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How short-term rentals are changing the neighborhood

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Abstract

This paper examines how short-term rentals are changing living conditions and the composition of the population in the affected parts of the town. First, to analyze the relation between quality, distance, and rents, we develop two different models: an urban economics model and a non-spatial housing market model. Second, in an exploratory study for the city of Berlin (Germany) in 2019 for 200 m networks, we show that the proportion of poor quality and noisy residential units on average correlates negatively with the probability of Airbnb listings and the number of these listings, but positively near the city center. Third, applying fixed effect and IV strategies, we investigate the impact of Airbnb listings on living conditions and the composition of the population in the almost 450 planning areas of Berlin in the years 2016-2019. We show that Airbnb offers increase the number of residents with long periods of residence and reduces the number of residents in poor quality residential environments, but we do not find above average effects on socially weak groups. *Keywords*: Short-term rental, Airbnb, housing markets, gentrification *JEL Classification*: R21, R31, Z32

1 Introduction

In metropolitan areas with knowledge-based industries and in cities with natural and manmade amenities, rents and property prices have been rising for years. Life in these regions is becoming unaffordable not only for the low-skilled and families, but increasingly also for the middle class. The affordability crisis has negative economic, social and political consequences. The demographic development (aging, immigration, shrinking household size) and increasing positive agglomeration effects are primarily responsible for the price increase. In addition, short-term rentals to business travelers, but above all to tourists, via platforms (particularly Airbnb) that have been brokered since the beginning or mid-2010s have increased. Housing is being converted: Apartments and rooms for travelers are being converted from apartments that are used for the long term. Short-term rentals are squeezing housing for regular tenants and further increasing rents and property prices (Horn and Merantea, 2017; Barron et al., 2018; Ayouba et al., 2020; Garcia-López et al., 2020; Koster et al., 2019; Chen et al., 2019). Externalities associated with noise in particular have a negative impact on residents (Filippas and Horton, 2018). Not only residents, but also hotels, whose competitive position is deteriorating, are affected by platform-mediated short-term rentals of apartments and rooms (Zervas et al., 2017). For tourists, traveling to attractive destinations is easier and cheaper (Tussyadiah and Pesonen, 2016). The residents of the affected districts fear competition on the housing market and suffer from overcrowding. The rapid development of short-term rentals of apartments and rooms in residential areas is the subject of fierce public debate and is provoking political counter-reactions. The supposed beneficiaries of such regulation are urban voters; Airbnb beneficiaries do not have voting rights in the communities. Therefore, short-term rentals are increasingly restricted by regulation (Hajibaba and Dolnicar, 2018; Aguilera et al., 2019).

The political explosiveness of short-term rents is exacerbated by the fact that they are likely to displace residents socially selectively and thus promote gentrification (Wachsmuth and Weisler, 2018). On the one hand, short-term rented residential units are not evenly distributed across the city area, on the other hand, the selection of the newly built or converted residential units for this purpose is not random, but is determined by economic considerations. The decisive factor is whether high-quality or low-quality living space is used for short-term rentals and whether economically weaker or stronger residents are being squeezed out of the attractive residential areas. An analysis of the decision-making situations of landlords, tenants and homeowners allows conclusions to be drawn as to which social groups are being pushed out by new forms of short-term rentals: tenants with low credit ratings and unstable living conditions. Unlike tenants, homeowners benefit from higher prices. Owner occupiers are less likely to reallocate their homes from the long- to the short-term rental market (Barron et al., 2018). Therefore, tenants are displaced rather than homeowners and thus people with a rather low income. Landlords opt for short-term rental if the property is not suitable for regular renting or the transaction costs for new rentals and monitoring are low. Individual rooms and complete apartments with high levels of noise pollution or in poor condition, which tenants are only willing to accept temporarily, are badly suited for permanent rentals. However, apartment quality also has a negative impact on rentability and rent for short-term rentals. Short-term rental contracts are also only suitable for rent-oriented landlords who are not interested in the social environment of the apartments. Apartments that have a comparative advantage for being rented out to travellers are otherwise likely to be rented primarily by socially and economically weak people due to the associated apartment characteristics. Members of this group of people are disadvantaged on the rental apartment market compared to tenants with a higher credit rating and often have to accept comparatively expensive apartments.

In this paper, we investigate whether short-term rental contracts tend to replace permanent use in low-quality rather than high-quality apartments and tend to displace economically weak rather than strong people in the city of Berlin.

First, to hypothesize on the effects of short-term rentals on housing markets and sociodemographics in affected neighborhoods, we develop two different models: an urban economics model with housing quality and a simple non-spatial housing market model. From the urban economics model we learn that the displacement effects of platform-based housing offers vary in size for different apartment qualities and locations. Unsurprisingly, based on realistic assumptions about the importance of travel costs for tourists and business people on the one hand and regular tenants on the other hand, the model shows that Airbnb will push out regular tenants closest to the city center the most. However, it can also be derived from the model that the strength of the displacement effects for different quality segments of the housing market depends on the proximity to the center and that the direction and strength of this relationship depend on the underlying willingness to pay for quality of Airbnb users. The non-spatial housing model, which focusses on the heterogeneity of preferences of short-term renters as compared to long term renters, shows not surprisingly that additional short-term rentals increase rents and reduce regular rentals. Less obvious, the change is more pronounced in the market segment in which the variance in regular rents is smaller, which is most likely the low-quality housing-market segment. From the model, we also conclude that an increase in short-term renters has stronger negative effects on the number of regular tenants in those areas where short-term renters care less about housing quality, which are most likely the easily accessible neighborhoods in the city center.

Second, in an explorative study for the city of Berlin (Germany) in 2019, controlling for distance to the center, land values, and land use regulation, we demonstrate for 200m grids that on average the share of poor quality and noisy housing units is negatively correlated with the probability of having Airbnb listings and the number of those listings. However, in line with the predictions from the theoretical model, close to the city center, poor quality and noisy housings are positively correlated with Airbnb listings.

Third, to identify the causal effect of Airbnb listings on average housing conditions and the composition of the population in the affected neighborhoods, we employ a two-way fixed-effect approach and an instrumental-variable approach. Using the spatial structure of listings in other European cities as instruments for Airbnb listings in Berlin, we purge the estimates from Berlin-specific spatial relations between Ainbnb listings and residential environment characteristics. We show that more offers of short-term housing via Airbnb increase the number of residents with long periods of residence, reduce the number of residents in poor quality residential environments. From this we conclude that short-term leasing via platforms changes the living space available for regular tenants and also has an impact on fluctuation. However, we could not identify any specifically affected socially weak groups.

With this paper we primarily contribute to research into the causes of gentrification in attractive inner-city areas. By focusing on platform mediated short-term rentals and apartment quality, relationships are addressed that have not yet been sufficiently analyzed in the literature. The paper shows theoretically and empirically that platform mediated short-term rentals have different effects on apartments of different quality. Due to the increasing displacement of residents of simple dwellings and dwellings with greater noise pollution as well as dwellings with greater fluctuations, short-term rentals to tourists and business people are increasing gentrification - especially in the city center's districts. Since Airbnb is the dominant platform for short-term rents, the paper specifically contributes to the discussion about increased gentrification by Airbnb.

The paper is organized as follows. Section 2 provides a short literature review. To support our basic hypotheses, Section 3 develops the theoretical background. Section 4 presents the data and institutional background. Section 5 shows explorative results on the number of Airbnb listings. Then, Section 6 develops the empirical model on the causal effects of Airbnb listings and Section 7 describes the results. Section 8 draws conclusions from these findings.

2 Literature review

The tourism economics literature analyzes the determinants of short-term-rental demand and supply. Using a data set of all Vienna Airbnb listings for one year, Gunter and Önder (2018) show that listing size, number of photos, and responsiveness of the host are positively, but listing price, distance from the city center, and response time of the host are negatively correlated with Bookings via Airbnb. Employing a mixed-effects negative binomial model, Yang and Mao (2018) analyze determinants of Airbnb supply for 28 major US cities and also demonstrated that stricter regulation significantly decreases Airbnb unit supply. Benítez-Aurioles (2018) illustrates for the Spanish cities of Barcelona and Madrid the negative effect of distance to the center on Airbnb demand. In a 2SLS regression, she finds a similar price elasticity of demand in both cities but greater sensibility of demand with respect to distance to the center in Barcelona than in Madrid.

Economists also examine how the sharing economy affects the hotel industry. Analyzing Airbnb's entry into the state of Texas, Zervas et al. (2017) find that Airbnb has a substantial detrimental impact on hotel revenue. Cheap hotels and hotels in which only tourists stay are most affected. Hotel prices fall most sharply in times of particularly high demand. Estimating a model of competition between price-setting hotels and and price-taking peer hosts with data from major US cities, Farronato and Fradkin (2018) study welfare effects of Airbnb. They show that welfare gains are concentrated in places and times when hotels are capacity constrained. As Zervas et al. (2017) discovered, Farronato and Fradkin (2018) find that peer hosts expand supply and keep hotel prices low especially at peak times.

The urban economics literature focuses on the impact of Airbnb on housing rents and prices. Analyzing the growth of Airbnb in Boston neighborhoods, Horn and Merantea (2017) show that an increase in Airbnb listings is associated with an increase in asking rents. Using the number of establishments in the food service and accommodations industry interacted with the Google search interest as instrument, Barron et al. (2018) demonstrate for the entire United States that Airbnb has a positive impact on house prices and rents which is stronger if the share of owner-occupiers is low. Then also show that the total supply of housing is not affected by the entry of Airbnb. Estimating a hedonic equation for each single city on individual data for apartments, Ayouba et al. (2020) show that the density of Airbnb rentals puts upward pressure on rents in some French cities, but has no significant effect in other cities. Employing panel fixed-effects models with neighborhoodspecific time trends, an instrumental variable shift-share approach with proximity to tourist amenities as instrument, and event-study designs, Garcia-López et al. (2020) show that, in the city of Barcelona, Airbnb has raised rents and transaction prices. The estimated impact in neighborhoods with high Airbnb activity is substantial. Using home sharing ordinances as quasi-experiment and applying a panel regression-discontinuity design around the cities' borders and a difference-in-difference approach, Koster et al. (2019) show for Los Angeles County that ordinances reduced listings, housing prices and rents substantially. Taking advantage of the regulatory differences across the city and employing a differencein-discontinuity approach, Valentin (2020) demonstrates for New Orleans that short-termrental regulation has strong spatial spillover effects as usage in neighboring areas near those most impacted by the regulated areas increase. Leveraging a city specific Airbnb-platform policy in New York City, San Francisco, and Portland that caps the number of properties a host can manage in a city, Chen et al. (2019) find that rents in the rental market and home values in the housing market dropped after the platform policy was introduced, whereas the price-to-rent ratio stayed relatively constant over time. More broadly, urban economists also examine the effect of housing for tourists on local economic development. For example, analyzing the 'Swiss Second Home Initiative', which banned the construction of new second homes in desirable tourist locations, Hilber and Schöni (2020) show that the ban substantially reduced (increased) primary (secondary) home prices and increased unemployment in the affected areas.

There is also great interest among sociologists and economists in the social balance of the effects of increased short-term rentals. Examining the short-term-rental market in New York City, Wachsmuth and Weisler (2018) claim that Airbnb induces gentrification. They argue that Airbnb has introduced revenue flow into housing markets which is systematic but geographically uneven, creating a new form of rent gap in culturally desirable and internationally recognizable neighborhoods.

3 Theory on quality selection

For the theoretical analysis of the relationship between short-term rentals and apartment quality, we present two models, the first of which is based on the differences in the trade off between quality and distance between short-term and regular tenants, and the second on the comparatively great heterogeneity of preferences of regular tenants.

3.1 Trade off between quality and distance

To model the trade-off between housing quality and distance, we set up a standard urban model. We consider a monocentric linear city with two types of households. Each household derives utility, u, from consumption, x, housing, h, and housing quality, q. The utility function, u(x, h, q) is strictly quasi-concave in consumption and housing. The price for housing of quality, q, at distance from the center, d, is denoted p(q, d). The bid rent, $\psi(q, d)$, gives the maximum price the household is willing to pay for one unit of housing of a given level of quality at a certain distance (see Fujita, 1989); it solves for a household with income, y, and travel costs, T(d), with T'(d) > 0, the optimization problem

$$\psi(q,d) = \max_{h} \left\{ \frac{y - \tilde{x}(h,q,u) - T(d)}{h} \right\},$$
(1)

where $\tilde{x}(h, q, u)$ is derived from u(x, h, q) = u. The envelope theorem implies

$$\frac{\partial \psi(q,d)}{\partial q} = -\frac{1}{h} \frac{\partial \tilde{x}}{\partial q} > 0 \quad \text{and} \quad \frac{\partial \psi(q,d)}{\partial d} = -\frac{T'(d)}{h} < 0.$$
⁽²⁾

The bid rent increases as quality increases because for a given utility level the consumption level declines. For longer distance, travel costs are higher and, therefore, the bid rent for housing is lower.

To illustrate the relationship between quality, distance and bid rents, we consider two different household types and assume Cobb-Douglas utility, $u = x^{\alpha} h^{\beta} q^{\gamma}$, with $0 < \alpha, \beta, \gamma < \beta$ 1. Household type 2 is richer and has a higher preference for quality, but also faces lower travel costs.¹ Figure 1 shows iso-bid-rent curves for both households. Since household 1 faces higher travel costs, its marginal rate of substitution of quality for proximity is larger than for household 2 and, therefore, at the intersection point of the two bid-rent curves, its iso-bit-rent curve is steeper. Figure 2 shows the bid rents as functions of quality for a given rather high level of distance². Household 2's willingness to pay for housing increases with increasing quality more than household 1's. At a relatively large distance from the center, household 2's willingness to pay for high-quality housing is greater than that household 1's. In contrast, at the city center, household 1 is willing to pay more for high quality housing than household 2. Figure 3 depicts the bid-rent curves for low and high quality³ for both households. In the distance range [0, A), household 1 outbids household 2 for low and high-quality dwellings; in the area beyond B it is the other way round. For intermediate distances, namely for (A, B), household 1 outbids household 2 for low-quality housing, but household 2 is willing to pay more than household 1 for high-quality housing.

Next, we consider the urban equilibrium in a symmetric open linear monocentric city with two types of households with perfect mobility, modelled as continuums of agents, where the utility level of each household type is determined outside the city and $d \in [0, \overline{d}]$. Furthermore, we focus on the short run where the housing stock already exists. We allow for unit size adjustments, but not for quality adjustments. Hence, for every distance from the city center there are given housing stocks of low and high quality, q_l and q_h . We

¹For simulations we assume linear travel costs, T = td, and $y_1 = 10$, $t_1 = 2$; $u_1 = 5$, $\alpha_1 = 0.5$, $\beta_1 = 0.3$, $\gamma_1 = 0.12$, $y_2 = 20$, $t_2 = 1.2$; $u_2 = 6$, $\alpha_2 = 0.4$, $\beta_2 = 0.3$, $\gamma_2 = 0.2$.

 $^{^{2}}d_{0} = 1.6$

 $^{{}^{3}}q_{l} = 1, q_{h} = 2$

define a short-run equilibrium as a set of housing prices for every distance within the city's boundaries: $(p(q_l, d), p(q_h, d))$ that induces the population and the individual demand of both household types to adjust such that the housing market for both quality levels and every distance clears:

$$\psi_i(q_j, d) \le p(q_j, d), \quad i = 1, 2; j = l, h; d \in [0, \bar{d}],$$
(3)

$$\psi_i(q_j, d) < p(q_j, d) \Rightarrow n_i(q_j, d) = 0, \quad i = 1, 2; j = l, h; d \in [0, \bar{d}],$$
(4)

$$h_1(q_j, d)n_1(q_j, d) + h_2(q_j, d)n_2(q_j, d) = H(q_j, d), \quad j = l, h; d \in [0, \bar{d}],$$
(5)

where $n_i(q_j, d)$ denotes the mass of households of type *i* living in a dwelling of quality level q_j at distance *d*, $h_i(q_j, d)$ the individual housing demand, and $H(q_j, d)$ the respective available housing stock. The total mass of households of type *i* is endogenously determined as $N_i = 2 \int_0^{\bar{d}} [n_i(q_l, d) + n_i(q_h, d)] dd$ and utility is exogenously given as u_i .

If Figure 3 showed equilibrium bid-rent curves, households of type 1 would live in high-quality dwellings in the area [0, A] and in low-quality dwellings in the area [0, B], whereas households of type 2 would reside in high-quality dwellings in the area $[A, \bar{d}]$ and in low-quality dwellings in the area $[B, \bar{d}]$ (on both sides of the city center).

More generally, Equation (2) implies that the bid rent is the steeper, the higher the marginal travel expenses, the lower the level of utility and the higher the income. At every intersection of bid-rent curves, the household type with the steeper bid-rent curve lives closer to the center than the other household type.

Now we are applying this model to Airbnb rentals. The reference situation is a shortterm equilibrium, in which only type 2 households, the regular tenants, live in the city and use the entire living space.⁴ When type 1 households enter the city through Airbnb, they completely displace type 2 households near the center and partially in a medium-distant area. The composition of the population does not change on the outskirts. In the center, both type 2 tenants of low quality apartments and type 2 tenants of high quality apartments are displaced, in the middle area only type 2 residents of low quality apartments. Overall, the crowding-out effect is stronger for tenants of low quality apartments than for high quality apartments, but it is not equally strong everywhere.⁵

⁴The short-run equilibrium for a single household type is defined accordingly.

⁵These results hold not only for Cobb-Douglas utility if travellers have comparatively high travel ex-

The general message of this model is that the crowding-out effects of platform-based housing offers for short-term tenants vary in size for different apartment qualities and locations. Assuming that the inner-city travel times and costs are of comparatively great importance for short-term tenants compared to the quality of the apartment, this model supports the specific hypothesis that apartment offers for travelers via platforms such as Airbnb displace regular tenants closer to the center than to the outskirts.

With the additional assumption that travelers are generally less willing to pay for quality than regular tenants (as assumed in Figure 3), we can derive from this model the specific hypothesis that in medium distance to the center primarily regular tenants of low quality apartments are displaced. This also implies that the proportion of low-quality housing displacements in the majority of neighborhoods is greater than the proportion of high-quality housing displacements. If travelers were generally more willing to pay for quality (as assumed in Figure 4)⁶, in medium distance to the center, platform rents would primarily displace regular tenants of high quality apartments.

3.2 Differences in preference heterogeneity

To analyze the effect of differences in the heterogeneity of preferences for quality between short-term renters and regular tenants, we develop a simple non-spatial housing-market model. We consider a city with two separate housing-market segments, low and high quality housing, and suppose that the numbers of low-quality and high-quality units, f_l and f_h , are given. Both types of apartments can be rented to city dwellers in the long term or to tourists in the short term. Assuming no vacancies, the endogenous numbers of long-term and short-term renters, n_i and m_i , of units of quality *i* add up to the number of the respective housing units:

$$f_i = n_i + m_i, \qquad i = l, h.$$
(6)

To simplify the notation, the rental period for long-term rentals is standardized to one year. The corresponding rents of short- and long-term rentals, converted into annual rents, are

penses and sufficiently great financial resources.

 $^{^{6}\}gamma_{1} = 0.3$

denoted by r_i and p_i , i = l, h. For each new lease with short-term tenants there are costs, κ_i , i = l, h, the amount of which may depend on the quality of the apartment and may include the vacancy costs. For the sake of simplicity, it is assumed that k short-term rents per year are possible regardless of the quality of the apartment. The total number of shortterm tenants, m, is an exogenous factor that depends on the attractiveness of alternative travel destinations. For travelers, apartments of different quality are imperfect substitutes, but apartments of the same quality are perfect substitutes. Converted to the year, they each achieve quality-dependent benefit with money equivalents of α_l and α_h , with $\alpha_h > \alpha_l$. In an interior equilibrium, short-term rents must be so high that the traveller's utility, $v_i = \alpha_i - p_i$, i = h, l, i.e., the difference between benefits and rents, is the same for both apartment types:

$$v_h = v_l \,. \tag{7}$$

Short-term tenants of both types of housing units add up to the total number of travelers:

$$m = m_l + m_h \,. \tag{8}$$

For the city dwellers, however, the apartments of the same quality are only imperfect substitutes, so that different rents can be achieved for the various apartments on the longterm rental market. The achievable rents r_i , i = l, h, are uniformly distributed with density β_i on the interval $[r_i^0, r_i^1]$, i = l, h, for the given housing stock, so that in the absence of short-term rents $f_i = \beta_i (r_i^1 - r_i^0)$, i = l, h, holds. The higher the parameter β_i is and the more narrow the interval $[r_i^0, r_i^1]$ is, the less diverse the units of the housing stock are and the less dispersed the rent distribution is. A single landlord is indifferent between leasing out a unit of quality *i* short term and long term if and only if

$$\hat{r}_i = p_i - k\kappa_i, \qquad i = l, h.$$
(9)

Taken the distributions of long-term rents into consideration, Equation (9) determines the relationship between the critical long-term rent, \hat{r}_i , and the number of short-term renters, $f_i - n_i = m_i = \beta_i (\hat{r}_i - r_i^0), i = l, h$, implying

$$\hat{r}_i = \frac{f_i - n_i}{\beta_i} + r_i^0, \qquad i = l, h.$$
 (10)

The indifference conditions of travelers and landlords, Equations (7) and (9), determine together with the adding-up conditions for housing units and travelers, Equations (6) and (8), and the critical long-term rent condition, Equation (10), the endogenous variables $p_l, p_h, \hat{r}_l, \hat{r}_h, m_l, m_h, n_l$ and n_h in an interior equilibrium that we assume exists. Differentiating this system of equations with respect to the total number of short-term rentals, m, leads to

$$\frac{\partial p_l}{\partial m} = \frac{\partial p_h}{\partial m} = \frac{1}{\beta_l + \beta_h} \quad \text{and} \quad \frac{\partial n_i}{\partial m} = -\frac{\partial m_i}{\partial m} = -\frac{\beta_i}{\beta_l + \beta_h}, \quad i = l, h.$$
(11)

An influx of travelers increases short-term rents, p_i , and, therefore, also critical levels of long-term rents, \hat{r}_i , and average long-term rents, $(r_i^1 + \hat{r}_i)/2$, independent of the quality level. Accordingly, regular tenants are being replaced by short-term tenants in both residential market segments. More interestingly, the change is more pronounced in the market segment in which the distributional parameter, β_i , is larger, i.e., the variance in long-term rents is smaller. Since in the real world apartments in the market segment of high-quality apartments differ more from each other, the range of rents in this segment is comparatively large. Hence, this model can be used to substantiate the hypothesis that in every city a general increase in short-term leases is more likely to displace tenants from low-quality apartments. Similar results can also be achieved if heterogeneity of transaction costs for short term leases instead of long-term rents is assumed and the range of transaction costs in the segment of low-quality apartments is relatively small. When the results of this model are applied to neighborhoods, it can be seen that those neighborhoods experience a greater displacement of poor quality housing where the range of high quality housing is wider. Whether these will be more inner-city areas or suburbs is a question that needs to be answered empirically.

4 Institutions and data

Berlin is the capital and the largest city of Germany with 3.75 million inhabitants (June 30, 2019). Most people live in Berlin for rent, the home ownership rate was less than 20% in 2017 (Voigtländer and Sagner, 2019). Rents in Berlin were lower in 2009 than in many other German cities, but have risen sharply since then due to the strong internal and

international migration and low construction activity. Berlin had reached a similar rent level to Hamburg in 2019 and only in Munich, Frankfurt and Stuttgart was the rent level significantly higher. From 2009 to 2019, the average offered rent (excluding heating costs) increased by 104% in Berlin and only 62% in Munich (immowelt AG, 2019). To protect tenants, the rental market in Germany is strictly regulated. Rental contracts are generally unlimited and can only be terminated by the landlord in justified exceptional cases. Rent increases may not exceed certain limits. The rental law has been tightened several times in recent years, so that since 2015 upper limits for rents have also applied to newly concluded rental contracts (so-called "rent price brake", for an analysis of this instrument, see Mense et al., 2019). The rent index defines reference values for these upper limits, which differ according to the quality of the living environment, the year of construction, the size and certain characteristics of the dwelling and are regularly adjusted.

Since the 2001 administrative reform, Berlin has been made up of 12 districts. For urban planning purposes, the city is divided into three levels of areas: 60 prediction areas, 138 district areas, and 447 planning areas (December 31, 2018). The units were derived from social units, which respect natural or man-made borders, like for example, main roads or rivers. The areas were formed in such a way that on the one hand they ensure homogeneity and on the other hand they are sufficiently large to guarantee anonymity. On January 1, 2019, a new planning area was set up for a recently developed area and the boundaries of three existing planning areas were slightly changed. For our analysis, we choose the highest spatial resolution available and use social and geographical data for planning areas.

Our work is mainly based on data sets on Airbnb listings in various cities including Berlin, on population data of planning areas in Berlin, and on geodata. First, we got monthly data on Airbnb listings in Berlin and various other European cities from Inside Airbnb (cc0 1.0), starting in 2015 – different starting months in different cities. The monthly data on Airbnb offers that we use include data about the unit offered for shortterm renting (in particular, room type and price), on the host, and on the geocoded location of the unit provided by Airbnb, but also on the neighborhood where the unit is located. Since the Platform Airbnb coarsens the location of the objects in the public object descriptions, we cannot carry out an analysis at the level of the individual objects with exact geocoding. Since the Airbnb listings for Berlin have only been available since October 2015, we leave out 2015 in our impact analysis based on annual data.⁷

Second, the Statistical Office for Berlin-Brandenburg provides annual population data for planning areas in Berlin (cc-by, 4.0) which we accessed via www.govdata.de. The Statistical Office for Berlin-Brandenburg provides annual data for planning areas on housing conditions, total population, on the gender and age distribution, on the number of foreigners and on persons with migration background from 2014 until 2019 (Amt für Statistik Berlin-Brandenburg, 2019). For most data, data from previous years are also provided, which, however, we do not use for our analysis.

Third, the Senate Department for Urban Development and Housing of Berlin provides geodata for Berlin (Geoportal Berlin, 2019; Umweltatlas Berlin, 2019), including shapefiles of districts and planning areas and web feature services on housing units. These data enable us to calculate distances between the centroids of the planning areas and the city center, but also between each single unit offered for short-term renting and any location in Berlin we are interested in. To this end, we use the data on housing units prepared for rental control measures (394889 units). These data include a categorical variable on residential environment quality (Wohnlage) and a binary variable variable that indicates whether there is substantial noise pollution or not. Furthermore, we can determine in which planning area each listed unit is located.⁸ Moreover, we use data on standard land values (Bodenrichtwerte) collected by the committee of experts on land values (1129 spatial units), data on the of floor area ratios (FARs) and the building coverage ratios (BCRs) taken from the cadastral land register (25352 spatial units), data on the period of construction taken from the census 2011 and data on the completion of the buildings 2011-2015 provided by the Statistical Office for Berlin-Brandenburg (13091 spatial units).

⁷Since there were no offers available for March 2016 either, we are excluding data for Berlin for the entire period for each March.

⁸If the offer includes only imprecisely measured location data, our data suffer from measurement error. However, we assume that the measurement error is neither systematically linked to certain planning areas nor to the number of offers.

5 Explorative analysis of the probability of short-term rentals

Airbnb listings are not randomly distributed across Berlin, as Figure 5 demonstrates for 2019. In this section, we examine the likelihood that at least one unit has been listed on Airbnb in 2019 in the area of interest and the number of these listings. The observations of our estimate are 200m×200m grid units in Berlin (22954 observations). In part of the analysis, the dependent variable is a binary variable with the value 1 if an offer on Airbnb was listed in this grid unit at least once in 2019. Otherwise the value is 0. In the other part of the analysis, the dependent variable is the number of Airbnb listings in the respective grid unit in 2019. To analyze the likelihood of Airbnb listings, we perform binary logistic regressions. To examine the magnitude of listings, we carry out OLS regressions.

The focus of our interest is the quality of the residential environment. We measure the quality of the residential area using the shares of housing units with high quality residential environment, average quality residential environment, and poor quality residential environment. We differentiate between housing units that are exposed to noise pollution and those in quiet surroundings. In the end, we have six variables that indicate residential environment quality: noisy poor quality share, silent poor quality share, noisy average quality share, silent average quality share, noisy high quality share, and silent high quality share. The latter is our reference category. We also account for the total number of addresses in the grid unit (addresses). To illustrate the pattern of addresses and Airbnb listings, Figure 6 show them for a grid unit close to the city center and the surrounding area.

Since locations of Airbnb listings are coarsed in our data, a housing unit that is offered for short-term rent actually might be located not in the grid it is assigned to, but in a neighboring grid. To account for these spatial spillovers, we include the total number of addresses in the eight neighboring grid units as controls (neighboring grid units' addresses). In order to capture accessability, we include the distance to city center, which is of interest to both tourists and business people, as a control variable (distance center). In all specifications, we also include district fixed effects. We also consider the floor area ratio, the building coverage ratio, and the standard land value in the respective smallarea as control variables, since we assume that higher and denser buildings will increase the number of residential units available for short-term rentals. However, the direction of the relation between short-term rental and higher land values is not obvious, since better conditions for both regular and short-term renting can increase the land value. Since the reference values for rent increase over time, which are determined by the rent index in Berlin, depend on the period of construction, the period of construction also determines the landlord's scope for regular rents. To control for this relation, in some robustness test, we use construction-period fixed effects (not explicitly shown in the paper).

For many grid units, zoning rules that do not allow housing, e.g., forests and parks, but also industrial zones, apply. Around 64% of the grid units are, at least partially, intended for residential use (residential zone). However, since exceptions are possible to a limited extent, we also observe residential use in areas that are actually reserved for other purposes. In addition, the information on the type of use is only available at the block level, so that measurement errors occur due to the necessary assignment to grid units. For 66% of the grid units, we have actually addresses. The remaining grid units are not taken into account in the regressions. 10% of the grid units considered are not in a residential zone.

Table 1 shows coefficients of the binary logistic regressions. Model 1 includes the housing quality shares, total number of addresses, distance to the center, and as additional controls FARs, BCRs, and standard land values. In addition Model (2) also includes interactions of quality shares and distance to the center. First, all variables have consistent plausible coefficient signs across the two specifications, which increases confidence in the chosen models. Distance between the location and the city center has the expected negative effect on short-term rental offers. The positive coefficient of the FAR reflects the greater availability of space. In contrast, a higher BCR has a negative effect on listings, probably because more dense areas are less attractive. Higher local land values make short-term use more likely. More addresses available for housing in the considered grid and the neighboring grids increase the likelihood of listings as expected. Second, also the coefficients of the main variables of interest, the quality shares, are consistent. The share of silent high quality environment, i.e., the share of the highest quality segment, is the reference category. As compared to the reference category, on average, silent poor and average quality housing

units are less likely to be chosen for short-term rentals. Noise seems to neutralize the quality aspect, all noisy categories have no significant effects. Model (2), which includes interactions with distance to the center, reveals that at the city center both poor and average quality have a positive effect on the likelihood of being listed whether or not the units are in a noisy environment. As distance to the city center increases, all types of housing units are less likely to be used for short-term rentals.

When we regress the number of Airbnb listings on the same set of variables, we get quite similar, albeit not completely identical results. Table 2 shows the results for OLS regressions. Models (1) and (2) include all grids, Models (3) und (4) exclude grids without any listing. Interaction terms of quality and distance to the center are included in Models (2) and (4), but nit in Models (1) and (3). Table 2 shows that less quality, but also noise reduces the number of listings. For most quality categories the effect becomes more negative when distance increases, but not for silent high quality and noisy high quality. In the upper tail of the quality distribution, distance effects are rather similar. Closer inspection of Models (2) and (4) reveal that at the center for mean values of all other covariates low quality, independent of whether silent or noisy, and noisy medium quality have a positive effect on the number of listings that turn negative when distance increases and is negative for mean distance. Among the control variables, the number of addresses in neighboring units and FAR have positive effects on listings similar to what logistic regressions reveal, but the number of addresses in the grid under consideration has no significant effect. The coefficients of BCR and land values differ from their counterparts in the logistic regression.

Altogether, a greater share of housing units with a less beautiful living environment is associated with more listings in the city center, but with less listings on average. This suggests that short-term tenants are more willing to sacrifice quality for proximity to the city center than regular tenants.

6 Empirical model

In order to investigate the effects of short-term rentals on the living conditions and composition of the population of the affected neighborhoods and to identify causal effects, we carry out panel analyzes and use an instrumental-variable approach. The planning areas are the observational units and we use annual data. The estimation equations are:

$$y_{it} = \beta_0 + \beta_1 \, listings_{it} + year_t + plr_i + \epsilon_{it} \tag{12}$$

$$y_{it} = \beta_0 + \beta_1 \, listings_{it} + \beta_2 \, district_i \times \ln(t) + plr_i + \epsilon_{it} \,, \tag{13}$$

where *i* indicates the planning area, *t* the year, ϵ the error term, β_0 a constant, and plr_i a planning region fixed effect. y_{it} is the outcome variable and $listings_{it}$ the average monthly number of Airbnb listings in the respective planning area *i* in year *t*. The parameter of interest is β_1 , the coefficient of Airbnb listings. The first equation is a standard two-way fixed-effect regression with planning-area, plr_i , and year fixed effects, $year_t$. To control for spatially heterogenous time trends, in the second equation, we include district specific non-linear time trends, $district_i \times \ln(t)$, rather than year dummies.

In order to take into account the endogeneity of Airbnb listings, we also conduct an instrumental-variable analysis, where we use the spatial structure of listings in other European cities as instruments. These instruments purge the estimates from Berlin-specific spatial relations between Ainbnb listings and the outcome variable. To construct our instrument, we sort the Airbnb offers in the respective European city for each month based on the distance to the city center. We then re-scale the distance by dividing the distance by the maximum distance of an offer from the city center in that year so that the re-scaled distances are in the interval [0,1]. For each planning area in Berlin, we determine the correspondingly scaled distance of the respective centroid to the city center. Each Airbnb offer in the considered European city is then assigned to a planning area in Berlin, so that the difference between the (newly scaled) distances to the respective city center is minimized. The offers of the respective European city assigned to some Berlin planning area are added up monthly. We use the generated variable for a single city (Amsterdam) or a weighted sum of several European cities (Amsterdam, Barcelona, Paris, Vienna) as an instrument for the number of Airbnb offers in the corresponding planning area of Berlin. The weights are the inverse of the maximum number of listings in the respective city, implying that cities rather than single listings get similar weights. We select Amsterdam as main reference city because the time span where data ar available is most similar for Berlin and Amsterdam. For every year, the instruments based on a single city and a set of European cities are highly correlated (> 0.93).

We use various variables to measure the living conditions and composition of the population in the affected neighborhoods. First, the Statistical Office for Berlin-Brandenburg provides the percentage of residents who have lived in the same house for more than 10 years in relation to all residents who are at least 10 years old ($stay \ge 10$ years). Second, we calculate the share of residents who live in a poor quality residential environment. A poor quality residential environment is characterized by densely built-up areas, neglected streets, poor building conditions and unfavorable transport connections (*poor quality residential environment*).⁹ Third, the data set also contains information on the share of residents who are exposed to street noise, rail traffic noise and aircraft noise in their homes (*noisy areas*). Fourth, the statistics also cover the share of foreigners (*foreigners*), the share of people with a migration background (*migration background*)¹⁰, the share of children under the age of 6 who do not have to attend school (*young children*), and the share of people who are 65 and older (*elderly*).

We can use the variables $stay \ge 10$ years, poor quality residential environment, and noisy areas to determine whether short-term rentals are primarily offered in houses with relatively poor living conditions and are pushing out their most likely economically weak previous residents. The variables foreigners, migration background, young children and elderly indicate whether more short-term rents cause people who are economically weak due to their demographic characteristics to leave their homes comparatively often.

7 Results

Fixed effect regressions with year fixed effects or district specific non-linear time trends and instrumental-variable fixed-effect regressions with year fixed effects lead to statistically significant and consistent results for some indicators of housing conditions and socio-economic

⁹In 2019, the residential areas were reclassified so that the data on the quality of living cannot be compared with the previous periods. While we use the period 2016-2019 for all other variables, we therefore do not take 2019 into account when estimating the impact on environment quality.

¹⁰According to the official definition in Germany, a person has a migrant background if he or she or at least one parent did not acquire German citizenship by birth.

status and to non-significant results for other indicators. In Tables 3 and 4, the first column shows the results of the standard two-way fixed-effect regression, the second column the results of a fixed-effect regression with district specific time trends, the third column the results of an IV regression with year-fixed effects, where distances of the listings in a single city (Amsterdam) are used as instrument for listings in Berlin, and the fourth column the IV results with the same type of instrument, but for a set of European cities. An increase in the number of Airbnb listings has a consistently positive effect on the share of long-term residents (Table 3), but a consistently negative effect on the share of residents in poor quality residential environments (Table 4). For the indicators *noisy areas, foreigners, young children, migration background* and *elderly* the results are either statistically insignificant or inconsistent across estimation approaches (not shown in the paper).

The empirical findings are in line with decision-making economic models. First, the increasing proportion of long-term residents indicates displacement, especially of short-term tenants. Under the conditions of German tenancy law, not only apartment owners, but also long-term tenants will not leave the apartment. Homeowners are probably not affected, because homeowners are less mobile than tenants and are not threatened by termination of the tenancy. However, regular tenants are strongly protected by the rental law in Germany against termination of the rental contract by the landlord. Since existing rents rise much more slowly than new contract rents, the lock-in effect increases with the length of time and the willingness to leave the apartment decreases. The stronger lock-in effect counteracts the negative effects of short-term letting of neighboring apartments that reduce the quality of the apartment and the living environment.

Second, short-term rentals reduce the proportion of residents in poor quality residential environments, as these apartments are more likely to be rented than self-occupied and are more suitable for temporary use than for permanent use. This finding confirms the theoretical result that quality is an important determining factor for the extent of displacement.

8 Conclusion

This paper studied how short-term rentals are changing average housing conditions and the composition of the population in the affected neighborhoods. We investigated the relation between Airbnb listings on the one hand and characteristics of the population and living conditions in the almost 450 planning areas of the city of Berlin (Germany) on the other. We demonstrated that while, on average the share of poor quality and noisy housing units is negatively correlated with the probability of having Airbnb listings and the number of those listings, close to the city center, the correlation is positive. In order to identify the causal effect of Airbnb listings on the affected neighborhoods, we not only used panel data, but also used the spatial structure of listings in other European cities as instrumental variables. We showed that more offers for short-term use of housing via Airbnb increases the number of residents with long periods of residence and reduces the number of residents in poor quality residential environments. We did not find any effects on young children, migrants, foreigners, and the elderly.

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Figures and Tables





Figure 2: Bid-rent curves of two household types for varying quality





Figure 3: Bid-rent curves of two household types for two quality levels: case 1

Figure 4: Bid-rent curves of two household types for two quality levels: case 2



Figure 5: Spatial distribution of Airbnb listings in Berlin 2019



Airbn listings
 Residential addresses
 por quality
 high quality
 average quality

Figure 6: Airbnb listings and residential addresses

	(1)	(2)
noisy poor quality share	-0.0361	• • • • • • • • • • • • • • • • • • •
noisy poor quanty snare	(0.130)	(0.397)
silent noor quality share	-0.443***	0.581*
shelit poor quality share	(0.113)	(0.333)
noisy average quality share	-0.0616	1 739***
hoisy average quanty share	(0.123)	(0.382)
silent average quality share	-0.479***	0.512*
shene average quanty share	(0.101)	(0.302)
noisy high quality share	0.330	(0.502) -0.542
noisy nigh quanty share	(0.201)	(0.617)
addresses	0.0114***	0.0282***
autresses	(0.0114)	(0.0282)
distance center	-0.000155***	-0.0000288
	(0.000133)	(0.0000250)
floor area ratio	1 586***	(0.0000230)
noor area ratio	(0.107)	(0.107)
huilding coverage ratio	1.005***	0.878**
building coverage ratio	(0.424)	(0.428)
local land value	0.0003/0***	0.000376***
local faile value	(0.000540	(0.000575)
noighboring grid units' addresses	0.00342***	0.00370***
neighborning grid units addresses	(0.00342)	(0.00376)
noisy poor quality share × distance contor	(0.000331)	0.000330)
holsy poor quanty share \times distance center		-0.000233
silent poor quality share × distance contor		0.0000338***
shellt poor quality share \times distance center		-0.0000838
noisy average quality share × distance conter		0.0000219)
noisy average quanty share \times distance center		-0.000103
cilent evenese quality chara X distance contor		0.0000331)
shelit average quality share \times distance center		(0.0000820)
noisy high quality share V distance conter		0.0000244)
noisy nigh quanty share × distance center		(0.0000800)
addresses × distance center		0.0000484)
addresses × distance center		(0.00000139)
Constant	0.303*	2.041***
Constant	(0.218)	(0.360)
district FE	yes	yes
N	14417	14417
chi2	2385.7	2557.2
r2_p	0.362	0.368

Table 1: Logistic regressions of Airbnb listings

Dependent variable: Airbnb listing dummy

Robust standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

	(1)	(2)	(3)	(4)
noisy poor quality share	-1.066***	1.929**	-1.623***	2.833**
	(0.264)	(0.897)	(0.609)	(1.381)
silent poor quality share	-0.848***	0.938	-0.437	2.166*
Shone poor quanty share	(0.199)	(0.779)	(0.507)	(1.146)
noisy average quality share	-0.936***	1.949**	-0.619	4.597***
	(0.237)	(0.831)	(0.542)	(1.270)
silent average quality share	-1.373^{***}	-2.680***	-2.321***	-1.933^{*}
	(0.176)	(0.705)	(0.421)	(1.076)
noisy high quality share	-1.890***	-5.209***	-3.610***	-4.288^{**}
	(0.404)	(1.470)	(0.825)	(2.008)
addresses	0.00446	0.203***	0.0118	0.258***
	(0.00296)	(0.0104)	(0.00867)	(0.0197)
distance center	-0.0000898***	0.000343***	-0.000240***	0.000716***
	(0.0000147)	(0.0000451)	(0.0000422)	(0.0000928)
floor area ratio	5.245***	4.034***	4.462***	3.380***
	(0.322)	(0.288)	(0.569)	(0.511)
building coverage ratio	0.0947	2.203**	10.77***	11.10***
	(1.063)	(0.951)	(2.655)	(2.368)
local land value	0.000162**	0.000425***	-0.0000606	0.000264***
	(0.0000822)	(0.0000887)	(0.0000910)	(0.000102)
neighboring grid units' addresses	0.00555***	0.00717***	0.0163***	0.0183***
noishiothing sind antib addresses	(0.000558)	(0.000578)	(0.00181)	(0.00183)
noisy poor quality share x distance center	(0.000000)	-0.000250***	(0.00101)	-0.000494***
		(0.0000669)		(0.000142)
silent poor quality share \times distance center		-0.000119**		-0.000237^{**}
show poor quality share x distance conter		(0.000110)		(0.000291)
noisy average quality share X distance center		-0.000239***		-0.000621***
hoisy average quanty share × distance center		(0.000255)		(0.000021)
silent average quality share x distance center		0.000129***		0.0000134
show average quarty share x distance conter		(0.000120)		(0,00000000000000000000000000000000000
noisy high quality share × distance center		0.000334***		0.000164
hoisy high quality share × distance center		(0.000354)		(0.000174)
addresses × distance center		-0.000104		-0.0000280**
		(0.0000114)		(0.0000200
Constant	0.429	-5 125***	-1 618**	-10 15***
Constant	(0.504)	(0.873)	(0.802)	(1.294)
district FF	()	()	()	
$ \begin{array}{c} \text{ulstrict } \mathbf{F} \mathbf{E} \\ \text{only listings} > 0 \end{array} $	yes	yes	yes	yes
omy usings > 0	no	no	yes	yes
N	14417	14417	4979	4979
F	155.4	135.6	110.1	99.56
р	0	0	0	0
r2	0.494	0.533	0.508	0.543
r2_a	0.493	0.532	0.506	0.540

Table 2: OLS regressions of Airbnb listings

Dependent variable: number of Airbnb listings Robust standard errors in parentheses; * p<0.1, ** p<0.05, *** p<0.01

$\underline{}$					
	FE	$\rm FE$	IV1-FE	IV2-FE	
listings	0.0110***	0.00732*	0.0306**	0.0321**	
	(0.00408)	(0.00409)	(0.0132)	(0.0148)	
Constant	41.87^{***}	42.01***	41.15^{***}	41.09***	
	(0.103)	(0.132)	(0.417)	(0.477)	
N	1776	1776	1776	1776	
F	110.0	44.33			
chi2			19723.6	16352.4	
r2_w	0.161	0.170	0.152	0.150	
r2_b	0.102	0.0767	0.102	0.102	
r2_0	0.0150	0.00452	0.0574	0.0590	
df_m	3	14	448	448	
planning region FE	yes	yes	yes	yes	
year FE	yes	no	yes	yes	
district-specific trends	no	yes	no	no	

Table 3: Effects on stay ≥ 10 years

IV1: Amsterdam, IV2: European cities

Dependent variable: stay \geq 10 years share

Standard errors, clustered at the planning region level, in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

	Table I. Encere on poor quanty restactivity infinite					
	\mathbf{FE}	\mathbf{FE}	IV1-FE	IV2-FE		
listings	-0.000780^{***}	-0.000662^{**}	-0.00115^{***}	-0.00124^{***}		
	(0.000227)	(0.000277)	(0.000407)	(0.000414)		
Constant	0.418^{***}	0.414^{***}	0.432^{***}	0.435^{***}		
	(0.00974)	(0.0111)	(0.0167)	(0.0167)		
N	1332	1332	1332	1332		
F	6.646	2.258				
chi2			1670.2	1661.0		
r2_w	0.0782	0.0899	0.0654	0.0581		
r2_b	0.0291	0.0296	0.0291	0.0291		
r2_o	0.0256	0.0251	0.0259	0.0260		
df_m	2	13	447	447		
planning region FE	yes	yes	yes	yes		
year FE	yes	no	yes	yes		
district-specific trends	no	yes	no	no		

Table 4: Effects on poor quality residential environment

IV1: Amsterdam, IV2: European cities

Dependent variable: share of residents in poor quality residential environments

Standard errors, clustered at the planning region level, in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01