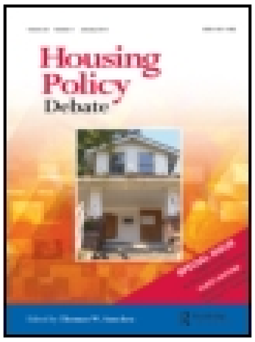

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ABSTRACT

As on-demand short-term rentals (STRs) grow popular with the rise of sharing platforms like Airbnb, regulations for the STR market have become the center of a debate among policymakers, housing interest groups, the hotel and lodging industry, and STR platforms. Washington, DC, the nation's capital and one of the most popular tourist destinations in the United States, is on the front lines of legalizing and regulating the STR business. With the heated policy debate over whether STRs disrupt the rental housing market in DC, a concrete discussion about what STRs impose on the owner housing market is left out. Using web-scraped data from Airbnb and property-level data from the city, I investigated the net impact of STRs on single-family property prices through a series of hedonic analyses. The results suggest that having Airbnb establishments in the neighborhood can significantly inflate property prices. Because of the uneven spatial market penetration of STRs, such price impact could inequitably affect low-income homebuyers and add another hurdle to resolving the housing affordability issue faced by policymakers in Washington, DC.

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1. From Niche to Mainstream: The Global and Local Rise of STRs

Charles Dickens would probably reckon, had he lived in the 21st century, that "It is the best of times; it is the worst of times—for sharing": We ride with strangers in an Uber; we sit in a cubicle next to an entrepreneur at WeWork; we dare to stay with other travelers in an Airbnb rental. The ideology behind sharing is collaborative consumption—a concept built upon a set of principles such as a critical mass of idling capacities, belief in the commons, and trust in strangers (Sundararajan, 2016). The sharing economy is painted by some as a utopian solution for the underutilized resources in our society and by others as a dystopian road to digital elitism (Kenny & Zysman, 2016).

The global success of on-demand short-term rental (STR) platforms like Airbnb highlights the phenomenal sharing economy. Thanks to advancements in information and communication technologies (ICTs) and the advent of an integrated (matching, booking, payment, etc.) peer-to-peer marketplace, the searching cost for STRs has notably decreased for both the demand and the supply side (Einav, Farronato, & Levin, 2016). Contrary to a centralized economy, where transactional cost is lowered through economies of scale, the sharing economy creates a decentralized market that facilitates heterogeneous product choices (Einav et al., 2016). In addition, crowd-based networks and access without ownership remove the hurdle for ordinary people to participate in the sharing economy, blurring the boundary between a personal property and a professional establishment (Sundararajan, 2016).

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In the global context, the soaring sharing economy translates into a rapid STR market expansion: Since its first booking in 2008, Airbnb has accumulated more than 5 million listings in 191 countries around the world and accommodated more than 300 million guests in the past decade (Airbnb, 2018). In the local context—the study area of this article—Airbnb entered Washington, DC, in 2009, and other platforms such as HomeAway and Vrbo followed suit. A typical STR host accommodates guests 32 days of a calendar year and makes an average income of $3,400, according to a survey conducted by Airbnb in 2016 (Airbnb, 2016). As of August 2017, the number of Airbnb listings in Washington, DC, exceeded 8,000, based on web-scraped Airbnb data.[1] The number of listings peaked around the inauguration of the Trump administration and the following Women's March in the middle of January 2017, when hundreds of thousands of visitors gathered in the nation's capital to witness these historical moments (*New York Times*, 2017). When filtered by whether a listing has any reviews, an indicator of STR business activities (Barron, Kung, & Proserpio, 2017), active Airbnb listings grew steadily in number. Figure 1 shows time trends for the total number of listings accessible through Airbnb.com, and the number of listings with at least one review from August 2015 to July 2017. According to an Airbnb report (2017), 88% of the hosts in Washington, DC, share space in their permanent home. In 2016, a total of 7,100 entire-home listings hosted at least one stay. In another report (Airbnb, 2016), the platform claimed that 76% of its hosts rent out their primary dwelling for STR activities. Cross-referencing different data sources, I come up with the following first impressions of STRs in DC: (a) Washington, DC, is an emerging STR market, owing to its unique status as the nation's capital and its numerous tourist attractions; (b) the majority of Airbnb's thousands of listings were registered under a primary residential dwelling, although Airbnb (or other STR platforms) never revealed the number of additional listings registered by a single host or whether all hosts complied with local zoning codes, which may strictly prohibit STRs at certain locations; and (c) there is a sizable commercial STR market, in which the primary function of a property is STR business instead of long-term rental or residency.

Spatially, STR listings tend to cluster at tourist hot spots and mixed-use residential areas. I plotted two kernel density maps of Airbnb listings at two points in time (February 2015 and February 2017) based on web-scraped, geocoded Airbnb listing data[2] (see Figure 2(a,b)). In addition to clusters in

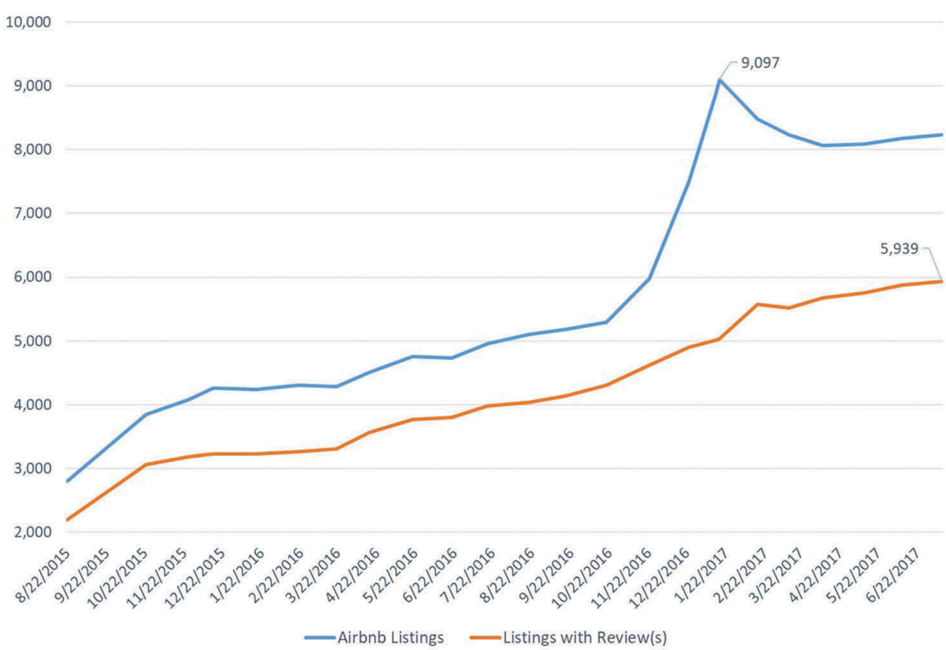

Figure 1. Number of Airbnb listings in Washington, DC, January 2015–July 2017.

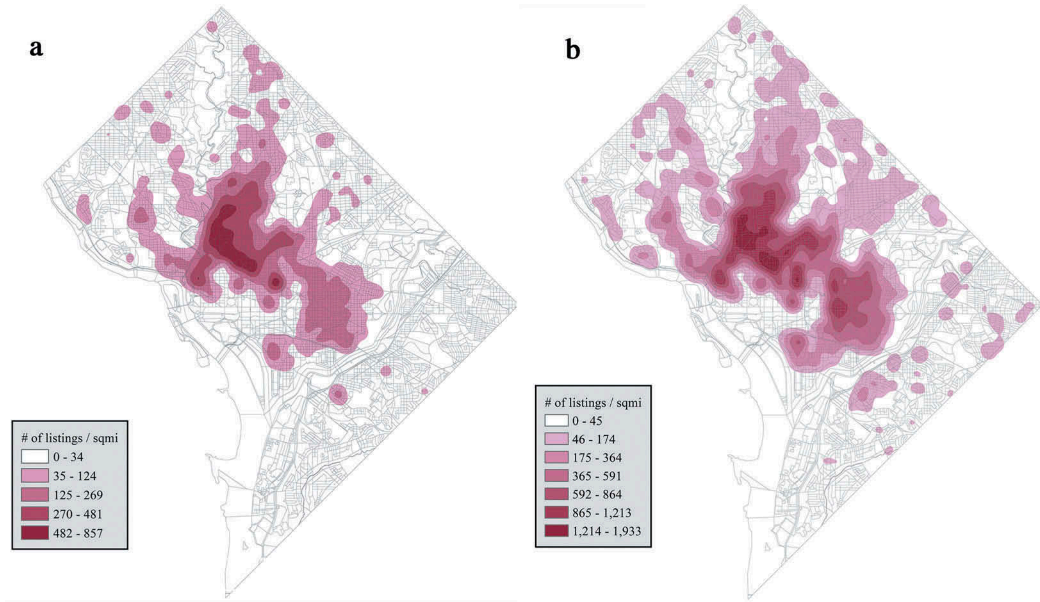

Figure 2. (a) Airbnb listing locations, February 2015. (b) Airbnb listing locations, February 2017.

the densely populated historical and commercial neighborhoods, STRs also expanded to residential neighborhoods in the Northwest and the Northeast, and across the Anacostia River (Southeast), within a 2-year span. This market expansion is intriguing as the east side of DC is traditionally a less heated housing market with a noticeable growth in recent years (*The Washington Post*, 2018a).

Innovations in business and technology often outpace legislation that confines the boundaries of their practice. Once a niche market product, STRs are no exception. Although triumphed by many who profited in the sharing economy, STR platforms increasingly clash with cities as issues, such as illegal listings and unmannerly guest behavior, start to make headlines. The central research question of this article is whether the thriving STR business in Washington, DC, is a significant factor that drives up single-family property prices in the owner housing market. In addition, it is vital to understand which neighborhoods are most impacted by STRs, especially the neighborhoods with high shares of racial minorities.

Many issues with and discussions about STRs are described in the literature. In the following section, I thoroughly review the broader literature on this novel yet controversial topic, with a focus on the welfare impacts STRs have imposed on different communities.

2. STR Literature Review

2.1. Virtues and Vices of STRs

STRs only became a popular research subject recently, because of their novelty. Early research focused on descriptive analyses of successes and setbacks of the STR business model: By adopting a trust and reputation system, STR platforms managed to minimize the potential risks of sharing with strangers (Abrahao, Parigi, Gupta, & Cook, 2017; Frenken & Schor, 2017). On the other hand, a rating system could introduce unintended statistical and social biases because of information asymmetry. For instance, Zervas, Proserpio, and Byers (2015) found that ratings on Airbnb were overwhelmingly positive, disguising variations in service quality. In addition, STR platforms introduced a two-sided feedback system for guests and hosts, where ratings were usually inflated out of fear of retaliation

(Tadelis, 2016). Fradkin, Grewal, and Holtz (2018) conducted two field experiments to improve the effectiveness of the rating system for Airbnb. They found that both financial rewards and simultaneous reviews could readily eliminate strategic reciprocity in the STR rating process.

Although addressing the importance of designing a robust rating system for STR platforms, researchers also found worrisome evidence that social biases were held against STR participants of color. Edelman, Luca, and Svirsky (2017) implemented an audit experiment on Airbnb and found a significantly higher number of booking request rejections of African American guests as compared with white guests. In addition, black hosts were found to earn significantly less rent from STRs than their white counterparts after controlling for housing conditions and location factors (Edelman & Luca, 2014). STR platforms claimed that they were not liable for such social biases as a result of their ambiguous policies on user profile photos and listing descriptions (Edelman & Luca, 2014). As allegations of discriminatory cases accumulate, public appeals for regulatory measures to hold STR platforms accountable for nondiscriminatory business conduct are also increasing.

Having observed the global success of STRs, researchers in tourism and hospitality tried to assess how this emerging market would impact the traditional lodging industry. Zervas, Proserpio, and Byers (2017) suggested that Airbnb could be responsible for a revenue loss of 8–10% for traditional hotel chains in Austin, Texas. The new competition from STR platforms, however, can substantially benefit consumers as lodging cost is brought down (Guttentag, 2015). It is no surprise that the incumbent hotels and lodging establishments will defend their business interests by pursuing legislation/regulation against the disruptive STRs. A major argument against the platforms is that they essentially created a deregulated market without enforcing regulation, such as business registration, on their participating hosts (Guttentag, 2015). Unlicensed accommodation providers could impose safety and public health risks on guests (Gurran, 2018). Furthermore, unlicensed STR listings could escape tax liabilities, providing an unfair advantage over traditional lodging establishments that obey tax rules (Gurran, 2018; Guttentag, 2015). This tax issue is typically resolved through tax agreements between a city government and STR platforms, allowing a city to collect hotel-like taxes on each booking (Bibler, Teltser, & Tremblay, 2018). Yet it is not commonly practiced by all city governments in the United States, especially those of small cities (DiNatale, Lewis, & Parker, 2018).

2.2. STRs' Externalities

In addition to affecting subscribers and the hospitality industry, STRs also impact the welfare level of the broader community through externalities. Externalities exist naturally, as the market is imperfect. Whereas subscribers (hosts and guests) and STR platforms are tied to a legally binding contract, nonsubscribers cannot hold platforms accountable for their behavior. Neither can nonsubscribers invoke market incentives, such as withholding their patronage, to change platforms' behavior (Edelman & Geradin, 2016).

In the context of STR, the most obvious externality comes from changes to quality of life. Neighborhood quality, unbounded by ownership, could fall victim to a tragedy of the commons, such as constant interruptions to the neighbors from STR guests, overconsumption of rivalrous public goods (e.g., parking space), and reckless guest behavior (e.g., hosting loud parties; Edelman & Geradin, 2016). Filippas and Horton (2017) theoretically articulate that negative home-sharing externalities cannot be entirely internalized in a *tenant decide* regime. The externalities associated with STRs are complicated in that they are both "technological" (i.e., spillovers) and "pecuniary" (Scitovsky, 1954, p. 146). Technological externalities of STRs are the social costs incurred by STR guests and borne by the public. Pecuniary externalities of STRs, on the other hand, are the overall housing price and value changes as a result of the advent of STRs in a city (Filippas & Horton, 2017). Empirically, quantifying externalities is a difficult task because of their nonmarket nature. Hedonic pricing is a popular empirical approach for valuation of nonmarket goods, which implicitly embeds nonmarket locational characteristics into determinants of property prices/values (Rosen, 1974).

Whereas policymaking toward eliminating technological externalities is straightforward, such as restrictions against the use of STRs for events and zoning compliance (e.g., Office of Short-Term Rentals San Francisco, 2018), policymaking toward remedying pecuniary externalities involves a complicated planning issue. Specifically, STR platforms are condemned for exploiting the affordable rental housing stock that could have been rented by long-term renters and for inflating rent and property value (Edelman & Geradin, 2016; Gurran, 2018; Gurran & Phibbs, 2017). Pecuniary externalities are a product of interdependence among members of the economy. They cannot be resolved by simply applying policy tools to move the economic equilibrium from the private optimum to the social optimum (Scitovsky, 1954). A change in policy to address pecuniary externalities, such as restricting the number of listings per host, is likely to change the dynamics of the entire STR market. A summary of STR externalities is provided in Figure 3.

Unlike green space or air pollution, which can be unambiguously categorized as an amenity or a disamenity, respectively, to quality of life, having STRs in a neighborhood can be considered both an amenity and a disamenity. What is revealed through differences in property prices/values is the net effect of STR externalities. Recent empirical results suggest that STRs seem to boost property values or rent (Horn & Merante, 2017; Sheppard & Udell, 2016; Wachsmuth, Kerrigan, Chaney, & Shillolo, 2017; Wachsmuth & Weisler, 2018), indicating that the positive externalities associated with STRs dominate the negative ones.

Previous literature theorizes potential mechanisms of STRs' positive impact on property prices. STRs offer an extra income that can help property owners maintain ownership for longer as the cost of ownership is reduced (Sheppard & Udell, 2016). This extra income stream is capitalized into property prices (Barron et al., 2017). This is a plausible mechanism in particular for those who would otherwise have been evicted from their property because of financial struggles. In addition, STRs could generate new interests in real estate investment: Urban space becomes more valuable as tourists and residents take advantage of STRs (Sheppard & Udell, 2016). With limited urban land supply for new development, investors will seek to convert the existing housing stock into STRs, bidding up property prices and making life more difficult for first-time homebuyers and long-term renters. This is exactly what Wachsmuth and Weisler (2018, p. 5) described as "gentrification without redevelopment": A rent (price) gap emerged as the result of a strong tourist demand for STRs. A strong economic incentive followed for real estate investors to evict existing long-term tenants or to cash out existing homeowners. They then converted properties into STRs without building anything new.

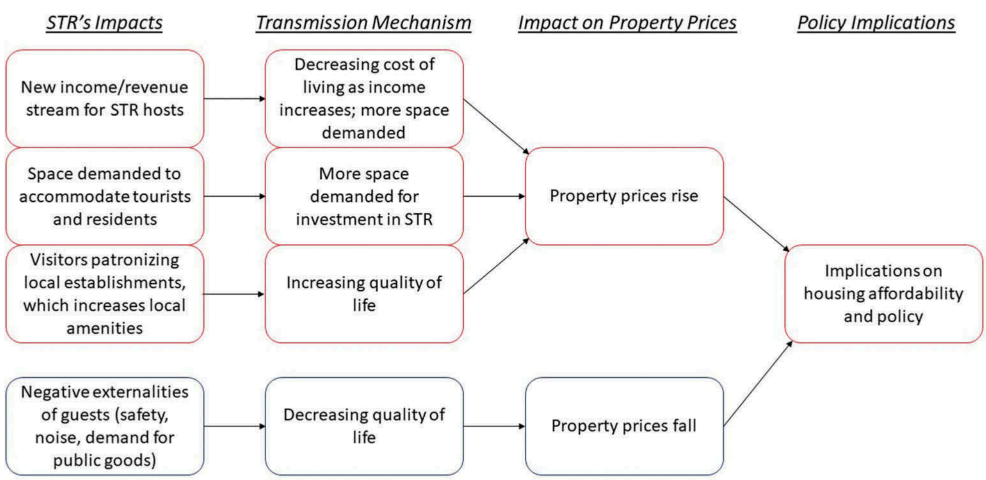

Figure 3. Short term rentals' (STRs') welfare impact and mechanism. Modified from Sheppard and Udell (2016, p. 9).

2.3. STRs' Housing Market Implications

Empirically, previous research reached an early consensus that the advent of STR platforms, such as Airbnb, resulted in net increases in either property prices or rent (Barron et al., 2017; Horn & Merante, 2017; Sheppard & Udell, 2016; Wachsmuth et al., 2017). As new evidence emerged, the debate intensified over whether STRs exacerbated the housing affordability crisis in major U.S. and international cities. Nevertheless, a lack of robust rental housing transaction data made it difficult for housing policy researchers to produce fruitful results to stir up a conversation. Previous analyses on rental data are aggregated either at the census tract level (e.g., Horn & Merante, 2017) or the metropolitan area level (e.g., Barron et al., 2017). No property/parcel-level rental housing analysis exists at this point, to my knowledge.

Many STR proponents found the argument of a direct substitution between STRs and long-term rentals unconvincing. A report on the impact of Airbnb on the Portland, Oregon, housing market suggested that "somewhere between 83 and 377 units (or 0.03% of the total housing stock in Portland) would be considered full-time Airbnb rentals" (ECONorthwest, 2016, p. 1). It is unclear whether restraining the number of full-time STR listings in a city could significantly shrink the rental housing shortage. Opponents of unregulated STRs focused on the issue in regard to commercial STR hosts, who rented multiple listings for an extended number of days in a year (from 3 months to year round). According to a local nonprofit organization, more than one third of all listings in DC could be categorized as commercial listings (DC Working Families, 2017). In Canada, researchers found that 13,700 entire homes out of 81,000 Airbnb listings were rented for more than 60 days a year in Montreal, Toronto, and Vancouver (Wachsmuth et al., 2017). The definition of an *entire home* is tricky, since it does not necessarily mean that the property owner lives elsewhere. In the ECONorthwest report (2016), a fair observation was made that Airbnb's definition of an *entire home* includes (a) accessory dwellings attached to a property, (b) parts of a property with a separate entrance and private rooms, and (c) a basement unit without a separate entrance. In addition, a property owner can list multiple bedrooms as multiple listings on the platform, contrary to the DC report's argument that a commercial host must have rented out more than one property. As Wachsmuth et al. (2017) point out, current observations about Airbnb are based on third-party information and data sources (e.g., web-scraped data). Any statement with a high level of confidence would require direct data from STR platforms with accurate details.

The rest of the article is organized as follows: In Section 3, I highlight controversies around STRs in Washington, DC, and ongoing efforts toward regulating the STR market. In Section 4, I summarize the Airbnb and property data used in the analysis. Empirical frameworks and results are presented in Section 5. Robustness checks are provided in Section 6. Lastly, I discuss policy implications and conclude the article in Section 7.

3. STR Controversies and Regulations in the District of Columbia

3.1. Growing STR Business Amid Controversies

There is no doubt that STR platforms like Airbnb provide economic benefit to DC residents. However, the relationship between STR platforms and the city is not always positive. A major concern about STRs is that commercial hosts occupy precious housing resources that could have housed long-term renters in the city. In its defense, Airbnb (2017) argued that only 0.22% of the *entire home* listings were booked for more than half a year in 2016. In addition, the average monthly income for an STR host ($680) is only a fraction of the average monthly rental income in DC ($2,299).[3] Therefore, from an economic perspective, part-time STRs, which comprise 60% of all *entire home* units, can hardly substitute for long-term rentals.

Another concern regarding STRs' housing market impact has to do with its spatial concentration around tourist hot spots. Areas like downtown and Capitol Hill are real estate heavens and attract heavy tourist traffic. It is, to say the least, worrisome that STRs may significantly change the housing market dynamics in these areas. If a property price premium is transmitted to the rental housing market in such areas, then long-term renters will have to endure inflating rent as a spillover from increasing housing prices.

Other stories unfolded that STR platforms barely regulated their hosts in terms of business registrations or compliance with local zoning ordinances, such as the strict condominium rules that prohibit short-term sublets (*The Washington Post*, 2017a). In one case, several apartment buildings were converted illegally into full-time STRs as opposed to being leased to long-term renters (Greater Greater Washington, 2017). STR platforms were not well received by all. Therefore, the city government decided to intervene in the unregulated STR market.

3.2. DC's STR Regulatory Framework

In January 2017, Kenyan McDuffie, city councilmember representing Ward 5, introduced the Home/Short-Term Rental Regulation and Affordable Housing Protection Act of 2017 (B22-92), which was the first official attempt to legalize and regulate STRs. Proponents and opponents fiercely expressed their positions during the first public hearing in April 2017 over the current state and practice of STRs in DC and to what extent the STR business should be regulated (Council of the District of Columbia, 2018).

The initial proposal was not well received as STR platforms and subscribers felt the bill "goes too far and is too restrictive" by capping the number of days in a year for STR operation at 15 days (*The Washington Post*, 2017b). After inaction for more than a year, the city council moved the legislation forward in October 2018 with significant amendments to the original bill: STR listings were capped at 90 business days per calendar year; the monetary penalty for violations was reduced; and any STR listing located outside of a host's primary residence requires a license for operation (Council of the District of Columbia, 2018). The city council passed the bill unanimously in November 2018, marking the end of an era of unregulated STRs in Washington, DC.

Table A1 highlights the legislative contexts of B22-92. It also describes approved STR bills and ordinances from the neighboring counties, including Arlington County, Virginia; Prince George's County, Maryland; and Montgomery County, Maryland. There are many similarities among these legislations: an STR is defined as the transient occupancy of a residential dwelling (owned or rented); a business license is acquired conditional upon inspections from the regulatory body; only the primary residence is allowed for STRs, where the physical presence of the residents is required for at least 180 days in a calendar year; and the maximum number of STR days in a calendar year and the maximum number of guests are specified. On the other hand, these bills and ordinances also differ from each other: whereas both counties in Maryland and the DC government passed jurisdictional bills, Arlington County only revised its zoning ordinances. Having the zoning commission enforcing the ordinances with the power to suspend or revoke a permit may yield better enforcement outcomes, but it could also cause an administrative burden. DC's STR bill remains the most restrictive in terms of its 90-day cap for STR (as opposed to 120 days or 180 days) with special exemptions. In addition, B22-92 is the only bill that specifies the penalty for each violation. In response to legislative approval, STR platforms quickly denounced the council's action and aimed to bring the case directly to a 2020 ballot initiative (*The Washington Post*, 2018b).

If passing legislation on STRs requires year-long efforts, then enforcing STR regulations entails administrative readiness and coordination. Underprepared implementation of STR regulations results in unintended consequences. One such consequence is a cumbersome registration process. As one of the first cities to pass an STR legislation in 2016, San Francisco, California, only registered 2,168 Airbnb hosts as of early 2018, leaving the majority of its 8,000 STR listings with no legal status (*San Francisco Chronicle*, 2018). Similarly, by 8 months after the legislation took effect, the Arlington County government had only issued 101 transient rental permits on an estimated owner base of 1,600 STRs (INSIDENOVA, 2017). If the low registration rate is a mixed outcome of uncooperative STR owners and inefficient administrative procedures, then the existence of unregistered/commercial listings heightens a lack of regulatory enforcement. AirDNA (2018) data suggest that 5,778 Airbnb listings in San Francisco remain active, despite the fact that the municipal STR bill has been in effect for 2 years. Should the platforms be fined for listing unregistered STRs? Should the city go after each unregistered STR owner? These unresolved issues are common to municipal lawmakers and governing bodies everywhere, including the District of Columbia.

In the housing policy debate over STRs' impact on DC's housing market, a missing piece of the puzzle is how STRs could impact property owners and homebuyers. In the following sections, I will empirically investigate this issue using unique open-source data.

4. Empirical Data

4.1. Data Sources

Airbnb data: Although data from STR platforms are almost impossible to acquire, third-party web-scraped data are available have become popular for research purposes (e.g., Wegmann & Jiao, 2017). Web-scraped STR data are subject to some limitations, such as the use of location proxies. Yet such data provide comprehensive information about an available listing, including listing amenities and reviews. Through real-time data scraping, researchers can describe STR activities subject to a degree of discretion. Researchers either design their own scraper (e.g., Barron et al., 2017) or rely on third-party scrapers, such as Inside Airbnb (e.g., Gurran & Phibbs, 2017; Horn & Merante, 2017) and AirDNA (e.g., Wachsmuth & Weisler, 2018). In this study, I used data collected by Tom Slee from September 2014 to July 2017.[4]

Six web-scraped Airbnb data sets at half-year intervals were combined to represent Airbnb listings in DC from early 2015 to mid-2017. The half-year intervals deliberately take into account seasonal fluctuations in tourism (March through August are typically the popular months for DC). Although the data do not cover the initial entry of Airbnb into the DC market, they cover the period when the STR business took off in DC (see Figure 1).

Housing data: Housing information came from the Open DC data portal with periodically updated property sales records and city-wide housing appraisal records. The appraisal data provide underlying housing attributes, such as the number of rooms, bathrooms, and stories; the square footage; and the estimated building year. Property sales records from the Integrated Tax System Public Extract (ITSPE) and appraisal data from the Computer Assisted Mass Appraisal (CAMA) database were extracted and combined using a unique identifier, Square Suffix Lot (SSL). After trimming the data set using matching criteria, completeness of attributes, and exclusions of extreme values, I derived the final data set of property sales records during September 2014–July 2017.

Neighborhood data: Aside from housing attributes, neighborhood characteristics are also deterministic in hedonic prices. I included the most important attributes in the final data set, such as access to Metrorail stations, public schools, and historical landmarks. In addition, underlying population attributes at the census tract level were extracted from the American Community Survey database and were incorporated into the final data set.

4.2. Data Processing

Because of the size of the housing data sets, neither sales records nor appraisal data were geocoded. I applied the Master Address Repository (MAR) geocoder to geolocate each SSL within the ITSPE database by a 92% matching criterion. Only 7,334 out of the 110,883 records were dropped because of low matching rates. The ITSPE data were then merged with the CAMA residential data based on SSL, and 52,577 single-family property sales records were successfully matched.[5] In the end, 12,680 records between September 2014 and July 2017 were kept in the final single-family housing data set.

I measured Airbnb density by counting the number of listings within a certain buffer distance of a property sales point at a given period of time. Four buffer sizes were included in the analyses: 100 feet, 200 feet, 500 feet, and 1,000 feet. Choosing a buffer size is more of an art than a science: whereas a smaller buffer captures an STR's most direct impact on a property's price, a larger buffer allows for more variations in Airbnb density and captures the broader economic impact of Airbnb activities on the neighborhood. As a comparison, Sheppard and Udell (2016) tested different buffer sizes from 200 meters (656 feet) to 2,000 meters (6,560 feet). Some studies calculated Airbnb density at an aggregated level, such as census tracts (Horn & Merante, 2017). I did not include a buffer size smaller than 100 feet or larger than 1,000 feet because (a) the variation in Airbnb density was insignificant for a smaller buffer, and (b) the neighborhood impact of a single listing was too weak for a much larger buffer. With an increased buffer size, more listings will be included, but the listings farther away from the centroid will have a smaller impact on property prices. Figure 4 illustrates the Airbnb density at different buffers in the ArcGIS environment.

4.3. Summary Statistics

Summary statistics of the final data set are presented in Table A2. The average number of Airbnb listings within 100 feet of a single-family property sales point is 0.21. The variation is so small for this

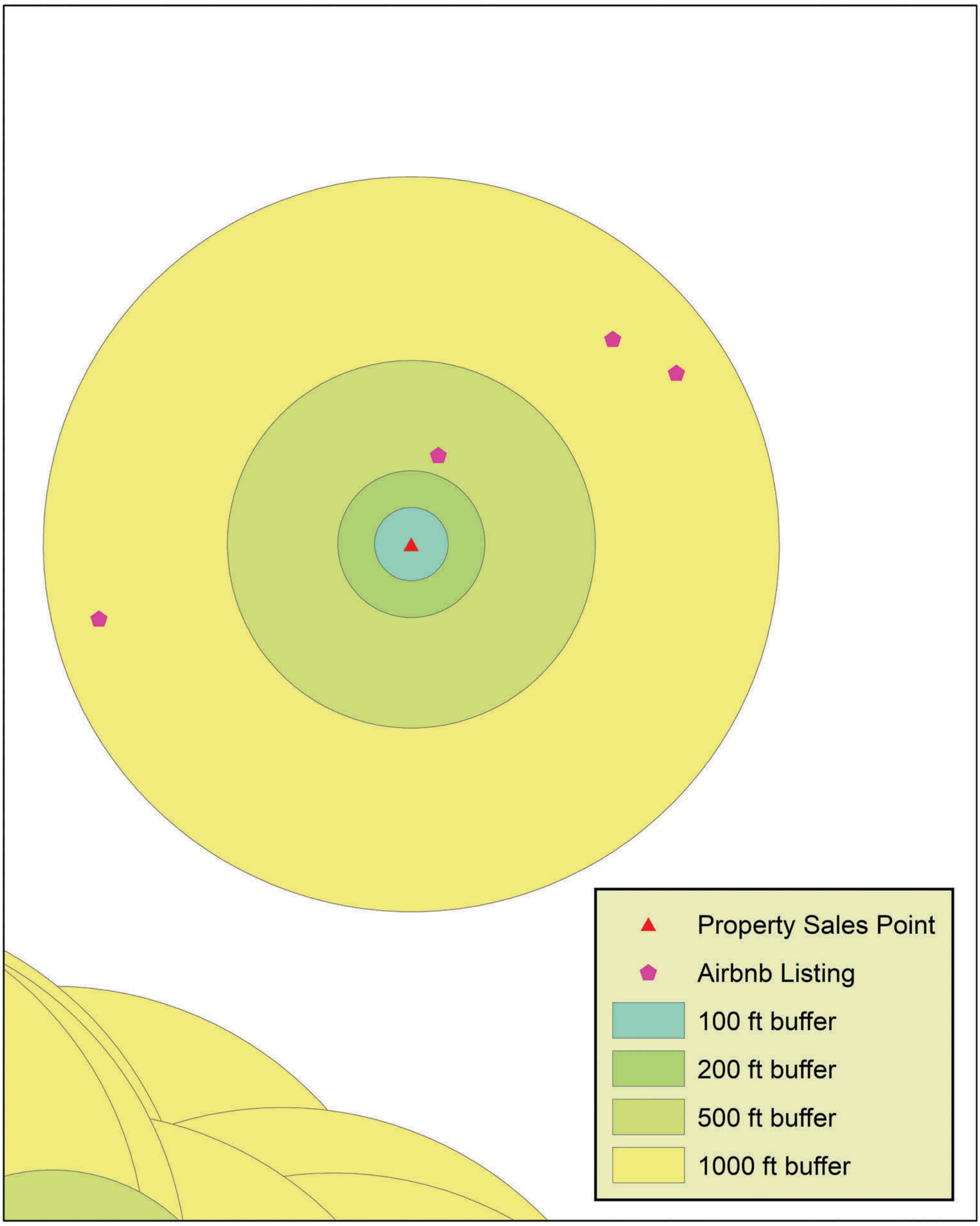

Figure 4. Example of Airbnb density buffers around a property sales point.

search radius that it may affect the precision of the point estimate in the hedonic regression model. The Airbnb density increases to 0.85, 5.06, and 18.63 for search radiuses of 200 feet, 500 feet, and 1,000 feet, respectively, from a property sales point. In theory, the marginal effect of each Airbnb listing on a property's price will decay as the buffer size increases. Therefore, I anticipate a declining magnitude in hedonic point estimates for the Airbnb density variable for a larger buffer.

The sample average single-family property price is $762,000 and the median price is $630,000, higher than the median home value in DC of $544,000 in 2017.[6] The sample average property land area is 3,000 square feet (sqft) and the average structure area is about 1,700 sqft, with 7.5 rooms, 2.2 bathrooms, 0.6 half-bathrooms, and 1.2 kitchens. In addition, basic amenities are usually included, such as a fireplace, an air conditioner, and a heating system.

As for neighborhood attributes, a typical property resides in a populated urban area with heavy traffic (as indicated by the number of crash incidents within a half-mile buffer) and some crime incidents. A property usually has a good access to public schools within walking distance (0.5 miles). A property also has an easy access to a Metrorail station and commercial areas. In Washington, DC, it is especially common to have historical landmarks in the neighborhood. Such amenities can have significant impacts on property prices.

In terms of neighborhood demographics, a typical DC property is located in a neighborhood with an employed, educated, middle-class population. However, the population demographics differ significantly by zip code. I carefully controlled for such zip code fixed effects and STR clustering effects in the models specified in the next section.

I conducted a Pearson's correlation test[7] to examine the preliminary bivariate relationship between Airbnb density and property prices and to detect the unusual signs of different housing and neighborhood attributes in explaining property prices. All Airbnb density variables were positively correlated with property prices, suggesting a net positive externality from STRs. Most signs of the correlation statistics made sense. No perfect collinearity was found except for income and education at the census tract level.

5. Hedonic Analyses of Airbnbs' Effect on Property Prices

Empirically, the hedonic pricing model is one of the most widely adopted approaches to study consumers' willingness to pay for nonmarket goods. In this study, Airbnb density, defined by the number of Airbnb listings within a particular distance from a property sales point, runs into the regression analyses as a hedonic attribute. I constructed three models to fully investigate Airbnbs' impact on property prices: a pooled cross-sectional model, a fixed-effects model at the census block level, and a first-difference model.

5.1. Model Specifications

The full-sample cross-sectional model considers the most comprehensive set of explanatory variables, including housing attributes, neighborhood factors, sociodemographic attributes at the census tract level, and a series of time and location fixed effects. The model is specified as follows:

$$lgprice_{in} = \alpha + Airbnb_{in}\beta + X_{in}\delta + N_n\varphi + \varepsilon_{in} \tag{1}$$

Housing price takes a logarithmic form to account for the right-skewedness in distribution, X_{in} represents housing and neighborhood attributes, and N_n represents demographic attributes that are common to each property i in census tract n.

The census-block-level fixed-effects model controls for unobserved time-invariant characteristics that may jointly affect housing prices and Airbnb activities, such as commercial activities, infrastructure, and public facilities. In addition, a time trend is added to the model to control for common housing market fluctuations over different periods. The model is specified as follows:

$$lgprice_{bt} = \alpha + Airbnb_{bt}\beta + X_{bt}\delta + N_{bt}\varphi + \omega_b + \theta_t + \varepsilon_{bt} \quad (2)$$

The unit of observation is a representative property in census block b during period t. Both block-level fixed effects ω_b and common time trends θ_t are included.

The nation's capital experienced a historical influx of visitors in January 2017. Both supporters and protesters congested the city during the Trump administration's inauguration and the Women's March the following day (the latter attracted much heavier traffic). Having anticipated the unprecedented demand for lodging, the local STR community expanded dramatically between November 2016 and January 2017, from 5,975 listings to 9,097 listings, according to the web-scraped data. This exogenous demand shock created a unique opportunity for me to conduct a before/after analysis on how new Airbnb listings/activities affected property prices.

I selected block-level data between March 2016 and November 2016 for the *before* period and data between February 2017 and July 2017 for the *after* period. The final data set consists of 2,047 observations for 1,027 blocks. I then applied a first-difference model to understand how changes in Airbnb density affected property prices:

$$\Delta lgprice_b = \alpha + \Delta Airbnb_b\beta + \Delta X_b\delta + \Delta N_b\varphi + \Delta\varepsilon_b \quad (3)$$

5.2. Empirical Results

The main estimation results are presented in Table A3. Panel A of the table reports the regression coefficients and standard errors for the most important variables in the pooled cross-sectional model. It is evident that (a) having Airbnb listings in the neighborhood mildly raises a single-family property's price, and (b) the average effect of a listing decays as the search buffer broadens. Other significant variables also help explain property prices, such as good property appraisal grades and conditions, having public schools and historical landmarks within walking distance, and dwelling in a wealthy community. The model's goodness of fit is high, with $R^2 > 0.80$.

Panel B shows regression coefficients and standard errors of the Airbnb listing density variables for the fixed-effects model. The coefficients on the Airbnb densities at the 200-foot, 500-foot, and 1000-foot buffers hold their statistical significance, and they are slightly larger in magnitude than those in Panel A. Whereas the fixed-effects model controls for unobserved time-invariant characteristics at the census tract level, the model's goodness of fit drops because of aggregation. Nevertheless, the results from both models suggest a price premium on properties because of the presence of Airbnb listings in the neighborhood.

Panel C of Table A3 shows hedonic regression results for the first-difference model. Again, the coefficients on Airbnb densities at the 200-foot, 500-foot, and 1000-foot buffers remain statistically significant. The magnitudes are much larger because of the dramatic increase in Airbnb density between November 2016 and January 2017. One possible explanation is that the transition to a new administration led to a temporary spike in housing demand to accommodate new residents. Airbnb (and STRs in general) fulfilled the transitional housing need.

5.3. STRs' Inequitable Impact on Property Prices

To quantify the impact of Airbnb listings on property prices, I calculated the aggregate impact by multiplying the point estimates from the fixed-effects model and the average density of Airbnb listings for each buffer size. The impacts were then summarized by zip code to account for the unbalanced spatial distribution of Airbnb listings. The results are presented in Table A4. In particular, the underlying demographic composition varies significantly across zip codes in DC because of historical redlining (Lloyd, 2016). Certain zip code areas have a much higher concentration of

Hispanic/Latino and/or African American populations. Historically, displacement of the black population was prominent in DC (Jackson, 2015). It is vital to understand whether STRs have significantly impacted people of color in the city.

For the entire city, Airbnb alone could account for an increase in single-family property price by 0.66% to 2.24%. The impact was mild yet nontrivial. Alarmingly, Airbnb was responsible for a significant leap (>5%) in property prices in tourist hot spots, such as downtown (zip code 20005), Shaw (20001), Adams Morgan (20009), Dupont Circle (20036), and Foggy Bottom–George Washington University (20037). These neighborhoods were already overheated in terms of housing demand because of their advantageous locations. STR-related housing investment will only aggravate the housing affordability issue.

What is more unsettling is that Shaw (20001), NOMA–Trinidad (20002), Capitol Hill (20003), and Columbia Heights (20010) also experienced a noticeable price inflation (> 3%) because of STRs. These zip code areas are populated by Hispanics and African Americans, as shown in the last two columns of Table A4. Although the increasing price is good news for current homeowners, it acts as a potential hurdle preventing new homebuyers from moving into these neighborhoods. Moreover, it is reasonable to worry that the price premium will be eventually borne by long-term renters, jeopardizing low-income minority renters who could be displaced from the city. This is the missing piece previously ignored in the debates over STRs' housing market consequences in Washington, DC: Not only could STR platforms occupy valuable housing stock, but their business could significantly drive up housing costs in neighborhoods with a concentrated minority population.

6. Robustness Checks

6.1. Robustness Checks on Active Airbnb Listings

As mentioned in Section 3, housing advocacy groups and other STR opponents were most concerned about the *entire home* STR listings that might have consumed the existing housing stock. To inquire into this issue, I subdivided the Airbnb listing data by two additional criteria: a listing (a) was categorized as *entire home*, and (b) had at least one review to signal its active status. About 70% of the observations were preserved after this additional screening.

After rerunning all three models, I present robustness check results in Table A5. Surprisingly, whereas the statistical significance of the regression coefficients and the goodness of fit resemble those in Table A3, the magnitudes of coefficients are larger for the 100-foot and 200-foot buffers and smaller for the 500-foot and 1000-foot buffers compared with the results in Table A3. Such interesting results can be explained by a perfectly reasonable rationale: Active STR listings have a stronger localized impact on property prices as their activeness indicates business success and attractiveness to new investors. On the other hand, broader economic benefit usually requires a cluster of listings in a larger buffer area. With fewer listings in a large buffer, the magnitude of the Airbnb density impact declines.

6.2. A Robustness Check on the Rental Housing Market

Although the focus of this article is the single-family owner housing market, it will enrich the discussion to look into STRs' impacts on the rental housing market. I could not access disaggregated rental transaction data, so the robustness check was done at the aggregate zip code level. I used Zillow Rent Index (ZRI), a smoothed measure of the median estimated market rate rent, across zip codes in Washington, DC, over time for this exercise.[8] When applied to the same empirical models, the rental data yielded statistically insignificant results (see Table A6). The most plausible estimate is the coefficient on the Airbnb density at the 200-foot buffer. The estimate is positive yet statistically insignificant. In addition, Washington, DC, adopted a strict Rent Control Act, in which any rent hike falls under rent control except for a few exemptions (such as rental units built after 1975 and federally/district-subsidized rental units).[9] From the housing data set, 74% of the single-family units and 60% of the multifamily/condominium units were built prior to 1975, suggesting that the majority of the older housing units in DC fall under the rent control umbrella. This is somewhat reassuring for the most vulnerable renters in the city. Nevertheless, I acknowledge that thorough and robust research using high-quality disaggregated rental housing data must be conducted to solve the rental housing puzzle of STRs' housing market consequences.

7. Discussion

7.1. Policy Implications

This article provides empirical evidence of STRs' impacts on property prices. The topic has pivotal welfare implications that should not be neglected. Previous attempts to understand STRs' housing market impacts in DC were descriptive and lacked rigor. In this article, I took advantage of innovative web-scraped Airbnb data to demonstrate the indirect impact (externalities) of Airbnb listings on single-family property prices through hedonic analyses. The results suggest that unregulated growth in STR business created an inequitable property price premium that could distress first-time home-buyers and negatively affect long-term renters if the price premium results in higher rent.

This study comes out in a particularly meaningful time in the wake of new STR regulations in the District of Columbia. The lengthy legislative process took almost 2 years to finish, with another 11 months of a transition period to go before the regulations come into effect. Although stories about how STR business helped struggling families afford their homes in one of the nation's most expensive cities (*The Washington Post*, 2018a) should not be neglected, cities ought to realize that anxious STR investors can make life much harder for people who are still seeking a home.

STR regulation should by no means deprive a resident of their right to earn an extra income through home-sharing. The unanimous criticism of the stiff cap on STR days in the original bill proposal is proof of this. Strict as it still is, the final version allows for a primary dwelling to be rented 90 days a year. Although it has yet to be tested how effectively the regulation will be enforced, the bill can hopefully cool down STR-related housing investment by prohibiting commercial listings outside of a host's primary dwelling. It remains challenging as the city must get STR platforms on board to make considerable efforts to remove illegal listings. Any attempt to resolve the conflict between pro-STR and anti-STR communities without a collaborative approach has no chance to succeed.

From a planner's perspective, functional zoning ordinances and an effective zoning board play critical roles in regulating STRs. Table A1 shows that all passed STR legislations revise zoning ordinances to unambiguously confine a residential property's STR usage. In the case of Arlington County, the zoning commission is also the issuer of STR licenses, empowering the county's planning body to oversee STR operation and law compliance.

In addition to revising zoning codes, planning and housing authorities should keep a keen eye on the affordable housing stock and ensure that the valuable rental housing resources for voucher holders and other affordable housing program participants are not jeopardized by illegal or irrational STR investments. On the other hand, there is a silver lining to foster collaboration between the housing authority and STR platform in home sharing programs (e.g., Department of Housing and Urban Development, 2016). Rather than treating STRs as a threat to affordable housing, cities could potentially benefit from the crowd-sourcing technology supported by STR platforms to match voucher holders and rental housing owners. Cities should embark on the smart city concept by thinking and acting innovatively to address existing conundrums. A new type of home sharing program through STRs would be a great experiment to produce a social good through a private–public partnership between a city and STR platforms.

7.2. Limitations and Beyond the Study

I acknowledge that this study cannot directly answer the question of how STRs gentrify a city. Gentrification is a complicated issue that goes beyond the scope of the partial equilibrium analyses presented in this article. We will have to reflect on the money-chasing real estate development that is by no means affordable to low-income households and racial minorities. We will also have to ask homeowners why they prefer to invest in the STR business.

Instead, this study confirms the hypothesis that STRs make it more expensive to own a property in a tourist paradise like Washington, DC. Moreover, and perhaps more alarmingly, they have made the historically minority-concentrated neighborhoods more expensive. Because of the short observation time, the data did not support a parcel-level repeated sales model, which would have been a more robust empirical approach. Nevertheless, all three hedonic models confirmed that STRs indeed inflated single-family property prices. To put this article into perspective, I compared the empirical results with the findings from previous studies: In this article, I find a 0.78% increase in property prices for each additional Airbnb listing within the 200-foot buffer; Barron et al. (2017) find a 0.64% increase in property prices with a 10% increase in Airbnb listings; and Sheppard and Udell (2016) find a 6–9% increase in property prices when the number of Airbnb listings doubles within a 300-meter buffer, which translates into a 1.30–1.96% increase in property prices for each additional Airbnb listing in New York City. Different as our methodologies, data, and studies areas are, we come to similar conclusions.

Although I included a robustness check on Airbnb's price effect on aggregated median rent at the zip code level, the results are rather inconclusive. Unsurprisingly, the level of geographic aggregation and the length of the time series limited the interpretability of the results. Following Barron et al. (2017) and Horn and Merante (2017), I believe that the story for Washington, DC, is probably not so different; that is, STRs also drive up rent. Recent studies using web-scraped Craigslist data (e.g., Boeing & Waddell, 2017) inspire a new research agenda on STRs' rental housing market consequences.

Last but not least, hedonic models were only able to allow me to derive the net impact of Airbnb density on property prices. It is unclear what the driving factor is in determining the positive net externality. Judging from the literature (Wachsmuth & Weisler, 2018), investors bidding up prices because of the extra income from STR is a more plausible mechanism than the other two (increasing quality of life and more space demanded by existing property owners).

As a new wave of jurisdictions start to legalize and regulate STRs, it will be interesting to compare the STR market before and after regulations take effect. One of the greatest debates is whether innovation and technology improve quality of life. In the case of STRs, it is a housing policy debate centering on an innovation in technology that redefines how we live and how we travel.

Notes

1. The main data source for this article is the Inside Airbnb website supported by Tom Slee (http://insideairbnb.com/about.html). I appreciate his data collection efforts, in terms of both frequency and quality. However, the data collection process stopped by mid 2017. According to another source, AirDNA, the current number of Airbnb listings in Washington, DC, fluctuates around 7,000. This could be a result of market saturation, policy uncertainty, or a combination of the two.
2. According to the declaimers on Inside Airbnb, the locational information of an Airbnb listing that is publicly available on airbnb.com is typically within a 450-foot distance from its actual address to protect anonymity of a host's information. This is not problem for the purpose of this study because Airbnb listings are characterized as a density attribute within a certain buffer distance.
3. According to Insider Airbnb, the estimated full-time STR monthly income is about $986 (http://insideairbnb.com/washington-dc/), still much lower than the average rental price (even for a studio).
4. The scraper operator, Tom Slee, stopped Airbnb data collection after the summer 2017 because of an overwhelming number of requests. He directed requestors to other open-data sources such as Inside Airbnb.
5. Another 39,886 records were matched for condominium and multifamily sales records. Condominium data were excluded from this study because of unobserved attributes (such as condominium management quality) that could be crucial in determining their prices.

6. The median value for condominiums is $440,000, but the condominium sample was excluded because of a lack of detailed condominium attributes in the appraisal database.
7. Because of the size of the Pearson's correlation matrix, I decided not to include it in the article.
8. See the methodology to calculate the ZRI here: https://www.zillow.com/research/zillow-rent-index-methodology-2393/
9. See the Rent Control Fact Sheet here: https://dhcd.dc.gov/sites/default/files/dc/sites/dhcd/service_content/attachments/Rent%20Control%20Fact%20Sheet%202018.pdf

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Disclosure Statement

No potential conflict of interest was reported by the author.

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Appendix

Table A1. Comparison of short-term rental legislative frameworks in the DC metropolitan area.

Jurisdiction	Washington, DC	Arlington County, VA	Montgomery County, MD	Prince George's County, MD
Legislative framework	B 22–92 (Proposed bill and amendments)	Zoning Code 12.9.11 and 12.9.12	Zoning Text Amendment 17–03 and Senate Bill 2-16	CB-10-2018 and CB-11-2018
Definition	STR means paid lodging for transient guests with the host present, unless it is a vacation rental. An STR is not a hotel, inn, motel, boarding house, or bed and breakfast.	An accessory homestay is a special type of home occupation that allows the occupant of a residential dwelling unit to host short-term overnight guests.	STR means the residential occupancy of a dwelling unit for a fee for less than 30 consecutive days. An STR is not a bed and breakfast.	STR means a residential dwelling unit occupied by an STR guest, other than a permanent occupant, for fewer than 31 consecutive days and no more than 90 days per calendar year.
Business license	A license issued by the Department of Consumer and Regulatory Affairs. Valid for a period of 2 years.	Accessory homestay permit from the Zoning Administrator. Renewed annually.	A license issued by the director of the Department of Health and Human Services is required. Renewed annually.	Annual issuance of a license by the Department of Permitting, Inspections, and Enforcement.
Zoning ordinance	DC Zoning Commission will revise zoning codes to permit STRs.	Arlington County Zoning Code 12.9.11 and 12.9.12	Montgomery County Zoning Text Amendment 17-03	CB-10-2018 (Sec. 27–464.09 "Tourist Home as an 'Accessory Use'")
Days of STRs in a calendar year	90 days (unless the host has received an exemption)	180 days	120 days (no cap for rental days with physical presence of the owner)	90 days if not occupied by the owner, or 180 days if occupied by the owner
Primary dwelling requirement	Primary residence only, which means the property is eligible for the homestead deduction pursuant.	Primary residence only. The dwelling unit must be occupied for at least 185 days per year.	Primary residence only (farm tenant dwelling or on-site accessory dwelling prohibited).	Must be primary residence to get the license. However, no stated restriction on rental dwellings once license is obtained.
Maximum number of dwellings per host	1	1 (single family; multifamily is subject to the same rule as condo/apartment)	1 (owner's property or owner-authorized resident's primary residence)	Multiple; however, the combined allowable time frames shall not exceed the permissible calendar days
Maximum number of rooms per dwelling	No cap, as long as all rooms/suites are within the property.	No cap. All rented bedrooms must be in the main building. Accessory dwelling allowed with a permit.	No cap. Only habitable rooms can be used by guests.	No cap. Only habitable rooms can be used by guests.
Maximum number of guests per dwelling	8 (or 2 per bedroom, whichever is greater)	6 (or 2 per bedroom, whichever is greater)	6 (only counting guests 18 years or older, and maximum 2 per bedroom)	8 (and no more than 3 guests per bedroom)
Safety code requirements	Smoke detectors and carbon monoxide detectors	Fire extinguishers, smoke detectors, and carbon monoxide detectors	Smoke detectors and carbon monoxide detectors; sanitation facilities	Smoke detectors and carbon monoxide detectors; fire extinguishers; posted emergency contact and floor plan

(*Continued*)

Table A1. (Continued).

Jurisdiction	Washington, DC	Arlington County, VA	Montgomery County, MD	Prince George's County, MD
Other requirements	Liability insurance required. No visitor parking permit for STR guests.	Forbidden for commercial meetings, or other gatherings for direct or indirect compensation.	HOA, condo, and co-op associations will be notified when an application is filed. An application is not prohibited by HOA, condominium document, or rental lease.	Liability insurance required. Compliance with the requirements of HOA, condo association, etc. One parking space for every three guests.
Tax	14.50%	7.25% transient occupancy tax	7%	7%
Penalty	Any host who violates regulations is subject to a civil penalty of $500, $2,000, and $6,000 for the first, second, and third violations, respectively. Suspension and revocation of the license.	The permit may be revoked with no new permit for 1 year in the event of three or more violations, failure to comply with the zoning ordinance, or refusal to cooperate with a complaint investigation.	The license is suspended for an applicant who has received at least three complaints that are verified as violations within a 12-month period. No new issuance within 3 years after a license is revoked.	An STR license may be suspended or revoked at any time because of noncompliance with the requirements, citations, or violations of the building, electrical, plumbing, or zoning code. In addition, subject to a civil fine of up to $1,000.
Legislative outcome	Adopted on November 13, 2018, and effective in October 2019.	Adopted in November 2017 and effective since January 2018.	Senate Bill 2–16 and ZTA 17–03 became effective on July 1, 2018.	Adopted on October 23, 2018, and effective October 1, 2019.

Note. HOA = homeowners' association. STR = short-term rental.

Table A2. Summary statistics.

Variable (name)	Mean	SD	Variable	Mean	SD
Airbnb attributes			Neighborhood attributes		
Airbnb listings within 100 ft (Airbnb100 ft)	0.21	0.56	Annual number of traffic incidents within 0.5 miles (numCrash)	152.3	114.7
Airbnb listings within 200 ft (Airbnb200 ft)	0.85	1.52	Annual number of crime incidents within 0.5 miles (numCrime)	326.0	265.3
Airbnb listings within 500 ft (Airbnb500 ft)	5.06	7.35	Number of public schools within 0.5 miles (pubschool)	2.38	1.82
Airbnb listings within 1,000 ft (Airbnb1000 ft)	18.63	26.12	Number of charter schools within 0.5 miles (chaschool)	2.60	2.59
Housing attributes			Number of metrorail stations within 0.5 miles (metro)	0.43	0.66
Property prices in $ (last_sale_price)	762,842	754,505	Number of historical sites within 0.5 miles (landmark)	9.53	15.12
Land area in 1,000s of sqft (landarea)	3.087	2.835	Demographic attributes (census tract level)		
Estimated year built (eyb)	1970	17.44	Total population in a tract (totalpop)	3,904	1,458
Number of rooms (rooms)	7.44	2.51	Population density per acre (popden)	15.20	9.69
Number of bathrooms (bathrm)	2.24	1.06	Percentage of adults (pct_adult)	0.18	0.06
Number of half-bathrooms (hf_bathrm)	0.65	0.60	Percentage Hispanic/Latino (pct_hisp)	0.09	0.08
Number of kitchens (kitchens)	1.24	0.63	Percentage highly educated—postbachelor (pct_educated)	0.29	0.19
Number of fireplaces (fireplaces)	0.60	0.89	Percentage high income—>$20,000 (pct_highinc)	0.15	0.14
Square footage (sqft)	1,693	818.6	Unemployment percentage (pct_unemp)	0.11	0.07
Air conditioning—dummy variable, 1 is yes (ac)	0.73	0.45	Poverty rate (pct_poverty)	0.15	0.10
Number of stories (stories)	2.19	0.80	Number of observations	12,680	
Grade: 1 is low, 12 is exceptional (grade)	4.25	1.38	Other housing attributes: exterior wall type (extwall), roof type (roof), interior wall type (intwall), heating type (heat), building structure (structure), land use code (usecode)		
Condition: 1 is poor, 6 is excellent (condition)	3.81	0.80			

Note: SD = standard deviation.

Table A3. Empirical results of the three models.

	100 ft buffer		200 ft buffer		500 ft buffer		1,000 ft buffer	
Variable name	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*
Panel A: Pooled cross-sectional model (dependent variable: logarithm of property price)								
Airbnb density	0.0065	(0.006)	0.0051*	(0.003)	0.0026**	(0.001)	0.0011**	(0.000)
Landarea	0.0107***	(0.002)	0.0107***	(0.002)	0.0108***	(0.002)	0.0109***	(0.002)
Estimated year built (eyb)	0.0002	(0.000)	0.0002	(0.000)	0.0002	(0.000)	0.0002	(0.000)
Air conditioning	0.0723***	(0.017)	0.0725***	(0.017)	0.0724***	(0.017)	0.0723***	(0.017)
Fireplaces	0.0227***	(0.006)	0.0228***	(0.006)	0.0226***	(0.006)	0.0224***	(0.006)
Rooms	0.0051*	(0.003)	0.0051*	(0.003)	0.0051*	(0.003)	0.0051*	(0.003)
Bathroom	0.0648***	(0.004)	0.0648***	(0.004)	0.0649***	(0.004)	0.0652***	(0.004)
Half bathroom	0.0278***	(0.005)	0.0278***	(0.005)	0.0278***	(0.005)	0.0278***	(0.005)
Sqft	0.0002***	(0.000)	0.0002***	(0.000)	0.0002***	(0.000)	0.0002***	(0.000)
Stories	0.0002***	(0.000)	0.0002***	(0.000)	0.0002***	(0.000)	0.0002***	(0.000)
Grade	0.0397***	(0.010)	0.0397***	(0.010)	0.0397***	(0.010)	0.0397***	(0.010)
Condition	0.1233***	(0.007)	0.1233***	(0.007)	0.1231***	(0.007)	0.1232***	(0.007)
Kitchens	− 0.0291	(0.018)	− 0.0288	(0.018)	− 0.0282	(0.018)	− 0.0281	(0.018)
Public school	0.0072**	(0.003)	0.0071**	(0.003)	0.0068**	(0.003)	0.0064**	(0.003)
Metro area	0.0229	(0.013)	0.0227	(0.013)	0.0220	(0.013)	0.0222	(0.013)
Landmark	0.0029***	(0.001)	0.0029***	(0.001)	0.0028***	(0.001)	0.0028***	(0.001)
Percentage_adult	0.3242**	(0.131)	0.3214**	(0.131)	0.3144**	(0.130)	0.3078**	(0.129)
Percentage_educated	0.5133***	(0.113)	0.5046***	(0.114)	0.4819***	(0.114)	0.4650***	(0.116)
Percentage_unemp	− 0.4268***	(0.136)	− 0.4306***	(0.136)	− 0.4365***	(0.135)	− 0.4387***	(0.137)
Constant	11.4146***	(0.882)	11.4154***	(0.879)	11.4058***	(0.862)	11.4174***	(0.846)
Other controlled variables	Heat type, land use type, structure type, interior and exterior wall type, roof type, number of traffic and crime incidents, number of charter schools, population density, % Hispanic population, % high-income households, poverty rate							
Zip code dummies	✓		✓		✓		✓	
Period dummies	✓		✓		✓		✓	
Cluster *SE*	✓		✓		✓		✓	
N	12,680		12,680		12,680		12,680	
R^2	0.8095		0.8095		0.8097		0.8099	
Panel B: Fixed-effects model at census tract level (dependent variable: average logarithm of property price)								
Airbnb density	0.0060	(0.008)	0.0078*	(0.003)	0.0037**	(0.001)	0.0012***	(0.000)
Other controlled variables	Land area, estimated year built, air conditioning, fireplaces, rooms, bedrooms, bathrooms, half-bathrooms, sqft, stories, grade, condition, heat type, land use type, structure type, interior and exterior wall type, roof type, number of traffic and crime incidents, constant							
Period dummies	✓		✓		✓		✓	
N	7,624		7,624		7,624		7,624	
N blocks	2,378		2,378		2,378		2,378	
R^2	0.3905		0.3910		0.3923		0.3925	
Panel C: First-difference model at census tract level (dependent variable: average logarithm of property price)								
Airbnb density	0.0212	(0.016)	0.0136*	(0.008)	0.0103***	(0.002)	0.0031***	(0.001)
Other controlled variables	Land area, estimated year built, air conditioning, fireplaces, rooms, bedrooms, bathrooms, half-bathrooms, sqft, stories, grade, condition, heat type, land use type, structure type, interior and exterior wall type, roof type, number of traffic and crime incidents, constant							
After	0.0283	(0.017)	0.0275	(0.017)	0.0249	(0.017)	0.0240	(0.017)
N	2,047		2,047		2,047		2,047	
N blocks	1,027		1,027		1,027		1,027	
R^2	0.3704		0.3712		0.3804		0.3792	

Note. SE = standard error. The robust standard error is given in parentheses.
*$p < .1$. **$p < .05$. ***$p < .01$.

Table A4. Aggregate impact of Airbnb on property price by zip code.

	200-ft		500-ft		1,000-ft			
Zip code	Density	Impact (%)	Density	Impact (%)	Density	Impact (%)	Hispanic (%)	Black (%)
20001	2.61	2.04	15.33	5.67	55.49	6.66	9.22	50.75
20002	1.51	1.18	8.78	3.25	32.45	3.89	4.39	61.33
20003	1.45	1.13	8.64	3.20	31.37	3.76	5.12	36.41
20005	2.68	2.09	24.23	8.97	102.09	12.25	16.77	15.17
20007	0.79	0.62	4.92	1.82	17.72	2.13	7.12	3.12
20008	0.41	0.32	2.53	0.94	9.74	1.17	7.67	5.10
20009	3.43	2.68	20.63	7.63	79.21	9.51	15.13	20.69
20010	1.89	1.47	11.41	4.22	43.68	5.24	30.11	31.07
20011	0.44	0.34	2.7	1.00	10.11	1.21	21.18	65.31
20012	0.21	0.16	1.4	0.52	4.71	0.57	11.22	64.29
20015	0.17	0.13	1.09	0.40	3.54	0.42	6.52	9.00
20016	0.15	0.12	0.98	0.36	3.55	0.43	7.30	4.25
20017	0.35	0.27	2.15	0.80	7.54	0.90	6.49	71.42
20018	0.16	0.12	1.05	0.39	4.21	0.51	5.87	85.08
20019	0.15	0.12	0.7	0.26	2.16	0.26	2.41	94.98
20020	0.21	0.16	1.32	0.49	4.44	0.53	1.41	95.00
20024	0.7	0.55	5.62	2.08	18.11	2.17	5.16	54.50
20032	0.07	0.05	0.38	0.14	1.12	0.13	2.33	90.00
20036	4.36	3.40	29.64	10.97	86.79	10.41	7.62	7.78
20037	3.2	2.50	19.97	7.39	65.79	7.89	5.77	6.32
DC	0.85	0.66	5.06	1.87	18.63	2.24	9.10	50.03

Table A5. Robustness check using entire-unit Airbnb listings with reviews.

	100 ft buffer		200 ft buffer		500 ft buffer		1,000 ft buffer	
Variable name	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*
Panel A: Pooled cross-sectional model (dependent variable: average logarithm of property price)								
Airbnb density	0.0140	(0.008)	0.0071*	(0.003)	0.0028**	(0.001)	0.0011***	(0.000)
N	12,680		12,680		12,680		12,680	
R^2	0.8091		0.8091		0.8092		0.8092	
Panel B: Fixed-effects model at census tract level (dependent variable: average logarithm of property price)								
Airbnb density	0.0096	(0.011)	0.0086*	(0.005)	0.0033**	(0.001)	0.0008***	(0.000)
N	7,624		7,624		7,624		7,624	
N blocks	2,378		2,378		2,378		2,378	
R^2	0.3906		0.3909		0.3913		0.3910	
Panel C: First-difference model at census tract level (dependent variable: average logarithm of property price)								
Airbnb density	0.0258	(0.022)	0.0050	(0.011)	0.0057*	(0.003)	0.0017*	(0.001)
N	2,047		2,047		2,047		2,047	
N blocks	1,027		1,027		1,027		1,027	
R^2	0.3705		0.3698		0.3718		0.3715	

Note. *SE* = standard error. The robust standard error is given in parentheses.
$^*p < .1$. $^{**}p < .05$. $^{***}p < .01$.

Table A6. Empirical results for median rent price at the zip code level.

	100 ft buffer		200 ft buffer		500 ft buffer		1,000 ft buffer	
Variable name	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*
Panel A: Fixed-effects model at the zip code level (dependent variable: logarithm of median rent price)								
Airbnb density	− 0.0002	(0.016)	0.0065	(0.005)	0.0011	(0.001)	0.0004	(0.000)
Other controls	Land area, estimated year built, air conditioning, fireplaces, rooms, bedrooms, bathrooms, half-bathrooms, sqft, stories, grade, condition, number of traffic and crime incidents, constant							
N	119		119		119		119	
N Zip codes	20		20		20		20	
R^2	0.4202		0.4310		0.4283		0.4373	

Note. SE = standard error. The robust standard error is given in parentheses.
$^*p < .1$. $^{**}p < .05$. $^{***}p < .01$.