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Abstract

An increasing number of cities implements home sharing ordinances (HSOs) to address concerns about commercial activity on home sharing platforms such as Airbnb. We assess the impact of such HSOs on Airbnb listings, reservations, and the number of properties offered. We find that, on average, commercial listings are reduced by 19 % - 31 % and relative effects on reservations and numbers of properties are even larger. In addition, effects are more pronounced in local areas that have been highly penetrated by Airbnb activity prior to the HSO. Although HSOs reduce commercial activity, we find evidence that commercial activity is not entirely banned from the platform pointing to the fact that the HSOs are not well enforced. Moreover, occasional Airbnb activity which reflects the original idea of the sharing economy is (unintentionally) also reduced by HSOs. We finally test if the reduction in Airbnb activity leads to a decrease in long-term rents but cannot find strong evidence.

JEL classification: R21; R31; H31

Keywords: sharing economy; house prices; housing market regulation

1 Introduction.

Recent years have seen a rapid emergence of IT-facilitated business models that enable peer-to-peer sharing of underutilized goods and service capacity (Schlagwein et al. 2020). A prominent example of this "sharing economy" is home sharing that offers visitors an alternative to traditional hotel accommodation by allowing them to connect with people (i.e., hosts) who are willing to share their homes short-term for a fee. Airbnb is the leading home-sharing platform worldwide. In March 2021, Airbnb had 5.6 million active listings (i.e., properties available for at least one day per year) in 100,000 cities around the globe (`https://news.airbnb.com/about-us/`). Especially cities that attract many visitors, in recent years, have experienced a steep increase in Airbnb listings. This led to considerable opposition by local residents, however, who fear that properties are repurposed from long-term residential use to short-term rentals in tight urban housing markets, that house prices and rents increase and that there are negative externalities from raucous behavior of visitors. In some cities, mounting frustration resulted in anti-tourism graffiti, vandalism, and protests against Airbnb (`https://www.nytimes.com/2021/09/22/travel/barcelona-airbnb.html`).

These negative effects of Airbnb on local residents largely relate to commercial Airbnb hosts who offer whole properties exclusively for short-term rental rather than subletting their own residence during occasional absence only. They are the ones who strip properties from long-term residential housing markets and divert them to pure short-term rental use. Potential annoyances from visitors are also particularly pronounced when properties are exclusively used for short-term rentals, implying constant visitor streams in apartment buildings. Commercial hosts act, in a sense, like hotel or B&B managers who maximize their return on investment and undermine the very idea of home sharing: to have a peer-to-peer market.

Despite the apparent tension between commercial use and the nature of the home sharing business model, Airbnb and other short-term rental providers never took actions to ban or reduce commercial activity on their platforms. Their incentives to do so are limited as they earn attractive fees from such activity. In addition, commercially offered listings may improve visitors' perceived value of the platform by adding to the availability of properties and providing higher quality and convenience (e.g., professional cleaning/housekeeping, easy check-in and -out).

Many cities, in turn, responded to concerns by local residents and recently introduced home sharing ordinances (HSOs) that aim to restrict short-term rentals, in particular, commercial activity. Next to complete bans of short-term rentals as recently enacted by the city of Barcelona (`https://openjaw.com/newsroom/other-news/2021/09/27/barcelona-first-city-in-eu-to-ban-airbnb/`), cities have mostly taken actions to reduce the scope of the short-term rentals, among others by explicitly limiting the number

of days hosts can rent out properties.

Airbnb expects that public policy concerns will lead to further regulations in the future (`https://bit.ly/3x3UeSc`) and that these regulations may ultimately have material adverse effects on Airbnb's business model. For stakeholders – local residents, policymakers, Airbnb and other home sharing platforms – it is thus relevant to understand how HSOs impact commercial and occasional short-term rentals.[1] Are HSOs effective in pushing back commercial activity from Airbnb? How do they impact occasional activity? The latter effect is theoretically ambiguous: If HSOs are not well targeted to commercials, they may also shy off occasional hosts. If they are well-targeted, occasional hosts might benefit from the decreased activity of commercial hosts as some of the short-term rental demand is redirected to them.

How HSOs influence commercial and/or occasional activities on home-sharing platforms is an empirical question. To date, there is hardly any evidence. Research about the home-sharing economy has focused on trust and reciprocity in peer-to-peer markets (e.g., Proserpio et al. (2018); Zervas et al. (2021)), the effects of home sharing on the tourism industry (e.g., Farronato and Fradkin (2018); Li and Srinivasan (2021); Zervas et al. (2017)), and the housing market (e.g., Barron et al. (2021)). There are only few studies that examine effects of HSOs (Bekkerman et al. (2021); Koster et al. (2021);Valentin (2021)) and these studies largely focus on testing how the regulations impact rental and property prices.

It is the aim of this paper to fill this gap and evaluate the impact of HSOs on the short-term rental activity of commercial and occasional hosts. Our testing ground is the introduction and tightening of HSO regulations in three leading German cities: Berlin, Hamburg, and Munich. These cities are among those with the highest Airbnb penetration outside the US (`https://www.airdna.co/resources/blog`). Our empirical analysis relies on rich data that contains information on the population of Airbnb listings and reservations in Germany. The data frame is 2015 and 2020. We use this data to proxy for commercial and occasional activity on the Airbnb platform. While the platform does not directly classify commercial activity, there are indications that point in one or the other direction. In the base analysis, we classify properties as commercial activity if i) the property is offered by a host who offers several properties for short-term rental at the same time; ii) the whole property is rented out for a large number of days per year; iii) or continuously offered as available on the Airbnb platform or iv) if renting out the property on the platform leads to high amounts of revenue. Properties are classified as occasional activity if none of these definitions applies. As some elements of the definition of commercial activity are necessarily ad hoc, we present extensive robustness checks, in which we document that our key insights are not sensitive to the particular definition of

[1]Some even claim that occasional hosts rely on the income to pay their bills and stay in their homes.

commercial and occasional activity on the Airbnb platform.[2]

Our empirical analysis tracks commercial and occasional activity around the time of the introduction and tightening of an HSO. The unit of observation is the 1kmX1km city grid per month. Drawing on a difference-in-differences (DiD) approach; we determine the average treatment effect on the treated (ATT) and estimate how the tightening of HSOs influence the commercial and occasional Airbnb activity per grid and month. The DiD approach allows us to absorb the significant general time- and seasonal trends in Airbnb activity.

Our results suggest that HSOs significantly decrease commercial activity on Airbnb. A decline in commercial activity emerges throughout all studied HSOs and for all Airbnb activity indicators. We find that HSOs reduces supply of commercial properties; actual short-term rental transactions (which are also determined by short-term rental demand) related to these properties and the number of commercial properties that are active on Airbnb (which captures extensive margin responses). The quantitative response is sizable and points to reductions in Airbnb activity well above 19 %. However, for all studied interventions, we find that HSOs are far from eliminating commercial short-term rental activity altogether. We provide direct evidence that many commercial hosts stay in the market, even if this violates HSO regulations. This finding points to significant enforcement problems.

As Airbnb activity is largely concentrated in a few city grids – mostly located close to the city center and to tourist sites –, we also present specifications where we zoom in on grids with a high Airbnb intensity and show that these local areas experience a strong *absolute* drop in Airbnb activity in the wake of HSO interventions. In relative terms, response rates are comparable to grids with lower Airbnb intensity, suggesting that commercial hosts respond similarly to HSO regulations no matter where within the city they are located.

The results turn out to be robust against several robustness checks, where we adjust the definition of commercial activity, change the set of control grids that enter the analysis and alter assumptions on the correlation structure of errors when estimating standard errors (clustering). Event study estimates, moreover, show common pre-treatment trends in the Airbnb activity of treatment and control grids, which supports the common trend assumption.

The results, furthermore, suggest that occasional activity on Airbnb – as again measured by listing, transactions and active properties – declines when HSOs are introduced or tightened. Again, the negative response is observed throughout all studied interventions and the decline is quantitatively substantial. HSO regulations hence tend to deter

[2]We, e.g., show that our baseline findings remain unchanged when we classify commercial hosts by each of the criteria (i) to (iv) separately. The same holds true if we alter threshold values for the sub-definitions.

commercial and occasional activity on Airbnb alike – despite the fact that the legislation mainly targets commercial short-term rental activity.

Finally, we determine whether and to what extent the HSO regulations dampen Airbnb-related externalities that were the very reason for local residents' opposition against home sharing activity in their cities. As described above, major concerns voiced by local residents related to a redirection of properties from long-term residential to short-term rental use and to rising property rents in long-term residential markets.[3] Our findings only point to moderate improvements at these margins. The estimated number of properties redirected from pure short-term rental to the long-term residential use in the wake of HSO reforms tends to be small, in particular when compared to the housing need of the studied urban areas. Based on data for long-term rental offers in Germany, we, moreover, show that long-term rental prices are largely unaffected by HSO regulations. The latter result also holds when we focus on city-center grids that are most strongly penetrated by home-sharing activities before the regulations.

Our findings contribute to shedding light on the effectiveness of HSO regulations in constraining short-term rental activity. The HSO regulations studied – as most HSOs worldwide – do not completely ban Airbnb activity but rather aim to limit short-term rental activity, with a particular focus on the activity of commercial hosts. We provide insights into the effects of HSOs on commercial and occasional short-term rental use, on platform providers and local housing markets. Our findings suggest that HSOs significantly affect commercial and occasional Airbnb activity and thus the business model of platform providers. The results, however, also point to substantial non-compliance with the regulations and to large enforcement gaps. This suggests that a more effective law enforcement may elevate regulation effects above the ones reported in this paper. Compared to other studies, we, moreover, find only weak effects of HSOs on the housing market, which dampens hopes that HSOs can significantly contribute to overcoming housing market challenges in large and growing urban areas. We discuss potential reasons for the differences in findings to prior research.

The rest of this paper is organized as follows. In Section 2, we discuss the related literature. Section 3 provides an overview of HSOs implemented in the US and Europe, while Section 4 gives an overview of our data. In Section 5, we explain in detail the methodology we use to determine the different effects of HSOs. Our main findings regarding the effects of HSOs on commercial activity are presented in Section 6, whereas Section 7 analyzes the effects of HSOs on long-term rents. Finally, Section 8 closes the paper with a discussion of implications for research and practice.

[3] As described in more detail below, housing markets in leading German cities are dominated by long-term renting. Only a small minority of city inhabitants own the apartment in which they live. Public and pollical discussions on short-term renting thus focused on potential adverse effects on long-term *rental* prices.

2 Literature.

There is an extensively growing literature on home sharing, and we refer the reader to Guttentag (2019) and Dann et al. (2019) who provide recent literature reviews. Yet, we want to highlight two specific literature streams that are strongly related to this study.

Several studies show that home sharing exerts an ambiguous effect on the local economy. On the one hand, studies demonstrate a negative impact of Airbnb activity on the hotel industry (Farronato and Fradkin (2018); Zervas et al. (2017)), although the effect can be mitigated by price strategy adjustments (Li and Srinivasan 2021). On the other hand, restaurants seem to benefit from Airbnb activity (Basuroy et al. (2021);Farronato and Fradkin (2018)).

Another stream of research examines the effects of home sharing on the housing market. Several studies show that Airbnb activity increases rents and house prices in leading cities in the US, France, Spain or Portugal (Barron et al. (2021); Francoab and Santos (2021); Garcia-López et al. (2020); Horn and Merante (2017); Lee (2016); Sheppard and Udell (2016)). Intuitively, the positive effect of Airbnb activity on rents and house prices is more pronounced in cities and neighborhoods that attract much tourism (Ayouba et al. (2020); Garcia-López et al. (2020)). While existing homeowners thus benefit from an increasing Airbnb penetration, long-term renters and homebuyers lose out. The reason for the increasing rents is that home sharing cannibalize the long-term rental supply (Calder-Wang (2020); Li et al. (2021)). The higher the Airbnb activity in a city, the larger the cannibalization effect (Li et al. 2021). Yet, this effect is weaker if the owner-occupiers rate (i.e., people who own the home in which they live) is high (Barron et al. 2021). Moreover, research suggests that the negative effect of Airbnb activity on rents is stronger when commercial hosts are active in a local market, where commercial hosts are platform users that rent out several properties or an entire property for more than 120 days per year (Ayouba et al. 2020).

In a recent study, Bekkerman et al. (2021) find that Airbnb listings decrease and residential permits decline after the introduction of HSOs in 15 US metropolitan areas. This result suggests that the option to participate in home sharing influences housing purchasing decisions. Bekkerman et al. (2021) find support for this notion since the effect on residential permits is stronger for accessory dwellings. The study by Koster et al. (2021) also supports the, on average, negative effect of HSOs on Airbnb listings for Los Angeles County. Similarly, Valentin (2021) finds negative effects of HSOs on Airbnb listings, especially in areas that ban short-term rentals completely. Yet, the negative effect of HSOs on Airbnb listings only seem to hold for entire properties, while room listings (shared spaces) are not affected Koster et al. (2021). Next to the negative effect of HSOs and Airbnb listings, Koster et al. (2021) as well as Valentin (2021) report decreasing house and rental prices, although these effects are overall only moderate.

In summary, the studies suggest that HSOs reduce Airbnb activity (i.e., listings), house prices and rents, on average. The reduction in property values implies that homeowners factor into their housing purchasing decisions the option to participate in the home sharing market (Bekkerman et al. 2021). This might indicate that especially commercial hosts are affected. Yet, a limitation of these studies is that they do not explicitly consider whether HSOs are effective in reducing commercial activity. Commercial activity on home sharing platforms is usually accused of being responsible for the detrimental effects of home sharing. Another limitation of the previous studies on HSOs is that they focus on average effects and do not examine heterogeneous effects within cities by considering small territorial grids with different levels of home sharing activity. In addition, none of the studies quantifies the number of properties reallocated from the short-term to the long-term market.

We contribute to the literature (i) by explicitly investigating whether HSOs reduce commercial activity on home sharing platforms, (ii) by showing that the effects of HSOs differ across territorial grids, and (iii) by illustrating reallocation effects of HSOs.

3 Governmental regulations of home-sharing.

When Airbnb was founded in 2008 in San Francisco, the main idea was to match individuals who want to rent out (part of) their property on short-term with individuals who need short-term accommodations. During this early stage of development, Airbnb did not face any specific market regulations. However, the platform quickly expanded firstly inside the US, from 2011 onwards also in Europe, and later on worldwide. Increasing Airbnb activity and, in particular, commercial activity on the platform caused opposition from, most of all, local residence and the hotel industry. In response, city governments in the US and worldwide started regulating the market for short-term rentals by HSOs. Although the design and tightness of HSOs differ – reaching from complete bans of short-term rental activity to simple agreements that ensure transparency, e.g., registration requirements – they all aim to prevent repurposing of residential housing.

Table 1 summarizes HSOs implemented in major cities in the US and in Europe in 2021. The main elements commonly specified by HSOs are: (i) day caps (i.e., maximum number of days a property is allowed to be rented out), (ii) type of homes they apply to (primary vs. secondary homes), (iii) whether the host needs to be present during the guest's stay, and (iv) whether a registration/license is required to rent out on short-term basis.

In our study, we assess the HSO regulations implemented by major German cities. Specifically, we consider Berlin, Munich, and Hamburg. As illustrated in Table 1, regulations implemented in these cities capture common features of HSOs that do not completely ban short-term rental activity but have the goal to prevent the misuse of the

Table 1: HSOs in major cities in the US and Europe

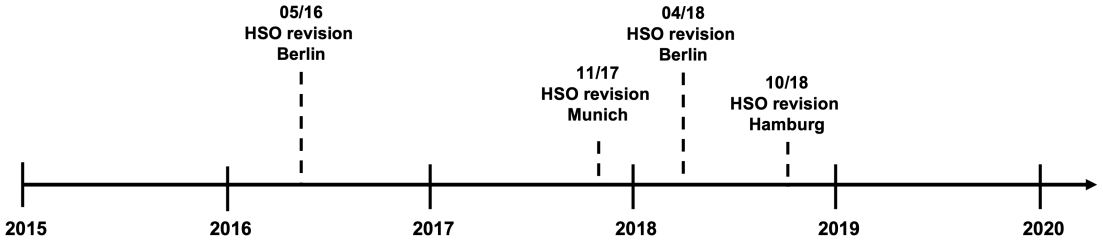
City	Day cap	Type of homes	Presence of owner required	License/registration required
Amsterdam, NED	≤ 30	primary and secondary	no	yes
Barcelona, ESP	none	primary and secondary	no	yes
Berlin, GER	none	primary	no	yes
	≤ 90	secondary	no	yes
Boston, USA	none	primary and secondary	no	yes
Chicago, USA	none	primary and secondary	no	yes
Copenhagen, DEN	≤ 70	primary and secondary	no	no
Dublin, IRL	≤ 90	primary	no	yes
	> 90	primary	no	yes
	none	primary	yes	yes
	none	secondary	no	yes
Hamburg, GER	≤ 56	primary	no	yes
Lisbon, POR	none	primary and secondary	no	yes
London, GBR	≤ 90	primary and secondary	no	no
Los Angeles, USA	≤ 120	primary	no	yes
Madrid, ESP	≤ 90	primary and secondary	no	yes
Munich, GER	≤ 56	primary and secondary	no	no
New Orleans, USA	none	primary and secondary	no	yes
New York, USA	none	primary and secondary	yes	yes
Paris, FRA	≤ 120	primary	no	no
	none	primary	yes	no
	none	secondary	no	yes
Rome, ITA	none	primary and secondary	no	yes
San Francisco, USA	≤ 90	primary	no	yes
	none	primary	yes	yes

home-sharing idea, in particular, commercial activity. Figure 1 shows the timeline of tightenings of the regulation of short-term rentals for all three cities.

Berlin was the first German city to regulate home sharing activity. It enacted an HSO in December 2013 that prohibits the "repeated renting" of more than half of a property on a short-term basis. The law, however, accounted for a transition period that allowed property owners to adjust to the new regulation. Thus, the restrictions only became effective in May 2016. Since there was a lot of uncertainty among Airbnb hosts and the public administration how to interpret and implement the law because a specific definition of "repeated renting" (e.g., a day limit) was lacking, the city of Berlin revised the HSO legislation in April 2018. The revised HSO explicitly sets a 90-day limit for short-term renting of secondary homes. Moreover, to foster compliance with the HSO fines were increased from up to EUR 100,000 to a maximum of EUR 500,000 for not obeying with the HSO. Additionally, Berlin forbid any short-term rental if the host owned more than one property (primary or another secondary) in Berlin highlighting that especially commercial home-sharing activity was targeted. Finally, short-term hosts needed to register with the city which increased administrative cost for hosts. The empirical analysis to come accounts for both tightenings of the HSO legislations in May 2016 and in April 2018.

Munich revised its HSO in November 2017. The revised law forbids renting out

Figure 1: Timeline of HSOs introductions in Germany



more than half of the living space of a property for more than eight weeks, i.e., 56 days, irrespective of whether it is the primary or secondary home. Violation of the law is fined with up to EUR 500,000. Residents can report potential repurposing of housing anonymously on a webpage (e.g., vacancy of residential space or excessive short-term rental). Since the webpage went live in beginning of 2018, an average of almost 80 reports per month have been submitted. The most common type of report was a suspected vacancy of residential space, followed by a suspected use of residential space for short-term rentals.

Hamburg restricted short-term rentals for the first time in June 2013. Back then, hosts were not allowed to rent out more than half of the property for more than 6 months, i.e., 183 days, per calendar year. The city adjusted its HSO regulation in October 2018, hosts are not allowed to rent out more than half of their property for more than eight weeks, i.e., 56 days, per year – analogously to the HSO in Munich. But in contrast to Munich, Hamburg's HSO targeted primary homes only. Fines were increased to EUR 500,000 (from EUR 50,000 in the initial regulation) and hosts were required to register with the city (effective from April 2019 onwards).

4 Data.

Our analysis relies on data on the population of Airbnb listings and reservations in Germany. The data is drawn from a private company that offers business consultancy services for the short-term rental market. The company consistently and continuously scrapes data from Airbnb's webpage and sells analyses based on this data to its customers. The data used in this paper comprises the population of Airbnb activity in Germany in the period from May 2015 to October 2019.

For each property, we observe the full set of days on which the property is listed on the Airbnb platform, i.e. the listings, and the full set of days on which the property is booked, i.e., the reservations. The data also allows us to link properties to Airbnb hosts and contains information on the revenues earned from short-term rental transactions. We can therefore identify entire listing and booking histories of properties and hosts. While the data does not directly show if properties are offered commercially – i.e. are exclusively

used for short-term rentals - or occasionally – i.e. are mainly used for residential purposes and only sublet during personal absence –, there are traces in the data that point to one or the other.[4] In the following, we rely on four pieces of information to distinguish between commercial and occasional activity:

1. the number of properties offered by the same host in a given city
2. the number of days a property is booked through the Airbnb platform in a given year (in the following referred to as the number of 'reservation days')
3. the number of days a property is listed as available on the Airbnb platform in a given year (in the following referred to as the number of 'listing days')
4. the revenue earned through Airbnb transactions by a property in a given year

The choice of criteria follows the notion that (ad 1) properties are more likely to be commercial if the host offers multiple properties in a city for short-term rent on the Airbnb platform (reflecting that plausibly only one property is used for own residential purposes); (ad 2) if properties are rented out for a large number of days per year; (ad 3) if properties are continuously listed as available for short-term rentals on the Airbnb platform and (ad 4) if a property generates large amounts of revenues on Airbnb per year. In the base analysis, we operationalize these criteria as follows: A property is classified as commercial if (ad 1) it is listed by a host who listed multiple properties for short-term rentals within a three-month period in a given city; or if (ad 2) its number of reservation days per year exceeds the allowed maximum set by a city's HSO legislation; or if (ad 3) it is, on average, listed on the Airbnb platform for more than 25 days per month in a given year; or if (ad 4) the average monthly revenue realized with the property on Airbnb amounts to 500 Euros or more. The latter threshold reflects that it only pays for hosts to use properties exclusively for short-term rentals if short-term rental revenues cover opportunity costs (the rent in the long-term residential market). In our sample of cities, the average square meter rent in areas with high Airbnb intensity is 12.8 Euros per month (cf. Table 11). Small apartments (with a size of 40 square meters) thus cost around 500 Euros per month.

The base analysis classifies properties as commercial if any of the definitions (1) to (4) applies. Inversely, properties are classified as occasional if neither of the definitions (1) to (4) applies. These classifications have ad hoc elements and there may be misclassifications. But the tighter the definitions, the more likely it is that activities tabbed as commercial are indeed commercial. We will present detailed robustness checks below, where we show how results change when we adjust the definitions of commercial and occasional activity.

[4] Prior research relies on irregularly scraped data (see e.g. Koster et al. (2021)), which does not allow for such a distinction.

Table 2: Number of Airbnb properties in 2017 by Airbnb activity type

		Berlin	Munich	Hamburg
All properties listed		13184	7270	7861
All properties reserved		9303 (70.56%)	5060 (69.60%)	6915 (87.97%)
Commercial activity				
(1) > 1 property	*(belonging to host that offer multiple prop.)*	756 (5.73 %)	384 (5.28%)	776 (9.87%)
(2) reservations threshold	*(reservations > HSO-threshold)*	2399 (18.20 %)	1600 (22.01%)	3571 (45.43%)
(3) listings threshold	*(mean monthly listings > 25)*	1800 (13.65%)	1267 (17.43%)	1699 (21.61%)
(4) revenue threshold	*(mean monthly revenue > 500 EUR)*	1912 (14.50%)	1133 (15.58%)	2168 (27.58%)
main specification:	**at least one definition (1)-(4) applies**	3972 (30.13%)	2748 (37.80%)	4387 (55.81%)
Occasional activity		9212 (69.87%)	4522 (62.20%)	3474 (44.19%)

Notes: The table offers descriptive statistics on Airbnb hosts in Berlin, Munich, and Hamburg in 2017. The first line depicts the number of properties listed on Airbnb at least once in 2017, the second line the number of properties reserved at least once in 2017 (in brackets as a fraction of all listed properties, cf. line 1). The third to sixth line depicts the number of commercial activity in the three cities in 2017 according to different definitions (see main text).

Table 2 depicts the number of active Airbnb properties in Berlin, Hamburg and Munich in 2017 – defined as properties with at least one listing and one reservation day during that year.[5] The listing-to-booking-ratio varies across cities. In Berlin and Munich, 70.56 % and 69.60 % of properties that are listed at least once are also booked at least once, while it is 87.97 % in Hamburg.

The table, moreover, documents the number and fraction of all commercial properties - defined following the base definition given above and each of the sub-definitions (1) to (4). For the sub-definitions, the table conveys that relatively few properties are listed by hosts who offer multiple properties for shot-term rental in a given city. In turn, properties with many reservation days (above the city's HSO threshold), properties which are continuously listed on the Airbnb platform and properties with high earnings from Airbnb bookings are more prevalent. According to our baseline definition (where properties are classified as commercial if any of sub-definitions (1)-(4) apply), 30.13 % of Airbnb properties in Berlin, 37.80 % of the Airbnb properties in Munich and 55.81 % of the Airbnb properties in Hamburg are commercial. While commercial activities are significant, there is variation across cities. In particular the high short-term rental activity per host in Hamburg stands out.[6]

Figure 2 shows that Airbnb activity (as measured by the number of Airbnb properties with at least one listing) is strongly concentrated in a few city areas, mostly in the city center. This highlights, again, that Airbnb activity is a local phenomenon. Thus, average effects within cities might not capture the full impact of the platform on local residence and the distinction between areas that are exposed to high Airbnb activity and areas that are only little affected by short-term rentals is important.

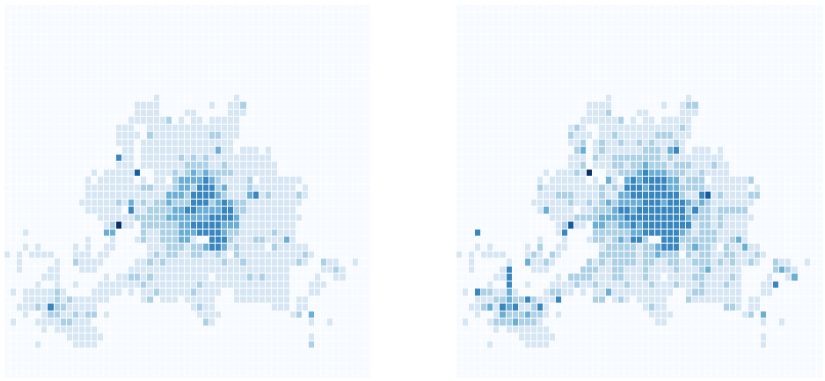
Table 3 depicts the mean, median, 75th, 90th percentile and the maximum of the

[5]The number of active Airbnb properties in Berlin is larger than in Hamburg and Munich, reflecting differences in city size.

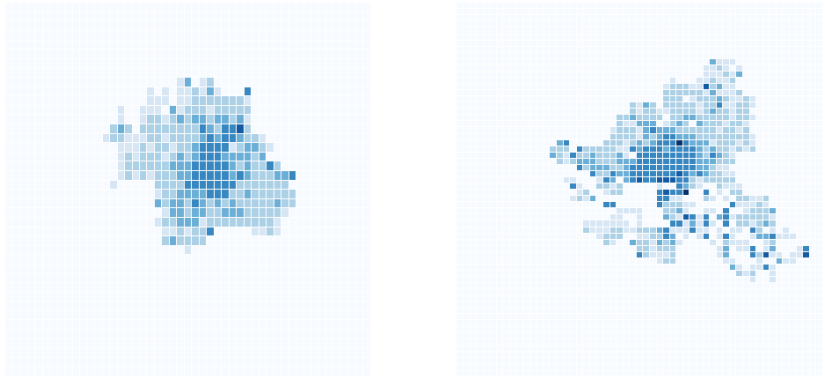
[6]Note that, for sub-definition (2), we apply the reservation day threshold given in the city-specific HSO law, even if implemented after 2017 and, as in the case of Berlin and Hamburg, not applying to all properties in the city but rather only main or only secondary residences respectively. Some of the variation in the ratio of hosts, for which sub-definition (2) applies, thus relates to the fact that the reservation days threshold given in Berlin's and Hamburg's HSO law is 56 days, while it is 90 days in Berlin. We will present robustness checks for the analyses to come where we document how changes in the commercial and occasional user definitions impact our findings.

Figure 2: Share properties listed at least once on Airbnb per grid

(a) Berlin 2016 (b) Berlin 2018



(c) Munich (d) Hamburg



Notes: The figures depicts the share of properties per grid that are listed at least once on Airbnb in the four quarters before the HSO reform. The colors distinguish grids with an Airbnb intensity $< 0.1\%$, $0.1 - 0.5\%$, $0.5 - 1\%$, $1 - 5\%$ and $5 - 10\%$ and $> 10\%$.

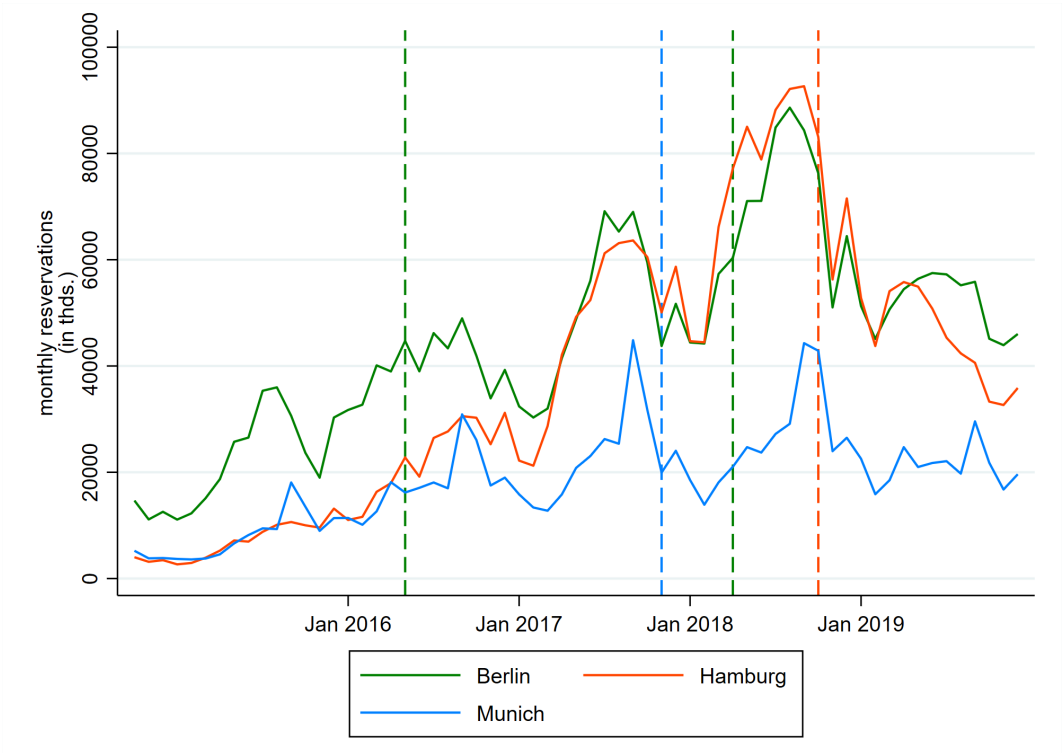
Airbnb intensity distribution across 1 km x 1 km grids defined based on the European geocoding standard ETRS89-LAEA for Berlin, Hamburg and Munich in 2017. The distribution shows that the large majority of city grids has a negligible Airbnb penetration. The average fraction of active Airbnb properties per grid is 0.2 % in Berlin, 0.51 % in Munich and 0.72 % in Hamburg. In the most highly treated grid of Berlin/Munich/Hamburg, 13.33 %, 10.0 % and 13.19 % of properties are listed on Airbnb. Columns (2) to (6) depict the fraction of commercial Airbnb (following the different definitions), which – intuitively – yields smaller penetration ratios.

Finally, Figure 3 shows the development of Airbnb activity in our sample cities over time (as measured by the aggregate number of Airbnb reservation days per month). The figure indicates an upward trend, but also some cyclicality. There is no obvious connection between tightenings of HSO legislation in the respective cities (indicated by vertical lines on the time axis) and aggregate Airbnb reservation numbers.

Table 3: Share of Airbnb Properties per Grid (in %) - Distribution

reform	cutoff	(1) *listed prop.*	(2) *> 1 prop.*	(3) *resv. thresh.*	(4) *list. thresh.*	(5) *rev. thresh.*	(6) *amy (2) to (5)*
Berlin 2016	*mean*	.2	.01	.02	.04	.04	.07
	> .50 q.	0	0	0	0	0	0
	> .75 q.	.12	0	0	0	0	.03
	> .90 q.	.62	.03	.06	.07	.1	.16
	> .95 q.	1.07	.06	.14	.12	.2	.31
	max	13.33	.9	1.52	8.33	3.03	8.33
Berlin 2018	*mean*	.35	.01	.07	.06	.06	.11
	> .50 q.	.09	0	0	0	0	0
	> .75 q.	.3	0	.07	.05	.04	.1
	> .90 q.	1.04	.04	.21	.16	.19	.33
	> .95 q.	1.72	.08	.36	.24	.35	.52
	max	16.67	1.77	3.03	8.33	3.03	8.33
Munich	*mean*	.51	.02	.09	.09	.08	.18
	> .50 q.	.34	0	.05	.05	.03	.12
	> .75 q.	.63	0	.14	.14	.12	.27
	> .90 q.	1.16	.05	.22	.27	.23	.44
	> .95 q.	1.45	.09	.28	.33	.32	.6
	max	10	.3	.66	.84	.72	1.2
Hamburg	*mean*	.72	.1	.36	.19	.27	.45
	> .50 q.	.27	0	.09	0	.04	.14
	> .75 q.	.71	.02	.34	.16	.23	.44
	> .90 q.	2	.2	.91	.45	.71	1.14
	> .95 q.	2.84	.44	1.57	.8	1.18	1.92
	max	13.19	8.33	9.890000000000001	5.56	6.67	9.890000000000001

Figure 3: Development of monthly Airbnb reservations in Berlin, Munich, and Hamburg over time.



Notes: The figure shows the monthly reservations in the HSO cites The first vertical green line shows the introduction of Berlin 2106 HSO and the second vertical green line shows the introduction of the Berlin 2018 HSO. The blue and the orange line refer to the introduction dates of HSOs in Munich and Hamburg, respectively.

5 Methodology.

We draw on a difference-in-differences design to identify the effect of tightenings of the HSO regulation on Airbnb activity. As there are strong long-term and seasonal trends in Airbnb listings and reservations, a simple pre and after comparison of Airbnb activity in cities that enacted adjusted their HSO regulation does not uncover the causal effect. We therefore use large German cities (with more than 100,000 inhabitants) without HSO regulation as a control group to difference out common trends in Airbnb activity. The observational unit is the 1 km x 1 km city grid g in month t, defined based on the European geocoding standard ETRS89-LAEA. The difference-in-differences analysis estimates the average treatment effect on the treated (ATT): the impact of the HSO regulations on Airbnb activity in treated city grids. We differentiate between commercial and occasional Airbnb activity by commercial and occasional hosts, $i \in \{commercial, occasional\}$. As sketched above, the HSO regulations in our treated cities - similar to many other HSO regulations worldwide - mainly target the commercial short-term rental activity of commercial hosts. If the laws bite, commercial Airbnb activity short-term rentals by commercial hosts is expected to decline or even to disappear from the market. The effect on occasional hosts Airbnb activity is ambiguous: On the one hand, such activity might increase as occasional hosts may absorb some of the short-term rental demand that was met by commercial hosts prior to the tightening of the HSO introduction (if HSO regulations indeed successfully reduced commercial Airbnb activity). On the other hand, occasional activity might also decline if HSO regulations – potentially unintendedly – impose costs or restrictions on occasional short-term rental activity too.[7]

We estimate a separate difference-in-differences model for each HSO tightening. All properties that were active in the year prior to the HSO intervention (in treatment and control cities) enter our sample. Commercial and occasional properties are defined as in Section 4, where the reference period is the 12 months prior to the intervention.[8] The difference-in-differences analysis captures how Airbnb activity by group i emerged in treated grids relative to control grids from before to after treatment. We account for six pre-intervention and 12 post-intervention months.

Commercial and occasional Airbnb activity is modeled by three measures: i) the overall number of listing days by group i in grid g in month t ; ii) the overall number of reservation days by group i in grid g in month t, and iii) the overall number of active

[7]Requirements to register with the authority, for example, come with fixed costs that may make it unattractive for occasional hosts to register and offer properties for short-term rentals.

[8]For treated *and* control cities, properties are classified as commercial if the host offered multiple properties in a three month period during the year prior to the HSO introduction; the property was rented out for more days than allowed in the *treated* city's HSO legislation, implemented later; it the property is listed on average for more than 25 days per month or earns more than 500 Euro per month, on average

Airbnb properties group i in grid g in month t.[9]

The number of listing days (i) captures the aggregate supply of short-term rental offers; the number of reservation days (ii) the aggregate short-term rental transactions on the Airbnb platform (which are determined by short-term rental supply and short-term rental demand). Measures (i) and (ii) capture both, responses at the extensive margin – staying in the market or leaving – and responses at the intensive margin – how many days properties are listed/rented out per month, conditional on properties staying in the market. Measure (iii) isolates extensive margin responses. The latter are of particular relevance: Many of the negative externalities of short-term rental activity relate to the presence of commercial hosts in the market, who use properties for short-term rentals only. If these hosts leave the market, housing units may be repurposed to long-term residential use and negative externalities from constant visitor streams in residential areas decline.

For each of our HSO regulation and each group i, we estimate difference-in-differences models

$$\mathrm{y}_{git} = \beta_i \ \mathrm{HSO}_{ct} + \lambda_g + \theta_t + \epsilon_{git} \tag{1}$$

where y_{git} measures the Airbnb activity by group i in grid g at time t.

HSO_{ct} is the treatment dummy that takes a value of one if an HSO is in place in city c in month t and zero otherwise. λ_g and θ_t are grid- and month-fixed effects, which capture time-constant differences in Airbnb activity across city grids and common changes to Airbnb activity over time. ϵ_{git} is the error term. β_i captures the average treatment effect on the treated: the change in Airbnb activity in treated grids relative to control grids after treatment for host group i.

To keep the set of control units as large as possible and to increase statistical power, the base analysis comprises grids in the treated city and grids in all German cities with more than 100,000 inhabitants and no HSO regulation during our sample frame. This follows the observation that Airbnb rentals are highly common also in second-tier German towns, many of which are attractive tourist locations. In robustness checks, we show that comparable results to the ones presented below emerge when we restrict the control group to the largest German cities without HSO regulation: Dusseldorf, Frankfurt and Essen.[10]

In the base analysis, we allow errors to be correlated over time within grids but assume independence of errors between grids. In robustness checks, we relax this assumption and allow errors to be correlated at the city level, which is also the level, where the policy variation takes place. As we then have few clusters in each estimation, conventional

[9] Active properties are properties with at least one Airbnb reservation in month t.

[10] An exception to this modeling of the control group are the difference-in-differences models for the HSO introduction in Berlin in 2016. As full information on Airbnb activity in Germany is available to us from 2017 onwards only, we need to rely on big control cities in this case, for which information is available for prior years, too: Dusseldorf, Essen, Frankfurt, Hamburg and Munich. Note that Munich did not have an HSO legislation in 2016; Hamburg had lax rules only.

inference methods based on large sample theory may provide a poor approximation to the finite sample properties of test statistics. We therefore perform bootstrap based inference based on the wild cluster bootstrap, which has been found to perform well in such settings (see MacKinnon et al. (2021); Roodman et al. (2019)).[11]

6 Results.

6.1 Effect of HSOs on Commercial Activity on Airbnb.

Table 4 presents difference-in-differences estimates for the impact of the HSO reforms on short-term rentalAirbnb activity by commercial hosts. We measure y_{git} by the sum of Airbnb listings in grid g and month t in Column (1), the sum of reservation days in grid g and month t in Column (2) and the sum of active properties by commercial hosts in grid g and month t in Column (3).

The first panel presents difference-in-difference estimates for the HSO reform in Berlin in 2016. The results suggest that the intervention lowered the sum of commercial listing days per grid and month by 10.107 days on average. Evaluated at pre-intervention listings, this translates into a relative drop by 20.84 %. Actual short-term rentals also decreased after the intervention: The number of reservation days for commercial properties, on average, declined by 8.896 days per grid and month or 40.82 %; the number of active commercial properties dropped by 0.589 properties or 41.05 %, on average. All difference-in-difference estimates are statistically different from zero at conventional significance levels (p-values are reported in brackets).

As Airbnb activity is concentrated in a few city areas (cf. Figure 2 and Table 3), we zoom in on grids with a high Airbnb intensity. Specifically, we reestimate Equation (1) for the subset of grids with an Airbnb intensity above the 90th percentile of the distribution (where Airbnb intensity is measured by the share of active Airbnb properties - properties with at least one Airbnb listing in the 12 months prior to the intervention).

In absolute terms, Airbnb activity in these high-intensity grids declines strongly in response to the HSO reform: Commercial Airbnb listings, on average, dropped by 122.95 per grid and month; reservation days by 99.475; the number of active commercial Airbnb

[11] Generally, bootstrap based inference relies on the idea to generate many bootstrap samples from the original sample, compute the test statistic in each bootstrap sample and then use the distribution of the bootstrapped test statistics for inference. The wild bootstrap procedure used in this paper has two important further characteristics. First, the bootstrap samples are constructed to keep the covariate distribution in each cluster identical to the original sample. Bertrand et al. (2004), show that bootstrap inference can become unreliable otherwise. Second, the bootstrap samples are constructed imposing the null hypothesis. Basing inference on samples where the null hypothesis holds improves inference because, intuitively, inference also involves the computation of probabilities under the assumption that the null hypothesis is true. To address remaining inference problems when only very few clusters receive treatment, we use a subcluster bootstrap, in which the bootstrap error terms are clustered at the even finer grid level (see MacKinnon and Webb (2018).

Table 4: Effect of HSO on commercial users (DiD estimation), all non-HSOs as control

	monthly listings	monthly reservations	numb. of prop. w. I[monthly reserv.]
Berlin 2016			
ATT	**-10.107**	**-8.896**	**-0.589**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-20.84%	-40.82%	-41.05%
observations	31374	31374	1374
ATT grids high Airbnb intensity	**-122.95**	**-99.475**	**-6.639**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-27.83%	-47.95%	-49.33%
observations	1638	1638	1638
Berlin 2018			
ATT	**-13.585**	**-4.499**	**-0.431**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-19.53%	-13.58%	-21.24%
observations	80517	80517	80517
ATT grids high Airbnb intensity	**-82.718**	**-32.364**	**-2.661**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-22.46%	-17.61%	-24.05%
observations	8140	8140	8140
Munich 2017			
ATT	**-27.557**	**-12.705**	**-0.744**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-30.19%	-34.74%	-34.01%
observations	50475	50475	50475
ATT grids high Airbnb intensity	**-147.077**	**-63.313**	**-3.767**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-31.50%	-33.59%	-33.54%
observations	3090	3090	3090
Hamburg 2018			
ATT	**-50.370**	**-49.704**	**-2.535**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-31.87%	-49.46%	-45.02%
observations	74045	74045	74045
ATT grids high Airbnb intensity	**-207.206**	**-205.380**	**-10.132**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-31.84%	-48.06%	-42.94%
observations	3066	3066	3066

properties by 6.639 properties. The strong response largely relates to the high pre-intervention level of Airbnb activity. In relative terms, commercial hosts' response rates are comparable to the full sample.

Adjustments of the definition of high Airbnb intensity grids do not materially alter this result pattern. Table A.1 in the Appendix presents estimates, where the sample is restricted to grids with intermediate and little Airbnb intensity - defined as Airbnb intensity between the 75th and 90th percentile of the intensity distribution and below the 75th percentile respectively. In line with intuition, the respective point estimates turn out to be smaller. The relative size of the effect is again comparable to the baseline estimates though.

Table 4, moreover, presents analogous estimates for the HSO reforms in Berlin 2018, Munich 2017 and Hamburg 2018. The qualitative findings resemble those of the 2016 reform in Berlin. For all three interventions, our difference-in-differences estimates suggest that commercial Airbnb activity – as measured by listings, reservations and active properties – dropped significantly in the wake of the reforms. Again, absolute responses are, moreover, stronger when we focus on grids with a high Airbnb intensity.

Summarizing, our results thus suggest that commercial Airbnb activity significantly

is reduced when HSOs are tightened. We find significant reductions in all Airbnb activity indicators and across all studied HSO reforms. None of the reforms fully eliminated commercial Airbnb activity, however. Our base line estimates (cf. Table 4) suggest that the number of monthly Airbnb reservations dropped by 18 % (in Berlin 2018) to 48 % (in Hamburg 2018). A significant share of commercial hosts remains in the market after the HSO reform.

Additional results reported in Figure 4 show that at least part of this non-response reflects non-compliance with HSO laws. Next to banning misuse of residential property for short-term rentals in general, all studied HSOs define explicit reservation day limits per annum, above which short-term renting is forbidden. While these limits apply only to primary residences in Hamburg and only to secondary residences in Berlin, they cover all properties in Munich. In consequence, if hosts in Munich are observed to rent out property for more than 56 days after 2018, this is direct evidence for non-compliance with the HSO law.[12]

Figure 4: Non-compliance: Distribution of reservation days by property for Munich

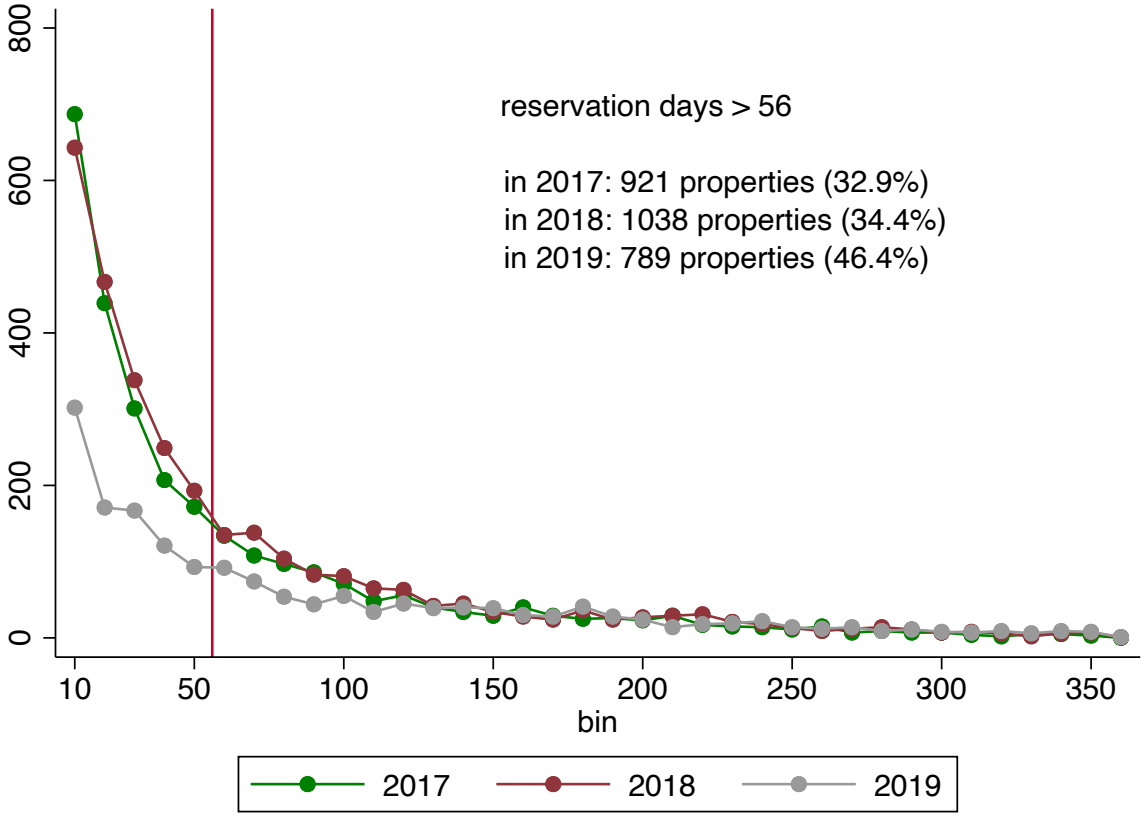


Figure 4 depicts the distribution of the number of annual reservation days by active

[12]We checked with the city of Munich, which confirmed that no exemptions from the reservation day limit in the HSO regulation were granted.

Airbnb hosts in Munich in 2017 – the year before the HSO introduction - as well as in 2018 and 2019 – the year after the HSO introduction. The distribution of reservation days is strikingly similar across the years. There is no bunching at the 56 days reservation day threshold and no indication for a reduction in the number of properties that are rented out on Airbnb for more than 56 days in 2018. In 2019, The number of active Airbnb properties declines - but it is mainly properties with less than 56 reservation days that drop out of the market. This descriptive evidence points to significant enforcement problems of HSO legislations and to significant non-compliance behavior. Similar results are reported for Berlin and Hamburg in Figure A.1 of the Appendix.[13]

There are a number of potential explanations for the differences in relative HSO responses across cities. These differences may relate to HSO design elements – or combinations of design elements – that vary across reforms and may differ in their impact on Airbnb activity. Obviously, hosts may also differ in their response to the introduction of HSO regulations and their modification. Differences in estimates may, moreover, relate to differences in the treated group of hosts. The documented relatively weak response of commercial hosts to the 2018 HSO tightening might, for example, reflect that key elements of the reform – the registration requirement and the reservation day limit – do not pose significant (additional) hurdles to commercial Airbnb activity. But it might also reflect that compliant host 'types' may have already left the market when the HSO regulation was initially introduced in 2016. The 2018 intervention hence have treated a relatively unresponsive subset of commercial hosts.

Finally, differences in response rates may, in principle, also relate to differences in enforcement activities across cities. While there is certainly some variation, enforcement is broadly comparable across cities. In Berlin, Munich and Hamburg, specific administrative units are in change for HSO enforcement. In all three cities, inhabitants can report misuse of residential property to the authorities. Berlin and Hamburg, additionally, require Airbnb hosts to register properties with the city. Importantly, in none of the cities, there is information sharing on platform activity between Airbnb and authorities. Comprehensive third-party reporting is thus missing - which is consistent with the enforcement problems documented in Figures 4 and A.1.

Next to variation in effect size across cities, we find variation in effect size across Airbnb activity indicators. For the HSO reform in Berlin 2016 and the HSO reform in Hamburg 2018, we find a quantitatively weaker relative effect on the sum of Airbnb listing days than on the sum of Airbnb transactions (measured by the sum of reservation days and the number of active Airbnb properties).[14] There are different potential explanations for this pattern. Hosts - to comply with HSO regulations - may become more selective in

[13]The evidence for Berlin and Hamburg is less straight forward to interpret as the reservation day limit does not apply to primary residences in the former and to secondary residence in the latter case.

[14]Note that, in line with intuition, the effect of HSO regulations on absolute activity is consistently smaller for the number of reservation days relative to the number of listing days.

accepting visitors. Alternatively, the results may reflect that short-term rental demand declines as well when HSOs are introduced or tightened: Visitors being aware of the laws may become reluctant to book properties from commercial hosts after the HSO reforms.[15]

6.2 Effect of HSOs on Occasional Activity on Airbnb.

Table 5 reports difference-in-difference estimates for the impact of the HSO legislations on occasional Airbnb activity. Occasional hosts are not the prime target of HSO legislations. They may benefit from the decline in commercial short-term rental supply when HSOs are introduced/tightened. But the laws may also restrict transactions by occasional hosts and decrease their short-term rental supply. The organization of Table 5 mirrors Table 4. The estimates show an ambiguous negative effect of HSO legislations on occasional short-term rental activity on Airbnb. Throughout all specifications, the difference-in-differences estimates are negative and statistically significant.

Table 5: Effect of HSO on occasional users (DiD estimation), all non-HSOs as control

	monthly listings	**monthly reservations**	**numb. of prop. w. I[monthly reserv.]**
Berlin 2016			
ATT	**-7.751**	**-3.806**	**-0.544**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-11.66%	-22.40%	-29.66%
observations	31374	31374	31374
ATT grids high Airbnb intensity	**-154.472**	**-54.917**	**-6.997**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-27.42%	-36.94%	-43.70%
observations	1170	1170	1170
Berlin 2018			
ATT	**-26.207**	**-6.162**	**-0.986**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-33.53%	-26.27%	-45.19%
observations	80517	80517	80517
ATT grids high Airbnb intensity	**-159.217**	**-44.520**	**-6.185**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-38.50%	-34.21%	-51.67%
observations	5739	5739	5739
Munich 2017			
ATT	**-23.835**	**-9.993**	**-0.826**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-35.99%	-48.75%	-49.83%
observations	50475	50475	50475
ATT grids high Airbnb intensity	**-98.680**	**-43.542**	**-3.423**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-37.60%	-52.40%	-52.32%
observations	2415	2415	2415
Hamburg 2018			
ATT	**-13.919**	**-6.454**	**-0.895**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-28.73%	-51.89%	-63.43%
observations	74045	74045	74045
ATT grids high Airbnb intensity	**-72.156**	**-32.502**	**-4.281**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-35.96%	-56.46%	-67.72%
observations	3066	3066	3066

The response rates by occasional users are also quantitatively sizable. The full sample

[15]There are indications on the Airbnb platform that allow visitors to proxy for commercial actors, e.g. the status of a "super hosts" or a high number of ratings.

specification for the Berlin 2016 intervention suggests that occasional listing days dropped by 7.751 days or 11.66 % per grid and month; the number of Airbnb reservation days declined by 3.806 days or 22.40 % per grid and month and the number of active Airbnb properties by 0.544 properties or 29.66 % per grid and month. In high Airbnb intensity grids, the effects are even stronger: Here, the HSO reform reduced the sum of occasional listings per grid and month by 154.472 listing days or 27.42 %, the sum of reservations by 54.917 reservation days or 36.94 % and the number of active occasional properties by 6.997 properties or 43.70 %.

Analogous results are presented for the other HSO reforms. All interventions led to a significant decline in occasional short-term rental activity. Again, there is some variation in the quantitative effect across cities, which partly reflects differences in initial occasional Airbnb activity. But effects also vary in relative terms: They are somewhat stronger for the HSO reforms in Munich and Hamburg than for the HSO reform in Berlin. In Munich and Hamburg the number of reservation days dropped by 48.75 % (52.40 %) and 51.89 % (56.46 %) in all city grids (city grids with a high Airbnb intensity), respectively.

The findings unambiguously suggest that occasional Airbnb activity dropped in the wake of the HSO tightenings. This decline was plausibly not intended by the legislators who deliberately chose not to ban Airbnb activity but only to restricts misuse and business models that rely on repurposing of residential property for short-term use. Although there is some variation across interventions (which will be discussed below), the drop of occasional activity in the wake of HSO reforms is, in relative terms, not less pronounced than the observed reduction in commercial Airbnb activity.

Our findings reject the notion that HSO laws can be targeted to commercial activity alone. Occasional hosts decrease their short-term rental activity as well. There is interesting variation in the size of the response across interventions: The response by occasional hosts to the HSO reform in Berlin in 2016, for example, tends to be weaker than the response by commercial hosts. Occasional hosts reduced the sum of reservation days per grid and month by 36.94 % in high Airbnb intensity grids, commercial hosts by 47.95 %. The picture is reversed for the 2018 HSO tightening in Berlin. Here occasional hosts respond more strongly: Their sum of reservation days per grid and month in high Airbnb intensity grids dropped by 34.12 %, while the sum of reservation days by commercial hosts declined by 17.61 %. This is consistent with design elements of the interventions: When Berlin initially introduced its HSO regulation, it explicitly banned the misuse of residential property for short-term rental purposes. While the legislation left misuse largely undefined, it was clear from the legal text that frequent and regular short-term rentals were forbidden. This is consistent with stronger responses by commercial hosts to the legislation.

The main element of the 2018 modification of the HSO law, in turn, was the introduction of a requirement of short-term rental hosts to register with the city. Given that

monetary and non-monetary registration costs are largely fixed in nature, theory predicts that occasional hosts are more strongly than commercial hosts, who can spread the registration costs across a larger activity base and hence are more likely to still break even. Consistent with this interpretation, we find a particularly strong drop in extensive margin responses by occasional users to the 2018 intervention: The difference-in-differences estimate suggests that the number of active occasional properties in high Airbnb intensity grids dropped by 51.67 %, while the number of active commercial properties dropped by 24.05 % only. The interpretation is also consistent with response behavior to Hamburg's HSO refinement in 2018, which among others introduced a requirement to register with the city. Again, our estimates suggest that the number of active occasional property drops sharply after the intervention by 67.72 %.

6.3 Extensive Margin Response.

Finally, Table 6 takes a closer look at the extensive margin response. This is of particular interest as some of the externalities of Airbnb use relate to a repurposing of residential property. If residential properties are exclusively used for short-term rental purposes, this reduces the supply of residential housing and may exacerbate residential housing needs. A simple back-of-the-envelope analysis yields an estimate for the number of commercial properties that are redirected from pure short-term to long-term residential purposes by HSO legislations.

Table 6: Effect of HSO on market exits

	market exists commercial users	market exists occasional users
Berlin 2016	-370.59	-322.97
Berlin 2018	-239.66	-549.79
Munich 2017	-185.49	-156.70
Hamburg 2019	-1067.55	-379.12

The analysis draws on $\hat{\beta}^{\text{commercial},j}$ for $j \in \{\text{low}, \text{intermediate}, \text{high}\}$ reported in Table 4 and Table A.1 in the Appendix. The number of redirected properties - following our above definition - read: $\sum_j \hat{\beta}^{\text{commercial},j} \cdot g^{\text{commercial},j}$ where $g^{\text{commercial},j}$ is the number of grids of type j in the considered city. The estimated change in the number of commercial Airbnb properties ranges between 185 in Munich and 1067 in Hamburg. Differences in this estimate largely relates to differences in the initial commercial host counts. In all cities, these estimates are dwarfed by the city's housing needs. This still holds if we use a laxer commercial host definitions and even if we, in the limit, assume that all Airbnb properties that exit the market are redirected from pure short-term to residential use (cf. the second Column of Table 6)

6.4 Robustness Checks.

We conducted a number of robustness checks. First, we reestimate our baseline model allowing for clustering – i.e. a correlation of errors – at the city instead of the grid level (see Section 5 on methodology). The results are presented in Figure A.2 of the Appendix: While p-values for the null hypothesis $\beta^{\text{commercial}} = 0$ increase throughout all specifications, the estimates remain statistically significant at conventional significance levels.

Second, we assess the robustness of our findings to adjustments in the definition of commercial activity. While the criteria for the identification of commercial activity (number of properties, number of listing days, number of reservation days, revenues earned) root in theory, specific definitional thresholds are necessarily ad hoc. Figure A.3 in the Appendix reports sensitivity checks along two dimensions: First, we report relative response rates to the HSOs separately for each definition of commercial activity (while our base analysis defines a property as commercial if any commercial activity definition applies); second, we document how the difference-in-differences estimate changes when we adjust the threshold values for the respective definition. The estimated HSO effects on commercial Airbnb activity are robust to adjustments of the commercial activity definition.

Third, we ran robustness checks where we restrict the control group to grids in very large German cities without HSO regulation. The results are presented in Table A.2 in the online appendix and again yield results similar to our baseline estimates.

We, furthermore, assess the dynamics of the intervention by estimating an event study of the following form:

$$\mathrm{y}_{git} = \sum_{d=-6}^{-2} \beta_d HSO_{ct}^d + \sum_{d=0}^{11} \beta_d HSO_{ct}^d + \lambda_g + \theta_t + \epsilon_{git} \tag{2}$$

where HSO_{ct}^d is a dummy variable that takes on the value 1 in the treated city in months with a d-month-gap to the reform date. The event study estimates are presented in Figures A.4 and A.5 in the Appendix and use total number of reservation of commercial properties in grid g at time t as dependent variable. Two important insights emerge: First, the estimates do not provide any indication for significant differences in the pre-trend of commercial Airbnb activity in treated and control grids. This supports the common trend assumption underlying our difference-in-differences design; second, we find that commercial activity drops relatively quickly after the intervention and remains constant at the decreased level thereafter. Furthermore, the figure documents that the estimated effects do not materially change with alternative definitions of commercial Airbnb activity (that draw on a single commercial activity dimension only).[16]

[16]Note that the absolute size of the response differs across definitions of commercial Airbnb activity

We ran analogous robustness checks for the analysis of occasional Airbnb activity. Figure A.3 in the Appendix shows that the difference-in-differences estimates remain statistically significant when we allow for clustering at the city level. Table A.3 in the Appendix reports results comparable to our baseline estimates when the set of control grids is restricted to grids in the largest German cities without HSO regulation (Dusseldorf, Essen, Frankfurt).

Figures A.7 and A.8, moreover, report event study estimates of Equation (2) where the dependent variable is the sum of occasional users' reservation days per grid and month. The dynamics of the intervention are similar to the ones reported for commercial hosts. The figure confirms parallel pre-trends in HSO activity prior to the interventions. After the intervention, Airbnb activity quickly drops in treated relative to control grids and remains stable at the reduced level thereafter.

Figure A.9 conveys that the result pattern remains largely unaffected when we adjust the definition of occasional Airbnb hosts. Our base analysis defines hosts as occasional users if none of our commercial host definition applies. The figure reports event study estimates for tighter occasional host definitions, where hosts are only classified as occasional if they have less than 50, 25 and 10 reservation days respectively.

7 Effect of HSOs on long-term rents.

7.1 Data and Estimation Methodology.

To determine the impact of HSOs on flat rents, we rely on data on real estate offers provided by the Research Data Centre of the Federal Statistical Office at RWI Essen (see RWI (2020) for details). The underlying information stems from Immoscout24, the leading market place for real estate transactions in Germany.[17] For each offer, we observe information on the property rent and various property characteristics. In the following, we will make use of information on the size of the property in square meters, the number of rooms, the living space and a proxy for utility costs, which are well covered in the data.

Rental offers in Berlin, Hamburg and Munich are dominated by flats. Data on offers for whole houses, moreover, comes with the limitation that property size is not separately given for the property's living space and the attached land area in our data. We therefore focus the analysis on flat rents. The sample is, moreover, restricted to properties in grids that are strongly penetrated by Airbnb in the year before the HSO reform – operationalized by a share of active Airbnb properties above the 90th percentile of the

as the number of Airbnb properties classified as commercial varies across definitions. In relative terms, response rates tend to be comparable. See Figure A.3 in the Appendix.

[17] Immoscout24's self-reported market share is 50 %; see Boelmann and Schaffner (2019).

distribution. As documented in the prior section, these are the grids where the HSO reforms (in absolute and relative terms) substantially decreased local Airbnb activity. If HSO reforms are instrumental in impacting prices in rental markets, we expect rental price shifts to emerge in these grids.

Table A.4 in the Appendix presents descriptive statistics for the micro data on flat offers. The observational unit is the rental offer in strongly penetrated grids in the three treatment cities (Berlin, Hamburg and Munich) and control towns (see definition below). To mitigate the impact of outliers, we drop flat offers with very low and very high rental prices and very low and high property size respectively (below the first and above 99th percentile of the respective distribution) from the analysis.

To quantify the impact of HSO reforms on rental prices, we again draw on a difference-in-differences design. The estimation model takes the following form:

$$\ln(r_{ict}) = \beta_1 \text{ HSO}_{ct} + \mathbf{X}_{ict}\beta + \lambda_i + \mu_t + \epsilon_{ict} \tag{3}$$

where r_{ict} is the average property rent in grid i of city c in month t.

Grid fixed effects absorb time-constant heterogeneity across grids, time fixed effects common trends in property prices across all grids. The vector $\mathbf{X}_{ict}$ includes control variables that absorb changes in the composition of offered properties in a given grid: We account for variation in the number of rooms, the living space (in square meter) and the utility bill. The latter variable serves as a proxy for property quality. To allow for a flexible functional form relationship between the sketched property characteristics and the rental price we, for each property characteristic, determine the share of properties per grid that fall into 5point-bins of the respective variable distribution and add the full set of shares to the vector of control regressors $\mathbf{X}_{ict}$.[18]

Analogously to Section 6, Equation (3) is estimated separately for each of the reforms. Grids in cities without HSO legislation serve as control group. As control units are 'never-treated', we do not have to assume homogeneous treatment effects for the estimator to be consistent (Goodman-Bacon 2021). Given that house price trends in Germany during our sample period differed markedly between leading urban areas and smaller-scale cities, we restrict the set of control units to grids in very large cities without HSO legislation; in robustness checks (see Table A.5) in the Appendix, we show that similar results to the ones presented below emerge when we rely on the full set of control cities without HSO legislation and more than 100,000 inhabitants (see our discussion in the prior section).

[18]Note that this is a more flexible model specification than using square meter rents as dependent variable and dropping the set of property size regressors. In robustness checks, we, however, reran our analysis with square meters as dependent variable, which yields similar results as the ones presented below (not reported, but available from the authors upon request).

7.2 Results.

The baseline results are presented in Column (1) of Table 7. For all four reforms, the difference-in-differences estimate is statistically insignificant and close to zero. The point estimates suggest that the impact of the studied HSO legislations on rental prices in strongly penetrated grids ranges between a small -2 % and +2 %.

The specifications in Column (2) rerun the base model for highly penetrated grids defined based on commercial Airbnb activity in the grid (a ratio of commercial hosts over all properties in the grid above the 90th percentile of the distribution in the pre-reform year).[19] This accounts for the possibility that rental price effects may be confined to shifts in commercial Airbnb activity: When commercial Airbnb hosts leave the market, properties are repurposed from short-term use to long-term residential use, which increases the property supply in the long-term rental market. Restriction of occasional Airbnb use, in turn, lower rental prices because tenants are stripped from the option to sublet apartments during personal absence, which lowers their willingness to pay. The difference-in-differences estimates in Column (2) turn out small, again rejecting major shifts in rental prices in the wake of HSO reforms even when we focus on the most highly penetrated grids based on professional Airbnb activity. With the exception of the 2018 reform in Hamburg, all difference-in-differences estimates are, moreover, not different from zero in a statistical sense.

Table 7: DiD: Effects of HSOs on Rents

		>90% Airbnb Exposure	
		listed properties	**commercials**
Berlin 2016	β	**0.01225**	**-0.00402**
	p-values	(0.32)	(0.72)
	Obs.	2587	2683
Berlin 2018	β	**0.02217**	**0.03691**
	p-values	(0.21)	(0.28)
	Obs.	2354	2190
Munich	β	**0.00716**	**0.00794**
	p-values	(0.68)	(0.75)
	Obs.	1801	1739
Hamburg	β	**-0.01871**	**-0.02205**
	p-values	(0.18)	(0.03)
	Obs.	1801	1739

Figure A.10 in the Appendix present results from event study specifications analogously to Equation (2). Two key insights emerge: First, the figure supports the parallel trends assumption, showing that rental prices emerged similarly in treatment and control group prior to the HSO reforms. Second, the figure supports the baseline finding that the HSO reforms did not substantially alter rental prices in the housing markets of treated cities. This – as depicted by the figures – also holds true when we follow alternative strategies to select highly treated city grids that enter the estimation sample.

Our findings hence reject the notion that HSO regulations benefit local residents by significantly lowering local rental prices. There are a number of potential explanations for

[19] We account for all possible definitions of a professional host sketched in Section 4.

this finding: First, German rental markets are heavily regulated, which may rationalize the absence of a significant price response. Second, downward price rigidities may prevent rental prices from adjusting. Third, Airbnb penetration rates may be too weak to induce rental price responses, even in the most highly penetrated grids in our treated cities.

8 Conclusion.

Home sharing platforms have decreased matching costs to bring property owners and short-term renters together and have led to an increase in business activities on home sharing markets. How individuals use these new possibilities on short-term rentals differs, however, a lot. Beside individuals that occasionally share their place of residence for shorter-period of times, we can identify platform users that commercially offer properties. Since increasing activities on short-term rental markets are under the suspicion to increase rents and property prices on already intense tradition housing markets, several European cities have recently followed the example of larger US cities and have implemented home sharing ordinances (HSOs). Evidence on the effectiveness of these HSOs is, however, surprisingly rare.

We analyze how various HSOs that have been implemented in German cities affect the listing behavior of commercial and occasional users and how rents and property prices are affected by these changes. Our data provides entire listing histories of platform users which allows us to classify commercial use of short-term renting based on i) the number of properties offered by the same host, the number of days a property is rented out per year, the availability of the property on the Airbnb platform, and the revenue realized with the property on Airbnb. Differentiating between commercial and occasional activities is crucial for policy implications, since commercial users are more likely affecting traditional housing markets by increasing demand for properties as an investment object and by reallocating properties from long-term rental markets to short-term rental markets. Our data covers Airbnb activities in entire Germany which allows us to identify counterfactual developments of listing behavior in cities that have not implemented an HSOs during our time of observation. Applying different-and-different analyses we are able to identify causal effects of HSOs on Airbnb activities and long-term rents.

We find evidence that HSOs are effective in reducing Airbnb activities. In line with the objective of HSOs, they decrease commercial activity although commercial activity is not entirely banned from the platform pointing to enforcement problems. As a not intended negative side effect we, however, find also a reduction in Airbnb activities of occasional users that unlikely affect traditional housing markets. Behavioral responses by occasional users may be explained, e.g., by increasing administration costs due to introduced registration requirements. In contrast to previous studies conducted for the US, we do not find any significant effects of HSOs on long-term rents; not even in areas

with the highest penetration of Airbnb. Although our data does not allow to explain the differences in results entirely, we identify some differences between the situation in the US and Germany that may drive differences in the effectiveness of HSOs: HSOs in the US are generally stricter, US cities often face higher Airbnb penetration than German cities, and housing market regulation in Germany may lead to rigid long-term rents.

We show that HSOs negatively affect business models that are based on short-term rentals. HSOs not only reduce Airbnb activities of commercial users but (unintentionally) also negatively affect occasional users; a side effect widely neglected in the political discussion. Our results contribute to an ongoing discussion in large cities around the world how to reduce Airbnb activities to release traditional housing markets. Although we find that HSOs can successfully reduce Airbnb activities, policymakers may be disappointed not seeing significant effects on long-term rents.

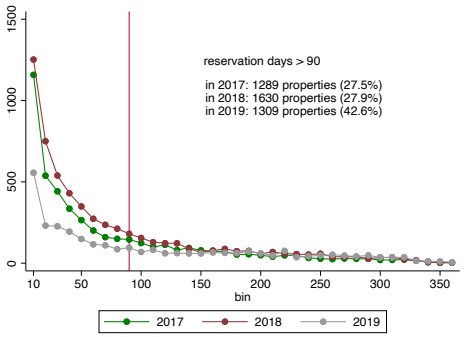
Appendix

Table A.1: Effect of HSO on commercial users (DiD estimation); all non-HSOs as control; grids with intermediate and little Airbnb intensity

	monthly listings	**monthly reservations**	**numb. of prop. w. I[monthly reserv.]**
Berlin 2016			
ATT grids intermediate Airbnb intensity	**-39.752**	**-33.855**	**-2.073**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-23.77%	-44.11%	-42.01%
observations	1836	1836	1836
ATT grids little Airbnb intensity	**-1.570**	**-1.248**	**-0.086**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-14.15%	-29.82%	-28.62%
observations	23274	23274	23274
Berlin 2018			
ATT grids intermediate Airbnb intensity	**-10.533**	**-2.37**3	**-0.391**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-11.17%	-5.59%	-14.53%
observations	16042	16042	16042
ATT grids little Airbnb intensity	**-0.244**	**0.373**	**0.008**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-3.82%	16.67%	5.69%
observations	55521	55521	55521
Munich 2017			
ATT grids intermediate Airbnb intensity	**-24.314**	**-10.629**	**-0.722**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-18.72%	-21.06%	-23.55%
observations	2550	2550	2550
ATT grids little Airbnb intensity	**-6.590**	**-3.503**	**-0.204**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-24.80%	-32.50%	-31.90%
observations	44355	44355	44355
Hamburg 2019			
ATT grids intermediate Airbnb intensity	**-63.941**	**-74.910**	**-3.978**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-23.06%	-43.17%	-40.48%
observations	5775	5775	5775
ATT grids little Airbnb intensity	**-6.058**	**-7.258**	**-0.403**
p-value	(0.00)	(0.00)	(0.00)
relative effect	-17.72%	-36.30%	-34.78%
observations	64469	64469	64469

Figure A.1: Non-compliance: Distribution Reservation Days by Property for Berlin and Hamburg

(a) Berlin



(b) Hamburg

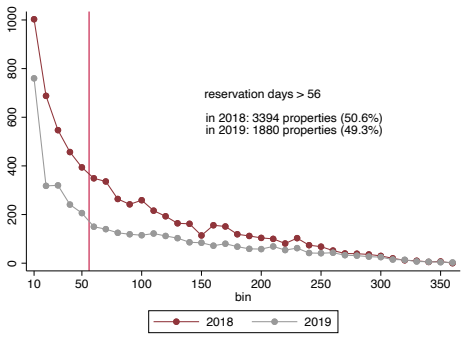
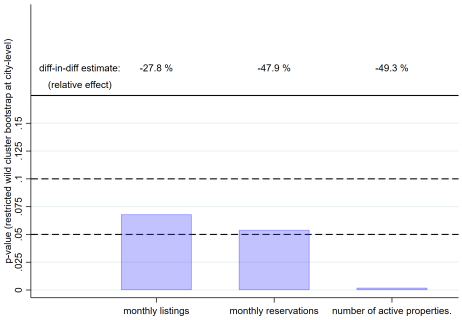
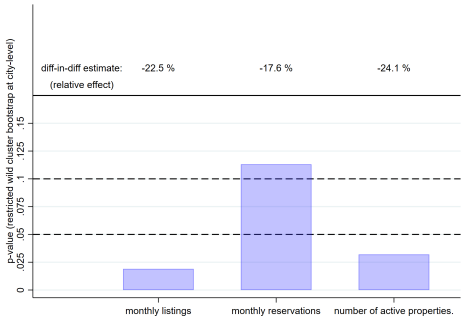


Figure A.2: DiD results for commercial activity and clustering on city level

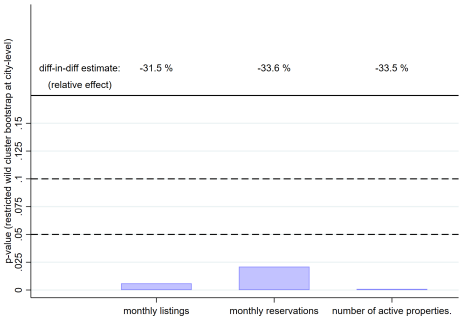
(a) Berlin 2016



(b) Berlin 2018



(c) Munich



(d) Hamburg

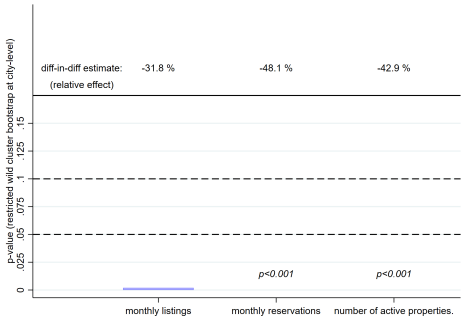
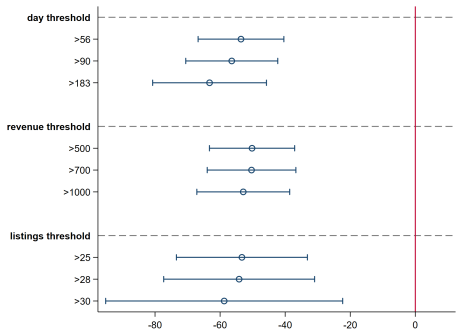
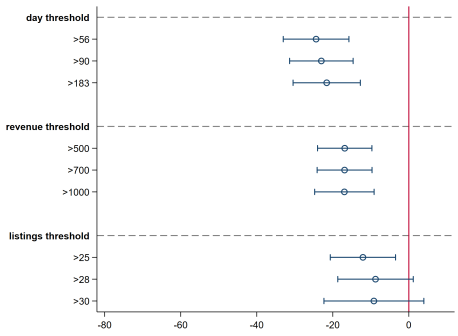


Figure A.3: DiD results with alternative definitions of commercial activity

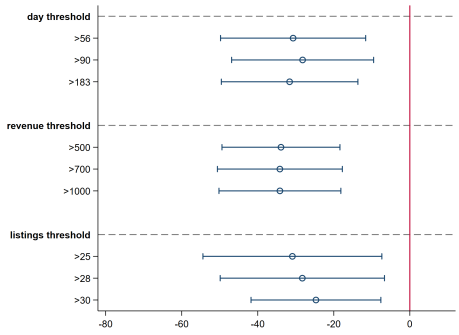
(a) Berlin 2016



(b) Berlin 2018



(c) Munich



(d) Hamburg

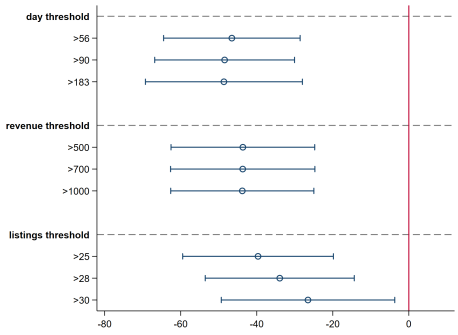


Table A.2: Effect of HSO on commercial users (DiD estimation), big cities as control

	monthly listings	**monthly reservations**	**numb. of prop. w. I[monthly reserv.]**
Berlin 2016			
ATT	**-14.232**	**-11.005**	**-0.686**
p-value	(0.36)	(0.39)	(0.57)
relative effect	-29.35%	-50.49%	-47.84%
observations	18900	18900	18900
ATT grids high Airbnb intensity	**-137.338**	**-107.114**	**-6.869**
p-value	(0.49)	(0.44)	(0.51)
relative effect	-31.08%	-51.63%	-51.03%
observations	1314	1314	1314
Berlin 2018			
ATT	**-4.263**	**-0.096**	**-0.094**
p-value	(0.67)	(0.98)	(0.73)
relative effect	-6.13%	-0.29%	-4.66%
observations	21692	21692	21692
ATT grids high Airbnb intensity	**-46.053**	**-12.934**	**-1.319**
p-value	(0.11)	(0.43)	(0.22)
relative effect	-12.50%	-7.04%	-11.93%
observations	2926	2926	2926
Munich 2017			
ATT	**-25.782**	**-9.406**	**-0.634**
p-value	(0.26)	(0.34)	(0.03)
relative effect	-28.24%	-25.72%	-29.00%
observations	16577	16577	16577
ATT grids high Airbnb intensity	**-144.886**	**-47.560**	**-3.375**
p-value	(0.20)	(0.39)	(0.00)
relative effect	-31.03%	-25.23%	-30.05%
observations	2181	2181	2181
Hamburg 2019			
ATT	**-35.738**	**-44.890**	**-2.216**
p-value	(0.23)	(0.10)	(0.13)
relative effect	-22.61%	-44.67%	-39.35%
observations	18102	18102	18102
ATT grids high Airbnb intensity	**-130.923**	**-172.240**	**-8.209**
p-value	(0.03)	(0.07)	(0.02)
relative effect	-20.12%	-40.03%	-34.79%
observations	1428	1428	1428

Figure A.4: Event study, commercial users, all grids

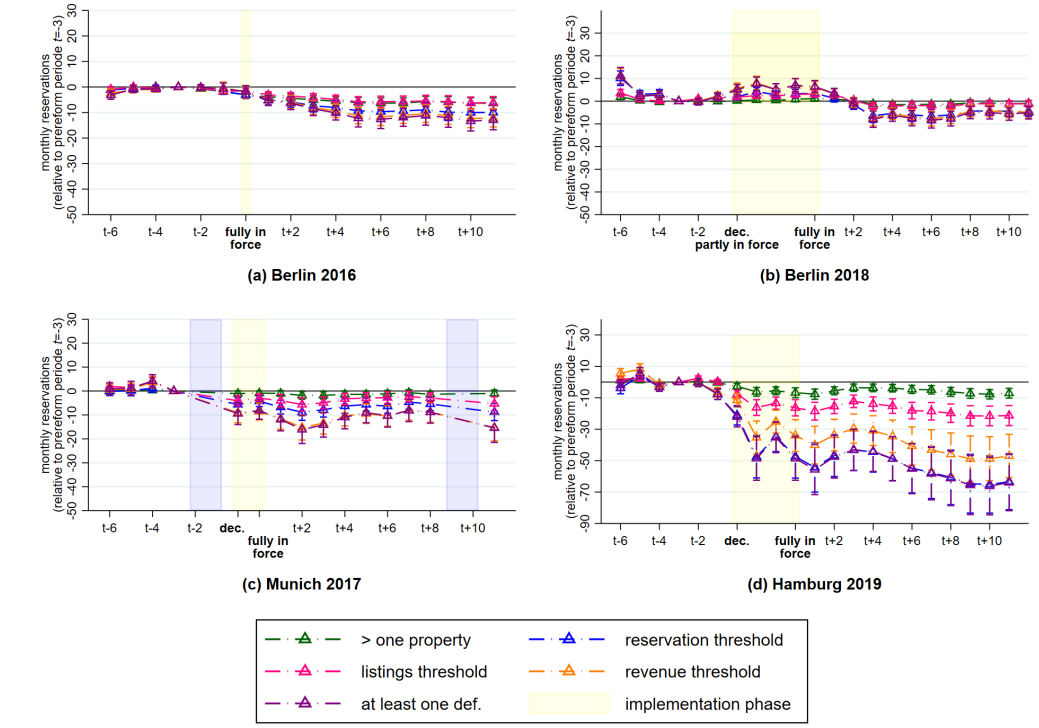


Figure A.5: Event study, commercial users, high-intensity grids

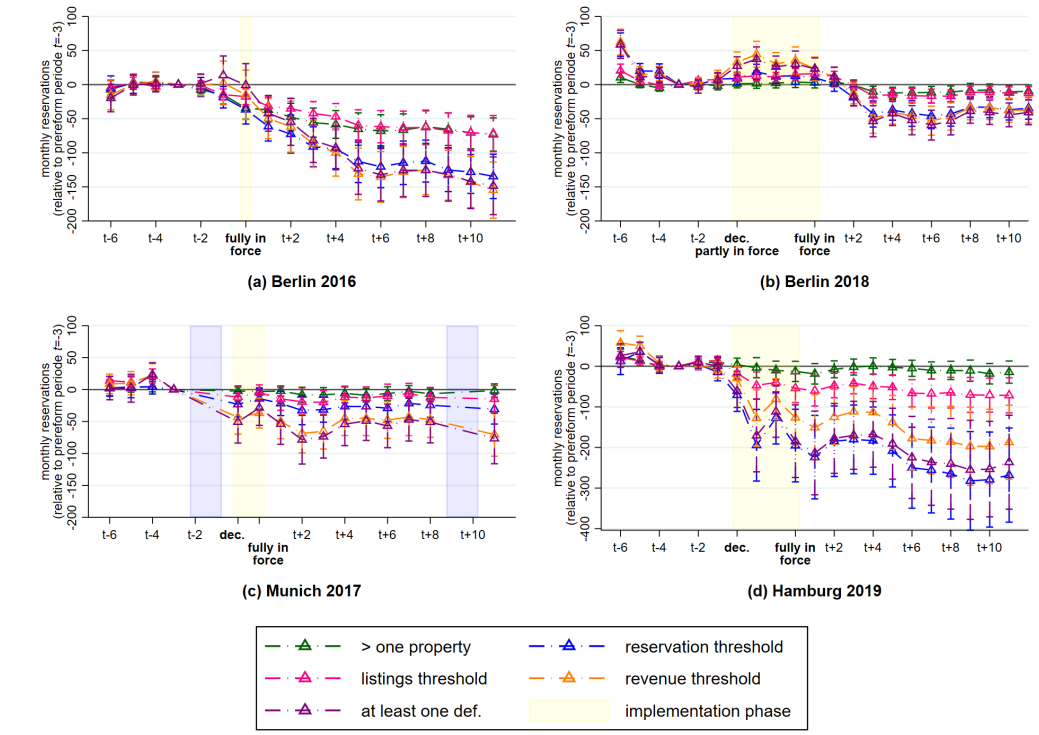
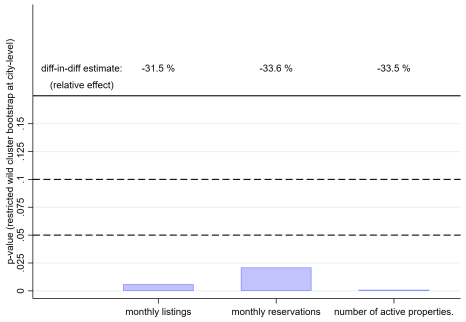


Figure A.6: DiD results for occasional activity and clustering on city level

(a) Berlin 2016

(b) Berlin 2018



(c) Munich

(d) Hamburg

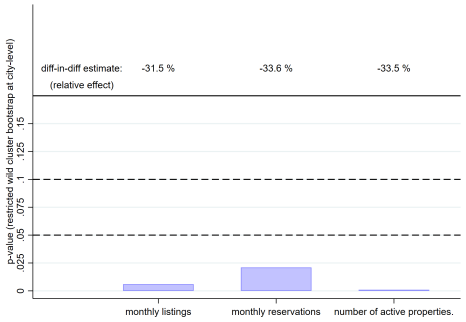


Table A.3: Effect of HSO on occasional users (DiD estimation), big cities as control

	monthly listings	**monthly reservations**	**numb. of prop. w. I[monthly reserv.]**
Berlin 2016			
ATT	**-15.218**	**-5.259**	**-0.643**
p-value	(0.47)	(0.40)	(0.48)
relative effect	-22.88%	-30.95%	-35.06%
observations	18900	18900	18900
ATT grids high Airbnb intensity	**-150.21**	**-53.843**	**-6.822**
p-value	(0.39)	(0.32)	(0.37)
relative effect	-26.66%	-36.22%	-42.61%
observations	1116	1116	1116
Berlin 2018			
ATT	**-14.565**	**-2.015**	**-0.570**
p-value	(0.39)	(0.66)	(0.34)
relative effect	-18.64%	-8.59%	-26.15%
observations	21692	21692	21692
ATT grids high Airbnb intensity	**-107.457**	**-26.163**	**-4.508**
p-value	(0.02)	(0.06)	(0.03)
relative effect	-25.98%	-20.10%	-37.66%
observations	2552	2552	2552
Munich 2017			
ATT	**-10.394**	**-0.753**	**-0.162**
p-value	(0.36)	(0.95)	(0.80)
relative effect	-15.69%	-3.68%	-9.80%
observations	16577	16577	16577
ATT grids high Airbnb intensity	**-33.282**	**5.509**	**0.096**
p-value	(0.43)	(0.90)	(0.97)
relative effect	-12.68%	6.63%	1.48%
observations	1711	1711	1711
Hamburg 2019			
ATT	**-4.482**	**-5.034**	**-0.680**
p-value	(0.62)	(0.28)	(0.24)
relative effect	-9.25%	-40.47%	-48.23%
observations	18102	18102	18102
ATT grids high Airbnb intensity	**-30.320**	**-25.997**	**-3.271**
p-value	(0.44)	(0.10)	(0.05)
relative effect	-15.11%	-45.16%	-51.75%
observations	1533	1533	1533

Figure A.7: Event study, occasional users, all grids

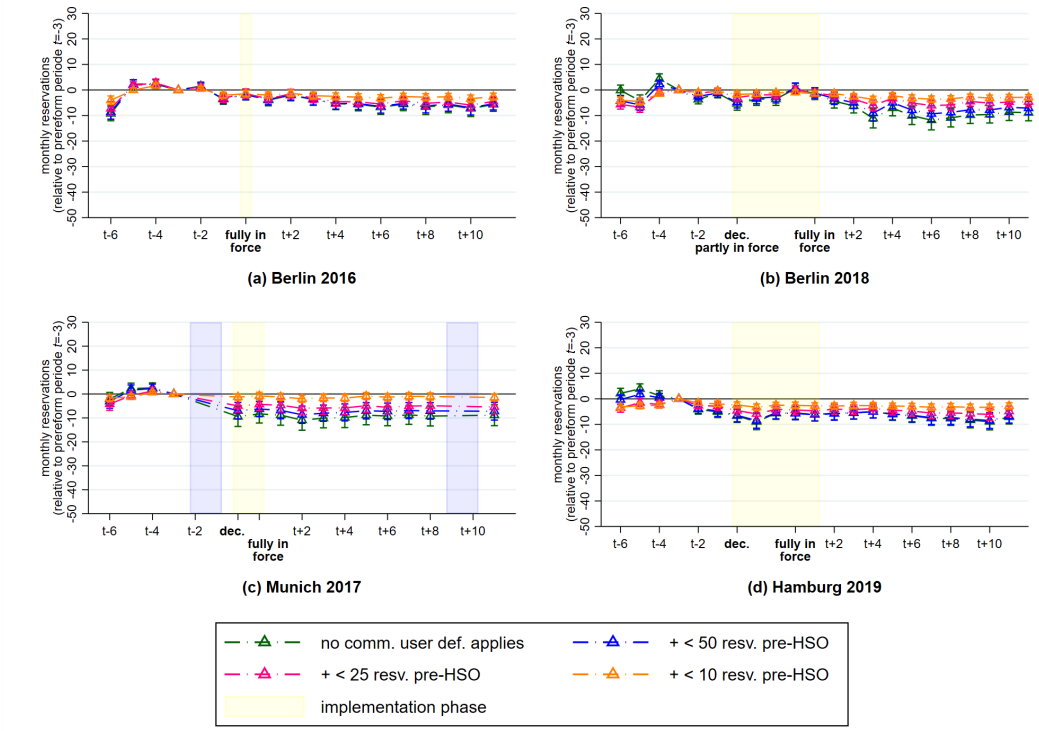


Figure A.8: Event study, occasional users, high-intensity grids

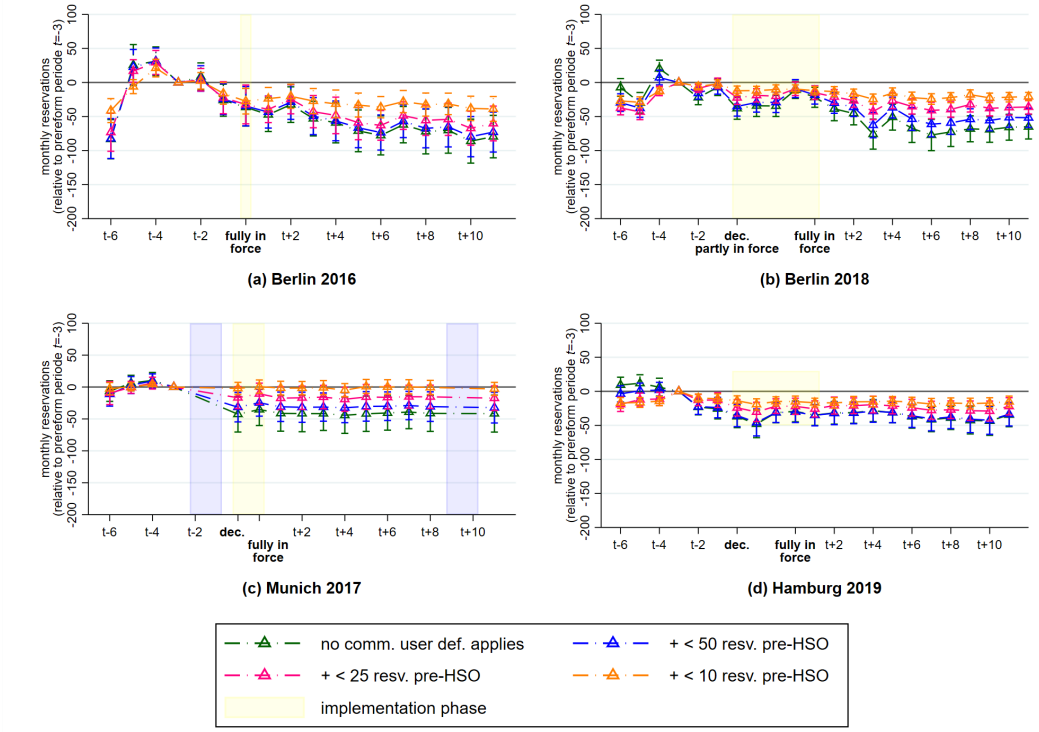
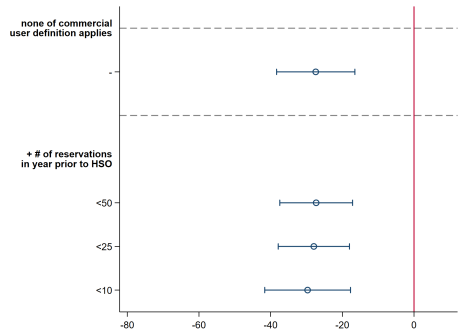
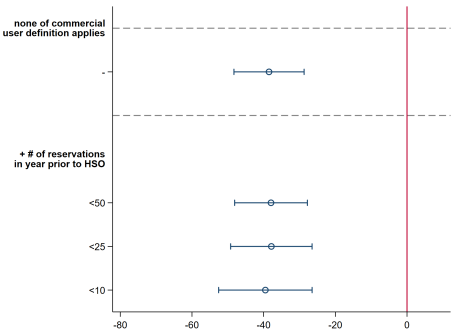


Figure A.9: DiD results with alternative definitions of occasional activity

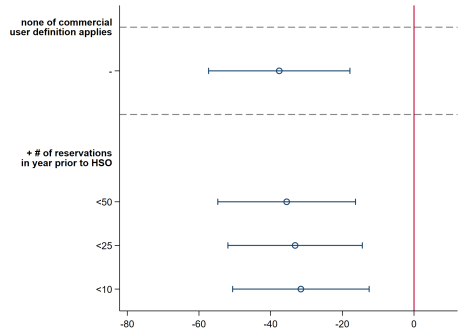
(a) Berlin 2016



(b) Berlin 2018



(c) Munich



(d) Hamburg

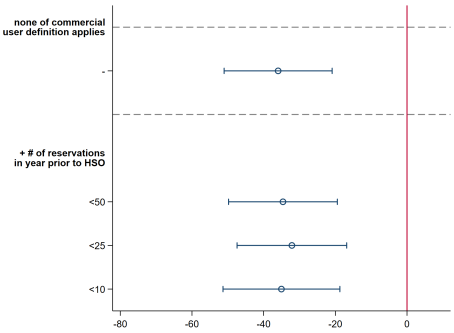


Table A.4: Summary Statistics for the Housing Characteristics

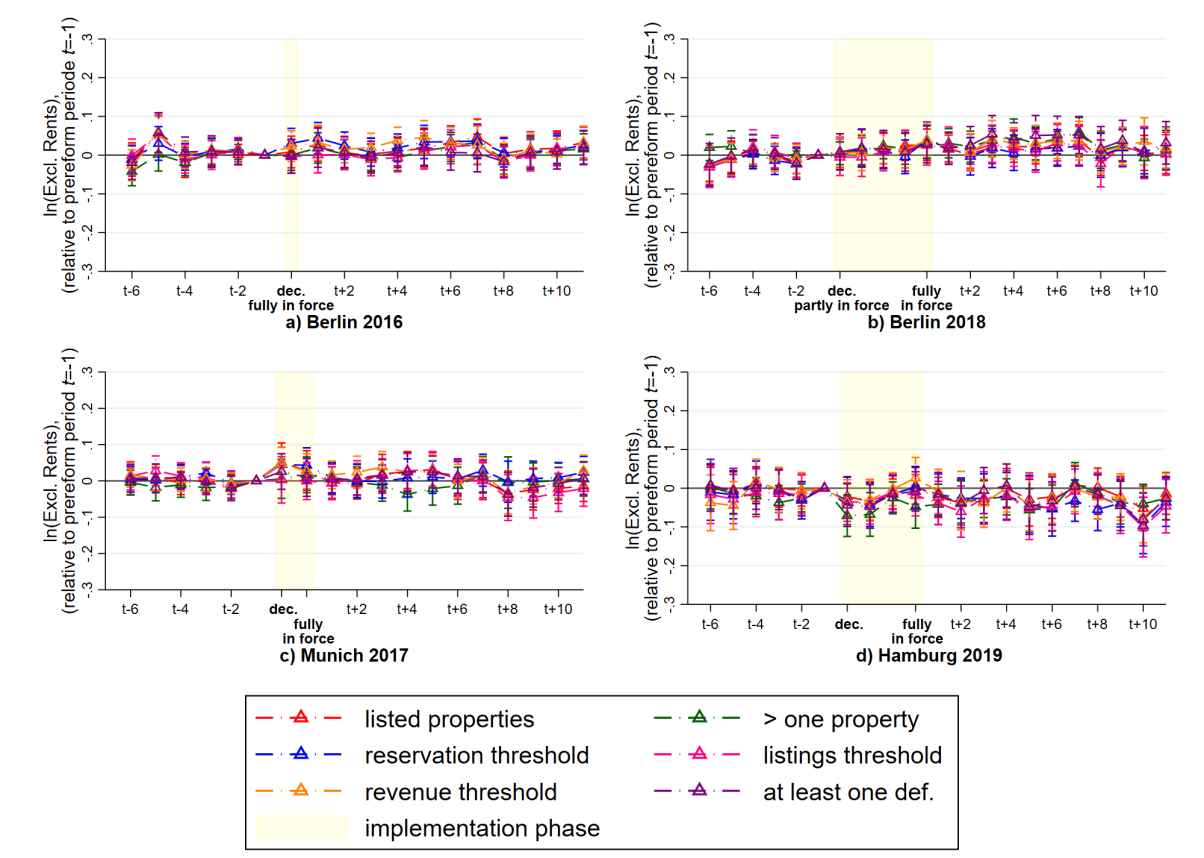
Apartment Rent Dataset								
Variable	**Mean**	**Std. Deviation**	**Min**	**Percentiles**			**Max**	**Obs.**
				25%	50%	75%		
Excl. Flat Rent	930.82	317.37	228.61	706.55	917.31	1143.48	2200.00	7059
Rent per Square Meter	12.83	3.58	4.49	10.15	13.05	15.38	24.00	7059
Utilities	169.09	59.61	0.00	131.88	160.56	194.50	667.00	7037
Living Area	73.39	15.42	18.20	63.60	71.89	81.21	165.00	7059
Number of rooms	2.41	0.44	1.00	2.14	2.40	2.64	5.75	7059
Number of Properties	23.84	27.87	1.00	7.00	15.00	30.00	299.00	7059

The table shows descriptive statistics of the housing characteristics of the Immoscout24 data provided by the FDZ Ruhr (see (RWI 2020)) of the RWI Essen. Values are based on our own calculations of grid-level averages. The sample is restricted to the grids of big cities or treated cities used in the estimation samples.

Table A.5: DiD: Effects of HSO on Rents (Controls: All non-HSO)

		>90% Airbnb Exposure	
		listed properties	**commercials**
Berlin 2016	β	**0.03274**	**0.03167**
	p-values	(0.02)	(0.02)
	Obs.	3582	3284
Berlin 2018	β	**0.02217**	**0.03691**
	p-values	(0.00)	(0.00)
	Obs.	8559	8959
Munich	β	**0.02633**	**0.02319**
	p-values	(0.07)	(0.09)
	Obs.	6676	7513
Hamburg	β	**-0.00901**	**-0.02266**
	p-values	(0.58)	(0.15)
	Obs.	7701	7657

Figure A.10: Event study; effects of HSOs on rents



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