ is constant within each CBSA. Since we don't have a good prior for ρ , we calibrate its value using k -fold cross-validation in a set of first-stage regressions, regressing $\text{Gent}_{n,t_0,t}$ on $\Delta \widetilde{\text{Prox}}_{n,t_0,t}$ and selecting the value of ρ that best predicts changes in the neighborhood share of college graduates.

Unlike local labor demand, industry wide employment shocks throughout the Great Recession are very predictive of future CBSA-wide labor demand. For that reason, we use employment shifts between $t' = 2007$ and $t = 2010$ to construct our Bartik shift-share, but construct the proximity shares in $t_0 = 2002$ for reasons we discuss below.

Identification. Identification here proceeds differently to our job market access instruments. Because our final estimating equations include CBSA-wide fixed effects, identifying variation must come from within CBSAs and so rules out identification from the CBSA-wide shift-shares

alone. Identification instead proceeds from the interaction between the “proximity” term and the Bartik shift-share.

Note that neighborhoods’ proximity to other neighborhoods with a high share of college graduates is likely correlated with underlying trends in exogenous amenities. To account for this possibility, we take two steps. First, we use lagged shares of neighborhoods’ proximity to other neighborhoods with a high share of college graduates. Second, we residualize $\Delta \widetilde{\text{Prox}}_{n,t_0,t',t}$ on the proximity terms themselves, so that identification comes solely from the *interaction* between the shift-shares and the proximity terms. Identification thus proceeds analogously to a difference-in-difference estimator: we compare differences in gentrification between neighborhoods near and far already gentrified tracts in CBSAs experiencing large labor demand shocks to differences in gentrification between neighborhoods near and far already gentrified tracts in CBSAs not experiencing large labor demand shocks.

6.3. Moment Conditions

The final collection of instruments are:

$$(16) \quad z_{1,n} = \Delta \widetilde{JMA}_{n,02,07}^{Coll}$$

$$(17) \quad z_{2,n} = \Delta \widetilde{JMA}_{n,02,07}^{Low-Income}$$

$$(18) \quad z_{3,n} = \Delta \widetilde{JMA}_{n,02,07}^{Coll} \cdot \varphi_n,$$

$$(19) \quad z_{4,n} = \Delta \widetilde{\text{Prox}}_{n,02,07,10},$$

where φ_n are neighborhood-level measures of the share of land in the census tract covered by urban development in 2011. The super-scripts *Coll* and *Low – Income* refer to the group for whom the instrument is constructed.⁴⁷ We estimate the moment restriction in equation 13 via linear GMM separately for each type- k household:

$$\mathbb{E} \left[z_n \Delta v_{xnn'\tilde{n}}^k \right] = 0.$$

A corresponding observation in this moment restriction is a set of residential paths for a type- k household with individual state, x . Each type- k household of city c has $2 \cdot (N^c + 1)$ initial states in period $t - 1$, N^c possible neighborhood choices in that same period, and $N^c - 1$ possible neighborhood choices in period t , implying $\sum_c 2 \cdot (N^c + 1) \cdot N^c \cdot (N^c - 1)$ observations for for both

⁴⁷We estimate the commute elasticities and the employment share parameters for Black and Non-Black low-income households jointly when constructing $\Delta \widetilde{JMA}_{n,02,07}^{Low-Income}$. This ensures the same variation identifies both type- k household’s preferences.

Black and Non-Black low-income renter households. Since the urban cores of our largest CBSAs contain roughly two thousand census tracts, the number of potential residential paths reach into the tens of billions. To ease the computational burden, we restrict the set of residential paths we analyze. Specifically, we restrict the set of residential paths to those that start from neighborhoods with the highest shares of type- k low-income renters in their CBSA. The cutoff for “highest shares” varies across CBSAs. For CBSAs with over 500 Census tracts in their urban core, we select the top ten percent of tracts in terms of their share of type- k low-income renters. For CBSAs with under 500 Census tracts in their urban core, we select the 50 highest tracts in terms of their share of type- k low-income renters. This choice ensures a minimum number of census tracts from each CBSA inform our estimates. We report our estimates in Table 4.

6.4. Parameter Estimates

The leftmost columns of Panel A in Table 4 report parameter estimates for households’ valuations of neighborhood characteristics while the same columns in Panel B report estimates on households’ moving frictions. Since logit models only identify relative changes in welfare, the rightmost columns in Table 4 translate the estimates into households’ willingness to pay measured in annual rents. The annual rent values for college share (β_A) and market access (β_w) reflect the extra annual rent payments households would incur to reside in a neighborhood with a 10% higher share of college graduates or market access, respectively.⁴⁸

The interpretation of the annual rent valuations differ across the moving friction parameter estimates. The annual rent values for physical move distance (β_d and β_d^{Sq}) represent the amount of annual rents households would be willing to pay to move to a census tract one mile closer to their origin neighborhood, conditional on moving. The annual rent values for social distance (β_s and β_s^{Sq}) represent the amount of annual rents households would be willing to pay to move to a census tract 10 percentage points more similar to their current census tract in terms of neighborhood college shares, again conditional on moving.⁴⁹ The fixed moving cost annual rent valuations represent how much in annual rents households would be willing to pay to avoid moving in any one year. The high residential tenure annual rent valuations represent how much the fixed cost of moving increases each additional year the household remains in their current neighborhood.

Our parameter estimates all have the expected sign, though Black households have a surprisingly low valuation for market access.⁵⁰ One explanation for Black households’ low valuation

⁴⁸We use the average neighborhood rent levels for Black and Non-Black households in Table ?? as the basis of the percentage change in rents.

⁴⁹The physical distance value of rent measures were calculated based on an initial move of 0 miles. The social distance value of rent measures were calculated assuming the average baseline share of college graduates for both Black and Non-Black households, as reported in Table ??.

⁵⁰While Black households appear to value some social distance conditional on moving, they have a distaste for

for market access is that the variation in market access induced by our job market access instruments is concentrated in industries primarily employing Non-Black workers; such variation would not induce migration responses from households not employed in these industries, suggesting no preference for market access. Future iterations of the paper will test the robustness of our parameter estimates to skill and race-specific measures of job market access.

Our parameter estimates reveal how costly it is to move across neighborhoods, even for renter households, and especially for those with a high level of residential tenure. Low-income Black renter households' within-CBSA migration decisions suggest that the fixed cost of moving neighborhoods is over \$3,000, and that this cost increases by around \$600 with every additional year of residential tenure. Surprisingly, the social distance between neighborhoods plays little role in households' residential migration decisions. One explanation for this result is that low-income households initially residing in gentrifying tracts move to tracts with a lower share of college graduates, conditional on moving. Our model would interpret these moves as revealing a preference for social distance. A different model specification may incorporate asymmetric moving costs, capturing the distinct cost of moving into a neighborhood with a higher share of college graduates than one's origin tract.

7. Welfare Analysis

In this section, we examine what our parameter estimates imply about the welfare effects of gentrification for incumbent renters in the year 2000. Our welfare calculations are based on the following counterfactual analysis. Consider a representative low-income renter living in a gentrifying inner-city neighborhood, n , in the year 2000. To this renter, the distribution of neighborhood-level rents and shares of college graduates across her CBSA are exogenous. Given the exogenous distribution of these market-level state variables, $\bar{\omega}_t^k$, as well as her expectations over their evolution, we compute her expected welfare in 2000. Then, to estimate the welfare impact of gentrification, we compare this measure to the expected welfare the same renter in neighborhood n would obtain in the year 2000 if the economy were instead in a steady state. If her expected welfare is lower in the steady-state equilibrium, we say that the changing distribution of neighborhood rents and college shares across the CBSA throughout 2000-2019 increased her welfare. The opposite is true if her expected welfare is higher in the steady-state equilibrium. We make these calculations separately for representative low-income renters in every low-income neighborhood in the year 2000.

moves that involve significant differences in neighborhood educational composition.

TABLE 4. Parameter Estimates

	Estimates		Value in Annual Rent	
	Black	Non-Black	Black	Non-Black
Panel A: Neighborhood Characteristics				
Rents (β_r)	-10.31*** (1.494)	-26.40*** (3.341)	–	–
College Share (β_A)	12.61*** (0.390)	7.343*** (1.437)	\$1,224	\$312
Market Access (β_w)	0.122 (1.635)	20.04*** (3.487)	\$12	\$851.4
Panel B: Moving Frictions				
Distance (β_d)	-0.2782*** (0.0004)	-.3091*** (0.0003)		
Distance Squared (β_d^{Sq})	0.0039*** (0.0000)	0.0044*** (0.0000)	-\$270	-\$130
Social Distance (β_s)	0.1335*** (0.0108)	-0.1751*** (0.0084)		
Social Distance Squared (β_s^{Sq})	-0.5598*** (0.0074)	-0.4096*** (0.0060)	\$5	-\$15
Within-CBSA Fixed Moving Cost (MC)	-4.558*** (0.000)	-4.318*** (0.0000)	-\$3,578	-\$1,692
Outside-CBSA Fixed Moving Cost (MC^c)	-4.458*** (0.000)	-4.621*** (0.0000)	-\$3,515	-\$1,801
High Residential Tenure ($\bar{\tau}$)	0.612*** (0.0002)	0.551*** (0.0001)	\$612	\$237
F-Stat	63.35	27.92		
N (1,000s)	2,573,000	10,630,000		

Notes: An observation is a set of residential paths described in section D.1. The number of residential paths in our analysis differ across Black and Non-Black low-income renter households because we predict fewer conditional choice probabilities for Black households in the first-step of the analysis, as discussed in footnote 37.

A steady state equilibrium in this framework holds the distribution of market-level state variables, $\bar{\omega}_t^k$, fixed at their 2000 levels for every period t in the future. It further fixes the value of exogenous neighborhood amenities, $\{\xi_n\}_n$, at levels which induce a stationary distribution among low-income renter households. A stationary distribution implies that the share of each type- k household of tenure level $\bar{\tau}$ in each neighborhood remains constant over time. We define these concepts formally in Appendix D.4.

For every low-income neighborhood across each of our 50 large CBSAs, we make the following calculation for a representative type- k household with tenure $\bar{\tau}$:

$$(20) \quad \Delta W^k(n, \bar{\tau}) = \frac{\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc}) - V_{ss}^k(n, \bar{\tau})}{\beta_r^k} \quad \forall k, n,$$

where $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$ is the expected welfare of a type- k incumbent renter living in neighborhood n with tenure status $\bar{\tau}$ in the year 2000. $V_{ss}^k(n, \bar{\tau})$ is the same calculation, but computed under the assumption that the economy is in steady state. To make comparisons across type- k households, we normalize $\Delta W^k(n, \bar{\tau})$ by households' marginal utility of log rent. We can therefore interpret $\Delta W^k(n, \bar{\tau})$ as the welfare impact of neighborhood change starting in 2000 on incumbent renters initially living in neighborhood n . We provide further details on our welfare calculations in Appendix D.4.⁵¹

$\Delta W^k(n, \bar{\tau})$ differs across neighborhoods to the extent that moving frictions mediate the welfare impacts of gentrification. If it were costless to move across neighborhoods and households did not accumulate neighborhood-level capital, households' individual states, $x(n_{i,t-1}, \tau_{i,t-1})$, become irrelevant and differences in welfare effects across neighborhoods within CBSAs disappear. This happens because, each period, households simply choose to live in the neighborhood that offers the most ideal bundle of neighborhood characteristics regardless of where they are currently located. By contrast, with high moving costs and much neighborhood capital accumulation, incumbent renters are averse to leaving their current neighborhood irrespective of changes in its characteristics. In this sense, incumbent renters bear the incidence of their changing neighborhood environment when there are substantial moving frictions.

Before we present our results, it is worth discussing two nuances surrounding our welfare analysis. First, when computing $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_t^{kc})$, we hold the distribution of exogenous neighborhood amenities fixed at their 2000 levels. As a result, the distribution of low-income renters across neighborhoods predicted by our model do not match their observed counterparts after the year 2000. While fixing exogenous neighborhood amenities at their 2000 levels helps isolate the welfare effects of gentrification, the discrepancy between the model's predicted choice probabilities and their observed counterparts highlights a limitation of our single-agent framework. Namely, that we cannot use our framework to assess counterfactual *policies* like rent control, as these policies will affect the distribution of $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_t^{kc})$ in ways we cannot predict. All counterfactual analyses we run therefore either directly manipulate households' preferences or elements in $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_t^{kc})$.

Second, we do not have a good measure of *absolute* changes in amenities during our analysis period. Recall that we model observed neighborhood amenities as a function of the share of college graduates in each neighborhood. The share of college graduates increased nationwide from 26.8% to 36.5% between 2000 and 2019.⁵² While changes in the distribution of college

⁵¹For all these welfare calculations, we keep the observed distribution of job market access at its 2000 levels. This choice is motivated by our reduced-form evidence in section 3, showing that gentrification has negligible impacts on the employment outcomes of incumbent renter households. While job market access factors into households' location choices, gentrification does not appear to affect market access in a way that impacts incumbent low-income renter households. This could result, for example, from gentrification skewing the composition of non-tradable employment opportunities toward higher-skilled workers. **Tighter Justification**

⁵²These are our own calculations based on publicly available IPUMS Census data (Manson et al. 2022).

graduates across neighborhoods within a city likely reflects changes in the relative distribution of neighborhood amenities (Su 2022), it is unlikely that the absolute level of amenities increased in proportion to nationwide educational attainment. For this reason, our welfare analysis focuses on differences in welfare effects across incumbent renters living in different neighborhoods in the year 2000.

Minimal Variation in Welfare Effects Across Neighborhoods. Table 5 reports results from regressions of $\Delta W^k(n, \bar{\tau})$ on our measure of gentrification defined in section ??.⁵³ The purpose of these regressions is to understand the welfare effects from gentrification for incumbent renters living in different neighborhoods within the same CBSA. The unit of analysis in these regressions is a 2010-delineated Census tract. The sample includes the poorest 50% of all Census tracts among the 50 largest urban cores in the US. These regressions include measures of neighborhoods' proximity to their CBSA's CBD. Neighborhoods closer to the periphery of the urban core have an artificially lower degree of access to other neighborhoods than do tracts closer to the CBD.⁵⁴ Tracts closer to the periphery of the urban core also experience less gentrification. The CBD proximity controls are designed to account for this correlation. The regressions also contain CBSA fixed effects and a set of baseline neighborhood controls which include baseline rents and college shares. These controls ensure our regression results compare the impact of gentrification across neighborhoods within the same CBSA and across neighborhoods with the same baseline levels of rents and college shares. Our results are not sensitive to excluding any of these controls.

The coefficients on gentrification in Table 5 reflect how gentrification impacts incumbent renters' welfare. The economically insignificant coefficients in Table 5 suggest the economic impact of gentrification in one's current neighborhood is negligible. A 10 percentage point increase in gentrification is associated with only a 0.0211 (0.00333) increase in log consumption units for Black (Non-Black) renters with high neighborhood tenure (only \$17.69 (\$3.12) in annual rents). Results are similar across households with high and low levels of accumulated neighborhood capital.

There are at least three explanations for the null results reported in Table 5. First, it may be that the benefits of improving amenities exactly offset the costs of higher rents as incumbent renters stay in their home neighborhoods. Under this scenario, gentrification is welfare neutral regardless of one's home census tract. Second, gentrification may sometimes benefit incumbent renters and sometimes harm them, depending on characteristics of their baseline neighborhood

⁵³Here we define gentrification with the end period, t , set to 2006. We found that gentrification defined over 2000-2006 explained the most variation in outcomes across a range of exploratory analyses.

⁵⁴We define an urban core in footnote XX. There are neighborhoods outside the urban core (inside the outside option) that residents of neighborhoods on the periphery of the urban core could have in practice easily moved to. Since it is equally costly to move to the outside option from anywhere in the urban core, our setup artificially lowers the level of access to neighboring tracts for incumbent residents' in the urban periphery.

environment. In this scenario, results in Table 5 are masking significant underlying heterogeneity. Third, it may be that incumbent renters are sufficiently mobile to render changes in their current neighborhood relatively unimportant for expected utility. Here, it is not that gentrification is welfare neutral, but that *where* incumbent renters initially live within their city is unimportant. We show that this third scenario is driving our results.

TABLE 5. Welfare Effects of Gentrification on Incumbent Renters

$\Delta W^k(n, \bar{\tau})$	(1)	(2)	(3)	(4)
Gentrification	0.126*** (0.0200) [1.613]	-0.0032 (0.0174) [1.249]	0.2111*** (0.0303) [1.591]	0.0333 (0.0191) [1.225]
Controls				
CBD Proximity Controls	✓	✓	✓	✓
Baseline Neighborhood Controls	✓	✓	✓	✓
CBSA Fixed Effects	✓	✓	✓	✓
Sample Restrictions				
<i>Race</i>	Black	Non-Black	Black	Non-Black
<i>Tenure Status</i>	$\bar{\tau} = 1$	$\bar{\tau} = 1$	$\bar{\tau} = 2$	$\bar{\tau} = 2$
Number of Tracts	1,539	1,560	1,539	1,560

Notes: Table 5 reports results from regressions of $\Delta W^k(n, \bar{\tau})$ on $\text{Gent}_{n,2000,2006}$. Standard errors in parentheses are clustered by CBSA. The average change in log consumption across all neighborhoods is reported in square brackets. For computational reasons, we have only computed $\Delta W^k(n, \bar{\tau})$ for five CBSAs: Boston MA, Chicago IL, Philadelphia PA, Portland OR, San Francisco CA. We will update Table 5 with our full sample very soon. We don't expect our qualitative results to change. Sources: Publicly available ACS (2005-2021) and Decennial Census (2000) (Manson et al. 2022).

Changes in Neighborhood Choice Sets Govern Welfare Impacts. We show here that the null results in Table 5 are not because gentrification is welfare neutral or because they mask significant underlying heterogeneity. Rather we show that gentrification's effects operate primarily through changing the characteristics of *other* neighborhoods in renters' choice sets. We show this by conducting the following counterfactual analysis. Consider a representative incumbent low-income renter residing in neighborhood n in the year 2000. Assume that neighborhood n 's observable characteristics evolve just as in the data like before. But also assume that all other neighborhoods' characteristics remain fixed at their 2000 levels. Then ask, do the changing characteristics of neighborhood n benefit or harm the incumbent renter in neighborhood n ? By

holding the characteristics of other neighborhoods fixed, this counterfactual analysis separates the role of changing neighborhood characteristics in one's home neighborhood and the changing characteristics of other neighborhoods across the CBSA. We perform this counterfactual analysis by constructing a modified measure of $\Delta W^k(n, \bar{\tau})$:

$$(21) \quad \Delta \tilde{W}^k(n, \bar{\tau}) = \frac{\tilde{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc}) - V_{ss}^k(n, \bar{\tau})}{\beta_r^k} \quad \forall k, n,$$

where $\tilde{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$ is constructed just like $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$, but the market-level state variables for $n' \neq n$ are fixed at their 2000 values for every year from 2000 onward.

Table 6 reports results from regressions of $\tilde{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$ on our measure of gentrification. We observe economically and statistically significant positive effects of gentrification on incumbent renters' welfare. This is true for both Black and Non-Black households (though results are stronger for Black households), who have meaningfully different valuations of neighborhood characteristics, and for households with high and low levels of accumulated neighborhood capital. For example, a 10 percentage point increase in gentrification increases Black (Non-Black) renters' welfare by 1.1408 (.08023) log consumption units (\$1,776.66 (\$78.08) in annual rents) when these renters have a high level of accumulated neighborhood capital (Table 6, columns (3) and (4)).

Table 6 shows that when we hold other neighborhoods' characteristics constant, gentrification meaningfully affects incumbent renters' welfare. Conversely, as we let other neighborhoods' characteristics vary, where an incumbent renter initially lives has little impact on their expected welfare. Tables 5 and 6 together suggest that how cities as a whole changed throughout 2000-2019 was more important for incumbent renters than how their own neighborhood alone changed throughout this time period.

8. Discussion

Beginning in the 1990s and intensifying after the year 2000, gentrification transformed the socioeconomic composition of vast areas within American inner cities. In this paper we show how this transformation affected incumbent renters of these cities. We first show that gentrification did not affect the employment outcomes of renters living in gentrifying neighborhoods. Nor did gentrification affect the length of time incumbent renters stay in their home neighborhoods. Gentrification did, however, impact the characteristics of neighborhoods incumbent renters lived in throughout our analysis period. This last finding suggested the possibility that gentrifi-

TABLE 6. Neighborhood Choice Sets Mediate Welfare Impacts

$\Delta \tilde{W}^k(n, \bar{\tau})$	(1)	(2)	(3)	(4)
Gentrification	11.9395*** (0.4420) [0.9793]	0.5645** (0.2407) [0.0398]	11.4080*** (0.3969) [0.9284]	.8023*** (0.1950) [-0.0200]
Controls				
CBD Proximity Controls	✓	✓	✓	✓
Baseline Neighborhood Controls	✓	✓	✓	✓
CBSA Fixed Effects	✓	✓	✓	✓
Sample Restrictions				
<i>Race</i>	Black	Non-Black	Black	Non-Black
<i>Tenure Status</i>	$\bar{\tau} = 1$	$\bar{\tau} = 1$	$\bar{\tau} = 2$	$\bar{\tau} = 2$
Number of Tracts	1,539	1,560	1,539	1,560

cation meaningfully affected incumbent renters' welfare. To test whether gentrification affected incumbent renters' welfare, we estimate a dynamic model of residential and workplace choice. We use our parameter estimates from this model to quantify the welfare effects of gentrification. We show using our framework that gentrification affected incumbent renters primarily through changing the characteristics of *other* neighborhoods in renters' choice sets.

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Appendix A. Aggregate Neighborhood Change Since 2000

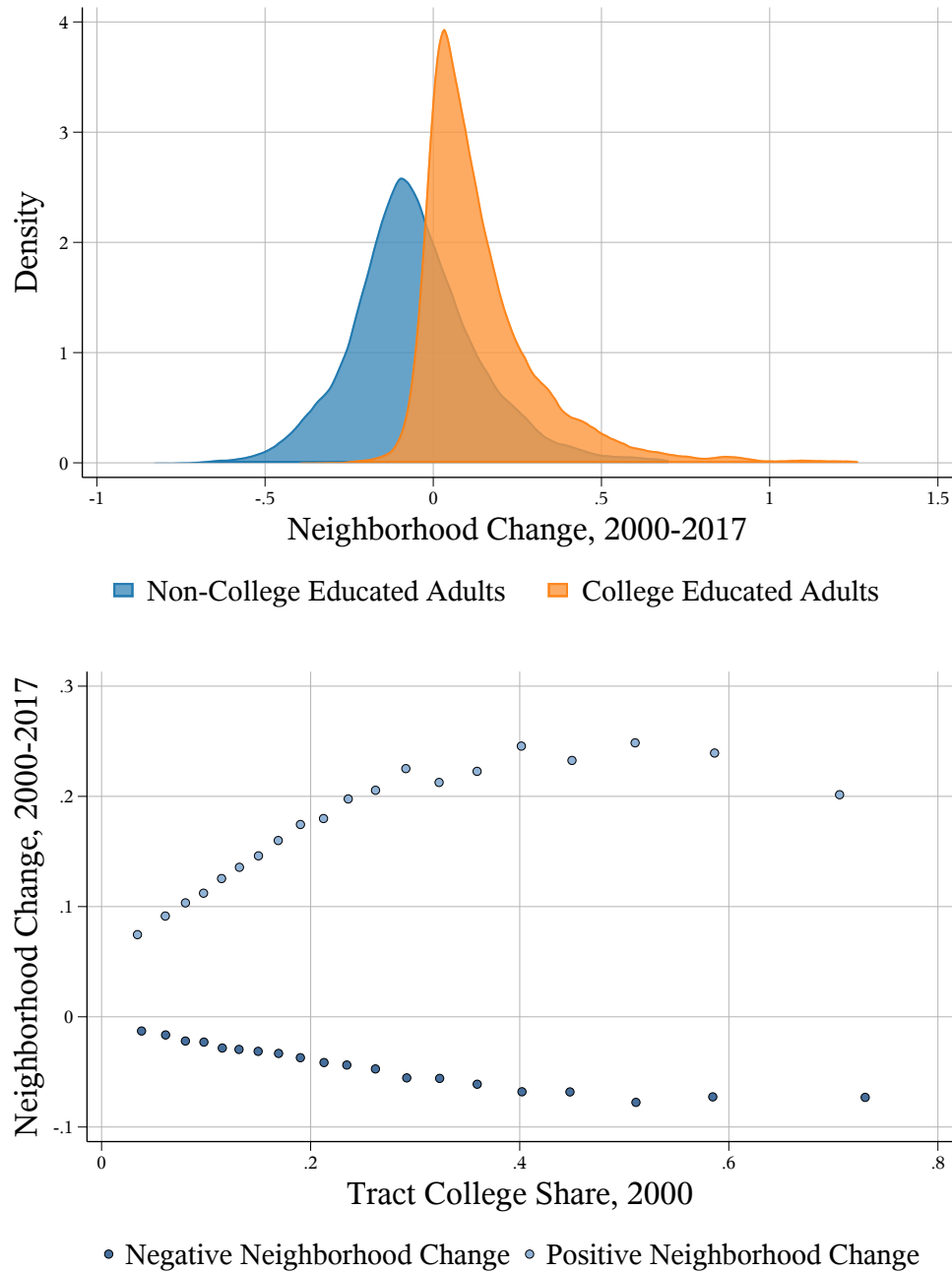


FIGURE A1. Neighborhood Change, 2000 - 2017

These figures are constructed using 2010 delineated census tract population counts for the 100 largest (ranked by population) US CBSAs from the publicly available 2000 NHGIS Census and the American Community Survey 2015-2019 5-year aggregates (Manson et al. 2022). We exclude tracts with fewer than 1,000 adult residents in 2000. Neighborhood change for non-college educated and for college-educated households is defined analogously to equation X. The top panel plots kernel densities of neighborhood change between 2000-2017 among Census tracts that contain the 20% of the CBSA's population that is closest to its CBD. The bottom panel plots our tract-level measure of neighborhood change (y-axis) against the tract's initial share of college-educated workers in 2000, separately for tracts that experienced positive and negative changes in their share of college-educated households.

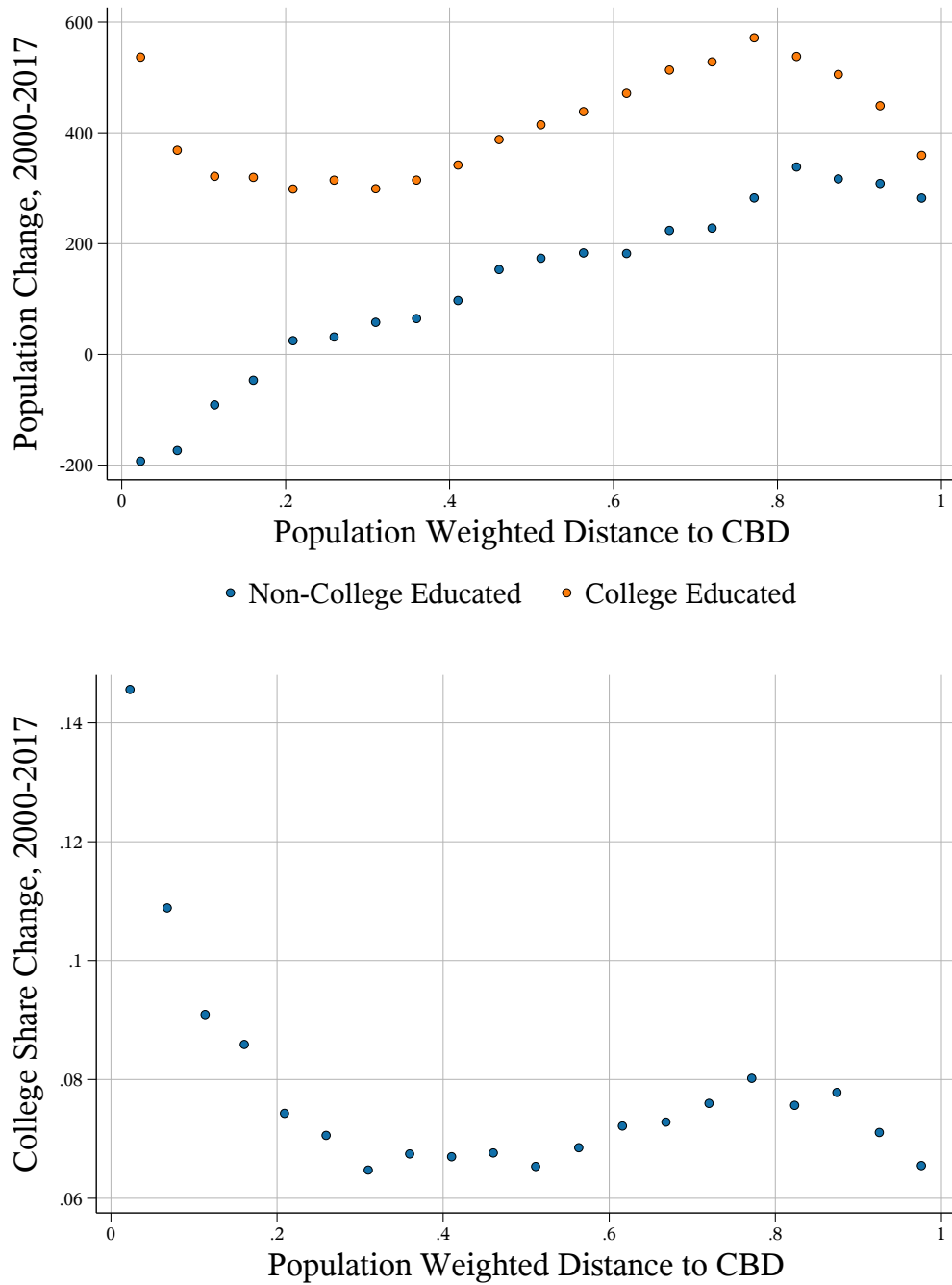


FIGURE A2. Neighborhood Change and Initial College Share

The figure is constructed using 2010 census tract population counts for the 100 largest (ranked by population size) US metropolitan divisions from the publicly available 2000 NHGIS Census and the American Community Survey 2015-2019 5-year aggregates (Manson et al. 2022). We exclude tracts with fewer than 1,000 adult residents in 2000. Neighborhood change is defined by equation X. The top panel plots the degree of population change for college and non-college educated households between 2000-2017 by the population-weighted distance to each metropolitan division's respective CBD. The bottom panel plots the change in the share of college educated households, also by the population-weighted distance to each metropolitan division's respective CBD.

Appendix B. Data Appendix

B.1. Data Descriptions

Master Address File Extract.

Master Address Auxiliary Reference File.

American Community Surveys.

Longitudinal Employer-Households Dynamics.

Longitudinal Business Database.

Core Logic.

B.2. Detailed Sample Construction

B.3. Aggregate Variable Construction

Appendix C. Reduced-Form Appendix

C.1. Control Variables

Household-Level Controls. Our vector of household-level controls, X_i , is designed to capture household characteristics that jointly determine one's origin location and our set of outcome variables, Δy_i and $h(t|i)$. These controls include i) average household income in defined as the mean income of all adults residing at the same address during 2010; ii) household size defined as the number of adults residing at the same address;⁵⁵ iii) a second-order polynomial in the household head's date of birth; iv) indicators for the household head's race, immigrant status, sex, and college degree attainment;⁵⁶ and v) the length of the household head's prior residential tenure in neighborhood $n(i)$. All variables are defined in our base year, 2010.

Neighborhood-Level Controls. Our vector of neighborhood-level controls, $X_{n(i)}$, is designed to capture characteristics of the household's origin neighborhood that are potentially correlated with our measure of neighborhood change and our set of outcome variables, Δy_i and $h(t|i)$. We first include neighborhood-level controls defined in 2010 which include i) the share of adults in the neighborhood with a college degree; ii) the share of adults in the neighborhood that identify as non-hispanic and white; iii) the median income among working age adults residing in the neighborhood; iv) the median property value and rent payment in the neighborhood; v) the degree of neighborhood churn which we define as the share of adults residing in the neighborhood during 2008 who also remain in the neighborhood during 2009; vi) second-order polynomials in the distance to the metropolitan division's CBD, measured in both the physical distance as well as in the cumulative share of the metropolitan division's residents residing closer to the CBD than those in tract $n(i)$; vii) fixed effects capturing five bands equidistant from the metropolitan division's CBD; and viii) the 5-year lag in our measure of neighborhood change.

In addition to our neighborhood-level controls defined in 2010, we also include a few contemporaneous neighborhood-level controls that are similarly designed to capture *changing* characteristics of the household's origin neighborhood that are potentially correlated with our measure of neighborhood change and our set of outcome variables, Δy_i and $h(t|i)$. In particular, we control for changes in job market access to *tradable* industries among low-skilled workers. In terms of equation 14, these changes in job market access among tradable industries for low-skilled workers are defined as $\Delta \sum_{d \in \mathcal{T}} JMA_{ndt} \tilde{\theta}_d^c$, where Δ corresponds to the difference in our *JMA* measure across 2010 and 2019, and $\tilde{\theta}_d^c$ is the share of non-college educated workers

⁵⁵We topcode this value to 10, as a few addresses record an infeasibly high number of adult residents.

⁵⁶While we run our analysis separately for Black and non-Black headed households, we include finer racial distinctions as part of our controls.

employed in industry d in CBSA c 's state.⁵⁷ We finally include in $X_{n(i)}$ a third-order polynomial in the change in neighborhood $n(i)$'s total population.

Recall that all specifications additionally include CBSA-level fixed effects α_{CBSA} , ensuring that variation in gentrification comes from across neighborhoods in the same CBSA.

C.2. Identification

A causal interpretation of our coefficients of interest, β_{NC}^{Cox} and β_{NC}^{LP} , is based on the conditionally random assignment of neighborhood change across neighborhoods between 2010 and 2019. That is, conditional on our control variables, we assume there are no unobserved neighborhood- or household-level characteristics that are correlated with our measure of neighborhood change. Given our setup, to interpret β_{NC}^{Cox} and β_{NC}^{LP} causally, we must ensure two conditions are satisfied:

- (a) First, residents in observably similar neighborhoods in 2010 must not differ in unobservable ways that correlate with our outcome variables, Δy_i and $h(t|i)$. If residents moving into gentrifying neighborhoods prior to 2010 are observably similar to their incumbent residents but different in unobservable ways that affect Δy_i and $h(t|i)$ (access to familial wealth, for example), β_{NC}^{Cox} and β_{NC}^{LP} will partly reflect sample selection.
- (b) Second, neighborhoods experiencing gentrification throughout our analysis period must not be undergoing changes in their unobserved characteristics which independently predict incumbents' outcomes. While changes to unobserved public and private amenities caused by increased neighborhood demand among college-educated residents constitute part of our treatment, our identifying variation must be purged of shocks to neighborhood characteristics that affect incumbent residents' outcomes independently of gentrification. These unobserved shocks may include changes in tradable job market access (Kain (1962); Miller (2021)), changes in transportation infrastructure that precedes gentrification (LeRoy and Sonstelie (1983); Glaeser, Kahn, and Rappaport (2008); Curci and Yousef (2022)), or changes in neighborhood valuations resulting from secular trends in preferences or from shifts to within-city income distributions (Brueckner (1987); Couture et al. (2023)). That suburbanization has continued unabated throughout our analysis periods - particularly for Black residents - makes these concerns especially acute (Bartik and Mast (2023); Couture and Handbury (2023)).

We take steps to help ensure conditions (a) and (b) are met. First, in addition to our rich household-level controls, we often subset our sample to those who have lived in their origin

⁵⁷Note that including non-tradable industries into this measure of job market access would induce a classic "bad controls" problem, as changes in non-tradable employment can easily be conceptualized as an outcome of neighborhood change (Angrist and Pischke 2009).

neighborhood for at least 5 years. While this decision focuses our analysis on longtime renters, it helps disambiguate the outcomes of gentrifiers and the outcomes of our target population of incumbent low-income renters, reducing the potential for sample bias. This is especially true when considering we control for the five-year lag in our measure of gentrification. Indeed, for sample selection to influence our results, it must be that low-income renter households predict with some accuracy how trends in neighborhood change will vary five years in the future and base their current residential choices on these predictions in a way that is uncorrelated with both their own observable characteristics (measured in 2010) and their chosen neighborhoods' observable characteristics (also measured in 2010).

Second, we are careful to control for changes in neighborhoods' unobserved characteristics that may independently predict incumbents' outcomes. By controlling for changes in access to low-skill tradable employment opportunities, we help ensure aggregate economic conditions that may independently affect neighborhood composition are not driving incumbents' outcomes. This concern is relevant given stark evidence of differential mobility responses to aggregate labor demand shocks across low- and high-skill workers (Notowidigdo 2020). By controlling for a cubic in neighborhood-level population change over our analysis period, we further control for unobserved neighborhood-level shocks that similarly affect incumbent residents and potential gentrifiers. To take an extreme example, consider a natural disaster during our analysis period that leads to a large depopulation of affected census tracts. In this scenario, we will observe low rates residential tenure among incumbent residents which we - without our population controls - would falsely attribute to a decline in our measure of neighborhood change. Note that the inclusion of our population controls implies that the coefficients on our measure of neighborhood change should be interpreted as the effect of changing neighborhood *composition* on incumbents' outcomes. Finally, our rich set of geographical controls ensure that we are comparing outcomes for incumbent residents across origin tracts that are equidistant from the Metropolitan Division's CBD, mitigating bias from secular trends toward suburbanization among our target population.

While we ensure our controls are carefully chosen to mitigate the impact of sample selection and changes in unobserved neighborhood-level characteristics, our estimates are robust to the exclusion of any small subset of control variables. It is finally worth noting that we explored using our instrumental variables detailed in section 6 to estimate our reduced-form equations. We find our reduced-form estimates are sensitive to the choice and composition (i.e. years and industries selected) of the instruments, indicating substantial heterogeneity in the complier characteristics of incumbent renters' origin neighborhoods across our instruments. It is therefore difficult to interpret the reduced-form IV estimates without placing more structure on our reduced-form equations to understand how each relevant equilibrium object (e.g. rents, non-tradable job market access, and neighborhood socioeconomic composition) mediates the impact of

gentrification on incumbent renters. For now we report our OLS estimates which we believe offer a more transparent depiction of the impact of neighborhood change on incumbent renters’ observable outcomes.

Cox Proportional Hazards Assumption. Identification in our Cox Proportional Hazards models further require that the proportional hazards assumption is met. Namely, that the impact of neighborhood change on incumbents’ hazard rates are constant across each year between 2010 and 2019. We test this assumption by plotting $-\log(-\log(\text{survival probability}))$ against $\log(\text{time})$ separately for incumbent residents originally residing in neighborhoods within each decile of our measure of neighborhood change. We observe parallel lines across all deciles of neighborhood change, consistent with the proportional hazards assumption. We also test the null hypothesis that the corresponding Schoenfeld residuals for our measure of neighborhood change are not serially correlated.⁵⁸ We report the results of Stata’s `phptest` command for our measure of neighborhood change in Table A1, which indicates that we cannot reject the null at the 95% confidence level for our full samples of Black and non-Black incumbent renters (though we are close to doing so for non-Black renters).

TABLE A1. Schoenfeld Residuals

<i>Schoenfeld Residuals</i>	Black	Non-Black
$\mathbb{P} \geq \chi^2$	0.317	0.056

Notes: Table A1 reports the results of Stata’s `phptest`, testing the null hypothesis that the Schoenfeld residuals are not serially correlated. The test statistic is distributed as χ^2 under the null hypothesis of no serial correlation.

⁵⁸The Schoenfeld residuals correspond to the difference between the observed covariate values and the expected covariate values under the Cox proportional hazards model for incumbent renters at each year between 2010 and 2019. If the proportional hazards assumption holds, these residuals should not be serially correlated (Kleinbaum and Klein 1996).

TABLE A2. Cox Model: Effect of Gentrification on Incumbent Renters' Tenure (2010-2019)

Hazard Rate	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Neighborhood Change	-0.0688 (0.0542)	-0.107* (0.0439)	-0.0793 (0.132)	0.187* (0.0781)	0.195 (0.147)	0.204* (0.871)	0.369 (0.204)	0.323* (0.108)	-0.777** (0.286)	-0.264 (0.325)	0.165 (0.555)	-0.901* (0.411)
Select Household-level Controls												
<i>Household Income (\$1,000s)</i>	-0.00381*** (0.000155)	-0.00341*** (0.000110)	-0.00320*** (0.000413)	-0.00277*** (0.000271)	-0.00273*** (0.000666)	-0.00275*** (0.000343)	-0.00326*** (0.000858)	-0.00257*** (0.000453)	-0.00365*** (0.000526)	-0.00300*** (0.000438)	-0.00301*** (0.000887)	-0.00476*** (0.000733)
<i>Household Head DOB</i>	0.0157*** (0.000216)	0.0157*** (0.000154)	0.0167*** (0.000581)	0.143*** (0.000381)	0.0157*** (0.000948)	0.0145*** (0.000503)	0.0151*** (0.00124)	0.0152*** (0.000675)	0.0175*** (0.000734)	0.0144*** (0.000593)	0.0189*** (0.00120)	0.0130*** (0.000973)
<i>Residential Tenure</i>	-0.102*** (0.000833)	-0.105*** (0.000555)	-0.116*** (0.00375)	-0.116*** (0.00230)	-0.112*** (0.00601)	-0.118*** (0.00311)	-0.120*** (0.00782)	-0.116*** (0.00411)	-0.116*** (0.00478)	-0.114*** (0.00343)	-0.105*** (0.00804)	-0.106*** (0.00596)
Select Neighborhood-level Controls												
<i>Neighborhood Churn</i>	-0.328*** (0.0171)	-0.358*** (0.0117)	-0.901*** (0.102)	-0.698*** (0.0639)	-0.696*** (0.144)	-0.693*** (0.0825)	-0.740*** (0.202)	-0.662*** (0.112)	-0.928*** (0.146)	-0.612*** (0.101)	-1.145*** (0.232)	-0.712*** (0.179)
<i>Rent (\$1,000s)</i>	0.272*** (0.0209)	0.197*** (0.0143)	0.0661 (0.0452)	0.122*** (0.0313)	0.135* (0.0617)	0.100*** (0.0303)	0.146 (0.0844)	0.100* (0.0399)	0.0749 (0.0664)	0.198** (0.0654)	-0.0528 (0.121)	0.134 0.0784
<i>College Share</i>	.141*** (0.0275)	0.212*** (0.0178)	0.235*** (0.0662)	0.285*** (0.0350)	-0.0866 (0.108)	0.143*** (0.0494)	0.116 (0.156)	0.138* (0.0676)	0.923*** (0.207)	0.818*** (0.163)	0.704* (0.352)	1.039*** (0.252)
<i>White Share</i>	0.0975*** (0.0150)	-0.113*** (0.0133)	0.221*** (0.0321)	-0.155*** (0.0246)	0.215*** (0.0578)	-0.0654 (0.0367)	0.0348 (0.0807)	-0.0666 (0.0461)	0.245*** (0.0383)	-0.195*** (0.0347)	0.140* (0.0586)	-0.123 (0.0629)
Sample Restrictions												
<i>Race</i>	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black
<i>Longtime Renters</i>			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<i>Initial College Share</i>					High	High	High	High	Low	Low	Low	Low
<i>Fraction Developed</i>							High	High				
N (1,000s)	314	688	56	156	21	89	13.5	54.5	35	67	10.5	20.5

Notes: Coefficients correspond to the percent change in the hazard rate from a one unit increase in the corresponding independent variable. A one unit increase in our measure of neighborhood change corresponds to a one hundred percentage point increase. Every specification includes the full set of controls listed and detailed in Appendix C. Standard errors in parentheses are clustered at the origin census tract level. Longtime renters are renters who have resided in their origin Census tract since at least 2005. Tracts with a “High” (“Low”) initial college share are tracts whose share of college-educated adults in 2010 is above (below) the population-weighted median in our full sample. Tracts with a “High” (“Low”) fraction developed are tracts whose developed land area in 2011 is above (below) the population-weighted median in our full sample.

TABLE A3. Linear Regression Model: Effect of Gentrification on Incumbent Renters (2010-2019)

Outcome Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Household Outcomes												
<i>Leave Tract</i>	-0.0176 (0.0223)	-0.0263 (0.0174)	-0.016 (0.0509)	0.07* (0.0278)	0.104 (0.0571)	0.0668* (0.0308)	0.129 (0.0738)	0.111*** (0.0368)	-0.305*** (0.106)	-0.0888 (0.0894)	-0.0458 (0.254)	-0.303 (0.158)
<i>Moved > 5 Miles</i>	0.038 (0.0217)	0.0167 (0.0171)	0.0066 (0.0406)	0.0803** (0.0261)	0.0438 (0.0505)	0.0709* (0.0294)	0.023 (0.0649)	0.0926** (0.0339)	-0.0324 (0.0783)	-0.0049 (0.0802)	0.386 (0.223)	-0.205 (0.154)
<i>Leave CBSA</i>	-0.0519*** (0.013)	-0.0375** (0.0122)	-0.0158 (0.0238)	0.0087 (0.0160)	-0.0194 (0.0300)	0.0191 (0.0178)	-0.0200 (0.0387)	0.0179 (0.0205)	0.0012 (0.0451)	-0.0194 (0.0432)	-0.0278 (0.1130)	-0.1500 (0.089)
<i>Income</i>	2,872** (948.8)	2,268** (736.4)	-932 (2,170)	-86.05 (1,375)	-1,458 (2,748)	-926.6 (1,547)	-1,875 (3,498)	311.5 (1,816)	-9,138* (3,854)	-551.8 (3,427)	-23,950** (9,225)	-3,874 (6,444)
<i>Commute Distance</i>	-0.2280 (0.776)	-1.905*** (0.531)	0.637 (1.609)	0.5900 (1.002)	3.106 (2.059)	-0.234 (1.146)	3.651 (2.529)	1.0800 (1.352)	-1.854 (3.132)	3.146 (2.775)	-9.659 (6.284)	-3.379 (5.352)
Panel B: Experienced Tract Characteristics												
<i>Rent</i>	0.271*** (0.0472)	0.0960*** (0.0288)	0.389*** (0.0620)	0.222*** (0.0329)	0.159** (0.0546)	0.132*** (0.0335)	0.171* (0.0701)	0.153*** (0.0434)	0.863*** (0.145)	0.607*** (0.096)	0.759** (0.241)	0.485*** (0.131)
<i>College Share</i>	0.726*** (0.104)	0.299*** (0.0598)	1.079*** (0.131)	0.567*** (0.0788)	0.539*** (0.0714)	0.392*** (0.0525)	0.570*** (0.0845)	0.379*** (0.0689)	3.726*** (0.250)	4.108*** (0.236)	3.559*** (0.565)	3.897*** (0.357)
<i>White College Share</i>	-0.298 (0.765)	0.635*** (0.156)	0.277 (1.393)	1.269*** (0.226)	0.822* (0.384)	0.449*** (0.0863)	0.806 (0.419)	0.358*** (0.098)	7.758* (3.951)	7.567*** (1.167)	2.832 (7.965)	5.206*** (1.169)
Sample Restrictions												
<i>Race</i>	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black	Black	Non-Black
<i>Longtime Renters</i>			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
<i>Initial College Share</i>					High	High	High	High	Low	Low	Low	Low
<i>Fraction Developed</i>							High	High				
N (1,000s)	277	599	50	138	19	78.5	12	48.5	31	59.5	9.3	18

Notes: Coefficients correspond to the impact of a 100 percentage point increase in our measure of gentrification on a change in the associated outcome variable over 2010 to 2019. The dependent variables “Leave Tract”, “Moved > 5 Miles”, and “Leave CBSA” are all indicator variables equal to one if the corresponding condition is satisfied. Income and rents are measured in 2010 dollars and commute distance is measured in miles. Experienced neighborhood characteristics are measured in percent changes. Every specification includes the full set of controls listed and detailed in Appendix C. Standard errors in parentheses are clustered at the origin census tract level. Longtime renters are renters who have resided in their origin Census tract since at least 2005. Tracts with a “High” (“Low”) initial college share are tracts whose share of college-educated adults in 2010 is above (below) the population-weighted median in our full sample. Tracts with a “High” (“Low”) fraction developed are tracts whose developed land area in 2011 is above (below) the population-weighted median in our full sample.

Appendix D. Microfoundations and Structural Estimation Details

D.1. Deriving our Estimating Equation

Consider the set of residential choices detailed in section 5.2. Given these residential choices, we start the derivation of our moment restrictions with an application of the Hotz-Miller inversion, which amounts to differencing equation 6 across the two neighborhood choices in period t , n and n' :

$$(A1) \quad \ln \left(\frac{p_{xnt}^k}{p_{xn't}^k} \right) = v_{xnt}^k - v_{xn't}^k \\ = \bar{u}_{xnt}^k - \bar{u}_{xn't}^k + \delta \left(\mathbb{E} \left[\bar{V}_{xnt}^k \right] - \mathbb{E} \left[\bar{V}_{xn't}^k \right] \right),$$

where the expectation operator is with respect to both the observable household-level and all the city-specific state variables. By assumption (a), we can write these expectations as

$$\mathbb{E} \left[\bar{V}_{xnt}^k \right] = \sum_{x'} \int_{\bar{\omega}'} \bar{V}_{xnt}^k dF^{\bar{\omega}}(\bar{\omega}' | \bar{\omega}) f^x(x' | n, x_{nt}, \bar{\omega}_t^{kc}) \\ = \sum_{x'} \mathbb{E}_{\bar{\omega}' | \bar{\omega}_t^{kc}} \left[\bar{V}(x', \bar{\omega}') | \bar{\omega}_t^{kc} \right] f^x(x' | n, x_{nt}, \bar{\omega}_t^{kc})$$

where x' and $\bar{\omega}'$ denote the next period values for x and $\bar{\omega}$. We can also replace the expectation of the ex-ante continuation values with respect to the city-specific state variables with their realized counterparts and an expectational error defined in equation 8:

$$(A2) \quad \mathbb{E} \left[\bar{V}_{xnt}^k \right] = \sum_{x'} \bar{V}(x', \bar{\omega}_{t+1}^{kc}) f^x(x' | n, x_{nt}, \bar{\omega}_t^{kc}) + e^{\bar{V}}(n, x_{nt}, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}),$$

with

$$e^{\bar{V}}(n, x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) \equiv \sum_{x'} e^{\bar{V}}(x', \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) f^x(x' | n, x_{nt}, \bar{\omega}_t^{kc}).$$

The use of these realized continuation values permits minimal assumptions about households' beliefs over the evolution of the city-specific state variables. Imputing our expression for households' expected continuation values conditional on their own household-level state variables in A2 to our expression for the difference in conditional choice probabilities in A1 yields

$$\ln \left(\frac{p_{xnt}^k}{p_{xn't}^k} \right) = \bar{u}_{xnt}^k - \bar{u}_{xn't}^k \\ + \delta \left(\sum_{x'} \bar{V}(x', \bar{\omega}_{t+1}^{kc}) f^x(x' | n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \bar{V}(x', \bar{\omega}_{t+1}^{kc}) f^x(x' | n', x_t, \bar{\omega}_t^{kc}) \right)$$

$$+ \delta \cdot \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc})$$

where $\tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc})$ is the difference between the expectational errors when residing in neighborhood n relative to neighborhood n' in period $t + 1$,

$$\tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) \equiv e^{\bar{V}}(n, x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) - e^{\bar{V}}(n', x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}).$$

Next, using equation 7 to substitute in for $\bar{V}(x', \bar{\omega}_{t+1}^{kc})$, we obtain,

$$\begin{aligned} & \ln \left(\frac{p_{xnt}^k}{p_{xn't}^k} \right) - \delta \left(\sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ &= \bar{u}_{xnt}^k - \bar{u}_{xn't}^k + \delta \left(\sum_{x'} v_{\tilde{n}}^k(x', \bar{\omega}_t^{kc}) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} v_{\tilde{n}}^k(x', \bar{\omega}_t^{kc}) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ &+ \delta \cdot \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) \end{aligned}$$

Recall that \tilde{n} is a renewal action for both households. Therefore, the household-level state variables are set to the same values for both households regardless of their values in period t . This yields identical continuation values in period $t+1$ for both households. The above expression therefore simplifies to,

$$\begin{aligned} & \ln \left(\frac{p_{xnt}^k}{p_{xn't}^k} \right) - \delta \left(\sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ &= \bar{u}_{xnt}^k - \bar{u}_{xn't}^k + \delta \left(MC_t^k(\tilde{n}, n) - MC_t^k(\tilde{n}, n') + \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) \right) \end{aligned}$$

Choosing n' as the city's outside option, applying assumption (b), and substituting in for the neighborhoods' flow utilities provides an equation linear in our model parameters,

$$\begin{aligned} & \ln \left(\frac{p_{xnt}^k}{p_{xn't}^k} \right) - \delta \left(\sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(p_{x\tilde{n}t}^k) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ &= \tilde{\alpha}_n^k + \alpha_t^k + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \ln(r_{n,t}) + \beta_A^k \ln \left(\frac{Coll_{nt}}{Pop_{nt}} \right) \\ &+ \beta_\tau^k \left(\sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ &- MC_t^k(n, n_{t-1}) + MC_t^k(n', n_{t-1}) + \delta \left(MC_t^k(\tilde{n}, n) - MC_t^k(\tilde{n}, n') \right) \\ &+ \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) + \tilde{\xi}_{nt}^k, \end{aligned}$$

where $\tilde{\alpha}_n^k = \alpha_n^k - \alpha^{ck}$. To condense notation, we write this equation as

$$Y_{xnn'\tilde{n}t}^k = \tilde{\alpha}_n^k + \alpha_t^k + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \ln(r_{n,t}) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) + \beta_\tau^k \tilde{\tau}_x - \widetilde{MC}_t^k + v_{xnn'\tilde{n}t}^k,$$

where

$$\begin{aligned} Y_{xnn'\tilde{n}t}^k &\equiv \ln\left(\frac{p_{xnt}^k}{p_{xnt'}^k}\right) - \delta \left(\sum_{x'} \ln(p_{xnt}^k) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(p_{xnt'}^k) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \right) \\ \tilde{\tau}_x &\equiv \sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n, x_t, \bar{\omega}_t^{kc}) - \sum_{x'} \ln(\tau_{xt}(x')) f^x(x'|n', x_t, \bar{\omega}_t^{kc}) \\ \widetilde{MC}_t^k &\equiv MC_t^k(n, n_{xt-1}) - MC_t^k(n', n_{xt-1}) - \delta \left(MC_t^k(\tilde{n}, n) - MC_t^k(\tilde{n}, n') \right) \\ v_{xnn'\tilde{n}t}^k &\equiv \tilde{e}(x_t, \bar{\omega}_t^{kc}, \bar{\omega}_{t+1}^{kc}) + \tilde{\xi}_{nt}^k. \end{aligned}$$

This is the same equation reported in 9.

D.2. First-Step Conditional Choice Probabilities

To see how equation 10 approximates the neighborhood choice problem of households in our dynamic model, start by considering our specification for a household's conditional value function defined in 5,

$$\begin{aligned} v_n^k(x_{it}, \bar{\omega}_t^{kc}) &\equiv \bar{u}_n^k(x_{it}, \bar{\omega}_t^{kc}) + \delta \mathbb{E}_t \left[\bar{V}^k(x_{it+1}, \bar{\omega}_{t+1}^{kc}) | n, x_{it}, \bar{\omega}_t^{kc} \right] \\ &= \alpha_n^k + \alpha_t^{kc} + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \ln(r_{n,t}) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) - MC_t^k(n_t, n_{it-1}) + \tilde{\xi}_{nt}^k \\ (A3) \quad &+ \sum_{\bar{\tau}=1,2} \left(\delta \mathbb{E}_t \left[\bar{V}^k(x_{it+1}(n_t, \bar{\tau}), \bar{\omega}_{t+1}^{kc}) | n, x(n_{t-1}, \bar{\tau}_{t-1}), \bar{\omega}_t^{kc} \right] \right. \\ &\quad \left. + \beta_\tau^k \ln(\bar{\tau}) \right) \cdot f^{\bar{\tau}}(\bar{\tau} | n_t, x(n_{t-1}, \bar{\tau}_{t-1}), \bar{\omega}_t^{kc}). \end{aligned}$$

Assume for now that $\bar{\tau}_{t-1} = 1$. Then, we can re-write A3 for some neighborhood choice n as,

$$(A4) \quad v_n^k(x_{it}, \bar{\omega}_t^{kc}) = \gamma_{nt}^k + \mu_{\bar{\tau}} \cdot \mathbb{1}\{n = n_{t-1}\} - MC_t^k(n, n_{t-1})$$

where,

$$\begin{aligned} \gamma_{nt}^k &= \alpha_n^k + \alpha_t^{kc} + \beta_w^k \ln(\bar{I}_{n,t}) - \beta_r^k \ln(r_{n,t}) + \beta_A^k \ln\left(\frac{Coll_{nt}}{Po p_{nt}}\right) + \tilde{\xi}_{nt}^k \\ &+ \delta \mathbb{E}_t \left[\bar{V}^k(x_{it+1}(n_t, \bar{\tau} = 1), \bar{\omega}_{t+1}^{kc}) | n, x(n_{t-1}, 1), \bar{\omega}_t^{kc} \right] \end{aligned}$$

$$\begin{aligned} \mu_{\bar{\tau}} = & f^{\bar{\tau}}(2|n_t, x(n_{t-1}, 1), \bar{\omega}^{kc}) \left[\beta_{\bar{\tau}}^k \ln(2) \right. \\ & - \delta \cdot \left[\mathbb{E}_t \left[\bar{V}^k \left(x_{it+1}(n_t, \bar{\tau} = 1), \bar{\omega}_{t+1}^{kc} \right) | n_t = n_{t-1}, x(n_{t-1}, 1), \bar{\omega}_t^{kc} \right] \right. \\ & \left. \left. - \mathbb{E}_t \left[\bar{V}^k \left(x_{it+1}(n_t, \bar{\tau} = 2), \bar{\omega}_{t+1}^{kc} \right) | n_t = n_{t-1}, x(n_{t-1}, 1), \bar{\omega}_t^{kc} \right] \right] \right] \\ & \underbrace{\hspace{10em}}_{\text{Difference in continuation values w.r.t. } \bar{\tau}_{t-1}} \end{aligned}$$

and where $MC_t^k(n, n_{t-1})$ is defined as usual. Equation A4 shows that if the difference in conditional values across tenure status (τ_{t-1}) from staying in one's origin neighborhood is independent of one's origin neighborhood, n_{t-1} , then we could simply estimate our first-step multinomial choice model using A4.⁵⁹ It is, however, unlikely that that the difference in continuation values with respect to neighborhood tenure is independent of one's neighborhood origin. To understand why, consider two neighborhoods n and n' in the same CBSA. If neighborhood n provides lower utility than neighborhood n' , then *all* residents of neighborhood n in period t are less likely to remain there in period $t + 1$ relative to residents in neighborhood n' . When all residents are unlikely to stay in a given neighborhood, the difference in continuation values for incumbent residents with different residential tenures will be small. The converse is true for neighborhoods offering higher utilities to residents.

Equation 10 must therefore capture how the difference in continuation values across neighborhood tenures vary with neighborhoods' mean utilities. We therefore augment equation A4 by incorporating an interaction term between the value of residential tenure and time-varying neighborhood utilities:

$$v_n^k(x_{it}, \bar{\omega}_t^{kc}) = \gamma_{nt}^k + \mu_{\bar{\tau}} \cdot \mathbb{1}\{n = n_{t-1}\} + \gamma_{nt}^k + \lambda_{\bar{\tau}} \cdot \mathbb{1}\{n = n_{t-1}\} - MC_t^k(n, n_{t-1}).$$

This is the expression that appears in equation 10 and we believe approximates the data generating process implied by our dynamic model well.

D.3. Microfounding Job Market Access and Expected Income

Setup. The workplace choice problem for college graduates is identical to the problem for each type- k household, as reported in section 4.2. In this section we therefore simply extend the index k to also include college graduates. For now, we assume that the labor market for each k -type is segmented.⁶⁰ Recall that in section 4.2, each household's workplace choice problem is

⁵⁹When $\bar{\tau}_{t-1} = 2$, the form of γ_{nt}^k remains the same, but $\mu_{\bar{\tau}}$ is no longer scaled by $f^{\bar{\tau}}(2|n_t, x(n_{t-1}, 1), \bar{\omega}^{kc})$. The current argument therefore remains unchanged when considering $\bar{\tau}_{t-1} = 2$.

⁶⁰Baum-Snow, Hartley, and Lee (2019) show how to extend the model to an integrated labor market with multiple types. The resulting expressions are identical to those we derive here when assuming segmented markets. The

to choose which neighborhood to work in to maximize their income net of commute costs:

$$\begin{aligned}\bar{I}_{n,t}^k &\equiv b_t^k \cdot \max_m \frac{z_{m,t}^i}{d_{n,m}} w_{mt}, \\ &= \max_m \frac{z_{m,t}^i}{d_{n,m}} w_{m,t}^k,\end{aligned}$$

To construct our JMA instrument, we simply amend this workplace choice problem by differentiating wages across industries, I , so that the household's conditional workplace choice problem becomes,

$$\begin{aligned}\bar{I}_{n,t}^k &\equiv \max_{m,I} \frac{\zeta_{t,I}^k z_{m,t}^i}{d_{h,m}} w_{m,t}^k, \\ &= \max_{m,I} \frac{z_{m,t}^i}{d_{h,m}} w_{m,t,I}^k,\end{aligned}$$

where $z_{m,t,I}^i$ is distributed iid Frechet, $F(z_{m,t,I}^i) = \exp\left(-\left(z_{m,t,I}^i\right)^{-\epsilon_c^k}\right)$ with $\epsilon_c^k > 1$, for each workplace-tract-industry in the city and for each worker i of education group k . $\zeta_{t,I}^k$ is an industry- and type-specific productivity shock that captures the comparative advantage of workers of each type across industries. The probability of worker i of education group k living in tract n taking a job in tract m is then given by,

$$\begin{aligned}\pi_{m|n,t}^k &= \frac{\sum_I (w_{m,t,I}^k / d_{n,m}^k)^{\epsilon_c^k}}{\sum_I \sum_{m'} (w_{m',t,I}^k / d_{n,m'}^k)^{\epsilon_c^k}}, \\ &= \frac{\sum_I (w_{m,t,I}^k / d_{n,m}^k)^{\epsilon_c^k}}{RMA_{n,t}^k},\end{aligned}$$

where $RMA_{n,t}^k \equiv \sum_I RMA_{n,t,I}^k \equiv \sum_I \sum_{m'} (w_{m',t,I}^k / d_{n,m'}^k)^{\epsilon_c^k}$.

Define labor supply to tract m in time t by $\ell_{m,t}^k = \sum_I \left[\left(w_{m,t,I}^k \right)^{\epsilon_c^k} \right] FMA_{m,t}^k$, where $FMA_{m,t}^k$, represents the access firms in tract m have to k -type workers. Equating labor supply of k -type workers to tract m in period t to workers' choice probabilities yields an expression for FMA in terms of

derivations in this section follow an established literature microfounding measures of “market access” in economic fundamentals (Donaldson and Hornbeck (2016), Tsivanidis (2022), Baum-Snow and Han (2023)).

RMA:

$$\begin{aligned}
\varrho_{m,t}^k &= \sum_n \pi_{m|n,t}^k \cdot \pi_{n,t}^k \cdot N^k \\
&= \sum_n \frac{\sum_I (w_{m,t,I}^k / d_{n,m}^k)^{\epsilon_c^k}}{RMA_{n,t}^k} \cdot \pi_{n,t}^k \cdot N^k \\
&= \sum_I \left[\left(w_{m,t,I}^k \right)^{\epsilon_c^k} \right] N^k \sum_n \frac{\left(\left(\pi_{n,t}^k \right)^{1/\epsilon_c^k} / d_{h,m}^k \right)^{\epsilon_c^k}}{RMA_{n,t}^k} \\
(A5) \quad &\equiv \sum_I \left[\left(w_{m,t,I}^k \right)^{\epsilon_c^k} \right] FMA_{m,t}^k
\end{aligned}$$

The penultimate equality obtains,

$$FMA_{m,t}^k = N^k \sum_n \frac{\left(\left(\pi_{n,t}^k \right)^{1/\epsilon_c^k} / d_{h,m}^k \right)^{\epsilon_c^k}}{RMA_{n,t}^k}.$$

Furthermore, dividing both sides of A5 by $(d_{h,m}^k)^{\epsilon_c^k}$ and summing over m yields an expression for $RMA_{n,t}^k$ in terms of $FMA_{m,t}^k$. We subsequently obtain the following system of equations for RMA and FMA:

$$\begin{aligned}
FMA_{m,t}^k &= N^k \sum_n \frac{e^{-\kappa \epsilon_c^k \tau_{n,m}^k} \pi_{n,t}^k}{RMA_{n,t}^k} \\
(A6) \quad RMA_{n,t}^k &= \sum_m \frac{e^{-\kappa \epsilon_c^k \tau_{n,m}^k} \varrho_{m,t}^k}{FMA_{m,t}^k},
\end{aligned}$$

where we have defined $d_{n,m}^k \equiv e^{\kappa \tau_{n,m}^k}$.⁶¹

Job Market Access Instrument. To transparently relate our job market access instruments to the recent advances in the quasi-experimental shift-share literature, we take linear approximations of equation A6 to obtain our measure of job market access that appears in expression

⁶¹ $1 - e^{-\kappa \tau_{n,m}^k}$ represents the portion of time that type- k workers in tract n spend commuting to tract m .

14:

$$JMA_{ndt} = \sum_{m \in \mathcal{N}^c \setminus n} e^{-\eta^c \tau_{nm}} l_{mdt},$$

This linear approximation of equation A6 relates to earlier notions of market potential in international and regional trade theory, which conceptualize the demand for goods in a given region as the sum of demands in surrounding regions, weighted by bilateral transportation costs (Harris (1954) , Hanson (2005)). It is common in the regional economics literature to take linear approximations of structural measures of market access (e.g. Donaldson and Hornbeck (2016) and Herzog (2021)).⁶²

Expected Income. Our workplace choice model also implies that expected income discounted by commuting costs for type- k households prior to drawing the vector of neighborhood- and period-specific productivity shocks is given by,

$$\bar{I}_{nt}^k = \Gamma \left(1 - \frac{1}{\epsilon_c^k} \right) \left(RMA_h^k \right)^{1/\epsilon_c^k}, \quad \forall i \in k,$$

where we directly use the identify $RMA_{n,t}^k \equiv \sum_I \sum_{m'} (w_{m',t,I}^k / d_{h,m'}^k)^{\epsilon_c^k}$ in this measure's construction. This is the expression that enters into the households' flow utilities.

We use the observed distribution of workplace wages among our sample of low-income renter households to construct $RMA_{n,t}^k$. We then regress observed workplace wages discounted by commute costs on our measure of $RMA_{n,t}^k$ and predict \bar{I}_{nt}^k solely using variation in $RMA_{n,t}$. This is to account for the fact that larger labor markets have mechanically higher levels of $RMA_{n,t}^k$.

Gravity and Forecasting Equations. Our workplace choice model yields gravity equations we can use to estimate $\kappa \epsilon_c^k$. We follow Baum-Snow, Hartley, and Lee (2019) and estimate $\kappa \epsilon_c^k$ separately for each type- k household in each city, c . Estimating $\kappa \epsilon_c^k$ separately for each type- k household in each CBSA increases the accuracy of our $RMA_{n,t}^k$ measures and thus also the power of our job market access instruments. CBSA-specific estimates allow labor demand shocks to impact job market access in neighborhoods accessible by longer commutes more in CBSAs where ϵ_c^k is lower. To obtain our estimates of $\eta^{kc} \equiv \kappa \epsilon_c^k$ we take the log of $\pi_{m|n,t}^k$ to obtain the

⁶²An alternative approach to taking a linear approximation of A6 would be to solve for the fixed point of $RMA_{n,t}^k$ and $FMA_{m,t}^k$. However, it is unclear exactly how to relate the findings of Goldsmith-Pinkham, Sorkin, and Swift (2020) and Borusyak, Hull, and Jaravel (2022) on linear shift-share instrumentation to such a setting.

following gravity equation,

$$\begin{aligned}
 \ln(\pi_{m|n,t}^k) &= \ln(RMA_{n,t}^k) + \ln \left(\sum_I \left(w_{m,t,I}^k \right)^{\epsilon_c^k} \right) - \kappa \epsilon_c^k \tau_{n,m}^k \\
 (A7) \qquad \qquad &= \alpha_{n,t}^k + \rho_{m,t}^k - \underbrace{(\kappa \epsilon_c^k)}_{\eta^{kc}} \tau_{n,m}^k,
 \end{aligned}$$

which we estimate separately for each city and type- k households (including separately for college graduates) using 2010 commute flows constructed using the LEHD.

We obtain estimates of $\tau_{n,m}^k$ using the median tract commute time for each type- k worker in the 2005-2015 ACS surveys between tracts n and m for all tract pairs that are reported to have positive commute flows for any k -type worker. Since there are far more potential tract-to-tract commuting routes than ACS survey respondents, many commute times are not observed in our data. To estimate the remaining commute times, we follow [Baum-Snow, Hartley, and Lee \(2019\)](#) and construct an empirical forecasting model to predict commute times between all neighborhood pairs using the distance between neighborhood centroids and the corresponding city's CBD. We estimate the following forecasting model separately for each type- k worker,

$$\ln \tau_{n,m}^k = \alpha_d^k \ln \text{Distance}_{n,m} + \alpha_r^k \ln(\text{Home CBD Dis})_n + \alpha_w^k \ln(\text{Work CBD Dis})_m + \nu_c + u_{h,m,c}^k.$$

With these predicted commute times in hand, we use the observed tract-to-tract commute flows for each type- k household observed in the LEHD to estimate equation A7.⁶³ As per Census Bureau Disclosure Guidance, we are unable to release our CBSA-specific estimates, but report summary statistics of our CBSA-level estimates in Table A4. We also report our estimates using distance - as opposed to commute time - between commuting tract pairs as a comparison. Our estimates suggest that a 1 minute increase in commute time leads to a 8.8 or 8.9 percent reduction in the flow of Black and Non-Black commuters, respectively. These semi-elasticities, while on the higher side, are consistent with the magnitudes found in the existing literature (e.g. [Ahlfeldt et al. \(2015\)](#)).

⁶³To maximize the size of the sample used to construct our commute flows, we do not restrict our sample to renter households.

TABLE A4. Commute Elasticities

	Time		Distance	
	Black	Non-Black	Black	Non-Black
Median CBSA Estimate	0.0876*** (0.0000)	0.0885*** (0.0000)	0.0807*** (0.0001)	0.0782*** (0.0001)
Standard Deviation of CBSA Estimates	0.01353	0.01528	0.01667	0.07824
N (1,000s)	966	3,752	966	3,752

Notes: Table A4 reports results from the gravity equations of equation A7. We use Poisson Pseudo Maximum Likelihood to estimate these models given the prevalence of tract-to-tract potential commuting routes with zero observed commute flows (Silva and Tenreyro 2006). To increase the number of non-zero commute flows we observe in the data, we estimate these gravity equations for all low-income households regardless of their rental status. The first row reports the (pseudo) median CBSA-level estimate along with its accompanying standard error in parentheses. The Second row reports the standard deviation of our 50 CBSA-level estimates. N reports the underlying number of commuters used to construct the commute flows in the LEHD.

D.4. Welfare Analysis

Recall that our baseline measure of change in expected welfare for incumbent renters is given by,

$$\Delta W^k(n, \bar{\tau}) = \frac{\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc}) - V_{ss}^k(n, \bar{\tau})}{\beta_r^k} \quad \forall k, n.$$

We now unpack $\Delta W^k(n, \bar{\tau})$, starting with $V_{ss}^k(n, \bar{\tau})$. $V_{ss}^k(n, \bar{\tau})$ is the expected welfare for an incumbent renter with residential tenure $\bar{\tau}$ residing in neighborhood n during 2000 under the assumption that the economy is in steady state. We calculate $V_{ss}^k(n, \bar{\tau})$ by finding time-invariant continuation values and levels of exogenous amenities, $\{\xi_{n,k}^k\}$, that induce a *stationary distribution* among our sample of low-income renter households when holding all the observed state variables fixed at their 2000 levels, i.e. $\omega_t^{kc} = \omega_{2000}^{kc} \forall t$.

Stationary Distribution. Denote $q_n^k(\bar{\tau})$ as the model-implied share of type- k households with tenure $\bar{\tau}$ living in neighborhood n . Stacking $q_n^k(\bar{\tau})$ yields the $2(N^c + 1)$ -dimensional vector \mathbf{q}^k . We define a stationary equilibrium among our sample of low-income renter households as $\mathbf{q}^k = \mathbf{\Lambda}^k \mathbf{q}^k$, where $\mathbf{\Lambda}^k$ is a transition probability matrix constructed so the distribution of type- k households' locations evolve as,

$$q_n^k(\bar{\tau}') = \begin{cases} \sum_{\bar{\tau}'} \sum_{\bar{n} \neq n} \left[q_{\bar{n}}^k(\bar{\tau}') p_{n,t}^k(x(\bar{n}, \bar{\tau}')) \right] + q_n^k(\bar{\tau} = 1) p_{n,t}^k(x(n, \bar{\tau} = 1)) (1 - g_n^k) & \text{if } \bar{\tau}' = 1 \\ q_n^k(\bar{\tau} = 1) p_{n,t}^k(x(n, \bar{\tau} = 1)) g_n^k + q_n^k(\bar{\tau} = 2) p_{n,t}^k(x(n, \bar{\tau} = 2)) & \text{if } \bar{\tau}' = 2. \end{cases}$$

Steady-State Equilibrium. We define a steady-state equilibrium in the year 2000 as a stationary distribution among our sample of low-income renter households, where continuation values are time-invariant and state variables are fixed at their 2000 level: $\bar{\omega}_t^{kc} = \bar{\omega}_{2000}^{kc} \forall t$.

The time-invariant continuation values in our steady-state equilibrium are precisely our steady-state measures of expected welfare, $\{V_{ss}^k(n, \bar{\tau})\}_{n, \bar{\tau}}$. We outline the procedure to compute these measures as well as the vector of exogenous amenities in Algorithm 1.⁶⁴

Algorithm 1 Compute Steady State Expected Welfare

- 1: Guess value of unobserved neighborhood amenities: $\{\xi_n^k\}_n$.

Compute continuation values:

- 2: Guess $\{V_{ss}^k(n, \bar{\tau})\}_{n, \bar{\tau}}$.
 - 3: Compute $V_{ss}^k(n, \bar{\tau}) = \ln \left(\sum_{n' \in \mathcal{N}^c} \exp \left(\bar{u}_{n'}^k \left(x(n, \bar{\tau}), \bar{\omega}_{2000}^{kc} \right) + \delta V_{ss}^k(n', \bar{\tau}) \right) \right) + \gamma, \quad \forall n, \bar{\tau}$
 - 4: Set $V_{ss}^k(n, \bar{\tau}) = V_{ss}^k(n, \bar{\tau}), \quad \forall n, \bar{\tau}$
- Repeat steps 2 - 4 until $\max_{n, \bar{\tau}} \{|V_{ss}^k(n, \bar{\tau}) - V_{ss}^k(n, \bar{\tau})|\} < \epsilon_V$ for some $\epsilon_V > 0$.

Compute exogenous amenities:

- 5: Compute the probability a type- k household chooses n given $\{V_{ss}^k(n, \bar{\tau})\}_{n, \bar{\tau}}$ and $\{\xi_n^k\}_n$

$$p_n^k \left(x(\bar{n}, \bar{\tau}), \bar{\omega}_{2000}^{kc} \right) = \frac{\exp \left(v_n^k \left(x(\bar{n}, \bar{\tau}), \bar{\omega}_{2000}^{kc} \right) \right)}{\sum_{n' \in \mathcal{N}^c} \exp \left(v_{n'}^k \left(x(\bar{n}, \bar{\tau}), \bar{\omega}_{2000}^{kc} \right) \right)}, \quad \forall \bar{\tau}, \bar{n}$$

- 6: Update exogenous amenities using observed neighborhood shares of households with low tenure, $q_n^k(\bar{\tau} = 1)$:
(A8)

$$\xi_n^k = \xi_n^k + \ln \left(\hat{q}_n^k(\bar{\tau} = 1) \right) - \ln \left(\sum_{\bar{\tau}'} \sum_{\bar{n} \neq n} \left[q_{\bar{n}}^k(\bar{\tau}') p_{n, \bar{\tau}}^k \left(x(\bar{n}, \bar{\tau}') \right) \right] + q_n^k(\bar{\tau} = 1) p_{n, \bar{\tau}}^k \left(x(n, \bar{\tau} = 1) \right) (1 - g_n^k) \right)$$

Set $\xi_n^k = \xi_n^k$.

Repeat steps 2 - 6 until $\max_{n, \bar{\tau}} \{|\xi_n^k - \xi_n^k|\} < \epsilon_\xi$ for some $\epsilon_\xi > 0$.

Take $\{V_{ss}^k(n, \bar{\tau})\}_{n, \bar{\tau}}$ as our measures of steady-state expected welfare.

We now turn to $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$, which is the expected welfare of a type- k household with tenure $\bar{\tau}$ residing in neighborhood n in the year 2000. In contrast to $V_{ss}^k(n, \bar{\tau})$, we do not

⁶⁴In step 6 of Algorithm 1, we exploit the fact that the values of exogenous amenities are the same for households regardless of their length of tenure. While we cannot guarantee Algorithm 1 induces a stationary equilibrium among type- k households with a high level of neighborhood tenure, $\bar{\tau} = 2$, we find that in practice it closely approximates a stationary distribution for these households. We define $\hat{q}_n^k(\bar{\tau} = 1)$ as the empirical counterpart to $q_n^k(\bar{\tau} = 1)$.

assume the economy is in a steady-state equilibrium when constructing this measure. We instead compute $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$ via backward induction starting in the year 2019. We do, though, hold exogenous neighborhood amenities fixed at the values found in Algorithm 1. By holding the values of exogenous amenities fixed at their 2000 levels, we can attribute variation in $\Delta W^k(n, \bar{\tau})$ to neighborhood-level changes in rents and college shares. To initiate our backward induction solution method, we assume that the economy is again in a steady state in 2019 and calculate steady-state continuation values for the year 2019 as in steps 2-4 in Algorithm 1. Since we are solely concerned with expected welfare changes from the perspective of the year 2000, this assumption is innocuous given a discount rate of $\delta = 0.85$.

To compute $\bar{V}^k(x = (n, \bar{\tau}), \bar{\omega}_{2000}^{kc})$, we must also take a stance on how households form their expectations over the market-level state variables, $\bar{\omega}_t^{kc}$. One option is to assume that households have perfect foresight. We experimented with this assumption, but found that households quickly reoptimize their location choices given perfect knowledge of future states. Instead, we assume that households' expectations are a weighted average of i) the future true states; and ii) neighborhoods' current states multiplied by the CBSA-wide average growth rate of each state variable:

$$(A9) \quad \mathbb{E}[\bar{\omega}_t^n | \mathcal{J}_{i,2000}] = \bar{\omega}_{2000}^n \cdot \left(1 + \frac{\sum_{n' \in \mathcal{N}^c} (\bar{\omega}_t^{n'} - \bar{\omega}_{2000}^{n'})}{\sum_{n' \in \mathcal{N}^c} \bar{\omega}_{2000}^{n'}} \right) \cdot \mu + \bar{\omega}_t^n \cdot (1 - \mu).$$

$\mu \in [0, 1]$ determines how accurate households' beliefs are. With $\mu = 0$, households have perfect foresight, and with $\mu = 1$, households believe all neighborhoods' state variables change at an identical rate. When $\mu = 1$, households are less mobile as they expect the relative levels of neighborhoods' flow utilities to remain constant over time. We calibrate μ to match the observed average neighborhood out-migration rates in our sample of low-income renter households (we assume μ is constant across household types).⁶⁵

Throughout our welfare analyses, we use publicly available 2010-delineated tract-level Census Survey data from IPUMS National Historical GIS (NHGIS) to compute annual rents and the distribution of households across Census tracts (Manson et al. 2022). We linearly interpolate these data between survey years (2000, 2007-2019). For 2007 onward, we use the 5-year ACS aggregates to compute the tract-level data. As the publicly available tract-level data are not disaggregated enough to compute the exact shares each type- k low-income renter household across census tracts and aggregated tenure states, $\bar{\tau}$, we approximate the empirical neighborhood shares used in Algorithm 1, $q_n^k(\bar{\tau} = 1)$, with the share of Black (non-Black) non-college-educated renter households living in each tract who have a tenure of less than three years.

⁶⁵Note that equation A9 is consistent with our rational expectations assumption (Assumption (c)) in so far as the true data generating process renders equation A9 unbiased.