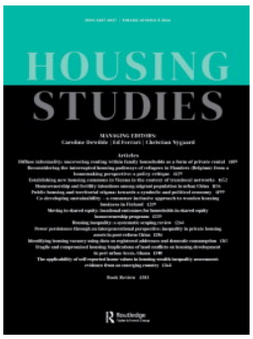

Housing Studies

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/chos20

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To cite this article: Pengyu Zhu, Yuqing Guo & Praveen Maghelal (12 Nov 2023): Does telecommuting influence homeownership and housing choice? Evidence based on pre-pandemic data, Housing Studies, DOI: 10.1080/02673037.2023.2277769

To link to this article: https://doi.org/10.1080/02673037.2023.2277769

Published online: 12 Nov 2023.

HOUSING STUDIES
https://doi.org/10.1080/02673037.2023.2277769

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Does telecommuting influence homeownership and housing choice? Evidence based on pre-pandemic data

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ABSTRACT

Telecommuting has become widespread during the pandemic and are expected to become mainstream work culture in the post-pandemic era. By applying a three-step Instrumental Variable analysis to the 2009 and 2017 U.S. National Household Travel Surveys, this study analyzes the impact of telecommuting on homeownership and housing type choices. Results show that, households with telecommuters are more likely to be homeowners and to live in detached or duplex houses compared to their counterparts. These effects are especially prominent for middle-aged (30–55) households. Relying on robust and national representative historical data before the COVID-19 pandemic, this study provides convincing evidence on how telecommuting affects people's housing decisions and thus has important implications for understanding the fast-evolving housing markets in the post-pandemic era when a growing number of telecommuters look for homeownership and extract spaces to accommodate home office. It will provide important guidance for revisiting existing housing policies for both urban and rural policymakers to meet the new demand and preferences.

ARTICLE HISTORY
Received 23 September 2022
Accepted 23 October 2023

KEYWORDS
Telecommuting; homeownership; housing type; housing choice; instrumental variable approach

1. Introduction

Telecommuting refers to a flexible work arrangement wherein workers work from home several times per week, while still maintaining a regular workplace (Nilles *et al.*, 1976; Zhu, 2012). It complies with the definition of telecommuting proposed by P. Mokhtarian (1991): (1) workers work physically away from their primary worksites and (2) commute travel is reduced as a consequence.[1] Telecommuting practices have rapidly grown in popularity in the last two decades, increasing 1.73-fold between 2005 and 2018 (Global Workplace Analytics, 2020). By 2019, 5.7 million Americans, accounting for 4.1% of the U.S. workforce, telecommuted at least half-time (Global Workplace Analytics, 2020). Underlying this trend is the growing availability and capability of information and communication technology (ICT) (Siha

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& Monroe, 2006). With growing ICT capabilities, telecommuting becomes easier and its advantages relative to traditional in-office work become more apparent. With the onset of the COVID-19 pandemic in early 2020, telecommuting suddenly spread to a wide swath of the population as an emergency measure to reduce the threat of infection and/or comply with national or local lockdown measures (Felstead & Reuschke, 2020; Reuschke & Ekinsmyth, 2021). After this sudden growth spurt, many expect the practice of telecommuting to remain highly popular in the post-pandemic era. Despite steadily growing popularity in the years before the pandemic, like many new practices, telecommuting faces significant barriers to adoption in regular times. These include the costs of buying and learning the relevant technology and of adjusting work practices, coordination, and management methods to suit long-distance work. By necessitating work from home among a large segment of the workforce, the pandemic has helped to overcome these initial barriers to adoption. The advantages of telecommuting, in terms of commute time saved, flexibility for employees, ability to connect across long distances, and potentially even in reduced office costs, should therefore be vastly more apparent than before the pandemic. A U.S. online survey carried out in 2020 reveals that 26% of workers expect to telecommute at least a few times a week after the pandemic (Salon *et al.*, 2021). According to the 2021 American Community Survey (ACS), 17.9% of people treat working-from-home as their primary commuting mode (Public Information Office, 2022). An unofficial survey conducted in February 2023 by the Pew Research Center focuses on people with teleworkable jobs and finds that 35% of respondents work from home all the time and 41% take hybrid mode (PARKER, 2023). The statistics in the post-pandemic time indicate that telecommuting has persisted into the normalization era.

This shift from in-office work to telecommuting is expected to have a significant impact on the economic and social life of cities and their residents (Handy & Mokhtarian, 1995; Zhu *et al.*, 2023). One area in which it may have a particularly large impact is on housing markets. Scholars began discussing the potential for dramatic changes in housing patterns and urban planning very early on in the pandemic, with Nicholas Bloom (2020) discussing the potential of a population shift towards suburban areas away from the urban core and towards low-rises over dense high-rise buildings. This is likely driven not just by short-term concerns about crowding and virus transmission in dense residential areas, but by the massive shift towards remote work, and the consequent reduction in constraints on residential location. In the US, the media has already noted a phenomenon of shifting residential patterns, pointing to an exodus from large cities to smaller towns advertising themselves as havens. However, some reports also claim that the exodus pertains only to America's largest cities, such as San Francisco and New York, while migration has primarily been toward smaller cities rather than to small towns or rural areas (Patino, 2020). In more scholarly studies, using U.S. home sales data, Liu & Su (2021) find that the COVID-19 pandemic indeed led to a decrease in housing demand in higher density neighborhoods and neighborhoods with higher pre-COVID housing prices. While the evidence so far suggests that a major shift in housing markets is indeed occurring, the causes of this shift remain unclear, and it is unclear whether such shifts are likely to persist as the pandemic is overcome.

While shifting housing patterns may also be related to temporary factors such as fear of crowding and the reduced appeal of urban cores in the midst of the pandemic, the shift towards telecommuting is likely a much more significant factor in the shift in housing preferences. If shifting housing patterns bear a strong relationship to telecommuting, we can expect the emerging shifts in housing preferences to also be permanent. Past studies have shown that remote workers are more likely than non-telecommuters to move to more affordable housing markets (Moos & Skaburskis, 2008; Muhammad *et al.*, 2007). In a survey of 5,000 employed adults across the U.S., 35% of those who expected to be remote workers in the post-pandemic era reported planning to relocate to find more affordable housing, in contrast to only 17% among those who did not expect to be telecommuting (Salviati, 2021). Indeed, there is a growing body of literature exploring the relationship between telecommuting, commuting behaviors, and housing preferences (Zhu & Guo, 2022). Given that society is projected to permanently shift towards telecommuting in (Zhu.., 2011) the post-pandemic era, it is important that policymakers understand how telecommuting affects housing tenure and housing type preferences, in order to better understand the shifts in the housing market that we are likely to witness.

This article attempts to cast light on how telecommuting influences homeownership and choice of housing type. It also explores the age heterogeneity of telecommuting's impact on homeownership and housing type, since housing choices are highly related to different lifecycle stages and events. To do so, instead of looking at current housing patterns, which may reflect a variety of temporary shock factors, we use data from the 2009 and 2017 U.S. National Household Travel Surveys (NHTS) to examine the historical relationship between telecommuting and housing preferences. A three-step Instrumental Variable (IV) approach is utilized to explore the causal impact of telecommuting on homeownership and housing type. Results show that telecommuting increases the probability of homeownership and living in a detached or duplex house in both 2009 and 2017. The study resonates with a previous study by Moos and Skaburskis (2008), which investigated the relationship between home-working and single-family dwellings based on 2001 Canadian observations. They reach a similar conclusion that home workers are more likely to become homeowners and reside in single-family houses. Our study extends the finding to more recent U.S. housing markets using 2009 and 2017 data. More importantly, this study establishes the causal impacts of telecommuting on homeownership and housing preferences using the instrumental variable method.

Using the pre-COVID data, this study reveals the consistency and the stickiness of the impact of telecommuting on homeownership and housing preference. Currently, a body of literature is quickly developing on the early-stage shift of housing preference during the COVID-19 pandemic, much of which is based on stated preference surveys. However, changes in housing preference very early on in the pandemic, such as a shift in preference towards low-rises over dense high-rise buildings (See AMG International Reality, 2020; Bloom, 2020), might easily fade away with the progress of vaccination programs and the end of the pandemic approaching. Hence, analysis using survey data collected during the pandemic might easily lead to a misleading conclusion concerning the relationship between telecommuting arrangements and housing preference. Analysis based on pre-COVID data enables a more

rigorous and accurate examination of the impact of telecommuting on housing preference regardless of the pandemic. Hence, our study carries crucial implications for the post-pandemic housing markets. Policymakers and planners may need to take proactive measures to meet the increasing demand for homeownership and more spacious housing in future urban development plans while still maintaining those sustainability goals.

2. Literature review

There are a variety of theoretical frameworks that provide insight into numerous factors that shape individual and household housing choices. Utility approaches focus on user costs and constraints imposed by budgets and wealth (Bourassa, 1995; Bourassa & Yin, 2006; Henderson & Ioannides, 1983). Life cycle theory emphasizes the impact of different life stages and life events, such as getting married or having children, on housing demand; these life cycle factors may at times exert more influence over housing choices than affordability considerations (Morrow-Jones & Wenning, 2005). From the perspective of urban equilibrium, the classic Alonso-Mills-Muth urban economics model theorizes the role of the distance between the residential location and the CBD and depicts the relationship between housing cost and transportation cost (Alonso, 1964; Mills, 1967; Muth, 1969). A rich set of empirical studies have shown that there is a wide range of elements that affect homeownership and dwelling type preference, including demographic and socio-economic characteristics at both the individual and household levels and macro-level conditions.

2.1. Determinants of homeownership

At the individual and household level, age, gender, race, marital status, the presence of children, education level, employment, income and wealth all influence the choice of housing tenure. The probability of homeownership increases with age (Bourassa & Yin, 2006; Carter, 2011; Goodman, 2003; Li & Li, 2006; Raya & Garcia, 2012). Similarly, marital status is an important predictor of homeownership (Bourassa & Yin, 2006; Clark *et al.*, 1997; Iwarere & John, 1991; Raya & Garcia, 2012). Another demographic attribute closely related to homeownership is the presence or the number of children in the household, especially for those in the early life stage. Studies find that the presence or number of children is positively correlated with the probability of homeownership, as it generates demand for a stable residential location and a more spacious dwelling (Bourassa & Yin, 2006; Carter, 2011; Clark *et al.*, 1997). However, raising children also imposes a financial burden on household and thus can make it more challenging to buy a house (Munro & Smith, 1989).

Compared to the impact of age, marriage and children, the effect of gender and race on homeownership is more contested. While many studies find that men are found to more likely to own a house, relative to women (Haurin *et al.*, 1994; Munro & Smith, 1989; Rosen, 1979), other studies come to the opposite conclusion, or find that there is no gender gap in homeownership, after controlling for confounding

factors (Goodman, 1988; Somerville, 1994). Apart from gendered differences, race is also believed to play an important role in the homeownership gap. A number of empirical studies find that white people are more likely to own a house, compared with minority groups and especially compared to the black community (Carliner, 1974; Cortes *et al*., 2007; Haurin *et al*., 1994; Kain & Quigley, 1972; Rosen, 1979). However, there are also studies which find no statistically significant difference between different racial groups once confounding factors are controlled (Goodman, 2003 ; Bourassa & Yin, 2006; Carliner, 1974; Clark *et al*., 1997; Goodman, 1988; Iwarere & John, 1991; Raya & Garcia, 2012; Bourassa & Yin, 2006; Carliner, 1974; Clark *et al*., 1997; Goodman, 1988; Iwarere & John, 1991; Raya & Garcia, 2012)

Education level also shows a significant influence on homeownership, with higher education levels associated with a higher probability of homeownership (Carter, 2011; Haurin *et al*., 1994; Li & Li, 2006). This effect is related to employment status, income and wealth. Those with higher education levels are more likely to be employed and to have higher income and greater wealth. There is a positive relationship between employment and homeownership (Kain & Quigley, 1972; Munro & Smith, 1989). Moreover, a longer duration of employment is associated with a higher probability of being a homeowner, possibly because it increases workers' sense of stability and reduces the expectation of relocation. Meanwhile, income and wealth directly impact the likelihood of homeownership. Those with higher income and greater wealth are more likely to be homeowners (Carliner, 1974; Haurin *et al*., 1994; Iwarere & John, 1991; Kain & Quigley, 1972; Megbolugbe & Linneman, 1993; Rosen, 1979). Allen C. Goodman (2003) differentiated between permanent income and transitionary income, and found that permanent income had a larger positive impact on homeownership than the transitionary income.

The micro-economic context also influences homeownership. First, the probability of homeownership is substantially influenced by the relative price of owning to renting. A higher relative price of owning to renting decreases the probability of homeownership (Bourassa, 1995; Bourassa & Yin, 2006; de Groot *et al*., 2013; Goodman, 1988; Rosen, 1979). Loan policies, tax policies and the inflation rate also alter the relationship between homeownership and rental costs and hence influence homeownership (Andrew, 2012;; Brueckner, 1986; Carliner, 1974; Carter, 2011; Clark *et al*., 1997; Megbolugbe & Linneman, 1993; Narwold & Sonstelie, 1994).

2.2. Determinants of housing preference

Individuals and households might decide on the tenure choice and dwelling type choice simultaneously, thus factors that affect house tenure choice also have an influence on preference of dwelling types. Take socio-economic attributes as an example. Age, gender, race, marital status, the presence of school-aged kids, employment status, income and etc. also substantially affect dwelling type choice (Barrios García & Rodríguez Hernández, 2008; Bhat, 2015; Cho, 1997; Colom & Molés, 2008; Frenkel & Kaplan, 2015; Jansen, 2012; Moos & Skaburskis, 2008; Quigley, 1976; Skaburskis, 1999). For instance, as people are getting older, the preference for larger houses or single-family detached units also increases (Barrios García & Rodríguez

Hernández, 2008; Cho, 1997; Jansen, 2012; Skaburskis, 1999). Life-cycle factors also increase the propensity to live in single-family houses. Households with married couples are more likely to live in single-family houses, compared with households only with single persons (Bhat, 2015). As for the number of children, it's found that regardless of the age of the children, square footage and the number of room increases with the number of kids in the family (Bhat, 2015).

In particular, studies about housing preferences are interested in how values or lifestyle influence choices of dwelling unit characteristics. Bhat (2015) constructs two latent variables to investigate how different lifestyle propensities impact choices of housing characteristics. One is 'Green lifestyle propensity', which is built from education status, race, gender; the other is 'Luxury lifestyle propensity', generated from household income. The study finds that a green lifestyle doesn't exert statistically significant impacts on housing characteristics, yet a luxury lifestyle is associated with bigger square footage and more rooms in the house. Frenkel and Kaplan (2015) focus on knowledge workers, and investigate how culture-oriented lifestyle and home-oriented lifestyle impact housing choices. Their analysis shows that a culture-oriented lifestyle is associated with a preference for small apartments, while workers with a home-oriented lifestyle prefer single detached houses.

2.3. How telecommuting influences homeownership and housing preference

According to the motivation and focus of research, the current literature on telecommuting and housing-related behaviors can be categorized into two main streams. The first stream focuses on the (interactive) impact of telecommuting on housing location choice. Lower commuting frequency and consequent tolerance for longer commuting distance reduces the constraints on residential location choice. This allows telecommuters a greater range of choice and potentially allows them to choose locations with more attractive residential environments that are further from jobs (e.g. suburban areas) (Ettema, 2010). Studies find that compared with non-telecommuters, telecommuters prefer rural green environment for their residential location (Muhammad *et al.*, 2007). Thus, this first stream of literature illuminates the relationship between telecommuting, real estate markets, and urban spatial structure (Ettema, 2010; Muhammad *et al.*, 2007; Zhu, 2013). The second stream focuses on the impact of telecommuting on commuting patterns (distance and duration), examining the travel behavior of telecommuters and the impact of telecommuting on vehicle miles traveled (VMT), congestion and emissions (Kim, 2017; Shabanpour *et al.*, 2018; Zhu & Mason, 2014). A common finding is that telecommuters overall have a longer commute distance than non-telecommuters (Mokhtarian *et al.*, 2004; Zhu, 2013; Zhu *et al.*, 2018).

By loosening the restrictions on residential location choice and transforming commuting behaviors, telecommuting could also lead to changing patterns of homeownership and housing type choice. Based on the classic Alonso-Mill-Muth (AMM) model, we posit that telecommuting may increase the likelihood of workers choosing homeownership. In the AMM model, workers spend their income on housing, transportation and a composite good. It assumes that houses located farther from

the CBD are more affordable than those located near the CBD. Since telecommuters do not need to commute to work every day, their transportation cost, both in terms of money and time, decreases as a result. Intuitively, as telecommuting reduces the frequency of commutes for workers, it may allow workers to choose more distant residential locations, with the increased commuting costs compensated for by low commute frequency. Thus, workers likely have more options for low-priced spacious housing due to the lessening of restrictions imposed by transportation costs. Moreover, as telecommuting may reduce the interdependency between residential location and job location, the motivation to relocate is less related to changes in a job location for telecommuters in the long term, increasing household stability and thus the propensity to purchase a house.

As for the relation between telecommuting and housing type, there are a few studies in line with the purpose of this research. Moos and Skaburskis (2008) studied the association between telecommuting and the propensity to live in a detached single-family dwelling. Using 2001 Public Use Microdata Files for the thirteen largest Canadian census metropolitan areas, the logistic regression indicates that households with both workers telecommuting have the highest propensity to live in a detached single-family dwelling, followed by households where only the primary worker works remotely, and then by those where only the non-primary worker telecommutes. Interestingly, the work from home variable increases the probability of single-family dwelling occupancy more than life-cycle variables, which are generally significantly associated with the household's housing decisions. However, this article does not empirically resolve issues of causality. More recently, Ng (2010) provides a literature review in an attempt to understand the relationship between the design and physical conditions of home offices and telecommuters' work behaviors. This comprehensive review of the literature on telecommuting and the home office environment suggests that telecommuting has an impact on telecommuters' housing size choices. In particular, the outcomes suggest that telecommuters prefer to live in more spacious housing, compared to non-telecommuters.

3. Methodology

3.1. Data and variables

The dataset used in this research is from the 2009 and 2017 U.S. National Household Travel Survey (NHTS), which provides information on US residents' socioeconomic characteristics, travel behaviors and current residence characteristics. The dataset was restricted to households with at most two workers, aged between 16 and 65. Observations with missing telecommuting information were omitted from the dataset. After data screening, 96,675 individual workers and 71,556 households are included in the 2009 sample; the 2017 sample includes 85,109 individual workers and 62,889 households. The baseline model to examine the impact of telecommuting on homeownership and housing type is specified as the following equation:

$$\begin{aligned} &Homeownership\,/\,housing\,type \\ &= f\left(Telecommuting\ status, socioeconomic\ factors, current\ residence\ characteristics\right) \end{aligned}$$

The binary dependent variable is individual/household homeownership or housing type. For homeownership, 'owning housing' takes the value '1' and 'renting housing' takes the value '0'. For housing type, 'detached and duplex house' takes the value '1' and 'townhouse and apartment' takes the value '0'. Independent variables include telecommuting status, socioeconomic characteristics and current residence characteristics. For telecommuting status, workers who report working at home instead of commuting to workplace at least once a week are defined as telecommuters, taking the value '1'. Those who infrequently/never telecommute are defined as non-telecommuters, taking the value '0'. Socioeconomic characteristics include gender, age, education, occupation, marital status, medical condition, household income, presence of a school-age children, number of vehicles per driver and race. Current residence characteristics include residential location (i.e. rural area, suburban area and urbanized area), residential density, number of housing units at the block group level and commute distance. The model also uses a set of Core Based Statistical Area (CBSA) dummy variables to control for regional fixed effect. Log-value is used for continuous variables. Dummy coding is used for categorical variables.

When estimating the household level model, several two-worker household-level characteristics are derived from aggregated individual-level characteristics. In particular, in the household-level analysis, telecommuting status takes the value of '1' if there is at least one telecommuter in the household. Gender is neglected at the household level. Household-level age takes the average age of the two workers. Household-level commute distance takes the average commute distance of two workers. Household-level marital status indicates the relationship between the two workers. If the two workers are married, it takes the value of '1'. Household-level educational level takes the highest education level of the two workers. Household-level occupation indicates whether at least one worker falls into a specific occupation type. For instance, if both workers work in 'Sale or Service' industry, then the dummy variable for 'Sale or Service' will be coded as '1'. In the case when both workers belong to different occupation types, say 'Sale or Service' and 'Clerical or administrative support', then both dummies will be coded as '1'. Considering that household demand for homeownership and housing type choice is heavily affected by life cycle stage, we partition the full household sample into three age subsamples to capture the heterogeneous impact of telecommuting on homeownership and housing type. The first age subgroup contains all households where the worker (or the oldest worker in two-worker households[2]) is aged between 16 and 29 (hereinafter referred to as the young/younger households). The second age category includes all households where the worker (or the oldest worker in two-worker households) is aged between 30 and 55 (hereinafter referred to as the middle-age households). The last category consists of all households where the worker (or the oldest worker in two-worker households) is aged between 56 and 65 (hereinafter referred to as the older households). Besides, we also investigate the spatial heterogeneity of the results, by dividing the sample according to their residential location: urbanized areas, urban clusters and rural. The division is based on the definition by the US census: an urbanized area is defined as an area with a population size larger than 50,000 people; an urban cluster refers to an area with a population less than 50,000 people but more than 2,500; the rest belongs to the rural area.

Table 1. Descriptive statistics of the dependent variables.

			Telecommuting households		Non-telecommuting Households	
			Mean	SD	Mean	SD
2009	Individual	Ownership	0.92	0.27	0.89	0.31
		Detached or duplex	0.92	0.27	0.88	0.32
	One-worker households	Ownership	0.88	0.33	0.85	0.36
		Detached or duplex	0.89	0.32	0.83	0.37
	Two-worker households	Ownership	0.95	0.23	0.92	0.27
		Detached or duplex	0.95	0.22	0.92	0.28
2017	Individual	Ownership	0.79	0.41	0.75	0.44
	One-worker households	Ownership	0.70	0.46	0.66	0.47
	Two-worker households	Ownership	0.83	0.37	0.80	0.40

Table 1 reports the descriptive statistics for the dependent variables. A higher homeownership rate and a higher percentage of detached or duplex dwelling types are observed among telecommuters and telecommuting households in both years. Table 2 presents the descriptive statistics for the independent variables. The average variance inflation factor (VIF) of the independent variables using individual samples is 1.33 for 2009, and 1.17 for 2017. The VIF for the telecommuting status variable is close to one for each survey years. It suggests that the chosen covariates do not have multicollinearity issue.

3.2. Model specification

The baseline model may suffer from endogeneity for at least two reasons. First, the choice to telecommute may be endogenous to housing choice because of the bi-directional causality. On the one hand, telecommuters require quieter working space at home, thus they might prefer to purchase a house away from main roads and with sparing spaces for a home office. On the other hand, workers living in a spacious house are more likely to have sufficient space for a quiet home office and hence more willing to opt for telecommuting. Second, the baseline model may exhibit omitted variable bias in such a way that telecommuting status may become correlated with the error term. For example, workers who are more familiar with technology may be more willing to switch to a telecommuting arrangement, relative to those with reluctant acceptance for technology usage. However, it is difficult to specifically control for technology familiarity in the baseline model, causing correlation between the telecommuting variable and the model error term. To address the endogeneity issue, this paper employs two variables to instrument the endogenous telecommuting choice. The 2009 model uses internet usage frequency, a binary variable taking value '1' if the worker reports using the internet every day[3]. As the 2017 NHTS dataset does not include the internet usage variable, the model for 2017 uses individual online purchase delivery frequency, a continuous variable of individuals' home delivery frequency in the last 30 days[4]. Frequency of internet usage is found to be strongly correlated with telecommuting choice (Zhu, 2012, 2013). Telecommuters whose work relies more on the internet and digital devices are more likely to use the internet frequently. Meanwhile, after controlling for workers' socio-economic attributes and residential location, internet usage can only influence housing preference via telecommuting status. According to 2009 Current Population

Table 2. Descriptive statistics of the independent variable.

	Individual level descriptive statistics							
	2009				2017			
	Mean	sd	Min	Max	Mean	sd	Min	Max
Telecommuting status	0.05	0.21	0	1	0.08	0.27	0	1
Socioeconomic characteristics								
Male	0.50	0.50	0	1	0.51	0.50	0	1
Age	47.17	11.06	18	65	44.59	12.55	16	65
Household income (log)	11.08	0.64	7.82	11.70	11.20	0.77	8.52	12.21
Education level								
High school graduate or GED	0.23	0.42	0	1	0.15	0.36	0	1
College degree	0.29	0.45	0	1	0.29	0.45	0	1
Bachelor's degree	0.26	0.44	0	1	0.29	0.45	0	1
Graduate degree or professional degree	0.20	0.40	0	1	0.25	0.44	0	1
Occupation								
Sales or service	0.23	0.42	0	1	0.20	0.40	0	1
Clerical or administrative support	0.13	0.33	0	1	0.11	0.31	0	1
Manufacturing, construction, maintenance, or farming	0.14	0.35	0	1	0.13	0.34	0	1
Professional, managerial, or technical	0.50	0.50	0	1	0.56	0.50	0	1
Other types of occupation	0.01	0.08	0	1	0.00	0.03	0	1
Whether has a medical condition	0.03	0.16	0	1	0.02	0.13	0	1
Whether has a partner	0.68	0.47	0	1	0.68	0.47	0	1
Whether has a school-age child	0.37	0.48	0	1	0.31	0.46	0	1
Presence of white people	0.86	0.35	0	1	0.82	0.39	0	1
Number of vehicle per driver	1.20	0.51	0	27	1.19	0.56	0	12
Number of household members	2.81	1.23	1	13	2.54	1.21	1	10
Current residence characteristics								
Distance to work (log)	2.15	1.15	−2.30	6.90	2.32	1.03	0	8.08
Residential location								
Whether living in a rural area	0.18	0.39	0	1	0.13	0.34	0	1
Whether living in a suburban area	0.60	0.49	0	1	0.71	0.46	0	1
Whether living in an urbanized area	0.22	0.41	0	1	0.17	0.37	0	1
Housing units at the block group level (log)	6.24	1.59	3.91	10.31	6.59	1.62	3.91	10.31

Survey (CPS), the percentage of individual respondents who use internet at home in 2009 was 73.5%, and the number was 80.3% among the employed. Reverse causality should not be an issue here as whether households choose to purchase or rent a house, or choose to live in a single-family house or an apartment could hardly have direct influences on their internet usage, after controlling for socio-economic characteristics. Besides, broadband or internet infrastructures might be related with the residential location preference of a household, yet they should not directly affect the decision on purchasing or renting a house, or choosing a specific housing type, as they are more subject to the influence of household financial situation and needs for specific housing characteristics. Therefore, while there

still exist geographical variations of internet quality, it should not influence one's decision-making on homeownership or housing type other than exerting impacts on the telecommuting status. Similarly, telecommuters are more inclined to online shopping due to their work routine and familiarity with technology. In 2017, as internet access has grown even more widespread, online purchase delivery should common enough in 2017 to be irrelevant to homeownership or housing type preference, after controlling for socio-economic characteristics. That is to say, after controlling for potential confounding socio-economic factors, such as education level, income, residential location etc., online shopping frequency can only influence dwelling occupancy and housing type preference via telecommuting status. We apply a weak instrument test to ensure the instrumental variables are associated with the choice of telecommuting. According to the first stage regression results for both the individual and household level models in Appendix B, the instrumental variables have a statistically significant impact on telecommuting choice. Furthermore, the *F* statistics for all models are greater than 10, indicating that the instrumental variables are sufficiently strong.

The three-step instrumental variable model is utilized in this paper to avoid the issue of 'forbidden regression', which happens when the first stage of the orthodox 2SLS is mechanically replaced by a nonlinear model (Wooldridge, 2010). The three-step IV helps resolve the problem and gives a consistent estimate. As the name suggests, the approach has one extra step compared to a standard two-step least squares approach. In the first step of the three-step approach, a Probit model is estimated for correlation between telecommuting status and the instrumental variables, socio-demographic variables and current residential characteristic variables. After that, the probability of telecommuting status $Pr(T_i)$ is predicted after fitting the model.

$$T_i = a_0 + a_1 X_i^S + a_2 X_i^R + a_3 IV_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots the\ 1^{st}\ step$$

The second and third steps are the same as the standard two-stage least squares estimation model, but with the instrumental variables replaced by the predicted probability of telecommuting status from the first step. In the second step of the three-step method, the telecommuting status is regressed on the socio-demographic variables, current residential characteristic variables and the predicted probability of telecommuting status $Pr(T_i)$ from the first step. The predicted value T_i from the second step is then used in the final step, where the outcome variable is the home ownership or housing type choice.

$$T_i = \beta_0 + \beta_1 X_i^S + \beta_2 X_i^R + \beta_3 Pr(T_i) + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots the\ 2^{nd}\ step$$

$$Y_i = \beta_0 + \beta_1 X_i^S + \beta_2 X_i^R + \beta_3 \hat{T}_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots the\ 3^{rd}\ step$$

4. Results

4.1. Telecommuting and homeownership

4.1.1. Results of the baseline models

Results of the baseline models are shown in Appendix A. Telecommuting in general has statistically insignificant impacts on homeownership at both individual and household levels. Telecommuting is observed to decrease the probability of homeownership among one worker households in the 2009 model. In 2017, the effect of telecommuting on homeownership in all the models. As discussed above, the baseline model may suffer from endogeneity and yield incorrect estimations. The Wald test (Appendix B) indicates that the problem of endogeneity exists. Therefore, the following discussion will focus on results obtained from the Instrumental Variable method.

4.1.2. Results obtained from the 3-step Instrumental Variable approach

Tables 3–5 present the estimation results with homeownership as the outcome variable. Note that all the tables in the results section report the average marginal effects of the explanatory variables. At an individual level, telecommuting has a statistically significant and positive impact on homeownership. As shown in Table 3, telecommuters are more likely to be homeowners than their non-telecommuting counterparts. The estimated marginal effects show that in 2009, telecommuters were 34.9% more likely to be homeowners. In 2017, telecommuters were 41% more likely to be homeowners. We further examine the impact of the presence of telecommuters on homeownership at the household level. Similar trends are found at a household level: both one-worker and two-worker households with telecommuter(s) are more likely to be homeowners than non-telecommuter households. For one-worker households, telecommuting households were 36.4% more likely to be homeowners in 2009 and 36.6% more likely to be homeowners in 2017. For two-worker households, telecommuting households were 54.7% more likely to be homeowners in 2009 and 41% more likely to be homeowners in 2017.

Other than telecommuting status, some socioeconomic and current residential attributes also have a statistically significant influence on individual homeownership. Both in 2009 and 2017, women were more likely to become homeowners than men. The results correspond to a study in 2019 showing that the percentage of single women home buyers was 10% higher than single men buyers (Smaby, 2019). Worker's age, household income, medical condition, and marital status were also important predictors of individual tendency to own a house in both years. In particular, household income is observed to have statistically significant and positive impacts on homeownership in all models. This is expected as financial capacity in general plays a determinant role in the tenure decision.

Since extant research indicates that homeownership is significantly influenced by household life cycle stages (Haurin, 1991), the household level model was categorized into three age groups to examine the age heterogeneity of telecommuting's impact on homeownership (see Tables 4 and 5). As shown in Table 4, among one-worker households, the presence of telecommuters only has a statistically significant impact on the middle-age subgroup (30–55). For this subgroup, telecommuting households

Table 3. Results from IV estimation for homeownership.

	Own (1) vs. rent (0)					
	2009			2017		
	Full	One-worker	Two-worker	Full	One-worker	Two-worker
Telecommuting status	0.349*** (0.06)	0.364*** (0.09)	0.547*** (0.08)	0.410*** (0.05)	0.366*** (0.09)	0.410*** (0.04)
Socioeconomic characteristics						
Male	−0.020*** (0.00)	−0.034*** (0.00)		−0.026*** (0.00)	−0.033*** (0.01)	
Age	0.003*** (0.00)	0.004*** (0.00)	0.004*** (0.00)	0.007*** (0.00)	0.008*** (0.00)	0.009*** (0.00)
Household Income (log)	0.079*** (0.00)	0.085*** (0.00)	0.074*** (0.00)	0.123*** (0.00)	0.113*** (0.01)	0.100*** (0.00)
Education level						
High school graduate or GED	0.044*** (0.01)	0.058*** (0.01)	0.060*** (0.01)	−0.012 (0.01)	0.042*** (0.02)	−0.032 (0.03)
College degree	0.042*** (0.01)	0.052*** (0.01)	0.063*** (0.01)	−0.022** (0.01)	0.037** (0.02)	−0.034 (0.03)
Bachelor's degree	0.051*** (0.01)	0.069*** (0.01)	0.069*** (0.01)	−0.026*** (0.01)	0.042** (0.02)	−0.023 (0.03)
Graduate degree or professional degree	0.040*** (0.01)	0.059*** (0.01)	0.049*** (0.01)	−0.036*** (0.01)	0.023 (0.02)	−0.021 (0.03)
Occupation						
Sales or service			−0.003 (0.00)			−0.009** (0.00)
Clerical or administrative support	0.007* (0.00)	0.011 (0.01)	0.008* (0.00)	0.009* (0.01)	0.003 (0.01)	0.011** (0.00)
Manufacturing, construction, maintenance, or farming	0.005 (0.00)	0.008 (0.01)	0.007* (0.00)	−0.007 (0.00)	−0.017** (0.01)	0.007 (0.00)
Professional, managerial, or technical	−0.001 (0.00)	−0.003 (0.01)	0.004 (0.00)	−0.012*** (0.00)	−0.016** (0.01)	−0.004 (0.00)
Other types of occupation	0.012 (0.01)	0.056** (0.02)	−0.022* (0.01)	−0.055 (0.04)	−0.066 (0.06)	−0.047 (0.04)
Whether has a medical condition	−0.022*** (0.01)	−0.018* (0.01)	−0.037*** (0.01)	−0.027*** (0.01)	−0.030** (0.01)	−0.038*** (0.01)
Whether has a partner	0.023*** (0.00)	0.020*** (0.00)	−0.002 (0.00)	0.013*** (0.00)	0.023*** (0.01)	−0.049*** (0.00)
Whether has a school-age child	−0.047*** (0.00)	−0.079*** (0.01)	−0.019*** (0.00)	−0.060*** (0.01)	−0.119*** (0.01)	0.012** (0.01)
Presence of white people	0.034*** (0.00)	0.042*** (0.00)	0.027*** (0.00)	0.046*** (0.00)	0.055*** (0.01)	0.031*** (0.00)
Number of vehicle per driver	0.063*** (0.00)	0.069*** (0.00)	0.072*** (0.00)	0.089*** (0.00)	0.096*** (0.01)	0.086*** (0.00)
Number of household members	0.028*** (0.00)	0.039*** (0.00)	0.022*** (0.00)	0.059*** (0.00)	0.073*** (0.00)	0.029*** (0.00)
Current residence characteristics						
Distance to work (log)	0.013*** (0.00)	0.018*** (0.00)	0.009*** (0.00)	0.006*** (0.00)	0.015*** (0.00)	−0.004* (0.00)
Residential location						
Whether living in a suburban area	0.011** (0.00)	0.008 (0.01)	0.014*** (0.01)	−0.002 (0.01)	0.011 (0.01)	−0.008 (0.01)
Whether living in an urbanized area	0.017*** (0.00)	0.012* (0.01)	0.022*** (0.01)	0.019*** (0.01)	0.024*** (0.01)	0.014** (0.01)
Housing units at the block group level (log)	−0.023*** (0.00)	−0.030*** (0.00)	−0.020*** (0.00)	−0.046*** (0.00)	−0.048*** (0.00)	−0.042*** (0.00)
CBSA FIPS code	Yes	Yes	Yes	Yes	Yes	Yes
N	84,851	33,585	56,711	82,289	31,395	54,320

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for residential location dummies is the 'Whether living in a rural area'; 'High school graduate or GED' is the base group for education level.

were 42.9% more likely to be homeowners in 2009 and 47.6% more likely to be homeowners in 2017. Yet, telecommuting status is observed to have a limited impact on younger and older households' tendency to own a home. However, the analysis for two-worker households reveals quite different age heterogeneity patterns, as shown in Table 5. Homeownership among middle-aged or younger two-worker households are both significantly influenced by the presence of telecommuters. According to the estimation, middle-age (30–55) two-worker households with a telecommuter were 67.6% more likely to be homeowners in 2009 and 40.1% more likely to be homeowners in 2017. Young (16–29) telecommuting two-worker households were 30.8% less likely to own a house in 2009 but 55.8% more likely to be homeowners in 2017. Older (56–65) telecommuting households were 12.2% more likely to be a homeowner in 2017.

Table 6 reports the spatial heterogeneity of the impacts. Among one-worker households, the impact of telecommuting on homeownership is consistently observed both in urbanized areas in two surveyed years. In 2009, telecommuters living in urbanized areas were 26.8% more likely to become homeowners, compared with their non-telecommuting counterparts. In 2017, the probability was increased to 34.7%. For two-worker households, homeownership of urbanized and suburban households is consistently influenced by telecommuting status in both 2009 and 2017. For urbanized two-worker households, telecommuting increased the probability of becoming a homeowner by 44.6% in 2009 and 37.2% in 2017. For suburban households, telecommuting households were 24.1% more likely to be homeowners in 2009 and 54% in 2017. The spatial heterogeneity shows that in general telecommuting status exerts statistically significant influences on homeownership among urbanized households, regardless of household type and survey year.

4.2. Telecommuting and housing preference

As the 2017 NHTS does not include information on housing type, the following analysis is only based on the 2009 data alone. The baseline models for housing type choice are reported in Appendix A. The impact of telecommuting on housing type choice is statistically insignificant in most of the models, except those for two-worker households. As in the homeownership model, the base models for housing type choice are affected by endogeneity; thus, the discussion below will focus on estimation results obtained from the Instrumental Variable models.

Tables 7 and 8 display the results for housing preference using the Instrumental Variable approach. As shown in Table 7, at both the individual and household levels, the presence of telecommuters has statistically significant positive influence on living in a detached or duplex house. According to Column 1, at the individual level, telecommuters are 29.9% more likely to live in a detached or duplex house than non-telecommuters. At the household level, telecommuting one-worker households were 28.1% more likely to live in a detached or duplex house, while telecommuting two-worker households were 58.3% more likely to live in a detached or duplex house.

Some socio-economic and residential location characteristics also have a statistically significant influence on housing type choice. We only elaborate here on the

Table 4. Results from IV estimation for one-worker household homeownership: age heterogeneity.

	One-worker_age subsample					
	Own (1) vs. rent (0)					
	2009			2017		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.423 (0.37)	0.429*** (0.10)	0.165 (0.11)	−0.319 (0.28)	0.476*** (0.10)	−0.027 (0.17)
Socioeconomic characteristics						
Male	0.009 (0.02)	−0.035*** (0.01)	−0.030*** (0.01)	0.038** (0.01)	−0.030*** (0.01)	−0.049*** (0.01)
Age	−0.009*** (0.00)	0.006*** (0.00)	0.002** (0.00)	0.006** (0.00)	0.009*** (0.00)	0.004*** (0.00)
Household income (log)	0.138*** (0.01)	0.090*** (0.00)	0.058*** (0.00)	0.125*** (0.01)	0.115*** (0.01)	0.083*** (0.01)
Education level						
High school graduate or GED	0.143*** (0.04)	0.062*** (0.01)	0.042*** (0.01)	0.010 (0.04)	0.074*** (0.02)	0.042* (0.02)
College degree	0.159*** (0.04)	0.056*** (0.01)	0.032** (0.01)	0.024 (0.04)	0.061*** (0.02)	0.060*** (0.02)
Bachelor's degree	0.200*** (0.05)	0.078*** (0.01)	0.044*** (0.01)	−0.066 (0.05)	0.092*** (0.02)	0.081*** (0.02)
Graduate degree or professional degree	0.205*** (0.05)	0.060*** (0.01)	0.053*** (0.01)	−0.067 (0.05)	0.062** (0.02)	0.070*** (0.02)
Occupation						
Sales or service						
Clerical or administrative support	0.023 (0.03)	0.005 (0.01)	0.018* (0.01)	−0.024 (0.03)	0.001 (0.01)	0.015 (0.01)
Manufacturing, construction, maintenance, or farming	−0.007 (0.03)	0.013 (0.01)	0.010 (0.01)	−0.049** (0.02)	0.000 (0.01)	−0.008 (0.01)
Professional, managerial, or technical	−0.020 (0.03)	0.005 (0.01)	−0.003 (0.01)	−0.038** (0.02)	−0.011 (0.01)	0.008 (0.01)
Other types of occupation	0.000 (.)	0.025 (0.03)	0.077*** (0.03)	0.000 (.)	−0.111 (0.09)	0.000 (.)
Whether has a medical condition	0.164* (0.09)	−0.023 (0.01)	−0.016 (0.01)	−0.024 (0.07)	−0.016 (0.02)	−0.035** (0.02)
Whether has a partner	−0.071*** (0.03)	0.008 (0.01)	0.058*** (0.01)	−0.107*** (0.02)	0.027*** (0.01)	0.109*** (0.01)
Whether has a school-age child	−0.127*** (0.03)	−0.056*** (0.01)	−0.064*** (0.02)	−0.224*** (0.02)	−0.081*** (0.01)	−0.073*** (0.02)
Presence of white people	0.096*** (0.02)	0.049*** (0.01)	0.016** (0.01)	0.067*** (0.02)	0.054*** (0.01)	0.053*** (0.01)
Number of vehicle per driver	0.133*** (0.03)	0.067*** (0.01)	0.059*** (0.01)	0.081*** (0.01)	0.095*** (0.01)	0.091*** (0.01)
Number of household members	0.062*** (0.01)	0.039*** (0.00)	0.022*** (0.01)	0.133*** (0.01)	0.058*** (0.00)	0.026*** (0.01)
Current residence characteristics						
Distance to work (log)	0.033*** (0.01)	0.022*** (0.00)	0.009*** (0.00)	0.023*** (0.01)	0.015*** (0.00)	0.014*** (0.00)
Residential location						
Whether living in a suburban area	0.031 (0.03)	0.006 (0.01)	0.005 (0.01)	0.032 (0.03)	0.024* (0.01)	−0.007 (0.01)
Whether living in an urbanized area	0.016 (0.03)	0.003 (0.01)	0.020** (0.01)	0.016 (0.02)	0.041*** (0.01)	0.010 (0.01)
Housing units at the block group level (log)	−0.044*** (0.01)	−0.029*** (0.00)	−0.027*** (0.00)	−0.049*** (0.01)	−0.052*** (0.00)	−0.035*** (0.00)
CBSA FIPS code	Yes	Yes	Yes	Yes	Yes	Yes
N	1777	20,563	10,607	3502	17,460	10,048

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for residential location dummies is the 'Whether living in a rural area'; 'High school graduate or GED' is the base group for education level.

Table 5. Results from IV estimation for two-worker household homeownership: age heterogeneity.

	Two-worker_age subsample					
	Own (1) vs. rent (0)					
	2009			2017		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.308* (0.18)	0.676*** (0.08)	0.011 (0.07)	0.558*** (0.14)	0.401*** (0.05)	0.122* (0.07)
Socioeconomic characteristics						
Male						
Age	0.002 (0.00)	0.004*** (0.00)	−0.000 (0.00)	0.027*** (0.00)	0.009*** (0.00)	0.003*** (0.00)
Household Income (log)	0.132*** (0.02)	0.082*** (0.00)	0.038*** (0.00)	0.140*** (0.02)	0.107*** (0.00)	0.060*** (0.00)
Education level						
High school graduate or GED	0.209*** (0.08)	0.042*** (0.01)	0.048*** (0.01)	−0.235** (0.09)	−0.011 (0.04)	−0.099** (0.04)
College degree	0.173** (0.08)	0.043*** (0.01)	0.057*** (0.01)	−0.230** (0.09)	−0.009 (0.04)	−0.104** (0.04)
Bachelor's degree	0.216*** (0.08)	0.049*** (0.01)	0.062*** (0.01)	−0.252*** (0.09)	0.008 (0.04)	−0.090** (0.04)
Graduate degree or professional degree	0.241*** (0.08)	0.027* (0.01)	0.057*** (0.01)	−0.323*** (0.09)	0.015 (0.04)	−0.092** (0.04)
Occupation						
Sales or service	−0.066*** (0.02)	−0.003 (0.01)	−0.001 (0.00)	0.025 (0.02)	−0.012** (0.01)	−0.022*** (0.01)
Clerical or administrative support	−0.085*** (0.03)	−0.002 (0.01)	0.013*** (0.00)	0.010 (0.02)	0.004 (0.01)	0.009 (0.01)
Manufacturing, construction, maintenance, or farming	−0.122*** (0.03)	0.010* (0.01)	−0.001 (0.00)	0.043*** (0.02)	−0.002 (0.01)	−0.002 (0.01)
Professional, managerial, or technical	−0.090*** (0.03)	0.005 (0.01)	0.001 (0.00)	−0.002 (0.02)	−0.005 (0.01)	−0.010 (0.01)
Other types of occupation	−0.049 (0.07)	−0.037** (0.02)	0.003 (0.01)	0.000 (.)	−0.015 (0.04)	−0.113 (0.07)
Whether has a medical condition	−0.095* (0.06)	−0.038*** (0.01)	−0.017*** (0.01)	0.001 (0.05)	−0.045*** (0.01)	−0.028*** (0.01)
Whether has a partner	0.072*** (0.03)	−0.005 (0.01)	0.038*** (0.00)	−0.031* (0.02)	−0.039*** (0.01)	−0.022** (0.01)
Whether has a school-age child	−0.063** (0.03)	−0.018*** (0.01)	−0.026*** (0.01)	−0.029 (0.02)	0.017*** (0.01)	−0.063*** (0.01)
Presence of white people	0.033 (0.03)	0.036*** (0.01)	0.005 (0.00)	0.017 (0.02)	0.038*** (0.01)	0.026*** (0.01)
Number of vehicle per driver	0.201*** (0.03)	0.071*** (0.01)	0.051*** (0.01)	0.105*** (0.03)	0.092*** (0.01)	0.056*** (0.01)
Number of household members	0.090*** (0.02)	0.018*** (0.00)	0.015*** (0.00)	0.080*** (0.02)	0.025*** (0.00)	0.031*** (0.00)
Current residence characteristics						
Distance to work (log)	0.043*** (0.01)	0.008*** (0.00)	0.005*** (0.00)	0.016** (0.01)	−0.003 (0.00)	−0.006* (0.00)
Residential location						
Whether living in a suburban area	0.010 (0.03)	0.012* (0.01)	0.008 (0.01)	0.008 (0.02)	−0.010 (0.01)	−0.010 (0.01)
Whether living in an urbanized area	−0.080** (0.03)	0.022*** (0.01)	0.013** (0.01)	−0.008 (0.02)	0.020*** (0.01)	0.003 (0.01)
Housing units at the block group level (log)	−0.009 (0.01)	−0.021*** (0.00)	−0.012*** (0.00)	−0.057*** (0.01)	−0.042*** (0.00)	−0.030*** (0.00)
CBSA FIPS code	Yes	Yes	Yes	Yes	Yes	Yes
N	1536	37,596	16,799	4242	35,290	14,384

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for residential location dummies is the 'Whether living in a rural area'; 'High school graduate or GED' is the base group for education level.

mechanism of influence at the individual level. For socioeconomic attributes, higher age, household income, education level and number of vehicles per driver were associated with a higher likelihood of living in a detached or duplex house. Moreover, the presence of partners and white people also increased the probability of living in a detached or duplex house. Meanwhile, individuals with medical conditions were less likely to live in such houses.

We repeat the age heterogeneity analysis for the household level housing type models (see Table 8). Only middle-aged (30–55) households' housing type choices are observed to be significantly influenced by telecommuting. The presence of a telecommuter significantly increased the probability of living in a detached or duplex house for middle-aged one-worker households, relative to the non-telecommuting households. Similar results are also observed among middle-aged two-worker households who have at least one telecommuter.

Similarly, we also test if telecommuting status has heterogenous impacts across different areas. Table 9 shows the results for urbanized, suburban and rural areas. For one-worker households, telecommuting has statistically significant impacts on the probability of living in a detached or duplex house in urbanized areas. Telecommuting households living in urbanized areas were 18.1% more likely to reside in detached or duplex houses. For two-worker households, telecommuting households are more likely to live in detached or duplex houses no matter where they are located.

Finally, we partition the sample into owner households and renter households, to investigate how telecommuting influences housing preference under different tenures. Table 10 shows that the impact of telecommuting on housing preference is only statistically significant among two-worker owners. For two-worker households, telecommuting increases the probability by 35.8%. There is no significant influence of telecommuting arrangements among renters. It suggests that the telecommuting status only has statistically significant impacts on homeowners. It could be explained by the strong connection between ownership and detached/duplex dwellings in the U.S. housing market, where the majority of detached/duplex dwellings is only available for purchasing but not renting. Based on the results, it could be inferred that telecommuting might further reinforce the relationship.

4.3. Robustness check

We also test whether the results are robust to different classifications of housing type choice by regressing the model on a new dependent variable. Previous estimates presented in Tables 6 and 7 treat single-family detached houses and duplex houses as one housing choice. However, a single-family detached house generally has larger spaces and more rooms than a duplex. We acknowledge this difference and separately code single-family detached housing as 1 and all other types (i.e. duplex house, townhouse and apartment) as 0 to examine if telecommuters (or telecommuting households) have a strong preference for single-family detached housing compared to other housing types. The analysis shows that estimation based on the new

Table 6. Results from IV estimation for household homeownership: spatial heterogeneity.

	One-worker household					
	2009			2017		
	Urbanized	Suburban	Rural	Urbanized	Suburban	Rural
Telecommuting status	0.268*** (0.10)	0.256 (0.18)	0.070 (0.23)	0.347*** (0.10)	−0.136 (0.18)	0.888*** (0.34)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	20852	6359	5830	22382	4713	4132
	Two-worker Household					
	2009			2017		
	Urbanized	Suburban	Rural	Urbanized	Suburban	Rural
Telecommuting status	0.446*** (0.10)	0.241** (0.12)	−0.117 (0.23)	0.372*** (0.05)	0.540*** (0.11)	0.344* (0.19)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
N	33,356	11,965	10,428	38,116	9133	6741

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table 7. Results from IV estimation for housing type.

	2009		
	Detached single house & duplex (1) vs. townhouse & apartment (0)		
	Full	One-worker	Two-worker
Telecommuting status	0.299*** (0.06)	0.281*** (0.09)	0.583*** (0.08)
Socioeconomic characteristics			
Male	−0.005** (0.00)	−0.013*** (0.00)	
Age	0.002*** (0.00)	0.002*** (0.00)	0.003*** (0.00)
Household income (log)	0.074*** (0.00)	0.082*** (0.00)	0.064*** (0.00)
Education level			
High school graduate or GED	0.044*** (0.01)	0.055*** (0.01)	0.042*** (0.01)
College degree	0.067*** (0.01)	0.088*** (0.01)	0.068*** (0.01)
Bachelor's degree	0.072*** (0.01)	0.093*** (0.01)	0.075*** (0.01)
Graduate degree or professional degree	0.067*** (0.01)	0.090*** (0.01)	0.064*** (0.01)
Occupation			
Sales or service			0.004 (0.00)
Clerical or administrative support	0.010** (0.00)	0.009 (0.01)	0.020*** (0.00)
Manufacturing, construction, maintenance, or farming	−0.012*** (0.00)	−0.016** (0.01)	0.002 (0.00)
Professional, managerial, or technical	0.000 (0.00)	0.001 (0.01)	0.010** (0.00)
Other types of occupation	−0.003 (0.01)	−0.007 (0.02)	0.007 (0.01)
Whether has a medical condition	−0.028*** (0.01)	−0.035*** (0.01)	−0.024*** (0.01)
Whether has a partner	0.031*** (0.00)	0.033*** (0.00)	0.001 (0.00)
Whether has a school-age child	−0.038*** (0.00)	−0.068*** (0.01)	−0.013** (0.01)
Presence of white people	0.023*** (0.00)	0.022*** (0.01)	0.025*** (0.00)
Number of vehicle per driver	0.050*** (0.00)	0.066*** (0.01)	0.043*** (0.00)
Number of household members	0.044*** (0.00)	0.061*** (0.00)	0.035*** (0.00)
Current residence characteristics			
Distance to work (log)	0.002 (0.00)	0.004** (0.00)	−0.001 (0.00)
Residential location			
Whether living in a suburban area	0.019*** (0.00)	0.014** (0.01)	0.029*** (0.00)
Whether living in an urbanized area	0.052*** (0.00)	0.048*** (0.01)	0.062*** (0.01)
Housing units at the block group level (log)	−0.017*** (0.00)	−0.022*** (0.00)	−0.014*** (0.00)
CBSA FIPS code	Yes	Yes	Yes
N	84,851	33,585	56,728

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for residential location dummies is the 'Whether living in a rural area'; 'High school graduate or GED' is the base group for education level.

dependent variable yields consistent results: telecommuters and telecommuting households prefer the dwelling type with larger space.

At the individual level, telecommuting arrangements have a statically significant and positive impact on worker's probability of living in a detached house. Compared with non-telecommuters, telecommuting workers were 37.1% more likely to reside in a single-family detached house. A similar tendency is observed at the household level. Telecommuting one-worker households were 33.8% more likely to live in a detached house. For two-worker households, the presence of a telecommuter increased the probability of living in a stand-alone detached house by 63.4% (see Appendix C). In particular, the impacts of telecommuting on propensity to live in duplex houses among one-worker household homeowners turn statistically significant: telecommuting increases the probability for one-worker homeowners to live in detached houses by 17.7%. Overall, no matter which measurement we use to represent housing type preference, the analysis gives similar results that telecommuting workers and households prefer more spacious dwellings with a more favorable environment.

5. Discussion

Previous research has documented the impact of telecommuting on commuting behaviors and residential location choice, but the literature on the effect of telecommuting on home ownership and housing type choice is limited. Both of these factors are relevant to the development of housing market and urban spatial structure in the post-pandemic era and thus are important for policymakers to understand as they make future urban development plans. Our research addresses this gap in the literature by applying a three-step IV analysis to 2009 and 2017 NHTS data to explore the causal impact of telecommuting on homeownership and housing type choice. Two major findings are obtained from this research.

First, the results of this study suggest that both individual telecommuters and telecommuter households are more likely to be homeowners. The impact is statistically significant in both 2009 and 2017. The heterogeneity analysis further indicates that the effects of telecommuting on homeownership are especially strong for middle-aged (30–55) households. These results suggest that telecommuting facilitates demand for homeownership, especially among middle-age telecommuters. Thus, with the major increase in telecommuting due to the pandemic, we are likely to see an increase in demand for homeownership in the post-pandemic era. Policymakers may both need to consider this factor in planning new development, in order to provide sufficient housing to meet new demands. If the housing stock in most US metropolitan areas does not increase substantially, it's foreseeable that demand for homeownership due to telecommuting could heat up the housing market. Moreover, as the heterogeneity analysis shows, telecommuting status has statistically significant and persistent influences on homeownership in urbanized areas, which have a higher home rentership compared to one in rural areas. Hence, in some cities with overheated rental markets, this may bring advantages and relieve the need for rent control or policies to control short-term vacation rentals (e.g. Airbnb).

Table 8. Results from IV estimation for housing type: age heterogeneity.

	Age subsample					
	Detached single house & duplex (1) vs. townhouse & apartment (0)					
	One-worker household			Two-worker household		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.634 (0.39)	0.383*** (0.10)	0.003 (0.13)	0.119 (0.20)	0.806*** (0.08)	−0.119 (0.09)
Socioeconomic characteristics						
Male	0.026 (0.02)	−0.017*** (0.01)	−0.004 (0.01)			
Age	−0.005 (0.00)	0.003*** (0.00)	0.002 (0.00)	0.002 (0.00)	0.004*** (0.00)	−0.000 (0.00)
Household income (log)	0.111*** (0.01)	0.084*** (0.00)	0.069*** (0.01)	0.067*** (0.02)	0.068*** (0.00)	0.048*** (0.01)
Education level						
High school graduate or GED	0.077** (0.04)	0.052*** (0.01)	0.055*** (0.02)	0.021 (0.06)	0.030** (0.01)	0.042*** (0.02)
College degree	0.140*** (0.04)	0.090*** (0.01)	0.075*** (0.02)	0.120* (0.06)	0.053*** (0.01)	0.066*** (0.02)
Bachelor's degree	0.161*** (0.04)	0.093*** (0.01)	0.086*** (0.02)	0.138** (0.07)	0.054*** (0.01)	0.081*** (0.02)
Graduate degree or professional degree	0.091* (0.05)	0.086*** (0.01)	0.098*** (0.02)	0.109 (0.08)	0.035** (0.02)	0.097*** (0.02)
Occupation						
Sales or service				−0.067*** (0.03)	0.003 (0.01)	0.011** (0.01)
Clerical or administrative support	0.005 (0.03)	0.003 (0.01)	0.017 (0.01)	−0.052* (0.03)	0.014** (0.01)	0.017*** (0.01)
Manufacturing, construction, maintenance, or farming	−0.025 (0.03)	−0.009 (0.01)	−0.026** (0.01)	−0.068** (0.03)	0.002 (0.01)	−0.005 (0.01)
Professional, managerial, or technical	−0.015 (0.03)	0.006 (0.01)	0.002 (0.01)	−0.098*** (0.03)	0.007 (0.01)	0.019*** (0.01)
Other types of occupation	0.000 (.)	−0.014 (0.03)	−0.003 (0.03)	−0.092 (0.07)	−0.008 (0.02)	0.050** (0.02)
Whether has a medical condition	0.283*** (0.08)	−0.027* (0.01)	−0.054*** (0.01)	−0.111** (0.06)	−0.026** (0.01)	−0.007 (0.01)
Whether has a partner	−0.004 (0.02)	0.023*** (0.01)	0.058*** (0.01)	−0.023 (0.03)	−0.006 (0.01)	0.043*** (0.01)
Whether has a school-age child	−0.058** (0.03)	−0.052*** (0.01)	−0.109*** (0.02)	0.024 (0.03)	−0.016** (0.01)	−0.014 (0.01)
Presence of white people	0.081*** (0.02)	0.026*** (0.01)	−0.006 (0.01)	0.034 (0.03)	0.031*** (0.01)	0.010 (0.01)
Number of vehicle per driver	0.075*** (0.03)	0.065*** (0.01)	0.064*** (0.01)	0.101*** (0.03)	0.039*** (0.01)	0.043*** (0.01)
Number of household members	0.067*** (0.01)	0.061*** (0.00)	0.053*** (0.01)	0.026* (0.01)	0.035*** (0.00)	0.025*** (0.00)
Current residence characteristics						
Distance to work (log)	0.003 (0.01)	0.006** (0.00)	0.001 (0.00)	−0.006 (0.01)	0.000 (0.00)	−0.003 (0.00)
Residential location						
Whether living in a suburban area	0.006 (0.03)	0.015* (0.01)	0.009 (0.01)	0.034 (0.03)	0.024*** (0.01)	0.020*** (0.01)
Whether living in an urbanized area	0.056* (0.03)	0.048*** (0.01)	0.045*** (0.01)	0.084** (0.04)	0.055*** (0.01)	0.049*** (0.01)
Housing units at the block group level (log)	−0.033*** (0.01)	−0.021*** (0.00)	−0.020*** (0.00)	−0.043*** (0.01)	−0.008*** (0.00)	−0.016*** (0.00)
CBSA FIPS code	Yes	Yes	Yes	Yes	Yes	Yes
N	1777	20548	10631	1529	37559	16876

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for residential location dummies is the 'Whether living in a rural area'; 'High school graduate or GED' is the base group for education level.

Table 9. Results from IV estimation for housing type: spatial heterogeneity.

	One-worker household		
	Detached single house & duplex (1) vs. townhouse & apartment (0)		
	Urbanized	Suburban	Rural
Telecommuting status	0.181** (0.09)	0.317 (0.20)	0.487 (0.34)
Covariates	Yes	Yes	Yes
N	20852	6390	5841
	Two-worker household		
	Detached single house & duplex (1) vs. townhouse & apartment (0)		
	Urbanized	Suburban	Rural
Telecommuting status	0.249*** (0.09)	0.559*** (0.16)	1.333*** (0.15)
Covariates	Yes	Yes	Yes
N	33430	12121	10403

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table 10. Results from IV estimation for housing type: tenure heterogeneity.

	Detached single house & duplex (1) vs townhouse & apartment (0)			
	One-worker household		Two-worker household	
	Owner	Renter	Owner	Renter
Telecommuting status	0.112 (0.07)	0.165 (0.30)	0.358*** (0.08)	−0.101 (0.28)
Covariates	Yes	Yes	Yes	Yes
N	28,545	4551	51,989	4188

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Second, telecommuters are more likely to choose single detached or duplex houses, compared to townhouses or apartments, both at the individual and household level of analysis. In general, single-family detached houses are larger in terms of square-footage and the number of rooms. According to 2017 American Housing Survey (AHS), among groups of houses larger than 1000 square footage, (i.e. 1,000–1,499, 1,500–1,999, 2,000–2,499, 2,500–2,999, 3,000–3,999 and 4,000 or more), single detached houses account for more than half of the total. In particular, the percentage of single detached houses exceeds 90% when it comes to houses more than 2000 square footage. Similarly, single detached houses constitute the majority of the houses with more than 2 bedrooms. Therefore, they can easily accommodate a dedicated home office for people to telecommute. The significant growth in telecommuting resulting from the pandemic is thus likely to increase the demand for more spacious housing, including detached and duplex houses, and reduce that for more compact housing such as apartments. Besides, the preference for homeownership and detached/duplex houses might reinforce each other. The heterogeneity analysis based on tenure shows that the impacts of telecommuting are only significant for house owners, which suggests that when telecommuters purchase a house, they are inclined to buy a detached or duplex house. Hence, the positive impacts of telecommuting on homeownership could further increase the demand for this type of houses.

The heterogeneity analysis based on urbanization level reveals that telecommuters living in urbanized and rural areas show preference for detached or duplex houses. Planners and policymakers in suburbs, smaller cities and towns may be able to take advantage of this shifting housing demand to attract new residents and boost their local economies. Meanwhile, they may have to consider how to accommodate this

new demand for low-density housing without generating unsustainable urban sprawl. With the need for regular commutes to work significantly reduced among the population of telecommuters, promoting integration between commercial areas, public facilities, and residential housing, to reduce daily non-commute travel, may become a key part of sustainable planning for neighborhoods that attract a large number of telecommuters. Furthermore, similar to the pattern in homeownership, the heterogeneity analysis finds that the effect of telecommuting on housing type is particularly prominent for middle-aged (30–55) households. This suggests that any new low-density development catering to telecommuters may need to accommodate certain types of lifecycle needs, including facilities for children and family leisure. Nonetheless, telecommuters might stay in more urbanized areas out of preference for high amenities. For policymakers and real-estate developers in big cities and urbanized regions, planning for more detached or duplex houses might be tricky due to compact development, yet they can consider increasing the number of rooms in the apartment to make it possible for telecommuters to accommodate home offices. Given relatively smaller square footage, apartment developers in urban areas can pay more attention to interior space design to cater to the needs of telecommuters for home offices. Understanding these patterns of demand that are likely to result from telecommuting gives planners an opportunity to attract this new population and answer to their needs.

6. Conclusion

The rapid improvement and popularization of a wide variety of information and communication technologies (ICT) has facilitated a growing trend of remote work over the past two decades. With the COVID-19 pandemic and the associated lockdown restrictions, remote work has suddenly become a necessity for a large section of the workforce, leading to unprecedented numbers of people engaging in remote work. A worldwide survey of more than 10 thousand workers from 29 countries shows that 23% of respondents prefer complete or more frequent telecommuting arrangements (IPSOS, 2021). With the practice of telecommuting projected to persist as a mainstream work mode in the post-pandemic era, the landscape of work and commuting will look significantly different than it did before the pandemic. With work and home as two major nodes of urban life, and much city and transportation planning oriented around the daily commute, the sudden shift towards telecommuting has major implications for urban policymakers and planners and opens up many new possibilities for the shape of urban life. Using national data generated before the Covid, the study could rule out the temporary influence of health concern and stay-at-home policies during the pandemic, and provide robust evidence concerning the influence of telecommuting status on people's housing choice.

While there are already a number of studies indicating the effects of telecommuting on residential location choice and commuting behavior, there are few looking at other elements of housing preference, including housing tenure and housing type preferences. Whether the growing population of telecommuters prefer to rent or own, and what types of housing they prefer, have major implications for real estate markets and for urban planning.

Theoretically, by reducing the need for daily commutes, telecommuting makes longer distances between work and home acceptable, opens up a wider span of

residential location choice, and makes it possible to rebalance household budgets in favor of more spacious housing. Furthermore, spending more time in the home may increase the demand for housing conditions of higher quality, both in terms of spaciousness and neighborhood environment. Meanwhile, by reducing the inter-dependency between work and residential location, telecommuting theoretically makes greater stability in residential location possible, and therefore makes homeownership more attractive. Our analysis based on actual travel and residential data from the 2009 and 2017 NHTS confirms that telecommuters are indeed more likely to be homeowners and to live in more spacious housing. We find that the effect is especially strong for middle-aged households. This may suggest that a stronger underlying demand for spacious housing and homeownership already exists within this group, but that the fulfillment of such demands is hindered by the need for proximity to work. By reducing this need, telecommuting makes it possible for middle-aged households to pursue their desires for homeownership and specific housing attributes.

These findings suggest new directions and challenges for policymakers and urban planners in the post-pandemic era. With a massive rise in telecommuting from only around 4.1% of the workforce in 2019, to a projected 25–30% long term in the post-pandemic era (Global Workplace Analytics, 2020, 2021), the demand for homeownership and more spacious housing may increase significantly in the next few years. This will necessitate planning to accommodate the demand for low-density spacious housing, and considerations on the part of policymakers of how to do so without promoting unsustainable sprawl. Whereas large cities and core urban areas have attracted much attention in debates on urban sustainability, the rising trend of telecommuting may increase the importance of sustainable development in small towns and periphery areas, which are likely become new growth regions in the post-pandemic era. Given that telecommuting reduces the frequency of commutes, although not necessarily overall commute VMT, the new trend and the associated housing preferences may also raise new possibilities for different types of sustainable urban design where commute considerations do not play such a dominant role.

Finally, while the study is based on U.S. data, it still has international implications for housing markets in other regions. It's reasonable to expect that telecommuting influences the housing market in a way slightly different from the one in U.S., given inherent differences in the market structures and lifestyles. However, the relationship revealed in the analysis implies an underlying assumption related to the AMM model: as telecommuters are less restricted by the commuting distance, they are more footloose and likely have more options for low-priced spacious housing due to the lessening of restrictions. As telecommuting becomes more popular worldwide, other parts of the world might also expect increases in homeownership and stronger preferences for dwelling types that provide spaces/rooms for telecommuting. The local housing markets will need to pay attention to the changing demand patterns induced by a growing percentage of telecommuters.

For future studies, there are several directions for investigation that could contribute to a better and deeper understanding of this subject. First, as the world recovers from the pandemic, data collected during the post-pandemic time provides good opportunity to revisit the relationship between telecommuting and homeownership and housing preferences under post-pandemic circumstances. Nonetheless, analysis based on post-pandemic data

should pay attention to the potential confounding effects of values and attitudes towards homeownership and housing preference which might undergo significant changes during the pandemic. Second, it's also worth investigating the impacts of telecommuting on regions with housing markets substantially different from the case of North America. For instance, regions featuring compact development, such as Hong Kong, Singapore and other Asian cities, might also experience a shift in homeownership and housing preferences due to telecommuting, yet in a different way. Their unique housing characteristics, housing policies (e.g. supply of public houses) and land scarcity issue might result in a distinctive pattern of relationship between telecommuting and dwelling preferences. Investigating the influences of telecommuting under different circumstances helps to complete the story.

Our study has one limitation pertaining to the instrumental variable approach. As previously discussed, internet coverage might be absent in some rural areas in exceptional circumstances and connection quality also varies spatially. We argue that the spatial variation of the internet connection should not influence homeownership and housing preferences. However, improvement of the model can be achieved by controlling for the internet infrastructure coverage in the regression, so that the potential influence of internet coverage, if it exists, can be ruled out from the estimates.

Notes

1. Previous literature acknowledges the difference between telecommuting and remote working, where the latter includes a broader type of practices, such as working at home after office hours or working while traveling etc. Nonetheless, to avoid overuse of 'telecommuting' and word repetition we use "telecommuting" interchangeably with "working from home" and "remote working".
2. For two-worker households, we partition the household sample based on the age of the oldest worker.
3. For two-worker households, the internet usage dummy variable takes value "1" if both workers report using internet every day.
4. For two-worker households, the online shopping continuous variable takes the average frequency of the two workers.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix A. Results from baseline models

Table A1. Results from baseline models for homeownership.

	Own (1) vs. rent (0)					
	2009			2017		
	Full	One-worker	Two-worker	Full	One-worker	Two-worker
Telecommuting status	−0.004 (0.00)	0.364*** (0.09)	0.547*** (0.08)	0.410*** (0.05)	0.366*** (0.09)	0.410*** (0.04)
Socioeconomic characteristics						
Male	−0.016*** (0.00)	−0.034*** (0.00)		−0.026*** (0.00)	−0.033*** (0.01)	
Age	0.003*** (0.00)	0.004*** (0.00)	0.004*** (0.00)	0.007*** (0.00)	0.008*** (0.00)	0.009*** (0.00)
Household income (log)	0.077*** (0.00)	0.085*** (0.00)	0.074*** (0.00)	0.123*** (0.00)	0.113*** (0.01)	0.100*** (0.00)
Education level						
High school graduate or GED	0.039*** (0.00)	0.058*** (0.01)	0.060*** (0.01)	−0.012 (0.01)	0.042*** (0.02)	−0.032 (0.03)
College degree	0.039*** (0.00)	0.052*** (0.01)	0.063*** (0.01)	−0.022** (0.01)	0.037** (0.02)	−0.034 (0.03)
Bachelor's degree	0.055*** (0.01)	0.069*** (0.01)	0.069*** (0.01)	−0.026*** (0.01)	0.042** (0.02)	−0.023 (0.03)
Graduate degree or professional degree	0.049*** (0.01)	0.059*** (0.01)	0.049*** (0.01)	−0.036*** (0.01)	0.023 (0.02)	−0.021 (0.03)
Occupation						
Sales or service			−0.003 (0.00)			−0.009** (0.00)
Clerical or administrative support	−0.000 (0.00)	0.011 (0.01)	0.008* (0.00)	0.009* (0.01)	0.003 (0.01)	0.011** (0.00)
Manufacturing, construction, maintenance, or farming	−0.002 (0.00)	0.008 (0.01)	0.007* (0.00)	−0.007 (0.00)	−0.017** (0.01)	0.007 (0.00)
Professional, managerial, or technical	−0.003 (0.00)	−0.003 (0.01)	0.004 (0.00)	−0.012*** (0.00)	−0.016** (0.01)	−0.004 (0.00)
Other types of occupation	0.008 (0.01)	0.056** (0.02)	−0.022* (0.01)	−0.055 (0.04)	−0.066 (0.06)	−0.047 (0.04)
Whether has a medical condition	−0.013** (0.01)	−0.018* (0.01)	−0.037*** (0.01)	−0.027*** (0.01)	−0.030** (0.01)	−0.038*** (0.01)
Whether has a partner	0.021*** (0.00)	0.020*** (0.00)	−0.002 (0.00)	0.013*** (0.00)	0.023*** (0.01)	−0.049*** (0.00)
Whether has a school-age child	−0.039*** (0.00)	−0.079*** (0.01)	−0.019*** (0.00)	−0.060*** (0.01)	−0.119*** (0.01)	0.012** (0.01)
Presence of white people	0.032*** (0.00)	0.042*** (0.00)	0.027*** (0.00)	0.046*** (0.00)	0.055*** (0.01)	0.031*** (0.00)
Number of vehicle per driver	0.057*** (0.00)	0.069*** (0.00)	0.072*** (0.00)	0.089*** (0.00)	0.096*** (0.01)	0.086*** (0.00)
Number of household members	0.024*** (0.00)	0.039*** (0.00)	0.022*** (0.00)	0.059*** (0.00)	0.073*** (0.00)	0.029*** (0.00)
Current residence characteristics						
Distance to work (log)	0.011*** (0.00)	0.018*** (0.00)	0.009*** (0.00)	0.006*** (0.00)	0.015*** (0.00)	−0.004* (0.00)
Residential location						
Whether living in a suburban area	0.011** (0.00)	0.008 (0.01)	0.014*** (0.01)	−0.002 (0.01)	0.011 (0.01)	−0.008 (0.01)
Whether living in an urbanized area	0.016*** (0.00)	0.012* (0.01)	0.022*** (0.01)	0.019*** (0.01)	0.024*** (0.01)	0.014** (0.01)
Housing units at the block group level (log)	−0.021*** (0.00)	−0.030*** (0.00)	−0.020*** (0.00)	−0.046*** (0.00)	−0.048*** (0.00)	−0.042*** (0.00)
CBSA FIPS code						
N	84,851	33,585	56,711	82,289	31,395	54,320

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table A2. Results from baseline models for one-worker household homeownership: age heterogeneity.

	One-worker_age subsample					
	Own (1) vs. rent (0)					
	2009			2017		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	0.003 (0.06)	0.429*** (0.10)	0.165 (0.11)	−0.319 (0.28)	0.476*** (0.10)	−0.027 (0.17)
Socioeconomic characteristics						
Male	−0.007 (0.02)	−0.035*** (0.01)	−0.030*** (0.01)	0.038** (0.01)	−0.030*** (0.01)	−0.049*** (0.01)
Age	−0.008*** (0.00)	0.006*** (0.00)	0.002** (0.00)	0.006** (0.00)	0.009*** (0.00)	0.004*** (0.00)
Household income (log)	0.143*** (0.01)	0.090*** (0.00)	0.058*** (0.00)	0.125*** (0.01)	0.115*** (0.01)	0.083*** (0.01)
Education level						
High school graduate or GED	0.125*** (0.04)	0.062*** (0.01)	0.042*** (0.01)	0.010 (0.04)	0.074*** (0.02)	0.042* (0.02)
College degree	0.141*** (0.04)	0.056*** (0.01)	0.032** (0.01)	0.024 (0.04)	0.061*** (0.02)	0.060*** (0.02)
Bachelor's degree	0.183*** (0.04)	0.078*** (0.01)	0.044*** (0.01)	−0.066 (0.05)	0.092*** (0.02)	0.081*** (0.02)
Graduate degree or professional degree	0.182*** (0.05)	0.060*** (0.01)	0.053*** (0.01)	−0.067 (0.05)	0.062** (0.02)	0.070*** (0.02)
Occupation						
Sales or service						
Clerical or administrative support	0.024 (0.03)	0.005 (0.01)	0.018* (0.01)	−0.024 (0.03)	0.001 (0.01)	0.015 (0.01)
Manufacturing, construction, maintenance, or farming	−0.017 (0.03)	0.013 (0.01)	0.010 (0.01)	−0.049** (0.02)	0.000 (0.01)	−0.008 (0.01)
Professional, managerial, or technical	−0.042* (0.02)	0.005 (0.01)	−0.003 (0.01)	−0.038** (0.02)	−0.011 (0.01)	0.008 (0.01)
Other types of occupation	0.145 (0.11)	0.025 (0.03)	0.077*** (0.03)	0.000 (.)	−0.111 (0.09)	0.000 (.)
Whether has a medical condition	0.103 (0.07)	−0.023 (0.01)	−0.016 (0.01)	−0.024 (0.07)	−0.016 (0.02)	−0.035** (0.02)
Whether has a partner	−0.087*** (0.02)	0.008 (0.01)	0.058*** (0.01)	−0.107*** (0.02)	0.027*** (0.01)	0.109*** (0.01)
Whether has a school-age child	−0.140*** (0.03)	−0.056*** (0.01)	−0.064*** (0.02)	−0.224*** (0.02)	−0.081*** (0.01)	−0.073*** (0.02)
Presence of white people	0.089*** (0.02)	0.049*** (0.01)	0.016** (0.01)	0.067*** (0.02)	0.054*** (0.01)	0.053*** (0.01)
Number of vehicle per driver	0.141*** (0.03)	0.067*** (0.01)	0.059*** (0.01)	0.081*** (0.01)	0.095*** (0.01)	0.091*** (0.01)
Number of household members	0.064*** (0.01)	0.039*** (0.00)	0.022*** (0.01)	0.133*** (0.01)	0.058*** (0.00)	0.026*** (0.01)
Current residence characteristics						
Distance to work (log)	0.033*** (0.01)	0.022*** (0.00)	0.009*** (0.00)	0.023*** (0.01)	0.015*** (0.00)	0.014*** (0.00)
Residential location						
Whether living in a suburban area	0.036 (0.03)	0.006 (0.01)	0.005 (0.01)	0.032 (0.03)	0.024* (0.01)	−0.007 (0.01)
Whether living in an urbanized area	0.017 (0.03)	0.003 (0.01)	0.020** (0.01)	0.016 (0.02)	0.041*** (0.01)	0.010 (0.01)
Housing units at the block group level (log)	−0.044*** (0.01)	−0.029*** (0.00)	−0.027*** (0.00)	−0.049*** (0.01)	−0.052*** (0.00)	−0.035*** (0.00)
CBSA FIPS code						
N	2051	20,563	10,607	3502	17,460	10,048

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table A3. Results from baseline models for two-worker household homeownership: age heterogeneity.

	Two-worker_age subsample					
	Own (1) vs. rent (0)					
	2009			2017		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.003 (0.04)	0.676*** (0.08)	0.011 (0.07)	0.558*** (0.14)	0.401*** (0.05)	0.122* (0.07)
Socioeconomic characteristics						
Male						
Age	0.005 (0.00)	0.004*** (0.00)	−0.000 (0.00)	0.027*** (0.00)	0.009*** (0.00)	0.003*** (0.00)
Household income (log)	0.149*** (0.02)	0.082*** (0.00)	0.038*** (0.00)	0.140*** (0.02)	0.107*** (0.00)	0.060*** (0.00)
Education level						
High school graduate or GED	0.221*** (0.08)	0.042*** (0.01)	0.048*** (0.01)	−0.235** (0.09)	−0.011 (0.04)	−0.099** (0.04)
College degree	0.192** (0.08)	0.043*** (0.01)	0.057*** (0.01)	−0.230** (0.09)	−0.009 (0.04)	−0.104** (0.04)
Bachelor's degree	0.227*** (0.08)	0.049*** (0.01)	0.062*** (0.01)	−0.252*** (0.09)	0.008 (0.04)	−0.090** (0.04)
Graduate degree or professional degree	0.214** (0.09)	0.027* (0.01)	0.057*** (0.01)	−0.323*** (0.09)	0.015 (0.04)	−0.092** (0.04)
Occupation						
Sales or service	−0.060** (0.02)	−0.003 (0.01)	−0.001 (0.00)	0.025 (0.02)	−0.012** (0.01)	−0.022*** (0.01)
Clerical or administrative support	−0.059** (0.03)	−0.002 (0.01)	0.013*** (0.00)	0.010 (0.02)	0.004 (0.01)	0.009 (0.01)
Manufacturing, construction, maintenance, or farming	−0.106*** (0.03)	0.010* (0.01)	−0.001 (0.00)	0.043*** (0.02)	−0.002 (0.01)	−0.002 (0.01)
Professional, managerial, or technical	−0.091*** (0.03)	0.005 (0.01)	0.001 (0.00)	−0.002 (0.02)	−0.005 (0.01)	−0.010 (0.01)
Other types of occupation	−0.075 (0.06)	−0.037** (0.02)	0.003 (0.01)	0.000 (.)	−0.015 (0.04)	−0.113 (0.07)
Whether has a medical condition	−0.081 (0.06)	−0.038*** (0.01)	−0.017*** (0.01)	0.001 (0.05)	−0.045*** (0.01)	−0.028*** (0.01)
Whether has a partner	0.065*** (0.03)	−0.005 (0.01)	0.038*** (0.00)	−0.031* (0.02)	−0.039*** (0.01)	−0.022** (0.01)
Whether has a school-age child	−0.074*** (0.03)	−0.018*** (0.01)	−0.026*** (0.01)	−0.029 (0.02)	0.017*** (0.01)	−0.063*** (0.01)
Presence of white people	0.032 (0.03)	0.036*** (0.01)	0.005 (0.00)	0.017 (0.02)	0.038*** (0.01)	0.026*** (0.01)
Number of vehicle per driver	0.205*** (0.03)	0.071*** (0.01)	0.051*** (0.01)	0.105*** (0.03)	0.092*** (0.01)	0.056*** (0.01)
Number of household members	0.102*** (0.02)	0.018*** (0.00)	0.015*** (0.00)	0.080*** (0.02)	0.025*** (0.00)	0.031*** (0.00)
Current residence characteristics						
Distance to work (log)	0.037*** (0.01)	0.008*** (0.00)	0.005*** (0.00)	0.016** (0.01)	−0.003 (0.00)	−0.006* (0.00)
Residential location						
Whether living in a suburban area	0.012 (0.03)	0.012* (0.01)	0.008 (0.01)	0.008 (0.02)	−0.010 (0.01)	−0.010 (0.01)
Whether living in an urbanized area	−0.055* (0.03)	0.022*** (0.01)	0.013** (0.01)	−0.008 (0.02)	0.020*** (0.01)	0.003 (0.01)
Housing units at the block group level (log)	−0.019** (0.01)	−0.021*** (0.00)	−0.012*** (0.00)	−0.057*** (0.01)	−0.042*** (0.00)	−0.030*** (0.00)
CBSA FIPS code						
N	1692	37,596	16,799	4242	35,290	14,384

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table A4. Results from baseline models for housing type.

	2009		
	Detached single house & duplex (1) vs. townhouse & apartment (0)		
	Full	One-worker	Two-worker
Telecommuting status	0.010* (0.01)	0.281*** (0.09)	0.583*** (0.08)
Socioeconomic characteristics			
Male	−0.003 (0.00)	−0.013*** (0.00)	
Age	0.002*** (0.00)	0.002*** (0.00)	0.003*** (0.00)
Household Income (log)	0.074*** (0.00)	0.082*** (0.00)	0.064*** (0.00)
Education level			
High school graduate or GED	0.041*** (0.01)	0.055*** (0.01)	0.042*** (0.01)
College degree	0.064*** (0.01)	0.088*** (0.01)	0.068*** (0.01)
Bachelor's degree	0.075*** (0.01)	0.093*** (0.01)	0.075*** (0.01)
Graduate degree or professional degree	0.075*** (0.01)	0.090*** (0.01)	0.064*** (0.01)
Occupation			
Sales or service			0.004 (0.00)
Clerical or administrative support	0.004 (0.00)	0.009 (0.01)	0.020*** (0.00)
Manufacturing, construction, maintenance, or farming	−0.017*** (0.00)	−0.016** (0.01)	0.002 (0.00)
Professional, managerial, or technical	−0.002 (0.00)	0.001 (0.01)	0.010** (0.00)
Other types of occupation	−0.005 (0.01)	−0.007 (0.02)	0.007 (0.01)
Whether has a medical condition	−0.020*** (0.01)	−0.035*** (0.01)	−0.024*** (0.01)
Whether has a partner	0.029*** (0.00)	0.033*** (0.00)	0.001 (0.00)
Whether has a school-age child	−0.033*** (0.00)	−0.068*** (0.01)	−0.013** (0.01)
Presence of white people	0.023*** (0.00)	0.022*** (0.01)	0.025*** (0.00)
Number of vehicle per driver	0.047*** (0.00)	0.066*** (0.01)	0.043*** (0.00)
Number of household members	0.041*** (0.00)	0.061*** (0.00)	0.035*** (0.00)
Current residence characteristics			
Distance to work (log)	0.001 (0.00)	0.004** (0.00)	−0.001 (0.00)
Residential location			
Whether living in a suburban area	0.018*** (0.00)	0.014** (0.01)	0.029*** (0.00)
Whether living in an urbanized area	0.050*** (0.00)	0.048*** (0.01)	0.062*** (0.01)
Housing units at the block group level (log)	−0.016*** (0.00)	−0.022*** (0.00)	−0.014*** (0.00)
CBSA FIPS code			
N	84,851	33,585	56,728

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table A5. Results from baseline models for housing type: age heterogeneity.

	Age subsample					
	Detached single house & duplex (1) vs. townhouse & apartment (0)					
	One-worker household			Two-worker household		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.022 (0.06)	0.383*** (0.10)	0.003 (0.13)	0.119 (0.20)	0.806*** (0.08)	−0.119 (0.09)
Socioeconomic characteristics						
Male	0.014 (0.02)	−0.017*** (0.01)	−0.004 (0.01)			
Age	−0.004 (0.00)	0.003*** (0.00)	0.002 (0.00)	0.002 (0.00)	0.004*** (0.00)	−0.000 (0.00)
Household income (log)	0.117*** (0.01)	0.084*** (0.00)	0.069*** (0.01)	0.067*** (0.02)	0.068*** (0.00)	0.048*** (0.01)
Education level						
High school graduate or GED	0.071* (0.04)	0.052*** (0.01)	0.055*** (0.02)	0.021 (0.06)	0.030** (0.01)	0.042*** (0.02)
College degree	0.142*** (0.04)	0.090*** (0.01)	0.075*** (0.02)	0.120* (0.06)	0.053*** (0.01)	0.066*** (0.02)
Bachelor's degree	0.150*** (0.04)	0.093*** (0.01)	0.086*** (0.02)	0.138** (0.07)	0.054*** (0.01)	0.081*** (0.02)
Graduate degree or professional degree	0.095* (0.05)	0.086*** (0.01)	0.098*** (0.02)	0.109 (0.08)	0.035** (0.02)	0.097*** (0.02)
Occupation						
Sales or service				−0.067*** (0.03)	0.003 (0.01)	0.011** (0.01)
Clerical or administrative support	0.002 (0.03)	0.003 (0.01)	0.017 (0.01)	−0.052* (0.03)	0.014** (0.01)	0.017*** (0.01)
Manufacturing, construction, maintenance, or farming	−0.036 (0.03)	−0.009 (0.01)	−0.026** (0.01)	−0.068** (0.03)	0.002 (0.01)	−0.005 (0.01)
Professional, managerial, or technical	−0.048* (0.03)	0.006 (0.01)	0.002 (0.01)	−0.098*** (0.03)	0.007 (0.01)	0.019*** (0.01)
Other types of occupation	−0.015 (0.09)	−0.014 (0.03)	−0.003 (0.03)	−0.092 (0.07)	−0.008 (0.02)	0.050** (0.02)
Whether has a medical condition	0.227*** (0.07)	−0.027* (0.01)	−0.054*** (0.01)	−0.111** (0.06)	−0.026** (0.01)	−0.007 (0.01)
Whether has a partner	−0.005 (0.02)	0.023*** (0.01)	0.058*** (0.01)	−0.023 (0.03)	−0.006 (0.01)	0.043*** (0.01)
Whether has a school-age child	−0.066** (0.03)	−0.052*** (0.01)	−0.109*** (0.02)	0.024 (0.03)	−0.016** (0.01)	−0.014 (0.01)
Presence of white people	0.077*** (0.02)	0.026*** (0.01)	−0.006 (0.01)	0.034 (0.03)	0.031*** (0.01)	0.010 (0.01)
Number of vehicle per driver	0.087*** (0.02)	0.065*** (0.01)	0.064*** (0.01)	0.101*** (0.03)	0.039*** (0.01)	0.043*** (0.01)
Number of household members	0.069*** (0.01)	0.061*** (0.00)	0.053*** (0.01)	0.026* (0.01)	0.035*** (0.00)	0.025*** (0.00)
Current residence characteristics						
Distance to work (log)	0.005 (0.01)	0.006** (0.00)	0.001 (0.00)	−0.006 (0.01)	0.000 (0.00)	−0.003 (0.00)
Residential location						
Whether living in a suburban area	0.014 (0.03)	0.015* (0.01)	0.009 (0.01)	0.034 (0.03)	0.024*** (0.01)	0.020*** (0.01)
Whether living in an urbanized area	0.068** (0.03)	0.048*** (0.01)	0.045*** (0.01)	0.084** (0.04)	0.055*** (0.01)	0.049*** (0.01)
Housing units at the block group level (log)	−0.037*** (0.01)	−0.021*** (0.00)	−0.020*** (0.00)	−0.043*** (0.01)	−0.008*** (0.00)	−0.016*** (0.00)
CBSA FIPS code						
N	2058	20,548	10,631	1529	37,559	16,876

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Appendix B

Table B1. First stage results of the IV estimation.

	Individual level descriptive statistics					
	2009			2017		
	Full	One-worker	Two-worker	Full	One-worker	Two-worker
Internet/online shopping	0.029*** (0.00)	0.027*** (0.00)	0.028*** (0.00)	0.022*** (0.00)	0.019*** (0.00)	0.037*** (0.00)
Socioeconomic characteristics						
Male	0.007*** (0.00)	0.011*** (0.00)		0.023*** (0.00)	0.013*** (0.00)	
Age	0.000*** (0.00)	0.000*** (0.00)	0.000 (0.00)	0.001*** (0.00)	0.000* (0.00)	0.001*** (0.00)
Household Income (log)	0.013*** (0.00)	0.016*** (0.00)	0.021*** (0.00)	0.018*** (0.00)	0.018*** (0.00)	0.034*** (0.00)
Education level						
High school graduate or GED	−0.009** (0.00)	−0.011* (0.01)	−0.013 (0.01)	−0.001 (0.01)	−0.014 (0.01)	−0.020 (0.03)
College degree	−0.004 (0.00)	−0.007 (0.01)	−0.010 (0.01)	0.004 (0.01)	−0.007 (0.01)	−0.024 (0.03)
Bachelor's degree	0.018*** (0.00)	0.017*** (0.01)	0.012 (0.01)	0.036*** (0.01)	0.024** (0.01)	0.012 (0.03)
Graduate degree or professional degree	0.030*** (0.00)	0.026*** (0.01)	0.040*** (0.01)	0.045*** (0.01)	0.042*** (0.01)	0.019 (0.03)
Occupation						
Sales or service			−0.003 (0.00)			0.004 (0.00)
Clerical or administrative support	−0.030*** (0.00)	−0.034*** (0.00)	−0.025*** (0.00)	−0.037*** (0.00)	−0.036*** (0.01)	−0.025*** (0.00)
Manufacturing, construction, maintenance, or farming	−0.023*** (0.00)	−0.027*** (0.00)	−0.026*** (0.00)	−0.026*** (0.00)	−0.023*** (0.01)	−0.021*** (0.00)
Professional, managerial, or technical	−0.012*** (0.00)	−0.015*** (0.00)	−0.008** (0.00)	−0.004 (0.00)	0.000 (0.00)	0.003 (0.00)
Other types of occupation	−0.011 (0.01)	0.007 (0.01)	−0.015 (0.01)	−0.006 (0.03)	−0.021 (0.04)	0.021 (0.03)
Whether has a medical condition	0.027*** (0.00)	0.027*** (0.01)	0.021*** (0.01)	0.010 (0.01)	0.010 (0.01)	0.014 (0.01)
Whether has a partner	−0.001 (0.00)	−0.004* (0.00)	0.015*** (0.00)	0.001 (0.00)	0.003 (0.00)	0.022*** (0.00)
Whether has a school-age child	0.015*** (0.00)	0.014*** (0.00)	0.015*** (0.00)	0.023*** (0.00)	0.018*** (0.01)	0.022*** (0.00)
Presence of white people	0.002 (0.00)	0.002 (0.00)	0.004 (0.00)	0.008*** (0.00)	0.008** (0.00)	0.017*** (0.00)
Number of vehicle per driver	0.000 (0.00)	0.001 (0.00)	−0.004 (0.00)	−0.000 (0.00)	−0.000 (0.00)	0.003 (0.00)
Number of household members	−0.003*** (0.00)	−0.003* (0.00)	−0.002 (0.00)	−0.004*** (0.00)	−0.003 (0.00)	−0.002 (0.00)
Current residence characteristics						
Distance to work (log)	−0.003*** (0.00)	−0.002** (0.00)	0.006*** (0.00)	0.008*** (0.00)	0.007*** (0.00)	0.019*** (0.00)
Residential location						
Whether living in an urbanized area	0.000 (0.00)	0.000 (0.00)	−0.002 (0.00)	−0.004 (0.00)		−0.004 (0.01)
Whether living in an urban cluster	0.001 (0.00)	−0.002 (0.00)	0.004 (0.00)	0.001 (0.00)	−0.004 (0.01)	−0.017*** (0.01)
Housing units at the block group level (log)	−0.002*** (0.00)	−0.001 (0.00)	−0.003** (0.00)	0.002*** (0.00)	0.005 (0.01)	0.008*** (0.00)
Intercept	−0.130*** (0.02)	−0.159*** (0.02)	−0.211*** (0.03)	−0.241*** (0.02)	0.001 (0.00)	−0.465*** (0.04)
CBSA FIPS code					−0.194*** (0.03)	
N	84851	33631	56892	82289		54320
Adj. *R*-squared	0.027	0.030	0.033	0.038	31468	0.047
F statistics	524.253	186.167	152.214	331.424	0.041	318.236
Wald test of exogeneity: (Prob > chi^2 =)						
Ownership	0	0	0	0	0	0
Housing type 1	0	0	0			
Housing type 2	0	0	0			

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Appendix C. Robustness check for housing type models

Table C1. Results from IV estimation for housing type (with 'single-family detached house as 1, others as 0').

	2009		
	Detached single house (1) vs. duplex, townhouse or apartment (0)		
	Full	One-worker	Two-worker
Telecommuting status	0.012* (0.01)	0.281*** (0.09)	0.583*** (0.08)
Socioeconomic characteristics			
Male	0.000 (0.00)	−0.013*** (0.00)	
Age	0.003*** (0.00)	0.002*** (0.00)	0.003*** (0.00)
Household income (log)	0.086*** (0.00)	0.082*** (0.00)	0.064*** (0.00)
Education level			
High school graduate or GED	0.055*** (0.01)	0.055*** (0.01)	0.042*** (0.01)
College degree	0.078*** (0.01)	0.088*** (0.01)	0.068*** (0.01)
Bachelor's degree	0.089*** (0.01)	0.093*** (0.01)	0.075*** (0.01)
Graduate degree or professional degree	0.092*** (0.01)	0.090*** (0.01)	0.064*** (0.01)
Occupation			
Sales or service			0.004 (0.00)
Clerical or administrative support	0.001 (0.00)	0.009 (0.01)	0.020*** (0.00)
Manufacturing, construction, maintenance, or farming	−0.016*** (0.00)	−0.016** (0.01)	0.002 (0.00)
Professional, managerial, or technical	−0.002 (0.00)	0.001 (0.01)	0.010** (0.00)
Other types of occupation	−0.011 (0.01)	−0.007 (0.02)	0.007 (0.01)
Whether has a medical condition	−0.025*** (0.01)	−0.035*** (0.01)	−0.024*** (0.01)
Whether has a partner	0.031*** (0.00)	0.033*** (0.00)	0.001 (0.00)
Whether has a school-age child	−0.045*** (0.00)	−0.068*** (0.01)	−0.013** (0.01)
Presence of white people	0.038*** (0.00)	0.022*** (0.01)	0.025*** (0.00)
Number of vehicle per driver	0.062*** (0.00)	0.066*** (0.01)	0.043*** (0.00)
Number of household members	0.049*** (0.00)	0.061*** (0.00)	0.035*** (0.00)
Current residence characteristics			
Distance to work (log)	0.001 (0.00)	0.004** (0.00)	−0.001 (0.00)
Residential location			
Whether living in a suburban area	0.011** (0.01)	0.014** (0.01)	0.029*** (0.00)
Whether living in an urbanized area	0.042*** (0.00)	0.048*** (0.01)	0.062*** (0.01)
Housing units at the block group level (log)	−0.026*** (0.00)	−0.022*** (0.00)	−0.014*** (0.00)
CBSA FIPS code			
N	84,851	33,585	56,728

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table C2. Results from IV estimation for housing type: age heterogeneity (with 'single-family detached house as 1, others as 0).

	Age subsample_3-step					
	Detached single house (1) vs duplex, townhouse or apartment (0)					
	One-worker household			Two-worker household		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	0.000 (0.06)	0.383*** (0.10)	0.003 (0.13)	0.119 (0.20)	0.806*** (0.08)	−0.119 (0.09)
Socioeconomic characteristics						
Male	0.009 (0.02)	−0.017*** (0.01)	−0.004 (0.01)			
Age	−0.005 (0.00)	0.003*** (0.00)	0.002 (0.00)	0.002 (0.00)	0.004*** (0.00)	−0.000 (0.00)
Household income (log)	0.123*** (0.01)	0.084*** (0.00)	0.069*** (0.01)	0.067*** (0.02)	0.068*** (0.00)	0.048*** (0.01)
Education level						
High school graduate or GED	0.097** (0.04)	0.052*** (0.01)	0.055*** (0.02)	0.021 (0.06)	0.030** (0.01)	0.042*** (0.02)
College degree	0.148*** (0.04)	0.090*** (0.01)	0.075*** (0.02)	0.120* (0.06)	0.053*** (0.01)	0.066*** (0.02)
Bachelor's degree	0.167*** (0.05)	0.093*** (0.01)	0.086*** (0.02)	0.138** (0.07)	0.054*** (0.01)	0.081*** (0.02)
Graduate degree or professional degree	0.115** (0.05)	0.086*** (0.01)	0.098*** (0.02)	0.109 (0.08)	0.035** (0.02)	0.097*** (0.02)
Occupation						
Sales or service				−0.067*** (0.03)	0.003 (0.01)	0.011** (0.01)
Clerical or administrative support	−0.022 (0.03)	0.003 (0.01)	0.017 (0.01)	−0.052* (0.03)	0.014** (0.01)	0.017*** (0.01)
Manufacturing, construction, maintenance, or farming	−0.010 (0.03)	−0.009 (0.01)	−0.026** (0.01)	−0.068** (0.03)	0.002 (0.01)	−0.005 (0.01)
Professional, managerial, or technical	−0.045* (0.03)	0.006 (0.01)	0.002 (0.01)	−0.098*** (0.03)	0.007 (0.01)	0.019*** (0.01)
Other types of occupation	0.035 (0.10)	−0.014 (0.03)	−0.003 (0.03)	−0.092 (0.07)	−0.008 (0.02)	0.050** (0.02)
Whether has a medical condition	0.189*** (0.07)	−0.027* (0.01)	−0.054*** (0.01)	−0.111** (0.06)	−0.026** (0.01)	−0.007 (0.01)
Whether has a partner	−0.025 (0.03)	0.023*** (0.01)	0.058*** (0.01)	−0.023 (0.03)	−0.006 (0.01)	0.043*** (0.01)
Whether has a school-age child	−0.099*** (0.03)	−0.052*** (0.01)	−0.109*** (0.02)	0.024 (0.03)	−0.016** (0.01)	−0.014 (0.01)
Presence of white people	0.072*** (0.02)	0.026*** (0.01)	−0.006 (0.01)	0.034 (0.03)	0.031*** (0.01)	0.010 (0.01)
Number of vehicle per driver	0.095*** (0.02)	0.065*** (0.01)	0.064*** (0.01)	0.101*** (0.03)	0.039*** (0.01)	0.043*** (0.01)
Number of household members	0.077*** (0.01)	0.061*** (0.00)	0.053*** (0.01)	0.026* (0.01)	0.035*** (0.00)	0.025*** (0.00)
Current residence characteristics						
Distance to work (log)	0.014 (0.01)	0.006** (0.00)	0.001 (0.00)	−0.006 (0.01)	0.000 (0.00)	−0.003 (0.00)
Residential location						
Whether living in a suburban area	0.023 (0.03)	0.015* (0.01)	0.009 (0.01)	0.034 (0.03)	0.024*** (0.01)	0.020*** (0.01)
Whether living in an urbanized area	0.046 (0.03)	0.048*** (0.01)	0.045*** (0.01)	0.084** (0.04)	0.055*** (0.01)	0.049*** (0.01)
Housing units at the block group level (log)	−0.042*** (0.01)	−0.021*** (0.00)	−0.020*** (0.00)	−0.043*** (0.01)	−0.008*** (0.00)	−0.016*** (0.00)
CBSA FIPS code						
N	2057	20,548	10,631	1529	37,559	16,876

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.
The base group for education dummies is the 'Less than a high school graduate'. The base group for residential location dummies is the 'Whether living in an suburban area'.

Table C3. Results from IV estimation for housing type: spatial heterogeneity (with 'single-family detached house as 1, others as 0).

	One-worker household		
	Detached single house (1) vs. duplex, townhouse or apartment (0)		
	Urbanized	Suburban	Rural
Telecommuting status	0.269*** (0.10)	0.032 (0.21)	0.271 (0.32)
Covariates	Yes	Yes	Yes
N	20,852	6425	5841
	Two-worker household		
	Detached single house (1) vs. duplex, townhouse or apartment (0)		
	Urbanized	Suburban	Rural
Telecommuting status	0.475*** (0.10)	0.339*** (0.13)	1.250*** (0.17)
Covariates	Yes	Yes	Yes
N	33,509	12,361	10,403

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table C4. Results from IV estimation for housing type: tenure heterogeneity (with "single-family detached house as 1, others as 0).

	Detached single house (1) vs duplex, townhouse or apartment (0)			
	One-worker household		Two-worker household	
	Owner	Renter	Owner	Renter
Telecommuting status	0.177** (0.09)	0.165 (0.30)	0.358*** (0.08)	−0.101 (0.28)
Covariates	Yes	Yes	Yes	Yes
N	28570	4551	51989	4188

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table C5. Results from baseline models for housing type: age heterogeneity (with 'single-family detached house as 1, others as 0).

	Age subsample_3-step					
	Detached single house (1) vs. duplex, townhouse or apartment (0)					
	One-worker household			Two-worker household		
	16–29	30–55	≥56	16–29	30–55	≥56
Telecommuting status	−0.002 (0.06)	0.021 (0.01)	0.030 (0.02)	−0.005 (0.04)	0.007 (0.01)	0.010 (0.01)
Socioeconomic characteristics						
Male	0.025 (0.02)	−0.000 (0.01)	0.006 (0.01)			
Age	−0.009*** (0.00)	0.004*** (0.00)	0.003** (0.00)	0.001 (0.01)	0.004*** (0.00)	−0.002*** (0.00)
Household income (log)	0.125*** (0.01)	0.098*** (0.00)	0.078*** (0.01)	0.075*** (0.02)	0.081*** (0.00)	0.050*** (0.00)
Education level						
High school graduate or GED	0.085** (0.04)	0.050*** (0.01)	0.046*** (0.02)	0.080 (0.07)	0.036*** (0.01)	0.078*** (0.02)
Some college or associates degree	0.118*** (0.04)	0.081*** (0.01)	0.061*** (0.02)	0.128* (0.07)	0.058*** (0.01)	0.111*** (0.02)
Bachelor's degree	0.138*** (0.04)	0.088*** (0.01)	0.064*** (0.02)	0.172** (0.08)	0.084*** (0.01)	0.114*** (0.02)
Graduate degree or professional degree	0.065 (0.05)	0.086*** (0.01)	0.072*** (0.02)	0.143* (0.08)	0.090*** (0.01)	0.127*** (0.02)
Occupation						
Sales or service				−0.121*** (0.03)	−0.003 (0.00)	0.009 (0.01)
Clerical or administrative support	−0.016 (0.03)	−0.008 (0.01)	0.009 (0.01)	−0.122*** (0.03)	−0.004 (0.00)	0.015** (0.01)
Manufacturing, construction, maintenance, or farming	−0.017 (0.03)	−0.018** (0.01)	−0.019 (0.01)	−0.119*** (0.03)	−0.007 (0.00)	0.005 (0.01)
Professional, managerial, or technical	−0.067** (0.03)	−0.001 (0.01)	0.004 (0.01)	−0.149*** (0.03)	−0.009* (0.01)	0.026*** (0.01)
Other types of occupation	0.013 (0.10)	−0.000 (0.03)	0.007 (0.04)	−0.086 (0.08)	−0.030** (0.01)	0.023 (0.02)
Whether has a medical condition	0.175** (0.07)	−0.014 (0.02)	−0.060*** (0.02)	−0.179*** (0.06)	−0.015* (0.01)	−0.019** (0.01)
Whether has a partner	−0.029 (0.03)	0.058*** (0.01)	0.115*** (0.01)	−0.072** (0.03)	−0.019*** (0.00)	0.042*** (0.01)
Whether has a school-age child	0.033 (0.02)	0.066*** (0.01)	−0.008 (0.02)	0.060** (0.02)	0.045*** (0.00)	0.017** (0.01)
Presence of white people	0.053** (0.02)	0.036*** (0.01)	−0.004 (0.01)	0.076** (0.03)	0.046*** (0.00)	0.013 (0.01)
Number of vehicle per driver	0.094*** (0.02)	0.064*** (0.01)	0.066*** (0.01)	0.091*** (0.03)	0.036*** (0.01)	0.052*** (0.01)
Current residence characteristics						
Distance to work (log)	0.012* (0.01)	0.007*** (0.00)	−0.001 (0.00)	0.006 (0.01)	0.005*** (0.00)	−0.003 (0.00)
Residential location						
Whether living in an urbanized area	0.018 (0.03)	0.025*** (0.01)	0.029** (0.01)	−0.033 (0.03)	0.015*** (0.01)	0.026*** (0.01)
Whether living in a rural area	−0.030 (0.03)	0.001 (0.01)	0.004 (0.01)	−0.023 (0.04)	−0.010* (0.01)	−0.006 (0.01)
Residential density at the block group level (log)	0.037** (0.02)	0.044*** (0.01)	0.047*** (0.01)	0.050** (0.02)	0.036*** (0.00)	0.028*** (0.00)
Housing units at the block group level (log)	−0.081*** (0.02)	−0.073*** (0.01)	−0.077*** (0.01)	−0.094*** (0.02)	−0.054*** (0.00)	−0.053*** (0.01)
CBSA fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2163	21,106	11,066	1639	36,468	16,705

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

The base group for education dummies is the 'less than a high school graduate'. The base group for occupation dummies in the individual and one-worker model is the 'sales or service'. The base group for residential location dummies is the 'whether living in an suburban area'.

Table C6. Results from IV estimation for housing type: spatial heterogeneity (with 'single-family detached house as 1, others as 0).

	One-worker household		
	Detached single house (1) vs. duplex, townhouse or apartment (0)		
	Urbanized	Urbanized cluster	Rural
Telecommuting status	0.369*** (0.11)	0.898** (0.41)	0.066 (0.18)
Covariates	Yes	Yes	Yes
N	20,852	2800	9384
	Two-worker household		
	Detached single house (1) vs. duplex, townhouse or apartment (0)		
	Urbanized	Urbanized cluster	Rural
Telecommuting status	0.496*** (0.10)	0.654*** (0.25)	0.755*** (0.15)
Covariates	Yes	Yes	Yes
N	33,509	4498	18,041

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table C7. Results from IV estimation for housing type: tenure heterogeneity (with 'single-family detached house as 1, others as 0).

	Detached single house (1) vs. duplex, townhouse or apartment (0)			
	One-worker household		Two-worker household	
	Owner	Renter	Owner	Renter
Telecommuting status	0.211** (0.09)	0.242 (0.28)	0.333*** (0.08)	0.028 (0.26)
Covariates	Yes	Yes	Yes	Yes
N	28,570	4551	52,267	4180

Note: Standard error in parenthesis. *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.