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THE EFFECTS OF SHORT-TERM RENTAL REGULATION: INSIGHTS FROM CHICAGO

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ABSTRACT

We provide an in-depth study of short-term rental (STR) regulation in Chicago. While many municipalities choose between outright bans or laissez-faire strategies concerning STR activities, Chicago pioneered a middle-ground ordinance, enabling the market to exist with limitations and registrations, and imposing a new tax. We show that compared to three control cities, the number of active Airbnb listings in Chicago declined 16.4% in the two years after the ordinance, but this effect is only significant after the city began receiving detailed data feeds from STR platforms. We further demonstrate (i) localized reductions in burglaries near buildings that prohibit STR listings as part of a new capability of the ordinance,(ii) Airbnb revenues declined more in zip codes with above-median hotel revenues, and (iii) Chicago's middle ground approach generated different and nuanced effects on different STR stakeholders, including the city itself in terms of its STR tax revenues.

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1 Introduction

The surge in home-sharing services has sparked vigorous debate on whether and how to regulate short-term rental (STR) markets. Since the launch of VRBO in 1995 and Airbnb in 2008, STR platforms have enabled hosts to list entire homes, private rooms, and shared spaces for short-term stays. Currently, STR platforms provide more listings than the top 5 hotel brands combined. Airbnb alone had more than 7 million rental listings in 2022, distributed across 100,000 cities in 220 countries (Mariotti, 2023).

As shown by Farronato and Fradkin (2022), Airbnb, the largest STR platform in the US, enables travelers to access alternative accommodation options that are less expensive and more diverse than hotels, while enabling hosts to better utilize their surplus capacity and generate additional revenues. STR bookings also provide a revenue source for local governments. According to a report published by Airbnb in April 2023 (Airbnb, 2023), the platform has collected and remitted over $7 billion in tourism taxes around the world; in the US alone, Airbnb has collected and remitted over $1.9 billion in tourism taxes in the year of 2022.

Despite these benefits, the rapid expansion of STR listings has prompted intensive debates due to the externalities they generate. In particular, profitable STR markets lure investors into acquiring properties and dwellings to avail to others for a short term. Consequently, the market comprises not only casual hosts that share their homes for additional income but also commercial operators that run full-fledged STR businesses with multiple properties in one or more cities. The contention is that STRs have disrupted the conventional lodging industry, diminished the availability of long-term rental (LTR) dwellings, and adversely affected the accessibility and affordability of LTR housing for local residents (Gurran and Phibbs, 2017). Moreover, residents have complained about increased noise, traffic congestion, parking and waste management difficulties, and safety concerns because STR listings frequently attract transient visitors to local residential areas (Gallagher, 2018; Gurran and Phibbs, 2017). Residents in Venice and Barcelona even organized anti-tourism marches to voice their anger toward rising rents and excessive transiency in their communities (Reed, 2017).

These concerns have motivated many local governments to adopt or consider STR regulations, but regulating STR markets turns out to be a challenging task. Many cities, such as Washington D.C., have initiated the discussion on STR regulation relatively early, but took years to enact a new STR law because of objections from platforms and hosts, as well as difficulties with enforcement. For cities that did enact an STR law and began enforcement, it remains unclear whether the regulation is effective and whether it has unintended effects on hosts, guests, and local residents.

Using STR data from Chicago, this paper provides an in-depth study on the impact of STR regulation.[1] Chicago was one of the first US cities that attempted to regulate STR activities in a comprehensive way. The city's ordinance aims to allow a market for STR listings on the one hand while addressing STR-related concerns regarding public safety, consumer protection, and affordable housing for local residents on the other. This approach is notably different from other large cities, such as New York City, with regulations in place that nearly ban STR activities and any corresponding tax revenue collection, yet face severe enforcement difficulties.[2]

[1] We refer to STR regulation as ordinance, regulation and legislation interchangeably.

[2] New York State, including New York City, has practically banned entire-home STR listings unless the dwelling's permanent

In particular, Chicago's STR legislation requires hosts to register and follow strict regulations. These regulations limit the number of units that can be offered as STR in a multi-unit building and mandate that STR hosts provide insurance and meet safety standards, such as installing smoke detectors and fire extinguishers. Chicago also imposes an additional tax surcharge on STR bookings on top of Chicago's overall 17.4 percent hotel accommodation tax (which, among others, also includes state and county taxes). Besides the citywide regulation, Chicago facilitates locality-specific STR restrictions based on the varying needs of communities. For example, owners of a residential building may choose to add the building to the city's Prohibited Buildings List so that no STR listings are allowed in that building.[3] Such a hybrid approach provides an excellent opportunity to study the effectiveness of different policies concerning STR activities. Another unique feature of Chicago is its collaboration with STR platforms: as of March 2017, nine months after its June 2016 STR legislation was enacted, Chicago began receiving direct data feeds from STR platforms to enhance its enforcement capability. The collaborative and relatively permissive mentality for STR listings, the city's hybrid approach, combined with STR-specific tax surcharge and data feeds from STR platforms, highlight Chicago's commitment to providing a relatively flexible and effective STR regulation.

We analyze Chicago's regulation from three perspectives: First, is the STR regulation effective in controlling the number of active STR listings? Is enacting the regulation sufficient to regulate STR listings, or are additional steps needed? Second, in terms of economic performance, how does the regulation affect the price, revenue, and quality of STR listings that remain in the market? How does it affect Airbnb's Gross Book Value (GBV) in Chicago? How does it affect the tax revenue that local governments collect from STR bookings in Chicago? Third, for other stakeholders aside from STR platforms, does the STR regulation boost hotel revenues? Is the regulation effective in reducing local crime rates in Chicago? Due to data limitations, our research questions cannot cover all of the potential externalities from STR activities, but the above perspectives can provide a balanced view on the effects of STR regulation on different stakeholders and offer valuable insights to other local jurisdictions as they aim to update and implement their own STR policies.

By comparing Airbnb listings in Chicago with three other large US cities from January 2016 to May 2018, we show that Chicago's regulation has led to a 16.4% decline in the total number of active listings, and this decline is driven by both more exits and fewer entries in Chicago. Conditional on the listings that have existed as of January 2016, we further distinguish professional and individual hosts depending on whether they operated three or more properties across all sampled cities before the regulation. For the listings operated by individual hosts, the probability of being active decreases as soon as the legislation was enacted; but for listings managed by professional hosts, the probability of being active did not start decreasing until the enforcement was supplemented by data feeds from STR platforms. Moreover, after Airbnb began sharing

occupant is present during the guest's stay. See Jia and Wagman (2020) for an analysis of the effect of two enforcement campaigns in Manhattan. In September 2023, NYC began enforcing its January 2022 STR law, which the Wall Street Journal describes as a de facto ban of STRs due to a number of stringent requirements in the law. See Wall Street Journal "New York City's 'De Facto Ban' on Airbnb" (2023/9/5) at `https://www.wsj.com/podcasts/the-journal/new-york-citys-de-facto-ban-on-airbnb/b1ec6fd1-dc6a-4819-b231-9110918b8d85`.

[3] As detailed in Section 2, dome precincts may also apply to be a Restricted Residential Zone (RRZ), which allows existing STR listings to continue operating but prohibits new STR listings. This is stricter than the citywide requirement but less strict than a prohibited building.

data with Chicago, professional hosts' listings were more likely to switch to medium-term rental (MTR) with a minimum stay of 31 days or longer, but this pattern is not observed in listings managed by individual hosts. These results suggest that professional hosts may have more knowledge and resources than individual hosts to skirt the STR regulation until the data-powered enforcement kicked in. On top of the citywide effect, local restrictions within Chicago further reduce the availability of STR listings. For example, the staggered entries in the city's Prohibited Buildings List reduce a listing's probability of being active, and as in the citywide regulation, individual hosts have an earlier response to prohibited buildings than professional hosts.

Surprisingly, neither enactment nor enforcement of Chicago's citywide STR regulation has any significant effect on the average price (before tax), revenue, and reservations per active listing on Airbnb, as compared to control cities. This oddity is likely driven by the significant STR-specific tax surcharge enabled by Chicago's STR regulation and subsequent amendments. Between March 2017 and May 2018 — when the tax surcharge was 4%, Chicago had data-powered enforcement, but other control cities had not adopted their own STR regulation — we find that Chicago's Airbnb's GBV decreased by 30.5% from listings operated by professional hosts and 22% from listings operated by individual hosts, as compared to the control cities. This decline in the tax base is large enough to offset the 4% STR tax surcharge, leading to an estimated 9.5% decline in Chicago's tax revenue from STR listings,[4] relative to what Chicago would have collected without the STR regulation. After Chicago's STR tax surcharge increased to 6% in December 2018, we find no additional impact on Airbnb's GBV from listings offered by professional hosts but Airbnb's GBV from listings offered by individual hosts declined by 47.6% rather than the prior 22%. This further decline in the tax base implies that Chicago's tax revenues from STR listings may drop by as much as 23.6% when the tax surcharge increased to 6%, relative to no STR regulation.

Whether the declines in STR activities and STR tax revenues are balanced by benefits to other stakeholders remains an open question. We find three limited pieces of evidence that may hint at such "benefits." First, the overall ratings of listings improved by a small amount after Chicago began to receive direct data feeds from Airbnb, and the number of listing photos posted on Airbnb as well as the maximum number of guests allowed per listing have increased slightly. Second, based on hotel data by zip-code-month, we do not find any significant increase in hotel revenues after Chicago's STR ordinance, likely because the volume of hotel revenues is much higher than that of Airbnb's GBV in the same zip code. That being said, we find limited evidence that Airbnb's GBV declines more in the zip codes that had above-median hotel revenues before Chicago's STR regulation in 2015. This suggests that the positive spillover effect of the STR regulation to hotels, if it exists at all, is quite limited. As to the impact of Chicago's citywide STR regulation on local residents, our cross-city comparison suggests no significant effect on the number of crime incidents. However, when investigating the influence of the Prohibited Buildings List within Chicago neighborhoods, we find that this more local policy component of the ordinance has significantly decreased the number of burglary incidents but had no significant effect on the incidents of theft, robbery, or assault. This limited finding suggests that local residents' and first responders' concerns about potential linkages between STR activities and local crime may not be completely unfounded.[5]

Overall, we conclude that Chicago's STR regulation has generated mixed effects on different stake-

[4] These tax revenues are collected by the State of Illinois, Cook County, and the City of Chicago.

[5] See CBS news on July 5, 2021 at `https://www.cbsnews.com/chicago/news/west-town-airbnb-rental-chicago-police-fliers/`.

holders. On the one hand, the regulation imposes effective restrictions on STR listings, leading to a lower Airbnb GBV and less tax revenues from STR activities despite a significant STR-specific tax surcharge. On the other hand, Airbnb's GBV decline is more conspicuous in zip codes with above-median hotel revenues before the regulation, there is a small improvement in some quality measures of listings active on Airbnb, and we find lower burglary incidents in the areas with more buildings prohibited from availing STR listings. Our findings also highlight the important role of platform data feeds in the enforcement of STR regulations, and particularly so with respect to professional hosts.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and articulates our contributions. Section 3 provides background information about Chicago's STR regulation. Section 4 summarizes the data, and Section 5 presents the impact of Chicago's regulation on the number and nature of listings. Section 6 extends the analysis to the impact of the regulation on price, quantity, revenue, tax revenue, and the quality of listings, and Section 7 presents the regulation's impact on hotel revenue and local crime. Section 8 concludes.

2 Related Literature and Our Contribution

There are three relevant streams of literature. The first stream examines how STR listings affect the hotel industry. Byers et al. (2013) find that hotels, particularly lower-tier ones, experience a revenue loss as STR listings gain popularity. Farronato and Fradkin (2022) show that the negative impact on hotel revenues from STR listings is more significant in a market where hotel capacity is at or near full capacity, but STR listings benefit consumers by offering more affordable and diverse accommodation options. Li and Srinivasan (2019) find that flexible STR supply benefits consumers by recovering the loss from hotel charging higher price during high-demand seasons and even simulate more demand in some cities. By constructing a structural model, Schaefer and Tran (2020) find that Airbnb increases average consumer surplus by 4.3 million euro per night and reduces average hotel revenues by 1.8 million euro.

The impact of STR listings on local residents is the subject of the second stream of the STR literature. Lin et al. (2022) show that STR markets provide additional income for residents and can help reduce mortgage and auto loan delinquencies. Hidalgo et al. (2022) find that STR activities may lead to urban transformation, enhancing tourist-oriented establishments such as restaurants, bars, cafes, and clubs. Gurran and Phibbs (2017), Nieuwland and Melik (2020), and Kim et al. (2017) demonstrate that STR activities may impose unfavorable externalities on local residents, such as increased traffic, garbage management issues, and neighborhood noise. When there is a high density of STR listings in a community, they may also cause a drop in real estate values (Kim et al., 2017). Moreover, there is a direct link between STR activities and local crimes, as demonstrated by Han et al. (2022), Xu et al. (2017), Maldonado-Guzmán (2022), Roth (2021), Ke et al. (2021).

The literature on regulating STR markets is particularly relevant. The ban on entire-home listings in New York City was examined by Jia and Wagman (2020). They show that enforcement campaigns under this ban in Manhattan generated some shifts from hosts offering entire-home listings to more permissible types such as long-term rentals or private-room listings, but the remaining listings benefited from increases in price and occupancy. According to Chen et al. (2023), both the number of listings from non-professional

hosts and their prices increased after the "One Host, One Home" policy that Airbnb voluntarily implemented in New York City and San Francisco on November 1, 2016 and in Portland on January 30, 2017. However, after the policy, Airbnb did not fare worse in securing bookings or revenue during the observation period between October 2014 and July 2017. Duso et al. (2020) study the STR policy reform in Berlin and find that the policy reform of banning STR activities without permission from local district authorities led to a 28% decrease in entire-home Airbnb listings. Garz and Schneider (2023) find that an agreement to share revenue data by the STR platform to the tax authority can reduce the probability of STR listings being offered by 14%. Moreover, the agreement leads to the commercialization of the local STR market; most listings that exit the market are from individual hosts, while multiple-property hosts in areas with initially low concentrations of Airbnb listings benefit from increased occupancy. Cui and Davis (2022) focus on the occupancy tax policy concerning STR markets and find that STR taxes have a significant negative impact on listing revenues and sales. Individual hosts who operate shared spaces experience more pronounced negative effects.

Our paper contributes to the literature in multiple ways. First, we compare Chicago with other large U.S. cities without STR regulations, which enables us to tease out the regulatory impact from other factors such as the organic growth of the STR market. Second, local restrictions within Chicago provide us with a unique opportunity to assess the impact of different types of local regulations, while controlling for Chicago-specific factors. This analysis highlights the role of local restrictions above and beyond citywide regulation. Third, our analysis covers a wide range of potential outcomes from the STR regulation, including the number of Airbnb listings per zip code as well as the listings' STR status, activity level, price, revenues, reservations, and the quality of individual listings, in addition to hotel revenues and local crime rates. These measures enable us to better understand how Chicago's STR regulation affects the economic incentives of different types of stakeholders, and clarify the importance of data access in regulatory enforcement. Fourth, we articulate that imposing an additional STR-specific tax surcharge may have mixed effects on the tax revenue collected from STR reservations, since STR reservations may decline as a result of the tax hike. This tradeoff is different from the impact on income taxation after STR platforms began sharing data with tax authorities, as documented by Garz and Schneider (2023), since the income tax effect is mostly an information effect without a tax rate change.

Overall, Chicago's hybrid approach of citywide and local restrictions, the timing distinction between legislation and data-powered enforcement, and its addition of an STR-specific tax surcharge enable us to conduct a more thorough analysis of whether Chicago's STR regulation is effective in re-balancing the interests associated with STR platforms, hosts, guests, hotels, local residents, and tax revenue collection. Such a re-balancing is the primary stated objective of STR regulations in many local jurisdictions.

3 Regulatory Background

Prior to the implementation of its 2016 ordinance, Chicago lacked regulations pertaining to STR listings advertised on platforms such as Airbnb and VRBO. The absence of regulatory oversight, coupled with the swift expansion of the STR market, raised a number of concerns, including the possibility of STR activities generating noise, disrupting residential neighborhoods, contributing to elevated crime rates, and inflating

prices for long-term rentals (Byrne, 2016). The safety of STR listings could be another concern, as they may not meet the same safety and fire code standards as more conventional lodging accommodations such as hotels and other commercial properties (Byrne, 2016).

In response, Chicago's City Council enacted a transformational regulatory framework in June 2016 and began receiving relevant data from Airbnb in March 2017, making it the first US city to receive data from STR platforms, enabling the city to establish enforceable regulations aimed at preserving the quality of life across the city. The 37th Ward Alderman and Chairman of the Committee on License and Consumer Protection at the time, Emma Mitts, stated that Chicago enacted this ordinance to enhance safety, safeguard citizens, and maintain innovation in the sector (ChicagoBACP, 2020).

Based on Sections 4-13, 4-14, and 4-14 of Chicago's Municipal code, the key component of Chicago's 2016 STR ordinance is a registration requirement, with the city setting registration standards and enforcing compliance. According to the 2016 ordinance, all STR listings on any platform are required to obtain a specific registration and renew it annually. Until an amendment of the ordinance had been enacted in June 2021, STR hosts could register directly through STR platforms and operate their STR listing(s) while their registrations were pending. Following the 2021 amendment, hosts must now submit registration applications through Chicago's Shared Housing Registration Online Portal, and no online platforms may list any unregistered or unapproved listings. After approval, hosts are required to enter their Registration Number in the designated field on STR platforms. By enforcing registration, Chicago set a minimum bar for STR quality and regulates their supply in the market.

To limit the supply of STR listings, the ordinance sets specific restrictions on the number of permitted units within buildings. For instance, among single-family homes, only those that are a host's primary residence can be rented short term; in buildings with two to four units, only one unit per building can be rented short term, and hosts generally need to prove the property is their primary residence or qualify for an exception. Buildings with more than four units can offer up to one-quarter of their total number of dwelling units or six rental units, whichever is smaller, for short-term rent, and the units need not be their hosts' primary residence.

As a supplement to directly regulating STR supply through eligibility and registration, the 2016 ordinance specified a tax rate for STR bookings charged by the city of Chicago, which includes a 4% home share surcharge that only applied to STR listings. The STR surcharge was increased to 6% in December 2018. As of today, the composite tax rate for STR listings in Chicago is 23.4% (including city, state and county taxes), which is 6% higher than the city's effective composite tax rate of 17.4% for traditional hotels, according to the Civic Federation.[6]

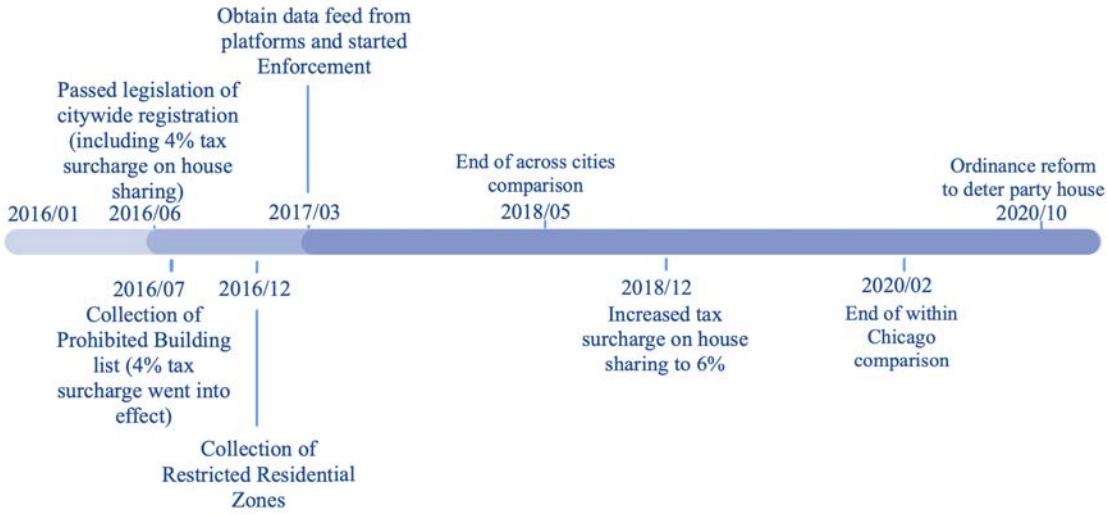
Some also argued that the tax surcharge on STR bookings is a mechanism adopted by Chicago to "throw visitors under the bus to protect the hotel industry."[7]

Additionally, local communities can impose more restrictive STR rules on top of the citywide regulation. In July 2016, the process of compiling the Prohibited Buildings List (PBL) began. Homeowner associations and building owners could submit applications to add their building to the PBL with the objec-

[6]See `https://www.civicfed.org/civic-federation/blog/city-chicago-passes-additional-20-tax-home-sharing` posted on July 27. 2018.

[7]See `https://www.illinoispolicy.org/chicago-city-council-enacts-airbnb-regulations/` posted on 2016/6/22.

Figure 1: Timeline of STR Regulation in the City of Chicago



tive of completely banning STR listings in their building. Furthermore, in December 2016, Chicago began taking applications for so-called Restricted Residential Zones (RRZ). If at least 25% of a precinct's registered voters sign a petition, the entire precinct may be added to the list of RRZ that prohibits any new STR listings from that precinct, while existing registered listings in the precinct may continue to operate.

Chicago's ordinance also outlines hosts' responsibilities in terms of establishing a minimum quality standard for STR listings. Descriptive information about the listing, such as cancellation, check-in, and check-out policies, must be provided. The legislation also details operational standards, including offering soaps and fresh linens, keeping track of visitor registrations, and adhering to all relevant food handling and licensing laws set forth by the Department of Public Health. The October 2020 amendment to the ordinance also banned one-night-stays and updated the regulation regarding loud noises in order to deter parties.

The enforcement measures associated with Chicago's 2016 ordinance changed over time. As of March 2017, Chicago began receiving data feeds from STR platforms and enforcing against non-compliant operators. All online platforms must receive a license from the city and take responsibility for maintaining compliance with the ordinance. Platforms must routinely share data with the city and maintain accurate records. If a listing is advertised on a platform without a valid registration number after 6 months of submitting an application, the platform must remove the listing. Penalties for violations are also specified, with anyone operating STR listings without registering with the city potentially fined at least $1,500 and a maximum of $3,000 for each offense, with each day that a violation exists treated as a separate and distinct offense.

Figure 1 depicts the timeline of Chicago's STR regulation.[8] Our sample period starts in January 2016. May 2018 is the last month of the sample period for cross-city comparison because some of our control cities started their own STR regulation as early as June 2018, and February 2020 is the last month for within-city

[8]All information about STR regulations, as well as some related datasets, are obtained from the website of Chicago's Department of Business Affairs and Consumer Protection at `https://www.chicago.gov/city/en/depts/bacp/supp_info/houseshearstrr.html`.

comparison to avoid market shocks from the COVID-19 pandemic.[9]

4 Data

4.1 Dataset Description

We combine several datasets for four US cities: Atlanta, Boston, Chicago, and Los Angeles. Atlanta, Boston, and Los Angeles serve as three control cities for Chicago because they implemented their own city-wide STR regulation in March 2021, June 2018, and December 2018, respectively, all after Chicago passed its own STR ordinance in June 2016. Consequently, these four cities are analogous in the sense that listings in those cities shared similar attributes prior to Chicago's STR ordinance, and all cities expressed the intent to regulate their STR markets through legislation. Admittedly, homeowner associations or building owners in every city may be able to impose some version of short-term rental restrictions; however, Chicago's city-wide ordinance differs from these pre-ordinance local restrictions because it grants homeowners a stronger legal mechanism to enforce their STR restrictions (e.g., by signing up to a prohibited buildings list). Our findings can be interpreted as the impact of possessing a direct enforcement mechanism in contrast to a lengthier, more costly and less certain legal process. Because the three non-Chicago cities had implemented their respective STR regulations after May 2018, our cross-city comparison uses data from January 2016 to May 2018. Our within-Chicago comparisons uses data up to February 2020, right before the COVID-19 pandemic took center stage in the US.

Our primary dataset includes the set of STR listings that had been advertised on Airbnb from January 2016 to February 2020 in the four US cities. This dataset was acquired from AirDNA, a company that specializes in collecting Airbnb data. For each listing-month, the dataset contains details such as the unique identifiers of listings and hosts, proxy latitude and longitude coordinates,[10] number of bedrooms, property classification (entire home, private room, or shared space), and amenities. The dataset also includes time-varying attributes such as average nightly rate (before tax),[11] number of reservations in a month, number of reserved days (nights) in a month, available days in a month, blocked days in a month, the number of reviews, ratings, and the minimum number of nights per stay.

We obtain Census Tract-level demographic data from the 2015-2019 American Community Survey, including racial composition, median household incomes, employment rate, age dependency ratio, percentage of population with high school education or higher, and the proportion of renter-occupied units. Additionally, we incorporate data from the 2016-2020 ZIP Codes Business Patterns gathered by the Census Bureau, which includes the number of establishments by zip code-year, such as the number of traveler accommodations, dining establishments, museums and historical sites, drinking places, scheduled air transportation, and grocery stores. We define a binary variable indicating whether a census tract is located in a city's downtown based on Origin and Destination data from Longitudinal Employer-Household Dynamics (LODES).

[9] The US President declared a country-wide emergency due to the COVID-19 pandemic on March 13, 2020.

[10] The proxy latitude and longitude coordinates we have are locations shown on the listing pages. Airbnb shows a general location for a listing such as the nearest cross street to protect host privacy. Therefore, the locations in the dataset are proxy locations of the exact addresses of Airbnb listings.

[11] Average nightly rate is computed as Total Revenue/Number of Booked Nights, and Total Revenue is the sum of Nightly Rates + Cleaning Fee.

A census tract is downtown if the number of people who work but do not live in the census tract (inflow) is larger than the number of residents in the census tract (regardless of their employment status).

To take seasonality into account, we use NOAA weather data and Google search patterns. For weather data, we have average temperature in a month, the number of days in a month that have temperatures below 32 Fahrenheit, the number of days in a month that have temperatures above 90 Fahrenheit, and precipitation and snow levels in a month over the sample period. The Google search trend is constructed by entering keywords of a city's name plus "Travel" and "s" into the search bar, restricting the category to "Travel," and using the sample period as the time period of interest.[12] The resulting trends offer a measure of the relative popularity of a topic over time.

From Chicago's city government, we obtain the list of prohibited buildings and the list of restricted residential zones, which include the precise geolocation and effective date of each prohibited building, and the submission and effective dates of each precinct added to the RRZ list.

To understand the potential impact of the STR regulation on traditional hotels, we obtain from Smith Travel Research total hotel booking revenues by zip code and month from 2010 to 2020 in our sample cities. This data does not contain hotel-specific information, so we cannot distinguish among different types of hotels within the same zip code.

To study the social impact of STR regulation, we gather municipal data on crime incidents from the cities of Chicago, Boston, Atlanta, and Los Angeles between January 2016 and February 2020, including the date and address of incidents at the city block level and the description of the incidents. We supplement the crime data with unemployment and earnings information from the U.S. Bureau of Labor Statistics (BLS), number of arrival passengers by air from the U.S. Bureau of Transportation (BTS), the number of bankruptcy cases from the Federal Judicial Center (FJC), and rent index from Zillow. Since the sample varies based on the specific analysis in question, sample construction and summary statistics are presented in each corresponding section. Below we provide some basic summary of Airbnb listings and Airbnb host types for background information.

4.2 Basic Summary of Airbnb Listings

To check the comparability between Chicago and the three control cities, we compare the average attribute of each city's Airbnb listings prior to the enactment of Chicago's ordinance. These attributes encompass occupancy rate,[13] average nightly rate, number of reservations in a month, minimum nights per stay, number of bedrooms, and number of reviews. Table 1 summarizes these attributes per active listing before the Chicago ordinance for each of the four cities, where we define a listing i as being active in month t if it has at least one day in t that is either reserved or open for booking. On average, active listings across all four cities were offered with short minimum stay requirements (1.75-2.52 days) before July 2016.

Figure A.1 in the Appendix provides a visual demonstration of the change in the availability of Airbnb listings in Chicago and Boston. From the map, we can see that more Airbnb listings in Chicago became

[12] Specifically, we entered "Chicago hotel, Chicago hotels,""Atlanta hotel, Atlanta hotels,""Boston hotel, Boston hotels," and "Los Angeles hotel, Los Angeles hotels" into the search field, specified the category as "Travel" and the time range of the sample period. We accounted for different spelling possibilities such as "LA hotel." The resulting trends for cities over time indicate the relative popularity of a searched topic in a time period. Plots of the Google Trends are in Figure A.3 in the Appendix.

[13] We define occupancy rate as (reserved days/available days) in a listing-month.

Table 1: Summary Per Active Listing Before Chicago's Ordinance

	Chicago	Atlanta	Boston	Los Angeles
Average Nightly Rate ($)	136.04	120.87	210.89	151.59
Occupancy Rate (0-1)	0.32	0.31	0.37	0.37
Reservations per Month	2.23	2.17	2.64	2.30
Min Nights per Stay	2.05	1.75	2.52	2.18
Bedrooms	1.31	1.41	1.21	1.25
Reviews	17.07	13.52	17.45	18.76

inactive after the enactment and enforcement of the citywide ordinance, relative to Airbnb listings in Boston.

Ideally, to investigate how STR hosts comply with Chicago's citywide regulation, we would like to track every listing's availability and STR registration status over time. A listing's STR status refers to the likelihood that a listing accommodates a stay no longer than 31 days conditional on being active. Registration status refers to whether a listing reports its registration status to the platform.

In theory, we can determine a listing's STR status according to whether an Airbnb listing sets a minimum stay requirement over 31 days. In practice, some Airbnb hosts choose not to specify any minimum stay requirement for their listings, so we have to infer their STR status from reservation patterns.[14] For instance, the listing must be offered as an STR listing in any month with three or more reservations.

Conditional on active listings, 80.8% of observations (listing-month) have minimum stay information, and, after our inference process for determining a listing's minimum stay requirement based on its booking patterns, 98.3% of observations have STR status information.[15]

Note that an Airbnb listing that sets a minimum stay requirement over 31 days (and is thus, by definition, not an STR listing) does not necessarily offer long-term rental (LTR) in the traditional sense. For example, they may offer a lease slightly longer than one month but shorter than the classical 6-month or 1-year lease of a long-term rental; they may also target travelers rather than local residents. For these reasons, we refer to non-STR listings availed on Airbnb as medium-term rental (MTR) listings. The distinction between STR and MTR listings matters from a public policy perspective. Unlike STR listings, MTR listings are not subject to STR regulations (including Chicago's STR tax surcharge) and thus hosts can essentially avoid STR regulations by adjusting the minimum stay requirements of their listings on Airbnb.[16]

Across all four cities, if we focus on the listings that have existed on Airbnb in January 2016 and were active (with at least one day available on their calendar) between September 2015 and December 2015, 89%

[14] If there is at least 1 reservation in month t but no reservation in months $t-1$ and $t+1$, then the listing is offered as an STR listing in month t. If the number of reservations in month t is 1 and there are reservations in month $t+1$ and no reservation in month $t-1$, and the sum of the reservation days of month t and month $t+1$ is less than or equal to 31, then the listing is offered as an STR listing in month t. Suppose that the number of reservations in month t is 1, and there are reservations in both month $t-1$ and month $t+1$. In that case, the listing is offered as an STR listing in month t if the sum of reservation days in month $t-1$ and t is less than or equal to 31 and the sum of reservation days in month t and month $t+1$ is less than or equal to 31. If the number of reservations in month t is 2, and there is no reservation in month $t+1$ (same for $t-1$), then the listing is offered as an STR listing in month t if month t is not fully booked. If the number of reservations in month t is 2, and there are reservations in both month $t-1$ and $t+1$, then the listing in month t is offered as an STR listing if the sum of reservation days in month t and $t+1$ is less than or equals 31. If the number of reservations in month t is greater than or equal to 3, then the listing is offered as an STR listing in month t regardless of reservation patterns in adjacent months.

[15] Without restricting to active listings, only 59.4% of observations have STR status information after the inference process.

[16] Technically, there is no guarantee that a listing that specifies a minimum stay over 31 days does not accommodate a shorter-term booking.

of them were active between January 2016 and June 2016. Conditional on being active, almost 100% of them were STR listings. These patterns confirm that the vast majority of Airbnb listings in our sample cities were offering STR services before Chicago's STR regulation.

A listing's registration status has even more potential data problems that its STR status, because it is only available for Chicago in our cross-city comparison period. Moreover, for each Chicago listing, we only observe a snapshot of its registration status as of December 2020 or its last observed date if it is before December 2020. As a result, we cannot determine the exact date when a registered listing obtained its registration number for the first time. A listing's registration status is gathered from the content that hosts enter in their listings' registration number field on the Airbnb platform (Figure A.4 in the Appendix provides an illustration). Information entered in this field can be a series of registration numbers, any English words (for instance "Registered" or "Registration Pending"), or no input at all. We categorize a listing as registered if the information in this field was a registration number or the term "Registered." Likewise, we classify a listing as "Registered or Pending" if it is either registered or if the information entered was "Registration Pending" or similar wording.

As of December 2020, only 53.2% of Airbnb listings in Chicago were registered and another 34.4% were pending. In comparison, as of September 2023, according to InsideAirbnb (another third-party data provider that tracks Airbnb data) reports that 74.7% of listings in Chicago are registered and another 1.8% are pending (InsideAirbnb, 2023). The slow progress is likely because listings were initially instructed to register through Airbnb (rather than directly through the city) and pending listings were allowed to continue operating on Airbnb — until the city enacted an amendment to the ordinance in June 2021 to close such loopholes.

Given the limited cross-sectional data on listings' registration status, we cannot do any panel analysis about registration. That being said, we have run an ordinary least squares (OLS) regression at the listing level to examine factors that may impact the probability of registering in Chicago. Results are consistent with the hypothesis that listings that entered or continued to operate after the enactment of the ordinance are more likely to be registered or pending as of December 2020. These findings indicate that the implementation of Chicago's STR ordinance encourages hosts to register, albeit with a slow and gradual pace.

4.3 Classification of Host Types on Airbnb

Many local governments are concerned of "investor units" in STR markets.[17] Accordingly, it is useful to distinguish commercial operators from casual hosts. However, neither STR platforms nor the STR registration process necessarily make a clear distinction between the two. In practice, many cities try to discourage some commercial operation by limiting the number of listings that each host can have on STR platforms (usually 1 or 2), by, for instance, requiring that a host's listing also be their primary residence, or by setting a limit on the total number of days a host can list a property on STR platforms in each calendar year, or by requiring a special operator license. Chicago's STR ordinance's restrictions according to building types and,

[17] For example, to curb the negative impacts on neighborhoods and their housing stock, Los Angeles's STR regulation limits STR listings to one's primary residence. See more details at `https://planning.lacity.gov/ordinances/docs/HomeSharing/FAQ.pdf`. According to former Boston Mayor Marty Walsh, Boston's STR regulation aims to ban the listing of "investor units" and deter remote operators and owners from monopolizing Boston's housing market with STR listings. See more details at `https://www.goodwinlaw.com/en/insights/publications/2018/06/new-short_term-rental-regulation-in-boston`.

in some cases, by whether a dwelling is the host's primary residence, tend to function similarly in limiting a host's ability to list multiple accommodation units, for instance, within their dwelling.

In light of these practices, we define a host to be 'professional' if they have three or more properties listed on Airbnb across all four of the sampled cities; otherwise, we label them as an 'individual' host.

A number of previous papers have used the number of listings per host to define professional or commercial operators. For example, Chen et al. (2023) define professional hosts as those who had ever operated more than one entire-home listing in a city in any month; Gauß et al. (2022) define commercial hosts as those who offer multiple properties; and Farhoodi (2021) defines institutional hosts as hosts with multiple properties. We use a slightly higher threshold (3+ rather than 2+) and count listings per host across all sampled cities rather than within each city for two reasons: first, some cities limit the number of listings per host to two rather than one (Seattle, Boston, Atlanta). Second, we aim for the definition to be consistent across all sampled cities: if a host is professional in one city, they should be categorized as professional in all of our sampled cities.

Using this definition, among all active Airbnb listings we observe from January 2016 to May 2018 across the four cities, 49,336 unique listings are managed by 7,737 professional hosts, while the other 83,893 unique listings are managed by 73,308 individual hosts. Although individual hosts outnumber professional hosts 9.5 times, each professional host, on average, manages 6.4 listings, as compared to 1.1 listings per individual host. As a result, roughly 30% of Airbnb's active listings in Chicago were managed by professional hosts before Chicago's STR ordinance, this fraction increased over time to 38% by May 2018. We observe similar increase in all of the four sampled cities, despite Chicago's STR regulation.

As detailed in Section 5, when we try to follow professional and individual hosts conditional on the listings that have existed as of January 2016, we may define professional and individual hosts *before the regulation* by the number of listings they have had on Airbnb before Chicago enacted its STR ordinance in June 2016.

5 The Effect on Listing Availability

To study the impact of Chicago's STR regulation on listing availability, we use listing-level data in the four US cities. We first report an analysis by zip-code-month, aiming to paint a bigger picture view of the volume of active listings and whether the change is driven by entry or exit. Next, we report detailed listing-level analyses, aiming to dive deeper into how different types of hosts react to Chicago's STR regulation. By examining how listings that had existed on Airbnb as of January 2016 may change their exit, level of activity, and STR status after the city's ordinance, we unpack different incentives and actions behind the compliance and, to some extent, evasion of the regulation. For listing-level analysis, we present the effects of Chicago's citywide STR ordinance and local STR restrictions separately, since they entail different data samples.

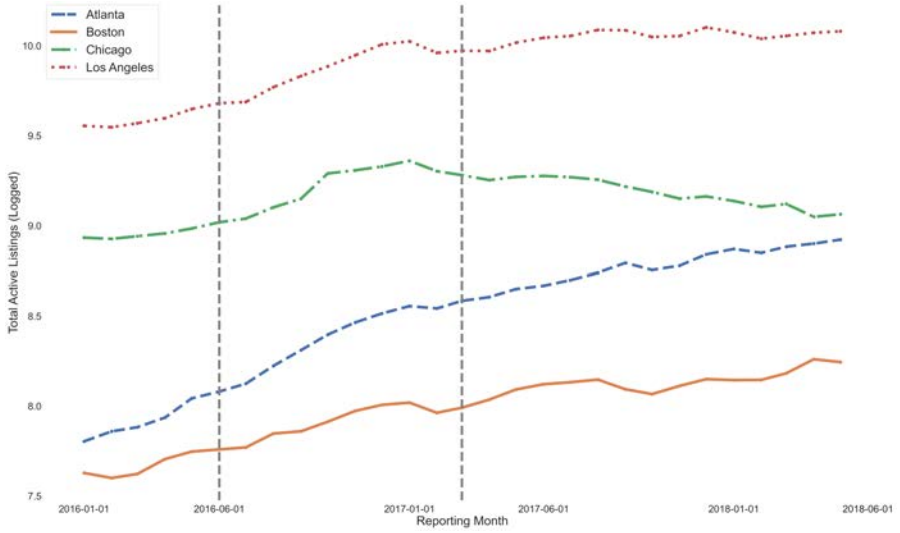
5.1 Zip Code-Level Analysis on the Number of Active Listings

To begin, we count the number of active Airbnb listings in each city-month, independent of whether they are STR or MTR listings, or whether they obtained STR registration. Figure 2 depicts the log of this count over

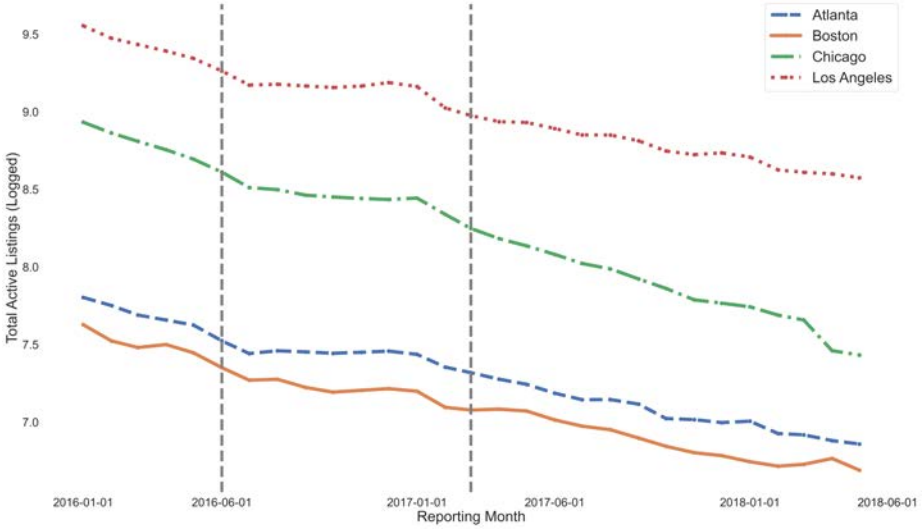
time, with the two vertical lines representing the enactment of Chicago's STR ordinance (June 2016) and the commencement of the city's data-powered enforcement (March 2017), respectively. Panel (a) depicts the logged overall number of active listings, and Panel (b) provides the logged count of active listings after limiting the sample to listings that existed in January 2016. In Panel (a), we observe a consistent upward trend in the number of active listings in Atlanta, Boston and Los Angeles. Conversely, Chicago experienced a decline in active listings starting in February 2017. Panel (b) indicates that among listings present in the market in January 2016, there was a subsequent decrease in the total number of active listings across all cities, likely due to natural attrition. Notably, starting in March 2017, Chicago experienced a more rapid decline in active listings. Both panels suggest that Chicago's citywide ordinance had a negative effect on the number of active listings in the city, and this effect did not fully manifest until Chicago was about to begin its data-powered enforcement in March 2017.

Figure 2: Number of Active Listings in Chicago and Control Cities

(a) Log # of Total Active Listings



(b) Log # of Total Active Listings Conditional on Existing in 2016/1



More formally, we construct the regression sample by zip-code-month and employ a difference-in-differences (DID) framework. We distinguish the enactment of Chicago's citywide legislation from its data-powered enforcement, as some hosts may not comply until strong enforcement measures had been put in place. More specifically, for each zip code z in month t, we have:

$$log(1+\#\ of\ active)_{zt} = \beta_1 LegislationPass_{zt} + \beta_2 Enforcement_{zt} + \gamma X_{zt} + \mu_t + \phi_z + \varepsilon_{zt} \quad (1)$$

where the $LegislationPass_{zt}$ equals 1 if the STR ordinance had been enacted and is applicable to zip code z by month t; $Enforcement_{zt}$ equals 1 if the STR ordinance had been enforced through direct data feeds from STR platforms in zip code z by month t; X_{zt} is a vector of control variables including variables from the ZIP Codes Business Patterns and city-specific Google search trends; μ_t denotes year-month fixed effect; ϕ_z denotes zip code fixed effects; and ε_{zt} is the idiosyncratic error term. The standard errors are clustered by city.

As shown in Column 1 of Table 2, the enactment of Chicago's STR ordinance does not have a significant effect on the number of active listings. Conversely, the subsequent data-powered enforcement of the ordinance leads to a 16.9% decline in the number of active listings in addition to the enactment effect.[18] To obtain the overall effect of the ordinance post its data-powered enforcement, we add up the point estimates of β_1 and β_2, which leads to an overall 16.4% decline in the number of active listings relative to before legislation.

The decrease in the number of active listings can be driven by an increase in listing exits or a decrease in listing entry. To examine the role of each of these possibilities, Column 2 of Table 2 restricts the sample to listings that have existed in the market in January 2016, and Column 3 focuses on the number of new listings. A listing is defined as a new entrant in month t if its first observed date is in month t. We apply the same DID model specification with the dependent variable as $log(1+\#ActiveListings)$ and $log(1+\#NewListings)$, respectively. As for the full sample, both subsamples are constructed at the zip code-month level. Regarding the effect on listing exits, Column 2 finds that the enactment of Chicago's STR ordinance does not yield a significant effect on exits. However, the ordinance's subsequent data-powered enforcement leads to a 11.6% reduction in the number of active listings among those that were present at the commencement of the sample period. Similarly, Column 3 shows that the enactment of the ordinance had no significant effect on listing entry; however, the ordinance's subsequent data-powered enforcement is coupled with a decrease in the number of new listings of 26.4%.

In short, the zip code-level analysis suggests that Chicago's STR ordinance reduced the number of active listings, but this negative effect — driven by both more exits and less entry — does not occur until the city began receiving direct data feeds from STR platforms.[19] Econometrically, we acknowledge that this pattern may reflect a mixture of a dynamic growing effect of the ordinance and an extra effect of the data-powered enforcement. Since any assumption on how the effect of the ordinance alone may change over time would be arbitrary, there is a potential identification problem. That being said, according to the raw data patterns

[18]The dependent variable is defined as log(1+Y). If the coefficient of x is β, then the marginal effect of a unit change of x can be expressed as $\beta = log(1+Y') - log(1+Y) = log(\frac{1+Y'}{1+Y})$, and thus the marginal effect of X on the percentage change of Y can be approximated as $\Delta Y = \frac{Y'-Y}{Y} \approx e^{\beta} - 1$.

[19]Chicago first began receiving direct data feeds from Airbnb; an agreement between the city and VRBO was not implemented until after the end of our sample period.

in Figure 2(a), the number of total active listings began to trend down in Chicago right before the city began receiving direct data feeds from Airbnb in March 2017, while all of the three control cities continued to grow. This pattern suggests that a dynamic growing effect of the legislation alone may be limited, if such an effect exists at all. It also dismisses the argument that the lack of response before enforcement is driven by some guests booking Airbnb listings in advance even though the time of stay is post the STR ordinance. If that were the main explanation, the response to regulation should not have been delayed for as long as nine months and the response should not have been large and significant as soon as Chicago started to receive data feeds from STR platforms.

Table 2: Effect on the Number of Active Listings and Entries

	(1)	(2)	(3)
Dependent Var.	log(1+#Active Listings)	log(1+#Active Listings)	log(1+#New Listings)
Sample	All Listings	Existing Listings	New Entries
Legislation Pass	0.006	-0.031	0.018
	(0.05)	(0.03)	(0.04)
Enforcement	-0.185***	-0.123***	-0.307***
	(0.04)	(0.04)	(0.04)
Business Pattern Controls	Yes	Yes	Yes
ZIP Code FE	Yes	Yes	Yes
Year by month FE	Yes	Yes	Yes
Observations	7,286	4,897	6,739

In parentheses are standard errors clustered by city. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.2 Listing-Level Analysis of Availability and STR Status

The overall decline in the total number of active listings in Chicago does not tell us how different types of Airbnb listings comply with or avoid Chicago's STR ordinance. To answer this question, we track a set of listings that existed on Airbnb as of January 2016 (referred to as the 2016/1 cohort), and follow those listings operated by professional and individual hosts separately. As detailed in Section 4.2, we cannot conduct any panel analyses on a listing's registration status because we only have a cross-sectional snapshot of registration for Chicago as of December 2020. Hence, our study focuses on how listings change their active (activeness) and STR statuses over time.

As described in Section 4.3, we define professional and individual hosts according to the number of listings they have on Airbnb across all four sampled cities. For the 2016/1 cohort, we refine this definition by the number of listings each host offered *prior to Chicago's STR ordinance.* One data complication is that some of the listings in the 2016/1 cohort are likely 'zombie' listings that rarely have any activity, but their existence may undermine the comparability of Chicago and control cities. To address this, we first remove all listings in the 2016/1 cohort that had not been active at all from September 2015 to December 2015 (recall that a listing is defined as active in a month if it has at least one day open in that month's calendar on Airbnb). According to Wilking (2020), Airbnb hosts have less than 10% likelihood to become active again if they have been inactive for 90 or more days. Conditional on the listings that remain in the 2016/1 cohort after this removal, we define a host as professional if they have 3 more listings across all of our sampled cities before June 2016, and as individual otherwise.

Table 3 summarizes the average attributes of listings prior to June 2016, separately for professional and individual hosts in each city. While the count of professional hosts is less than 10% of the count of individual hosts, the number of listings per professional host are 3 to 6 times higher. On average, listings managed by professional hosts are larger, more expensive to rent, and have higher occupancy rates. From the overall average occupancy rates (23-51%) and the average numbers of reservations per month (1.71 to 4.07), it is apparent that the average stay per reservation is no longer than 10 days, which suggests that most listings managed by professional and individual hosts are de-facto STR listings and are more likely to compete with traditional hotels than with mid-term or long-term rentals.

Table 3: Summary Per Active Listing Before Chicago's Ordinance By Host Type and City

	Professional Hosts				Individual Hosts			
	Chicago	Atlanta	Boston	Los Angeles	Chicago	Atlanta	Boston	Los Angeles
# Hosts	305	109	90	705	4673	1436	1114	8021
Listings per Host	6.00	5.06	8.66	5.35	1.12	1.13	1.11	1.13
Average Nightly Rate	151.00	124.32	257.51	163.95	126.80	121.49	195.04	146.34
Occupancy Rate	0.35	0.36	0.35	0.51	0.23	0.26	0.29	0.24
Reservations per Month	3.03	3.24	3.40	4.07	1.85	2.12	2.39	1.71
Min Nights per Stay	2.67	1.74	3.17	2.06	1.75	1.84	2.06	2.25
Bedrooms	1.55	1.42	1.35	1.39	1.24	1.40	1.16	1.19
Reviews	25.79	22.64	22.88	29.06	20.94	17.70	22.49	24.04

5.2.1 Listing-Level Analysis for Citywide Regulation

Our listing-level analysis for Chicago's citywide ordinance follows the difference-in-differences framework in Callaway and Sant'Anna (2021) with doubly robust estimation (CSDID). The advantage of using CS-DID is that it incorporates inverse probability weighting to increase the comparability of treated listings (in Chicago) and control listings (in the other three cities). This method can provide group-time average treatment effect (ATT) that is analogous to controlling group fixed effects (where 'group' is defined by treatment city versus control cities), and the doubly robust estimation can ensure an unbiased estimation of ATT if either the conditional parallel trend assumption is satisfied or the propensity score model is correctly specified. Covariates included in the CSDID are listing characteristics, census tract demographics, a binary variable indicating whether a census tract is downtown,[20] and indicators for levels of ZIP Codes Business Patterns. Under a conditional parallel trend assumption, we first estimate the group-month ATT, and then average the group-month ATT at different lengths of exposure to the treatment.

In particular, for all $t \geq g$, the group-month ATT is

$$ATT(g,t) = E[Y_t(g) - Y_t(0)|X, G = g] = E[Y_t - Y_{g-1}|X, G = g] - E[Y_t - Y_{g-1}|X, D_t = 0, G \neq g], \quad (2)$$

where X are covariates, D_t indicates whether being treated by month t, g represents the treatment group (all units that have treatment started in period g). The average effect of participating in the treatment for exactly

[20] As previoulsy, downtown is defined by comparing the inflow and the number of residents in a census tract. A census tract is downtown if the number of people who work but do not live in the census tract is larger than the number of residents of the census tract.

e periods is

$$\overline{ATT}(e) = \sum_{g \in \mathcal{G}} \mathbf{1}\{g + e \leq \tau\} P(G = g | G + g \leq \tau) \cdot ATT(g, g + e), \tag{3}$$

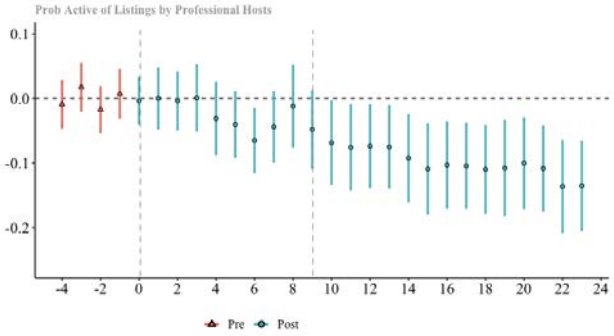
where $e = t - g$ denotes the time elapsed since the treatment was adopted, and G denotes when a unit is first treated.

We first report the CSDID results on listing availability. Given the results of the zip-code level analyses, we expect Chicago's STR ordinance to decrease the treated listings' probability of being active, especially after the city began data-powered enforcement. The estimated ATT in each period is displayed in Figure 3, for professional and individual hosts separately. The red triangular dots denote the pseudo-ATT before the treatment time (June 2016), which confirms the assumption that listings in Chicago and the three control cities follow similar pre-treatment trends. The blue circular dots denote the ATT of facing the STR ordinance in Chicago.

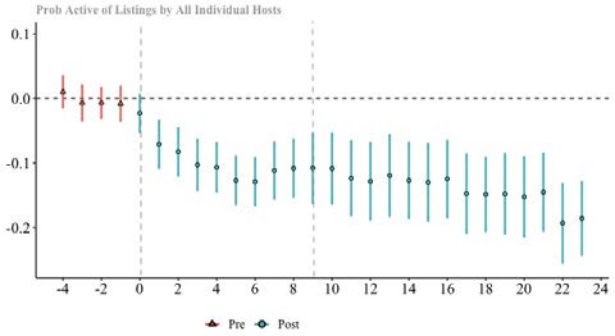
They suggest that, by the end of our sample period, the probability of a listing being active decreased by 14% for Chicago listings operated by professional hosts and by 18% for Chicago listings operated by individual hosts. Interestingly, for listings operated by professional hosts, the probability of being active did not start to decrease significantly until the city's data-powered enforcement began in March 2017. In contrast, for listings run by individual hosts, the likelihood of being active began to decline as soon as the ordinance was enacted in June 2016. This suggests that individual hosts responded more quickly to the citywide regulation than professional hosts.

Figure 3: Average ATT of Chicago's Ordinance on the Probability of Being Active

(a) Professional Hosts



(b) Individual Hosts



Note: Period 0 indicates when Chicago enacted the ordinance (June 2016) and period 9 indicates when Airbnb began to share data with the city (March 2017).

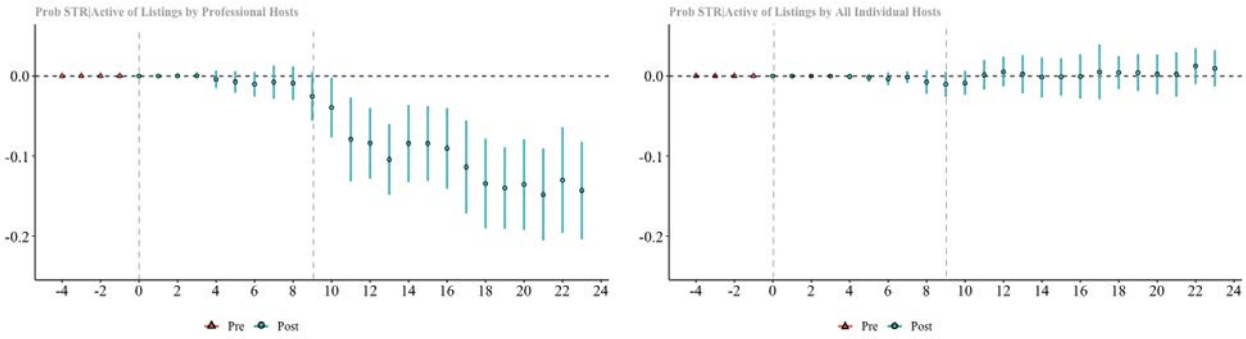
Next, we report the CSDID results on a listing's STR status conditional on it being active. As described in Section 4.2, the STR status of listings can be determined by their minimum stay requirements and their reservation patterns. Our hypothesis is that Chicago's STR ordinance makes it costlier to operate STR listings and therefore should have a negative effect on the probability of offering a listing as short-term rental conditional on the listing being active.

As shown in Figure 4, the estimated ATT suggests that, since Chicago's data-powered enforcement began, for listings run by professional hosts, there has been a considerable decline in the probability of a listing being offered for short-term rent conditional on being active. By the end of the sample period, this

probability decreased by around 12%. On the other hand, this probability does not change significantly for listings managed by individual hosts. In short, professional hosts appear to be more flexible and tend to switch to MTR availability, which is a potential way to readily comply with the law and continue using the Airbnb platform. The switch from STR to MTR may also help a host avoid the STR-specific tax surcharge that is part of Chicago's STR ordinance.

Figure 4: Average ATT of Chicago's Ordinance on the Probability of Being an STR Listing if Active

(a) Professional Hosts (b) Individual Hosts



Note: Period 0 indicates when Chicago enacted the ordinance (June 2016) and period 9 indicates when Airbnb began to share data with the city (March 2017).

5.2.2 Listing-Level Analysis for Local STR Restrictions within Chicago

Chicago's 2016 STR ordinance enables local communities to foreclose STR activities by adding a building to the Prohibited Buildings Listing (PBL); it also permits precincts to join the list of Restricted Residential Zones (RRZ). As of February 2020, over two thousand buildings were placed on the PBL, but only 52 of 1,069 precincts chose to enroll as Restricted Residential Zones. Hence, we only report the effect of the PBL in this subsection, while relegating the (negative but limited) impact of RRZ to Section B of the Appendix. Since our analysis of the PBL focuses on Chicago only, we are no longer limited by the regulation-free periods of other cities. In particular, we set the sample period from January 2016 to February 2020 and focus on a balanced panel of listings that were in the market in January 2016 in order to track listing-level behavior before and after the introduction of the PBL. We exclude months after February 2020 in order to avoid any overlap with the Covid-19 pandemic.

As in Section 5.2.1, we divide our sample of listings in the 2016/1 cohort by whether they were operated by professional or individual hosts before June 2016. The dataset includes the precise geolocation of prohibited buildings, the effective date of each prohibited building, the proxy longitude and latitude of Airbnb listings, and the exit time of listings (defined as the month in which a listing became perpetually inactive). We also integrate information about listing characteristics, demographic information at the census tract level, and zip code-level variables from the ZIP Codes Business Patterns.

Taking each new entry in the PBL as a potential treatment for nearby listings, the first task is to distinguish between treated and control listings. The main difficulty is that we do not know the exact address of listings and thus we cannot precisely identify whether a listing is within a prohibited building or not. After testing the proxy geolocation relative to the exact address of several Airbnb listings, we find that the proxy

geolocation is within 100 meters of a listing's actual location. In light of this, we create a circle around the proxy geolocation of each listing with a radius of 150 meters. If there are no prohibited buildings in effect in the circled area before a listing exits the market, then the listing is a control listing. If there is at least one prohibited building in the circle before the listing exits, we classify the listing as a treated listing. Listings with a nearby prohibited building (within the 150 meters radius) are treated only if the effective date of the prohibited building is prior to the listing's exit date. The treatment begins in month t if t is the first month in which the treated listing matched with a prohibited building that is in effect. Based on this definition, 44% of listings are classified as treated listings in the sample of the listings managed by professional hosts, and 40% are classified as treated listings in the sample managed by individual hosts.

Figure A.2 in the Appendix shows a map of prohibited buildings and Airbnb listings by treated and control groups. From the map, we can see that most prohibited buildings are in areas with more Airbnb listings, which raises the concern that prohibited buildings are not randomly selected and this may generate a selection of treated vs. control listings.

Table 4 compares PBL-treated and control listings in their attributes before Chicago enacted its STR ordinance in June 2016. For both professional and individual hosts, treated listings are more expensive, have a higher occupancy rate, and require a longer minimum stay than control listings. Treated listings managed by professional hosts are also larger than control listings, but treated and control listings managed by individual hosts are of similar size.

Table 4: Summary Statistics of PBL-Treated and Control Listings Before Chicago's Ordinance

	Professional Hosts				Individual Hosts			
	Treated		Control		Treated		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
# Listings	735		1254		1445		3028	
Average Nightly Rate	170.53	144.10	113.24	106.75	134.50	116.94	109.68	102.09
Occupancy Rate	0.29	0.34	0.23	0.33	0.26	0.33	0.18	0.31
Reservations per Month	2.09	2.96	1.46	2.54	2.01	2.88	1.26	2.40
Min Nights per Stay	3.26	3.96	1.97	2.00	1.67	1.24	1.61	1.43
Bedrooms	1.52	1.01	1.48	1.00	1.20	0.74	1.21	0.74

Given the fact that Airbnb's proxy geolocation does not reveal the precise address of listings, our analysis can be interpreted as a comparison of listings that are more likely to be treated by the PBL with listings that are less likely to be treated. The treatment is staggered because the effective date of each prohibited building is different and we do not observe any buildings removed from the PBL. This leads us to use Callaway and Sant'Anna, 2021's multiple period DID with doubly robust estimation (CSDID), with the dependent variable being a dummy variable indicating whether or not a listing is active in a particular month. CSDID compares between newly-treated units relative to never-treated units and not-yet-treated units.

This approach also enables us to address the potential selection in the PBL treatment by controlling for listing attributes and neighborhood characteristics such as census tract demographics, whether the census tract is downtown, and various variables from the ZIP Codes Business Patterns.[21] CSDID uses these covari-

[21] Due to the large number of treatment groups, matching based on the value of census tract demographics and ZIP Codes Business Patterns can be challenging. To address this, we opted to define a set of binary variables. Specifically, for each census tract demographic, a binary variable is set to 1 if the value of the census tract demographic is above the median level in Chicago.

ates for inverse probability weighting between treated and control units. Under the conditional parallel trend assumption and the limited treatment anticipation assumption, we first estimate the group-month ATT[22] and then average them by length of exposure to the PBL treatment.[23]

Figure 5 shows the estimated ATT for each period relative to the start date of the PBL treatment (which could be as early as Chicago began the PBL in July 2016 or as late as nearly the end of February 2020, depending on when the nearby building becomes a prohibited building). The red triangular dots represent pre-treatment pseudo ATT used to test the parallel trends assumption (conditional on covariates), while the blue circular dots indicate post-treatment ATT. We plot the estimates for listings managed by professional and individual hosts separately.

Figure 5a (professional hosts) supports the assumption of pre-treatment parallel trends in all months before treatment, but Figure 5b (individual hosts) suggests some violation of this assumption up to five periods right before the treatment, though the magnitude of the pre-treatment ATTs is small. One explanation is that individual hosts who are more likely to become inactive after the treatment may have anticipated the treatment (e.g., as building ownership debated the issue) and decided to devote more time and effort to renting short term for extra revenue before the building becomes prohibited.

The post-treatment ATTs in Figure 5 indicate that the likelihood of a listing being active decreased for listings close to prohibited buildings. This decline is more rapid and more significant for listings managed by individual hosts than by professional hosts. Assuming the probability of a listing being active reaches a new steady state at the end of the sample period, the earliest-treated listings had a decreased probability of being active by around 43% if they are managed by professional hosts, or around 42% if they are managed by individual hosts. This suggests that individual hosts are equally likely to comply with the PBL restriction as professional hosts but they do so more rapidly.

We present a few robustness checks. First, given that the longest distance we find between the precise address of a listing and the geolocation that Airbnb displays on the listing's page is 100 meters, and the radius we previously used is 150 meters, we carry out the same staggered CSDID analysis with a radius of 80 meters for the definition of PBL treatment instead. The results, presented in Figure A.5 in the Appendix, show a similar decreasing trend in the probability of a listing being active but with a slightly smaller magnitude. The second robustness check is removing control listings that have no treated listings within 300 meters throughout the whole sample period, which should strengthen the comparability of treated and control listings as prohibited buildings are more clustered in the Chicago downtown area. The CSDID results, presented in Figure A.6 in the Appendix, are almost identical to the results without this restriction on control listings.

Similarly, for each variable in ZIP Codes Business Patterns, a binary variable is set to 1 if the number of certain types of businesses is above the median level in Chicago.

[22] For all $t \geq g$, the group-month ATT is $ATT(g,t) = E[Y_t(g) - Y_t(0)|X, G = g] = E[Y_t - Y_{g-1}|X, G = g] - E[Y_t - Y_{g-1}|X, D_t = 0, G \neq g]$, where X are covariates, D_t indicates whether being treated by month t, g represents the treatment group (all units that have treatment started in period g).

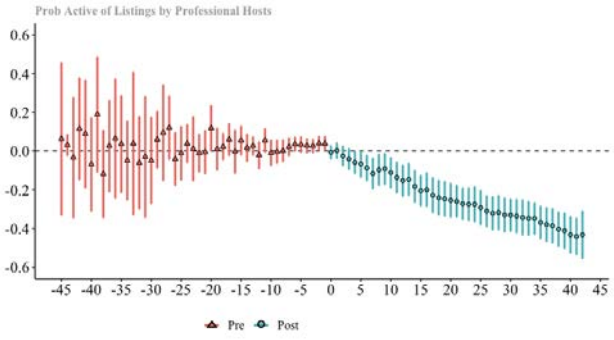
[23] The average effect of participating in the treatment e time periods after the treatment was adopted across all groups that are ever observed to have participated in the treatment for exactly e time periods is

$$\sum_{g \in \mathcal{G}} \mathbf{1}\{g + e \leq \tau\} P(G = g | G + g \leq \tau) ATT(g, g + e),$$

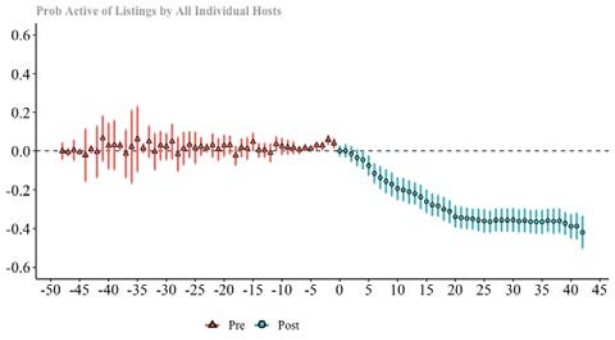
where $e = t - g$ denotes the time elapsed since the treatment was adopted and G denotes the time period that a unit is first treated.

Figure 5: Effect of Prohibited Buildings on Probability of Being Active

(a) Professional Hosts



(b) Individual Hosts



One shortcoming of the staggered treatment analysis is that it cannot identify the role of Chicago's data-powered enforcement, since for a specific PBL-treated listing the treatment time depends on when the focal or nearby buildings have joined the PBL, which can be any time after July 2016. However, the city's ability to access Airbnb data feeds since March 2017 should reveal listings' exact addresses to the city and aid the enforcement of the PBL. To better understand the role of the data feeds in PBL enforcement, we create a subsample using prohibited buildings that joined the PBL before March 2017. Our hypothesis is that we should observe a smaller effect of the PBL treatment on listing availability for this subsample because the prohibited building regulation can be difficult to enforce unless Chicago has direct data feed from STR platforms. In our sample, 1,074 of all prohibited buildings (45.6%) were filed before March 2017. Conditional on this subsample, we rerun the staggered CSDID analysis and confirm our hypothesis that the effect of the PBL does not manifest without the city's data-powered enforcement.

Another shortcoming of estimating the group-time average treatment effect is that it makes it difficult to study the effect of the PBL on listings' STR status conditional on being active. In particular, to do so, we need to compute group-month ATT for treated and control listings in each calendar month after June 2017 (because a local PBL treatment could occur in any month after Chicago began the PBL), but given that many listings became inactive over time because of the PBL, the sample of listings conditional on being active can be zero in some group-months and positive but small in other group-months, which makes it infeasible to produce reliable results from the CSDID method. This is why our analysis on the effect of the PBL only focuses on listing availability.

To summarize, as a complement to the zip-code-month analyses, our listing-level analysis highlights different behaviors of professional and individual hosts in response to Chicago's STR ordinance. A significant fraction of individual hosts responded rapidly to the legislation by exiting Airbnb, even when the city did not have direct data feeds from STR platforms to enforce the ordinance. In contrast, professional hosts did not exhibit any significant exits until the city's data-powered enforcement began, and they were more likely to transition to monthly or longer-term rentals rather than remain as STR listings or exit Airbnb altogether.

We can think of two economic reasons for these differences: First, the registration process and other listing requirements (such as safety measures) may entail non-trivial costs, which make more sense for professional hosts to incur both because of their scale and because their overall revenues from Airbnb are higher than those of individual hosts. Second, by operating three or more properties, professional hosts

may have more knowledge, or more incentives to seek knowledge, about the details of the ordinance and potential exceptions or loopholes. Such knowledge may help them find sophisticated ways to comply with Chicago's STR ordinance and continue operating on Airbnb.

6 Economic Impact of Chicago's Citywide STR Ordinance

Up to this point, our analyses suggest that Chicago's STR ordinance has had a large negative effect on the number of active listings on Airbnb, which is driven by both more exits and fewer entries as compared to control cities. Listings operated by professional hosts also exhibit a notable shift from being offered as short-term to medium-term rentals. This section addresses two remaining questions: (i) How does Chicago's STR ordinance affect the economic performance of listings remaining on Airbnb? (ii) How does the ordinance affect Airbnb's GBV and government tax revenue from STR activities?

6.1 The Effect on Listings' Economic Performance

To evaluate the effects of Chicago's STR ordinace on the economic performance of Airbnb listings, we continue the cross-city comparison between Chicago and the three control cities (Atlanta, Boston, Los Angeles). In particular, we aggregate all active listings by zip code and month from January 2016 to May 2018. In constructing the panel, we exclusively retain active listings, while excluding observations with prices falling below the 1 percentile or exceeding the 99th percentile. We do not condition on a listing's STR status because we cannot measure it perfectly for every listing in every month. To the extent that some STR listings may switch to being offered as MTR listings or alternate between being offered as STR and MTR listings, our analysis includes those listings' booking performance as STR and MTR listings. For zip code z and month t, we use a DID specification:

$$Y_{zt} = \alpha + \gamma_t + \phi_z + \beta_1 LegislationPass_{zt} + \beta_2 Enforcement_{zt} + X_{zt}\Gamma + \varepsilon_{zt} \tag{4}$$

where γ_t denotes year-month fixed effects; ϕ_z is zip code fixed effects; $LegislationPass_{zt}$ equals 1 if the ordinance had been enacted in zip code z by month t; $Enforcement_{zt}$ equals 1 if the ordinance had been enforced with direct data feeds in zip code z by month t; X_{zt} is a vector of control variables include ZIP Codes Business Patterns, weather information, and Google Search Trends; and ε_{zt} is the idiosyncratic error term. Depending on the specific analysis, Y_{zt} can be $log(price)$, $log(revenue\ per\ listings)$, and $log(reservation\ days\ per\ listing)$. The assumption is that, absent the STR ordinance, per-listing performance in Chicago follows a similar trend as in Atlanta, Boston and Los Angeles, conditional on zip code and seasonality controls. Table 1 provides listing-level summary statistics by city in the periods before Chicago enacted its STR ordinance.

The first three rows of Table 5 present the DID results on the economic performance per active listing, namely price (before tax), revenue, and reservation days per listing. Each row represents a separate DID regression, with the coefficients of legislation and enforcement dummies reported separately. The results suggest that none of these economic metrics has any significant change after Chicago enacted and/or enforced its STR regulation. The plots of the event study results for the same outcomes are available in

Table 5: Effect on Listing Performance and Quality

	Indep. Var.			
Dep. Var.	Legislation		Enforcement	
Log(price)	0.029	(0.04)	-0.010	(0.02)
Log(revenue per listing)	0.010	(0.05)	-0.005	(0.06)
Log(reservation days per listing)	0.002	(0.03)	-0.011	(0.02)
Max Guests	0.143**	(0.04)	0.117**	(0.04)
# Photos	-0.417*	(0.16)	1.266***	(0.06)
Rating Overall (0-100)	-0.702**	(0.18)	0.986*	(0.32)
Rating Check-in (0-10)	-0.052***	(0.01)	0.060***	(0.01)
Rating Communication (0-10)	-0.019**	(0.01)	0.046***	(0.01)

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Figure A.7.

Given that the citywide aspect of Chicago's STR ordinance has little effect on the economic performance of an active listing, we examine whether the ordinance affects the *quality* of active listings, using the same DID specification. As shown in the last five rows of Table 5, listings active in Chicago tend to offer a higher number of maximum guests after Chicago enacted and enforced its STR ordinance, while the other four quality measures — the number of photos posted per listing, its overall rating, and its ratings specific to check-in and communication — have first declined after the city's ordinance but increased after enforcement of the ordinance began. This fluctuation is understandable because guests may be confused about the legality of Chicago's STR listings shortly after the city enacted its ordinance, and this confusion may have been somewhat clarified over time as Chicago tightened its enforcement and enacted amendments to the ordinance.

For these four measures, the sum of the ordinance and enforcement coefficients is positive, suggesting that they may have improved after Chicago's data-powered enforcement relative to before the STR ordinance was in place. However, the net effects are small in magnitude. For example, the overall rating (0-100) increased 0.284 relative to the pre-ordinance average of 95.2, the maximum guests allowed increased by 0.26, and the net increase in the number of photos posted is less than one. Albeit small, these changes are arguably beneficial to potential guests, as they can have more information about listings upfront and may be able to reduce the number of listings they have to book simultaneously if the guest group is large.

6.2 The Effect on Airbnb's GBV and Government Tax Revenues

Although Chicago's STR ordinance does not lead to significant changes in the price, quantity, and revenues per active listing, it could lead to a decrease in Airbnb's general booking value (GBV) because the number of active listings in Chicago declined as a result of the ordinance. To quantify this effect, we calculate a zip code's total Airbnb GBV in a month by summing up the booking values of all active listings in that zip code-month. This analysis is based on a cross-city comparison between Chicago and the three control cities. To study the heterogeneous impact of Chicago's STR regulation, we separate the sample by listings operated by professional hosts and individual hosts. We define professional and individual hosts according to the number of listings each host has ever had in all of our sampled cities throughout the whole city-comparison

period because we intend to capture the aggregate GBV independent of when a listing (or host) started on Airbnb.

As shown in the first two columns of Table 6, where we conduct the four-city comparison between January 2016 and May 2018, we find that the enactment of Chicago's ordinance has no significant effect on the total GBV of Chicago Airbnb listings by professional hosts, but the city's subsequent data-powered enforcement of the ordinance brings a negative effect (-32.4%), leading to the combined effect of enactment and enforcement of -30.5%.[24] We observe similar effects on the total GBV of Airbnb listings by individual hosts. Specifically, the enactment-only effect is insignificant, the enforcement-only effect is -31.3%, and the combined effect of enactment and enforcement is -22%. The results are similar when we narrow the sample to only entire-home listings.

Table 6: Effect on Airbnb's GBV

		By May 2018		By December 2019	
Dep. Var.	Indep. Var.	Professional Hosts	Individual Hosts	Professional Hosts	Individual Hosts
		(1)	(2)	(3)	(4)
log(GBV)	Legislation	0.027	0.128	-0.017	0.100
		(0.09)	(0.08)	(0.11)	(0.09)
	Enforcement	-0.391***	-0.376***	-0.394***	-0.381***
		(0.07)	(0.08)	(0.09)	(0.11)
	Tax Increase	x	x	0.053	-0.366***
				(0.10)	(0.13)
N		4,655	4,739	5,646	5,764

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A priori, it is unclear whether Chicago's STR ordinance would increase or decrease local tax revenues from STR activities. There are two countervailing forces: On the one hand, according to the Civic Federation,[25] Chicago's 2016 ordinance introduced a 4% lodging tax specific to STR bookings, on top of the 17.4% tax that traditional short-term accommodation providers (predominantly, hotels) must pay. This STR-specific surcharge was increased further to 6% as part of the 2018 amendment to the ordinance, pushing the effective lodging tax rate to approximately 23.4% for STR listings in Chicago (including city, county and state taxes). These changes imply that, upon the 2016 STR ordinance, the local city, county and state governments were able to collect tax revenues on every Chicago STR booking made on Airbnb. On the other hand, our data analysis suggests that Airbnb's total GBV in Chicago declined significantly, especially after the city's data-powered enforcement began in March 2017. Assuming the post-enforcement periods of our cross-city comparison (March 2017-May 2018) presents a steady state post the STR ordinance, the total lodging tax revenue that STR listings could generate in Chicago may increase or decrease depending on which of the two forces dominates.

One difficulty in quantifying the net effect of Chicago's STR ordinance is that existing STR listings may remain active but switch to being offered as monthly (or longer) MTR rentals, and thus avoid any lodging tax.[26] From Figure 4, we know this change is different for listings managed by professional and individual

[24] More specifically, based on the coefficients in Table 6, Column 1, we have $exp(-0.391) - 1 = 0.324$ and $exp(0.027 - 0.391) - 1 = 0.305$.

[25] `https://www.civicfed.org/civic-federation/blog/city-chicago-passes-additional-20-tax-home-sharing`

[26] To our knowledge, revenue from LTR listings on Airbnb may be subject to income tax, but not subject to the 17.4% lodging tax or Chicago's 4-6% STR surcharge.

hosts, which implies that we need to incorporate the GBV changes by host type. To do so, we follow the following formula:

$$
\begin{aligned}
\%\Delta \textit{Tax Revenue } (4\% \textit{ Surcharge}) &= \frac{21.4\%(GBV'_{STR\_prof\_host} + GBV'_{STR\_indiv\_host})}{17.4\% \cdot GBV_{STR}} - 1 \\
&= \frac{21.4\%(\gamma' \cdot GBV'_{prof} + \beta' \cdot GBV'_{indiv})}{17.4\% \cdot \alpha \cdot GBV} - 1 \\
&= \frac{21.4\%(0.935 \cdot 0.695 \cdot \gamma \cdot GBV_{prof} + 0.78 \cdot \beta \cdot GBV_{indiv})}{17.4\% \cdot \alpha \cdot GBV} - 1 \\
&= \frac{21.4\%(0.935 \cdot 0.695 \cdot 0.34 + 0.78 \cdot 0.66)}{17.4\%} - 1 \\
&= -9.5\%
\end{aligned}
\tag{5}
$$

where GBV and GBV' denote the booking values of Chicago listings on Airbnb before and after the STR ordinance, respectively. Their subscripts denote whether the GBV is from STR (versus other) listings and whether the listings are operated by professional or individual hosts. Let α represent the fraction of GBV generated by STR listings before the ordinance, and $\{\beta, \gamma\}$ represent this fraction conditional on listings operated by professional hosts or individual hosts, respectively. Suppose the regulation has led β to change to β' and γ to change to γ'.

The first two columns of Table 6 suggest that, because of the STR ordinance, Airbnb GBV from Chicago listings operated by professional hosts declined by 30.5%, while Airbnb GBV from listings operated by individual hosts declined by 22%. This implies that $GBV'_{prof} = (1 - 30.5\%) \cdot GBV_{prof}$, and $GBV'_{indiv} = (1 - 22\%) \cdot GBV_{indiv}$. Figure 4 further suggests that, conditional on being active, listings offered by professional hosts, on average, reduced their STR status by 6.5% but there is no change in the STR status of listings operated by individual hosts conditional on being active. This implies that $\beta' = \beta$ and $\gamma' = 0.935\gamma$. Also, before the STR regulation, roughly 34% of GBV was generated by listings operated by professional hosts, implying $GBV_{prof} = 34\% \cdot GBV$ and $GBV_{indiv} = (1 - 34\%) \cdot GBV$. Combined, and given the fact that almost all Airbnb listings were STR listings before the ordinance (i.e. $\alpha = \beta = \gamma = 1$), we estimate the local governments' tax revenue from Chicago's STR market to decline 9.5%.

Since the increase in the city's STR tax surcharge in the 2018 amendment could further decrease the taxable GBV by decreasing the supply of STR listings in Chicago, the actual decline in local governments' tax revenue could be even larger than 9.5%. To understand how the increase in the tax surcharge affects the GBV, we compared the zip-code-month GBV of Airbnb listings in Chicago with GBV of Airbnb listings in Atlanta and Boston from January 2016 to December 2019, while adding a dummy indicating Chicago's extra STR tax surcharge from December 2018 onward. We exclude Los Angeles because the city passed its own STR regulation in December 2018. Atlanta did not enact its STR regulation until March 2021. Boston is also included in the control since Airbnb did not comply with the city's STR regulation until December 2019, although its STR regulation was enacted in June 2018. We separate the analysis for listings operated by professional hosts and individual hosts.

Results of this extended analysis are shown in the last two columns of Table 6. They show that the extra tax surcharge does not have an additional significant impact on the GBV of listings run by professional hosts, though the coefficient of the tax surcharge dummy does suggest a slightly lower drop in GBV (30.1%

vs. 30.5%).[27] In contrast, Chicago's increase in its STR tax surcharge has a significant negative effect on the GBV of listings offered by individual hosts. Specifically, the combined effect of enactment, enforcement, and tax surcharge is -47.6% for the GBV of listings offered by individual hosts.[28]

Using these updated estimates, the following calculation suggests that the decrease in Chicago's tax revenue from STR bookings could be as large as 23.6% after the STR tax surcharge increased, relative to no STR regulation:

$$\begin{aligned}
\%\Delta \textit{Tax Revenue } (6\% \textit{ Surcharge}) &= \frac{23.4\%(GBV'_{STR_prof_host} + GBV'_{STR_indiv_host})}{17.4\% \cdot GBV_{STR}} - 1 \\
&= \frac{23.4\%(\gamma' \cdot GBV'_{prof} + \beta' \cdot GBV'_{indiv})}{17.4\% \cdot \alpha \cdot GBV} - 1 \\
&= \frac{23.4\%(0.935 \cdot 0.699 \cdot \gamma \cdot GBV_{prof} + 0.524 \cdot \beta \cdot GBV_{indiv})}{17.4\% \cdot \alpha \cdot GBV} - 1 \\
&= \frac{23.4\%(0.935 \cdot 0.699 \cdot 0.34 + 0.524 \cdot 0.66)}{17.4\%} - 1 \\
&= -23.6\%.
\end{aligned} \tag{6}$$

To summarize, we find that the overall decline in the number of active listings led to a substantial reduction in Airbnb revenues after Chicago began enforcing its STR ordinance with direct data feeds. Moreover, this reduction was more than sufficient to offset the potentially positive effect of the STR tax surcharge on tax revenues. Since Chicago was already collecting city-specific (i.e., not state, county or the STR surcharge) tax revenues from STR listings before the 2016 ordinance, our estimates indicate that city tax revenues from STR listings in Chicago may have declined 9.5% to 23.6% relative to what the city would have collected without the 2016 ordinance.

7 The Effect on Hotels and Local Crimes

One aim of Chicago's STR ordinance is to re-balance the interests of different stakeholders in the city's community. In this section, we study the effect of the ordinance on hotel revenues and local crime rates.

7.1 The Effect on Hotel Revenues

Since Chicago's STR ordinance has adversely affected Airbnb's GBV in the city, under the assumption that the overall demand for short-term accommodations remains stable, one may expect hotels to benefit from the city's STR ordinance. To understand the effect of STR regulations on hotel revenues, we use hotel revenue data from Smith Travel Research. The plot of the log aggregated hotel revenue in a zip-code-month is available in Figure A.8 in Appendix A. From the plot, we observe that the seasonality of hotel revenues in Chicago and Boston match, but the seasonality of hotel revenues in Atlanta and Los Angeles are inconsistent with those of Chicago and Boston. Therefore, we use Boston as the only control for Chicago when examining the effect of Chicago's STR ordinance on hotel revenues.

[27] Based on the coefficients reported in Table 6, Column 3, we have $exp(-0.017 - 0.394 + 0.053) - 1 = 0.301$.

[28] Based on the coefficients reported in Table 6, Column 4, we have $exp(0.1 - 0.381 - 0.366) - 1 = 0.476$.

Since the distribution of hotels is concentrated in a small number of zip codes, we only keep the panel of zip codes that have positive average revenues before the enactment of Chicago's STR ordinance. This subsample contains monthly panel observations of 10 zip codes from Chicago and 9 zip codes from Boston from January 2010 to May 2018 [29]. For zip code z and month t, we use a two-way fixed effect (TWFE) specification:

$$log(Sum\_Hotel\_Revenue)_{zt} = \alpha + \gamma_t + \phi_z + \beta_1 LegislationPass_{zt} + \beta_2 Enforcement_{zt} + X_{zt}\Gamma + \varepsilon_{zt}, \quad (7)$$

where γ_t denotes year-month fixed effects; ϕ_z denotes zip code fixed effects; $LegislationPass_{zt}$ equals 1 if the ordinance had been enacted in zip code z by month t; $Enforcement_{zt}$ equals 1 if the ordinance had been enforced with direct data feeds in zip code z by month t; X_{zt} stands for the Google Search Trends variables; and ε_{zt} is the idiosyncratic error term.

The analysis fails to detect any significant impact of Chicago's STR regulation and enforcement on hotel revenues. The estimated β_1 coefficient is -0.037 with a standard error of 0.05, and the estimated β_2 coefficient is -0.005 with a standard error of 0.03. Event study results (with monthly-specific effect of the ordinance) are reported in Figure A.9 of the Appendix.

The lack of an effect could be explained by the vast difference in hotel revenues and Airbnb's GBV. In the relatively few zip codes with positive hotel revenues, we find that, on average, total hotel revenues are 370 times that of Airbnb's GBV in the same zip-code-months. Citywide, hotel revenues are, on average, 17 times that of Airbnb's GBV in Chicago, although Airbnb listings are much more dispersed than hotels within Chicago. It is possible that the city's STR ordinance did generate changes in hotel revenues within the few hotel-concentrated zip codes, but these changes are too small to identify in total hotel revenues.

To address this possibility, we compare changes in Airbnb's GBV in hotel-dense areas with those in hotel-sparse areas. Assuming an Airbnb STR listing is a close substitute to a hotel in the same vicinity, Airbnb's loss in GBV should be more substantial in hotel-dense areas after the enactment of Chicago's STR ordinance, if the ordinance indeed benefits hotels. More specifically, we stratify our zip codes that have positive hotel revenues into zip codes with above- and below-median levels of hotel revenues within each city before June 2016, and rerun the DID analysis for these two subsamples separately.

The findings presented in Table 7 confirm our expectations. When using a subsample of zip codes with below-median hotel revenues, Chicago's STR ordinance exhibits no significant effect on Airbnb's GBV. However, the ordinance has a significant negative effect on Airbnb's GBV in zip codes with above-median hotel revenues. In those zip codes, the ordinance leads to a 38.7% reduction in GBV. Additionally, upon comparing the magnitude and significance of the coefficients for the enactment and enforcement of the city's ordinance, we conclude that the decrease in GBV for listings in zip codes with above-median hotel revenues is predominantly driven by the city's data-powered enforcement.

[29] In practice, there may be more zip codes with positive hotel revenues; however, some zip codes in the dataset have missing information and we do not include them in our analysis.

Table 7: Effect on Airbnb's GBV by Hotel Density

		Below Medium Hotel Density	Above Medium Hotel Density
log(GBV)	Legislation	-0.300	0.055
		(0.30)	(0.25)
	Enforcement	-0.074	-0.544***
		(0.28)	(0.13)
N		592	521

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Non-professional hosts include full-time and part-time individual hosts.

7.2 The Effect on Local Crimes

Given that one of the declared purposes of Chicago's STR ordinance was the protection of local residents,[30] we examine whether the regulation affects local crimes. As in the prior analyses, we begin by comparing the number of crime incidents in Chicago and in control cities, and then examine within-Chicago changes by taking advantage of the local STR restrictions from the Prohibited Buildings List.

Our cross-city comparison uses Atlanta and Los Angeles as controls. We exclude Boston because Boston has a much lower crime rate than Chicago and the other two control cities. We construct the zip code-month panel from January 2016 to May 2018. Following the literature Han et al. (2020), we focus on the four most common crimes in the US (theft, burglary, assault, and robbery) according to the classification by the National Incident-Based Report system. Table 8 summarizes the average crime per zip-code-month by city before Chicago's ordinance.

Table 8: Average Crime Per Zip Code-Month before Chicago's Ordinance

	log (1+# of Crime Incidents)		
	Chicago	Atlanta	Los Angeles
log(1+Theft)	3.10	2.75	2.42
log(1+Robbery)	1.66	1.15	1.23
log(1+Assault)	3.03	1.08	2.42
log(1+Burglary)	2.18	1.64	2.17
Average	2.77	2.05	2.24

For zip code z in month t, we consider the following DID specification:

$$log(Crime_{zt}) = \beta_1 LegislationPass_{zt} + \beta_2 Enforcement_{zt} + \gamma X_{zt} + \mu_t + \phi_z + \varepsilon_{zt}, \tag{8}$$

where $LegislationPass_{zt}$ equals 1 if the zip code is in Chicago and t is post Chicago's enactment of the ordinance (June 2016 or later); $Enforcement_{zt}$ equals 1 if the zip code is in Chicago and t is post the city's data-powered enforcement (March 2017 or later); and X_{zt} is a vector of control variables including the number of incoming passengers arriving at airports in each city, county population, average monthly earnings of employees in the metropolitan area, the number of law enforcement employees in the county,

[30] See, e.g., `https://www.nlc.org/wp-content/uploads/2022/05/Short-Term-Rental-Regulations.pdf`.

unemployment rate in the metropolitan area, the number of bankruptcy cases in the zip code, rent index of the zip code, and weather.

As shown in Table 9, it follows from the DID results that the city's ordinance has no significant effect on the number of criminal activities. Because we construct the panel by zip-code-month, some zip codes may have no criminal incidents in some months. To avoid the bias caused by such zero observations, we first check their prevalence. For every type of crime, the percentage of zero observations is less than 20%. Therefore, we apply the inverse hyperbolic sine transformation to check the robustness of the results. The results using inverse hyperbolic sine transformation, available in Appendix Table A.1, are almost identical to the simple linear results shown in Table 9, confirming the conclusion that Chicago's STR ordinance has no significant effect on the number of crime incidents.

Table 9: Effect of Chicago's STR Ordinance on Local Crime

	log(1+# Theft)	log(1+# Robbery)	log(1+# Burglary)	log(1+# Assault)	Average
Legislation	-0.010	0.065	0.045	-0.025	-0.003
	(0.03)	(0.05)	(0.06)	(0.03)	(0.02)
Enforcement	-0.013	0.013	0.033	0.002	0.023
	(0.03)	(0.04)	(0.04)	(0.03)	(0.02)
N	8,100	8,100	8,100	8,100	8,100

In parentheses are standard errors clustered by zip code. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Turning to within-Chicago variations, we examine the effect of the Prohibited Buildings List (PBL) on local crime. This within-city comparison enables us to eliminate unobservable factors that may correlate with the number of crime incidents differently in the different cities. Not using any control cities also enables us to extend the end of the study period from May 2018 to February 2020. Similar to the cross-city comparison, we focus on crime incidents in theft, robbery, burglary, and assault.

To construct the sample, we calculate the count of crime incidents within a 500-meter radius for each prohibited building in each month. Since each prohibited building joined the list at different times, the treatment is staggered. Thus, we apply the staggered CSDID method (Callaway and Sant'Anna, 2021), while controlling for zip code fixed effects. In essence, areas of not-yet-treated and never-treated serve as the control group for the areas treated by the PBL. The ATT presented in Table 10 indicates that the prohibited building restriction has no significant effect on the numbers of thefts, robberies, and assaults but it does have a significant negative effect (-11%) on the number of burglary cases.[31]

This result is robust to using the inverse hyperbolic sine transformation for addressing the areas with zero crime incidence. The reduction in only burglary is conceivable because burglary hinges on illegal entry into a building or residence, and STR listings that allow stranger guests' access to a property may end up facilitating burglars' access as well.

[31] Based on the coefficient corresponding to the Burglary column in Table 4, we have $exp(-0.117) - 1 = -0.11$.

Table 10: Effect of Prohibited Buildings on Local Crime

	log(1+# Theft)	log(1+# Robbery)	log(1+# Burglary)	log(1+# Assault)	Average
Aggregated ATT	-0.022	0.0245	-0.117**	-0.004	-0.030
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
N	1,117,000	1,117,000	1,117,000	1,117,000	1,117,000

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

8 Conclusion

This paper presents the first in-depth analysis of a local regulation of a large short-term rental market in a major US city, Chicago. Unlike other large cities that either ban STR services or largely let the market take the reins, Chicago represents an early effort to accommodate popular STR services while at the same time addressing concerns from local residents and the hotel industry.

Our analysis suggests that Chicago's STR ordinance does make progress towards a middle ground. On the one hand, the number of active listings in the city dropped by 16.4% with almost no change in the average price (before tax), reservation days, and booking revenue per active listing. This implies a significant drop in Airbnb's GBV as well as reductions in tax revenues at the city, county and state levels from STR services in Chicago. On the other hand, although we cannot find any discernible effects of the citywide ordinance on local crimes and aggregate hotel revenues, (i) we observe a reduction in the incidence of burglaries in the areas near buildings that prohibit short-term rentals, and (ii) within the zip codes with above-median hotel revenues, we find a more significant decline in Airbnb's GBV.

Whether these initial signs of potential benefits translate into long-term, sustainable benefits to local residents and hotels remain an open question. Furthermore, due to data limitations, we cannot document other potential effects of the ordinance on local residents; however, some of them are conceivable (for example less neighborhood noise, less local traffic, and less local transiency and issues with waste disposal), given the significant decline in active listings in Chicago and the connection demonstrated by the prior literature regarding the effects of STRs on local residents. Whether the realized balance among STR activities and the changes for local residents and the hotel industry is the most appropriate balance that a short-term rental regulation could hope to achieve in a major US city is a promising direction for future research.

Chicago's early experience in regulating a substantial STR market provides four insights that may help policymakers in other cities: first, data-powered enforcement, with direct participation by STR platforms, is a critical component in effective regulation. The vast majority of the effects we detect from the citywide aspects of Chicago's ordinance did not take place until the city began receiving direct data feeds from STR platforms.

Second, STR registration was slow and incomplete four years post the enactment of the ordinance, partly because hosts were instructed to register through the platform rather than the city directly, and partly because listings were allowed to continue operating while their registrations were pending, even if they were ultimately likely to result in denials. Chicago shut down these two practices in its 2021 amendment of the ordinance, which may have contributed to the subsequent increase in the rate of registration. This experience highlights the difficulty of balancing a lack of resources in local governments on the one hand,

and the potential conflict of interest in giving some extent of regulatory or administrative authority to an intermediary party (in order to offset some of the administrative costs) on the other hand — especially given that the intermediary's profit is a function of the market stakeholders that are subject to the regulation.

Third, although Chicago imposed some direct restrictions on the number of STR listings by building type and whether they are a primary residence, it does not slow down the growth of the fraction of active Airbnb listings managed by professional hosts. From our analysis, professional hosts with 3 or more listings on Airbnb before the city's ordinance responded more slowly to the regulation than individual hosts with 1-2 listings, and were more likely to transition to monthly or longer rentals on Airbnb after the regulation. These more sophisticated responses by professional hosts may help explain why the fraction of active listings run by professional hosts on Airbnb (including STR and MTR listings) increases similarly in all four sampled cities, despite Chicago's STR ordinance.

Fourth, our analysis links a reduction in local crime to a local aspect of Chicago's STR ordinance — an ability to restrict short-term rentals at the building level. However, we find no such link from the citywide aspects of the ordinance. At the same time, both the citywide aspects and the local restrictions implemented by the ordinance are ultimately effective in reducing the number of active listings. This contrast raises questions regarding the relationship between citywide and local aspects of regulations, which is another promising direction for future work.

Declarations of Interest: None.

CRediT (Contributor Roles Taxonomy) Author Statement:

Jin: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Writing-Original Draft, Writing-Review & Editing, Supervision, Project Administration.

Wagman: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Funding Acquisition.

Zhong: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization.

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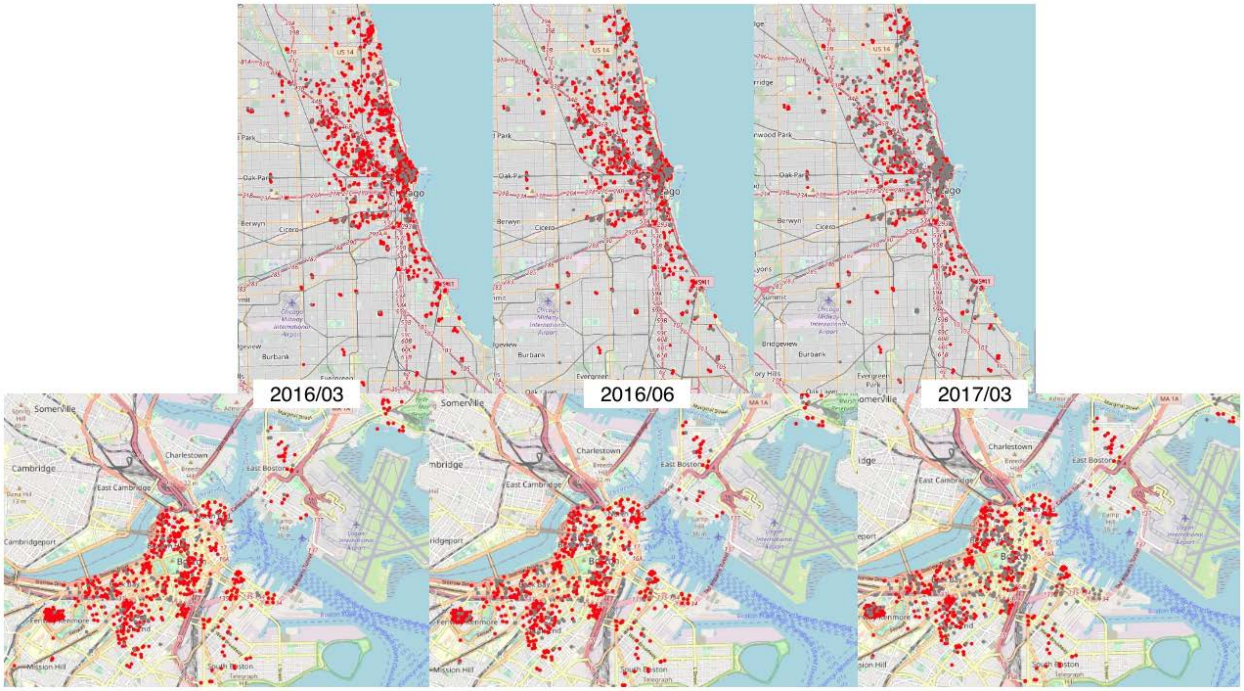
Appendix

A Additional Figures and Tables

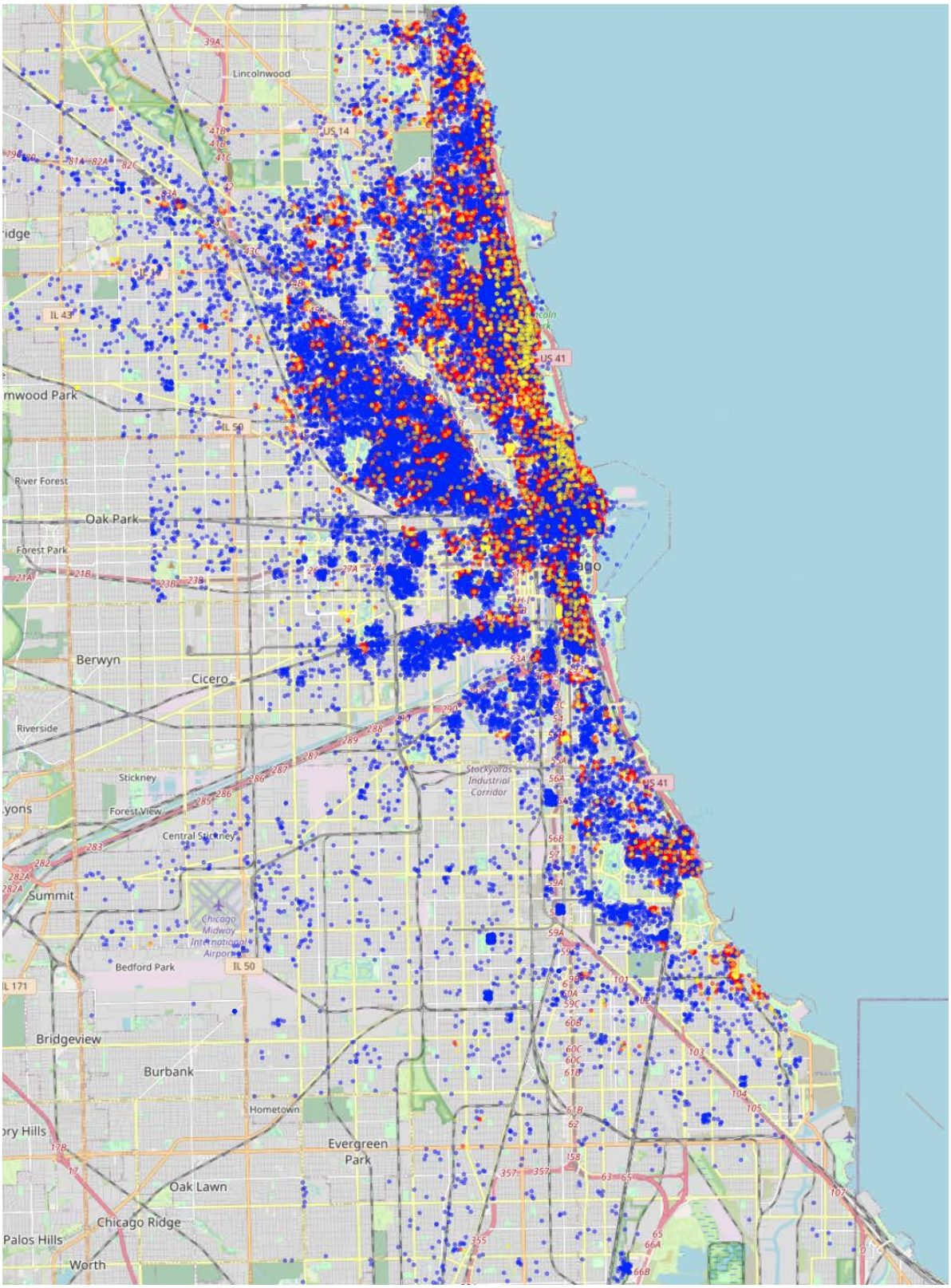


Notes: This map shows snapshots of Airbnb listings in Boston and Chicago taken in March 2016, June 2016, and March 2017. The top three maps show Airbnb listings in Chicago, and the bottom three maps show Airbnb listings in Boston. Red dots represent active listings and gray dots represent inactive listings.

Appendix Figure A.1: Airbnb Listings in Chicago and Boston

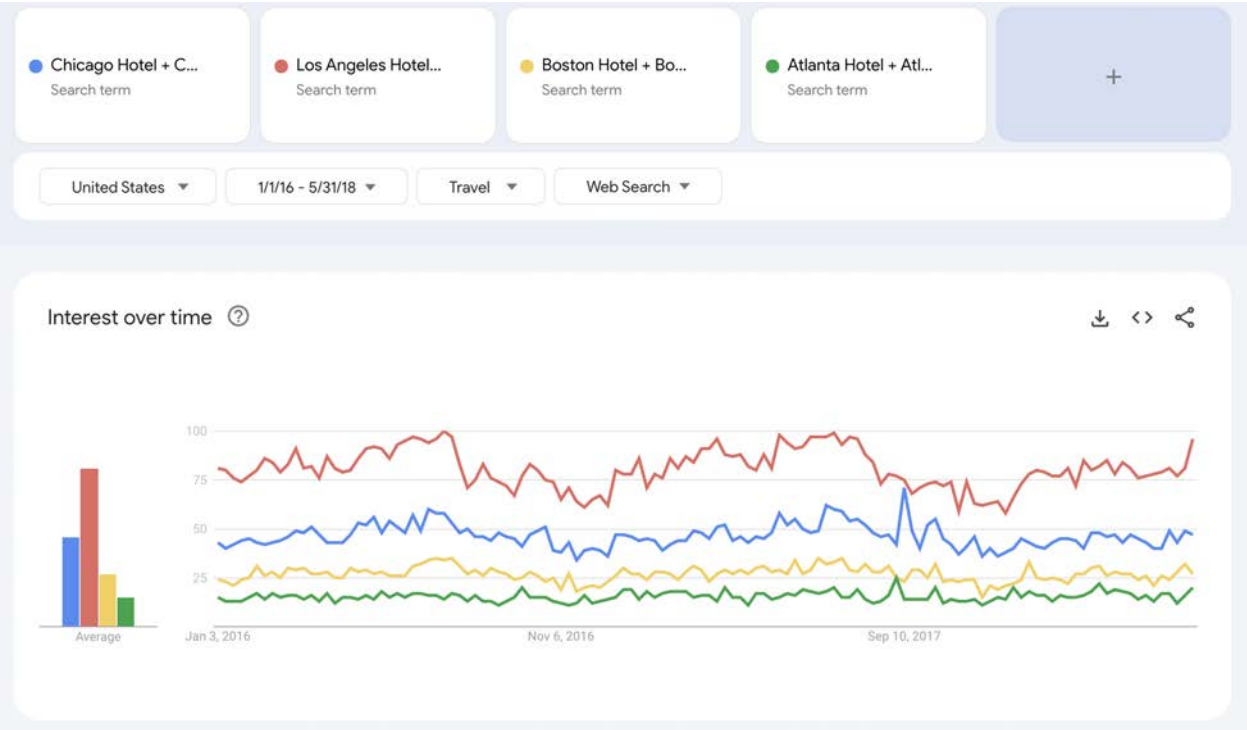
Appendix Table A.1: Effect of STR Regulation on Criminal Activities With Inverse Hyperbolic Sine (IHS) Transformation

	IHS Theft	IHS Robbery	IHS Burglary	IHS Assault	IHS Average
Legislation	-0.024	0.073	0.041	-0.028	-0.003
	(0.04)	(0.06)	(0.05)	(0.04)	(0.02)
Enforcement	-0.016	0.018	0.056	0.005	0.023
	(0.03)	(0.05)	(0.04)	(0.05)	(0.02)
N	8100	8100	8100	8100	8100



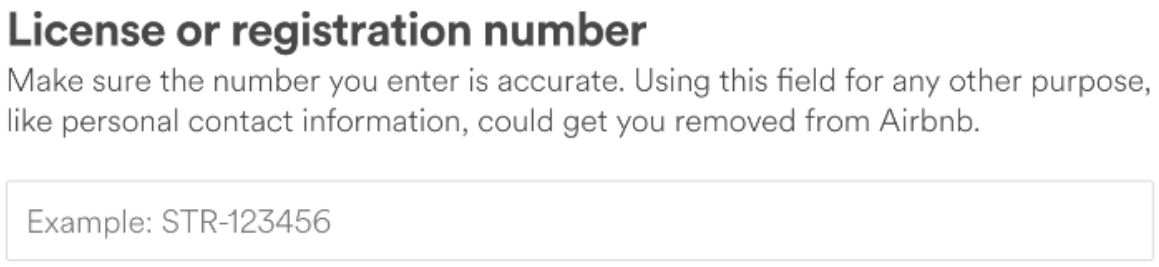
Notes: This map shows Airbnb listings and prohibited buildings in Chicago. Yellow dots represents prohibited buildings, blue dots represents Airbnb listings that never matched with a prohibited building before exiting the market, red dots represents Airbnb listings that have matched with at least one prohibited buildings before exiting the market. The marching is based on the 150 meters criteria.

Appendix Figure A.2: Prohibited Buildings and Airbnb Listings

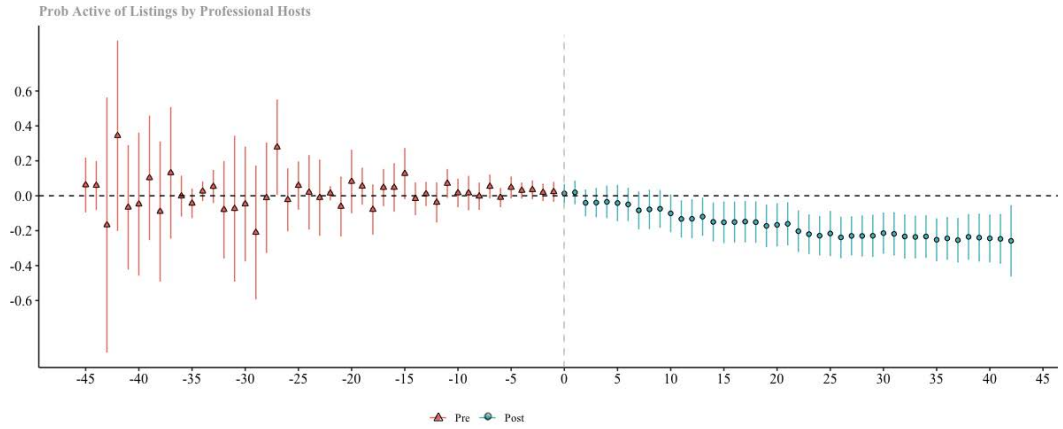


Notes: The plot is weekly trend, and the trend used in the regression analysis is at monthly level by taking average of weekly search in the month.

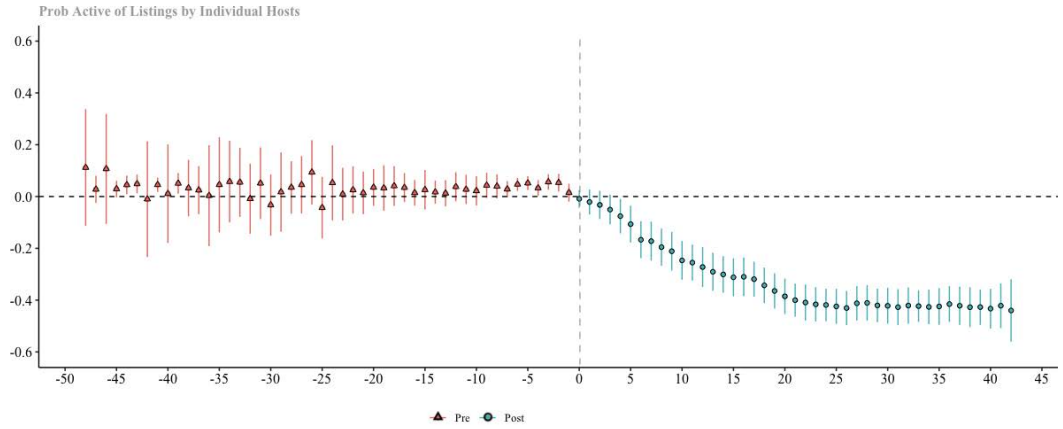
Appendix Figure A.3: Google Search Trends



Appendix Figure A.4: Field for Registration Number



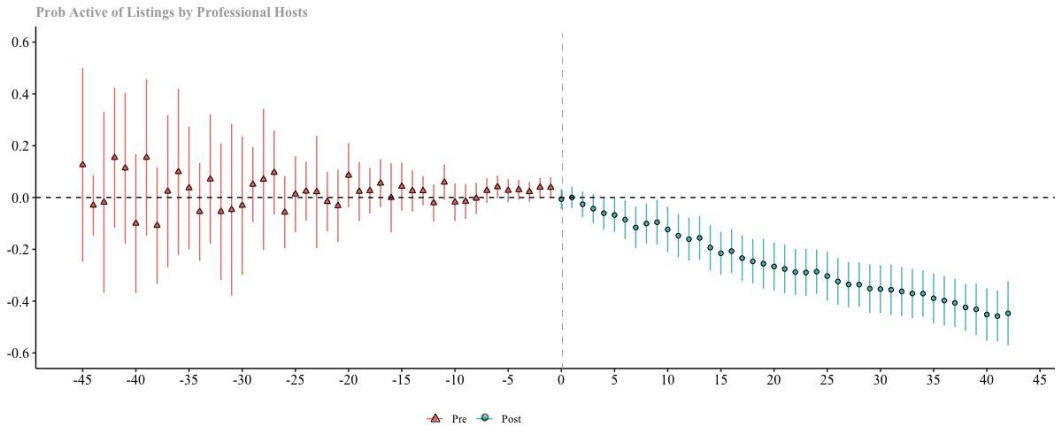
(a) Professional Hosts



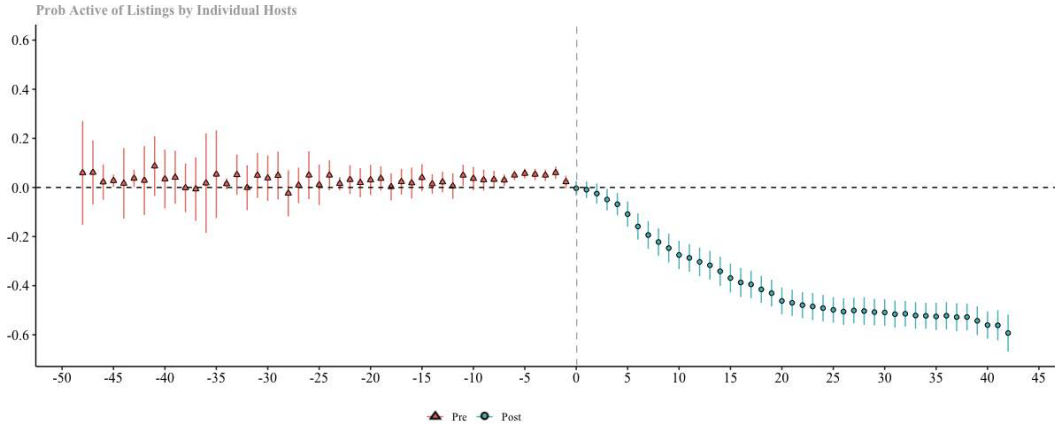
(b) Individual Hosts

Notes: In this analysis, the criteria to define treated listings and control listings is 80 meter. A listing is a control listing if none of the buildings within its 80 meters radius circle are on the Prohibited Buildings List before the listing exits the market. A listing is a treated listing if at least one of the buildings in its 80 meters radius circle are on the Prohibited Buildings list before the listing exits the market.

Appendix Figure A.5: Effect of Prohibited Buildings List on Listing Availability



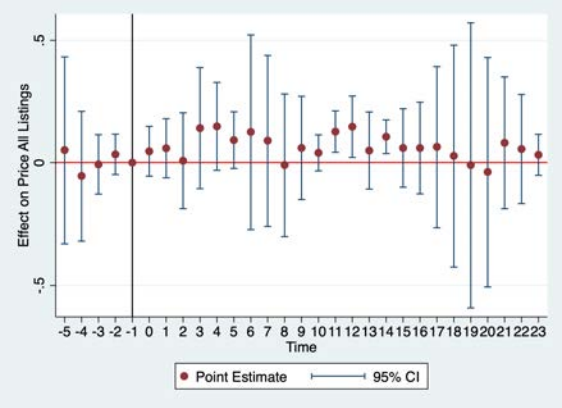
(a) Professional Hosts



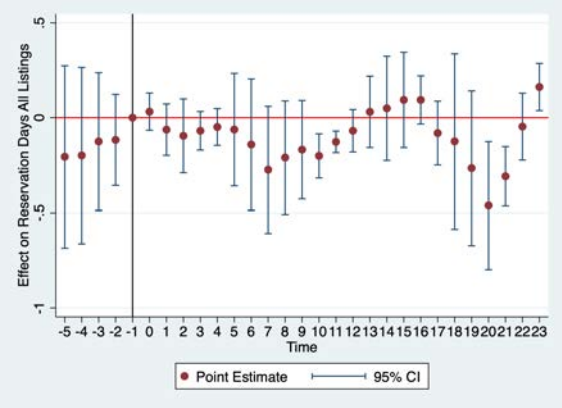
(b) Individual Hosts

Notes: In this analysis, control listings that do not have any treated listings in their 300 meters radius circle are excluded from the sample.

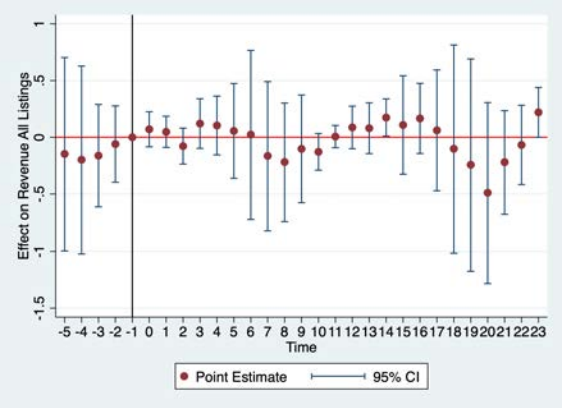
Appendix Figure A.6: Effect of Prohibited Buildings List on Listing Availability



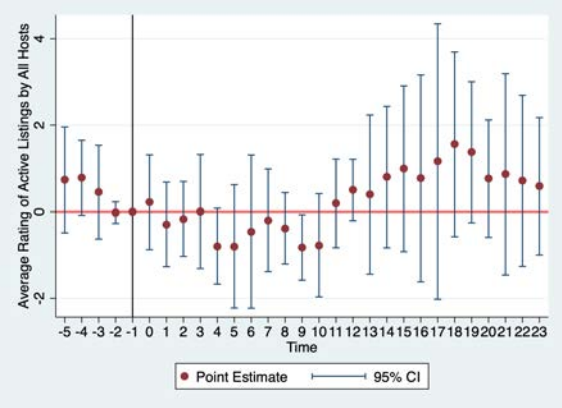
(a) Price



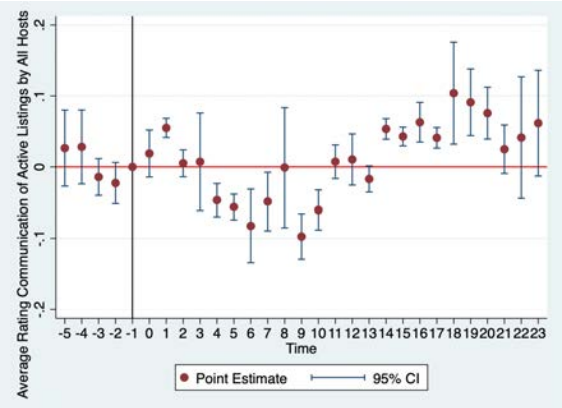
(b) Reservation Days



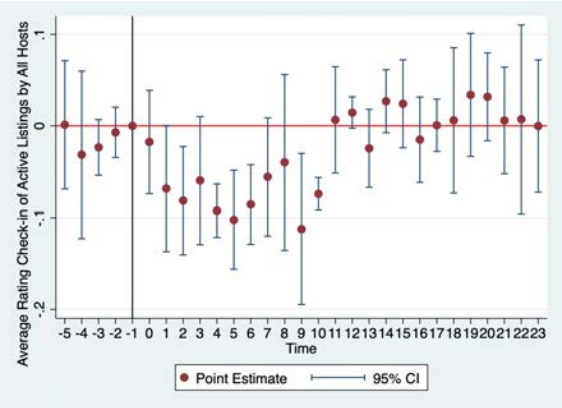
(c) Revenue



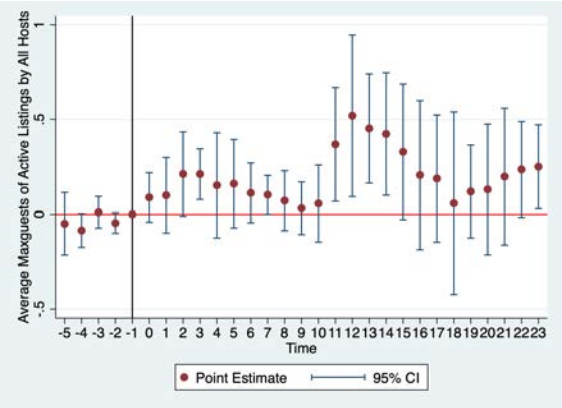
(d) Rating Overall



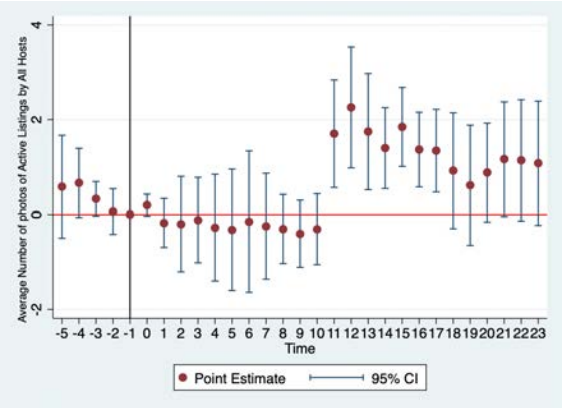
(e) Rating Communication



(f) Rating Check-in

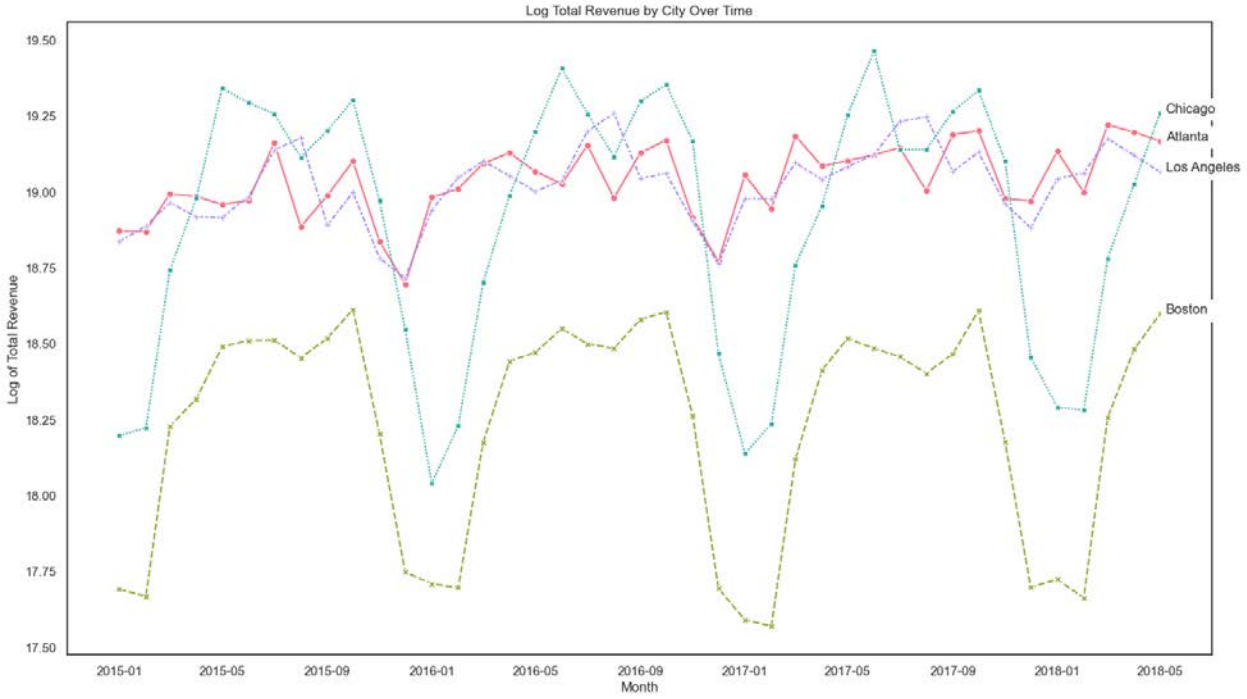


(g) Max Guests

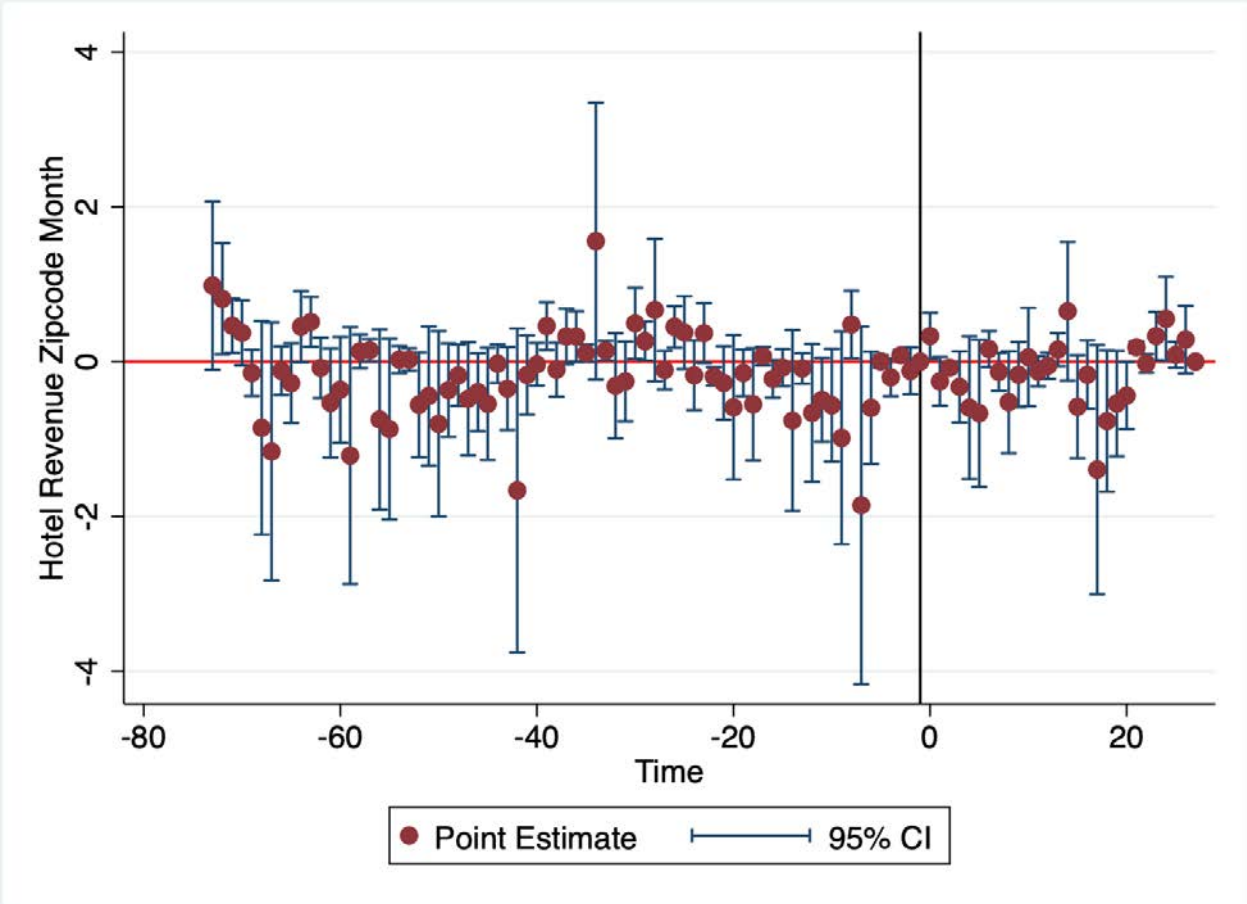


(h) # Photos

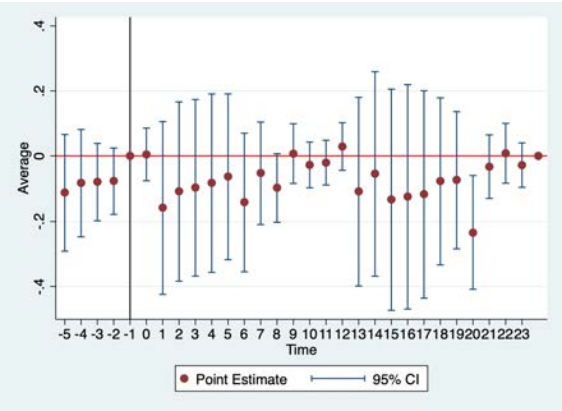
Appendix Figure A.7: Effect on Economic Performance and Quality



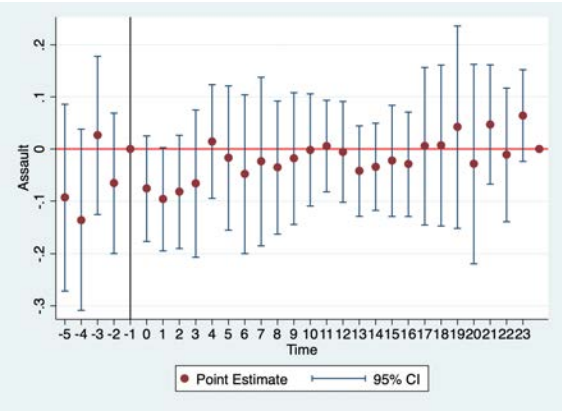
Appendix Figure A.8: Log Total Hotel Revenue per Zip Code Month



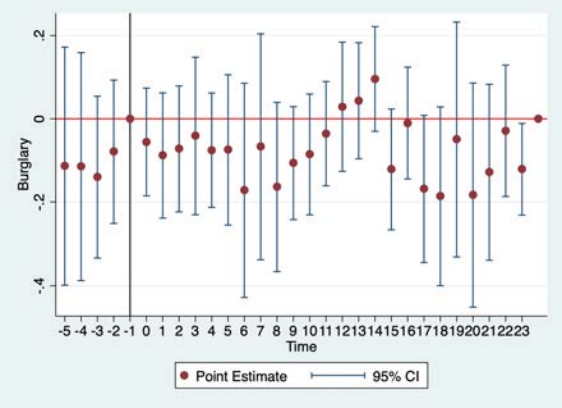
Appendix Figure A.9: Effect of STR Regulation on Log Hotel Revenue



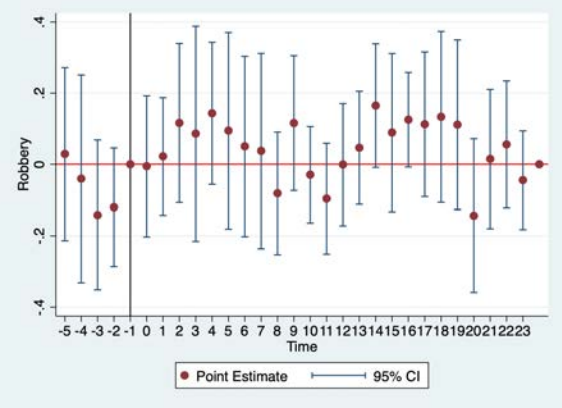
(a) Average Crime



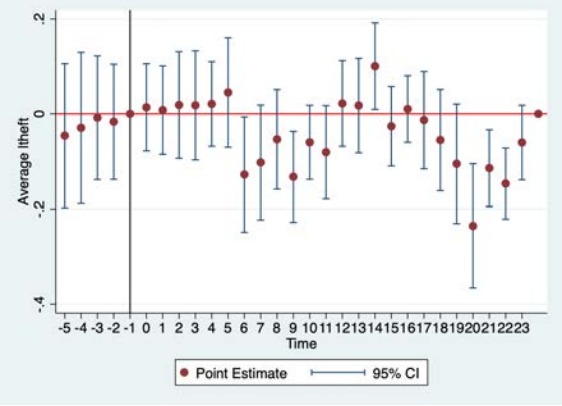
(b) Assault



(c) Burglary



(d) Robbery



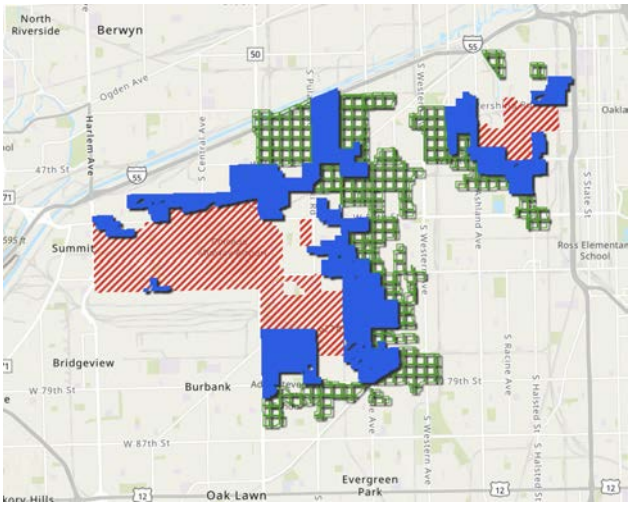
(e) Theft

Appendix Figure A.10: Effect on Crime Types

B Analysis of the Restricted Residential Zone (RRZ) Policy

The first application to be an RRZ took place in April 2017 with an effective date in July 2017. Since RRZs only prohibit new listings, a natural method to analyze the effect of the RRZ policy is to compare the number of new entries in RRZs with new entries in non-RRZs. However, most areas that joined the RRZ list are not Airbnb hot spots. In fact, each RRZ has zero or no more than three new Airbnb listings entering per month. This implies that the regression outcome on the number of new entries can be easily influenced by one ad-hoc entry. In light of this, we analyze the total number of active listings in all RRZs combined. In particular, we group all precincts that became effective RRZs by February 2020 into one treated region and all nearby precincts that never applied to become an RRZ into one control region.

Figure B.11 provides a visual representation of the treated and untreated areas. Precincts that became RRZs by February 2020 are indicated with red (diagonal line) grids. Precincts in blue (solid filled) are those that did not apply to become an RRZ by May 4, 2023 (the date the RRZ data was last updated). Blue (solid filled) areas are selected to ensure red (diagonal line) and blue (solid filled) areas have similar pre-treatment trends in their number of active listings before June 2016.



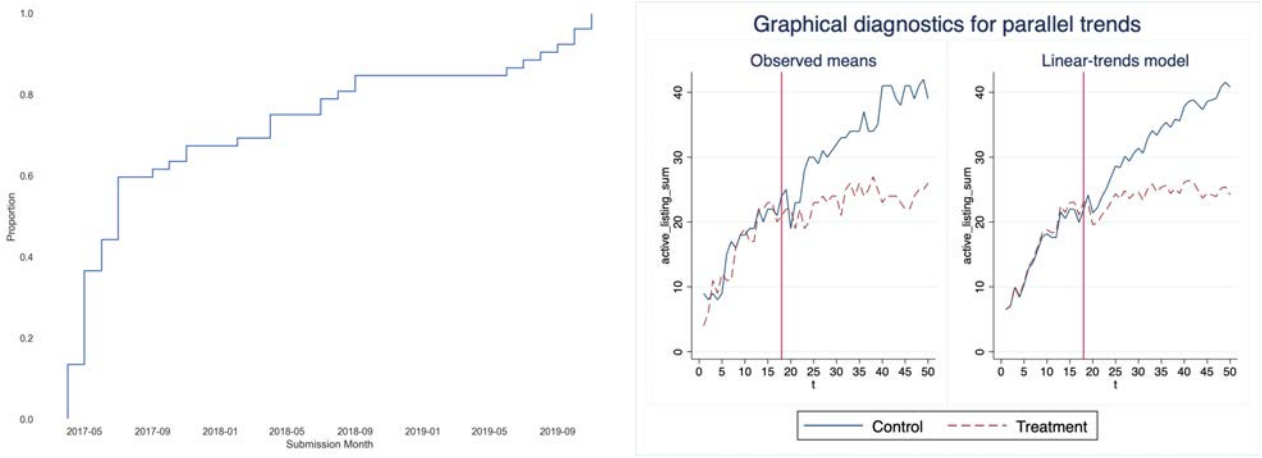
Appendix Figure B.11: Restricted Residential Zones (in Red diagonal line) and Similar Regions without the Restriction

Since various treated precincts have different submission and effective dates, we define treatment intensity in t as the proportion of the number of treated precincts by period t relative to the total number of treated precincts by February 2020. For instance, 14 out of 52 precincts have been designated as effective RRZs by September 2017. Thus, the treatment intensity in September 2017 is calculated as $14/52 = 0.269$. Figure B.12(a) depicts the value of treatment intensity over time, with the effective date used to define treatment intensity. The first effective date is July 2017; as more and more precincts became RRZs, the treatment intensity eventually reached 1. Prior to July 2017, no precinct in the sample is an effective RRZ, and the average number of active listings is 16 for the treated region (in red diagonal line) and 16.89 for the control region (in blue solid filled). Since July 2017, more and more precincts became effective RRZs, and the average number of active listings is 23.44 for the treated region (in red diagonal line) and 34.04 for control region (in blue solid filled). The specification to examine the effect of the RRZ policy on the number of active listings is

$$Total\_active\_listings_{it} = \alpha + \beta treatment\_intensity_{it} + \gamma treated_i + \delta_t f_t + \varepsilon_{it},$$

where f_t controls for time fixed effects and $treated_i$ controls for the treated region fixed effect. Our hypoth-

esis is that the coefficient for treatment intensity should be negative if the RRZ reflects less active listings. The regression finds β equals to -14.58 (with a standard error of 1.15), which indicates that, on average, the RRZ policy leads to approximately 15 less active Airbnb listings. The left panel of Figure B.12(b) plots the average number of active listings over time for both treated and control regions, as observed in the raw data. In comparison, the right panel of Figure B.12(b) plots the predicted number of active listings for these two regions after we apply the above linear model to the raw data. The vertical red line denotes July 2017, the effective date of the first RRZ. Both plots show that the number of active listings in treated and control regions follow similar trends before July 2017. After July 2017, the number of active listings in the control regions kept increasing, while the number of active listings in the treated regions did not increase significantly.



(a) Proportion of Treated by RRZ Submission Date

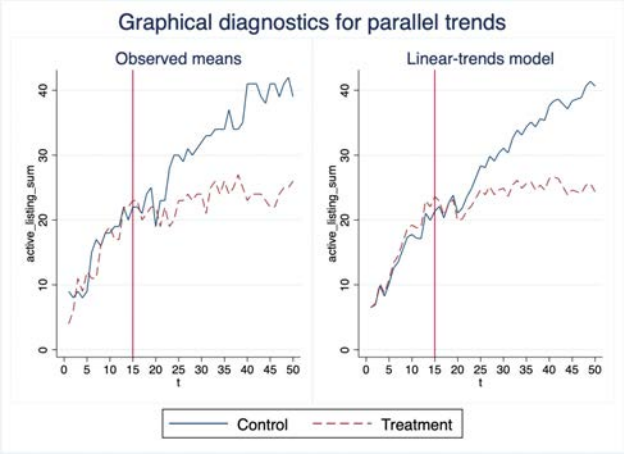
(b) Effect of RRZ on # of Active Listings

Appendix Figure B.12: Treated Intensity and Number of Active Listings

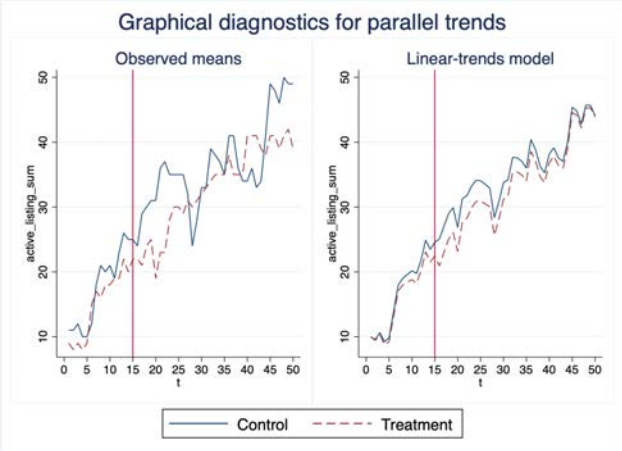
We conduct several robustness checks. First, we redefine the treatment intensity by using submission dates instead of effective dates to address the concern that residents in RRZs may be aware that the RRZ restriction will become effective, and some residents might enter the STR market before the policy becomes effective. If that happens, the policy effect could encourage STR listings, given that only new entries after the RRZ is in effect are prohibited. The results are only marginally smaller compared to using effective dates to calculate the treatment intensity.

Another robustness check attempts to rule out the possibility that the negative effect of the policy is caused by hosts strategically placing geolocators in adjacent precincts that are not RRZs (to the extent hosts have the technical ability to do so). We assume that it is costly for a host to place geolocators too far away from the actual address because if the geolocator shown on the booking page is far from the actual address, guests will leave negative reviews or report the listing to the platform or to municipal authorities. Under this assumption, hosts should be more likely to place geolocators shown in unregulated precincts closer to treated regions than unregulated precincts farther away. We perform a robustness test by comparing the control region (in blue solid filled) to non-RRZ regions farther from the treated region (that are in green gridded area). The result in Figure B.13(b) indicates that the trend of the number of active listings in control regions is comparable to the trend of the number of active listings in similar regions further from treated areas. Moreover, by comparing RRZs (in red diagonal) to control regions in green gridded area shown in Figure B.13(c), the RRZ policy has a similar effect to using control regions in blue (solid filled), with the coefficient of the treatment intensity being -13.40.

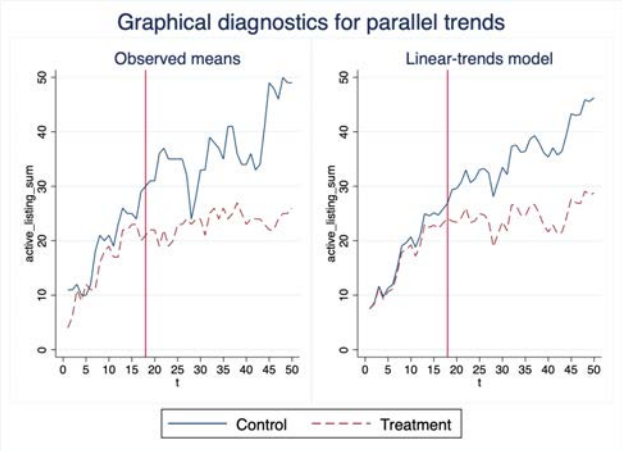
Although the RRZ feature of the ordinance only prohibits new STR entries, our analysis shows that listings entered prior to the effective dates are also impacted. After limiting the sample to listings that have been in the market between January 2016 and June 2016, Figure B.13(a) displays the count of active listings



(a) Compare Controls in Green (gridded) with Controls in Blue (solid filled), (Vertical Line Represents April 2017)



(b) Compare Controls in Green (gridded) with Controls in Blue (solid filled), (Vertical Line Represents April 2017)



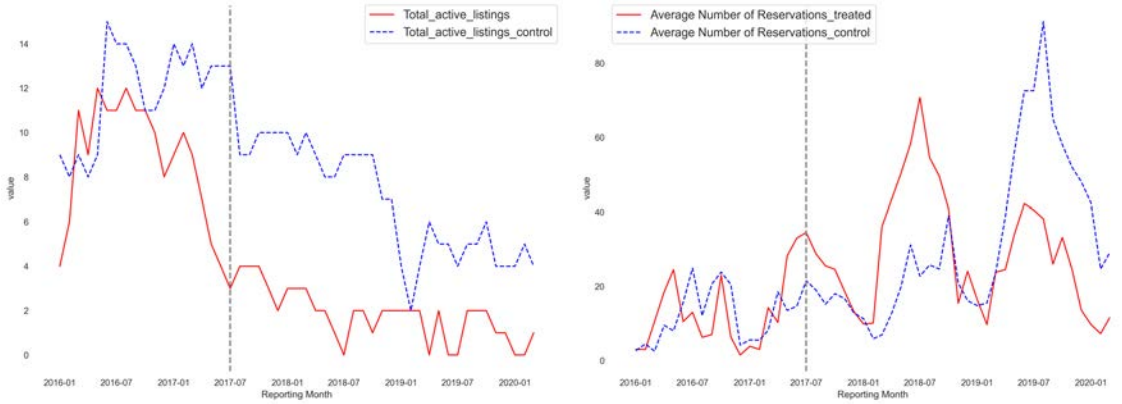
(c) Compare Restricted Residential Zones with Controls in Green Gridded Area (Vertical Line Represents April 2017)

Notes: Plotting the means of the number of active listings over time for both groups and the results of the linear-trends model. Figure (a) uses submission date to define the submission treatment intensity, with the treatment intensity variable exhibiting a value greater than 0 from April 2017 onward (the first submission date). Figure (b) compares the control region originally used with the control region farther away from the treated region. Figure (c) compares RRZs with regions without RRZs constraints and farther away from the treated region.

Appendix Figure B.13: Number of Active Listings in Restricted Residential Zones and Control Regions

of this sub-sample over time. We find that fewer existing listings in RRZs remain active compared to those in control regions. Since those listings entered before the effective date of the RRZ, they are not directly impacted by the RRZ policy.

The decrease in the number of active existing listings in treated regions could be explained by some other mechanisms. For example, their pending registrations may have been ultimately denied by Chicago due to their location in a now restricted residential zone. Another possible explanation is that there is less demand for STR listings in the RRZs because customers may be wary about places with few STR listings and prefer not to make reservations in those areas. To test this possible explanation, we plot the total number of reservations of active listings in both RRZs and comparable untreated areas. Figure B.13(b) demonstrates that while the number of reservations of active listings in the RRZs was similar to those of active listings in comparable locations without the RRZ constraint initially, the number of reservations became lower for active listings in the treated regions since October 2018. While the drop in demand may be a possible explanation, it is worth noting that the significant drop in the number of existing listings that remained active occurred much earlier than the decrease in reservations (Figure B.14). This suggests that some other factors may have contributed to the decrease in listing availability. For instance, residents in RRZs may hold more negative attitudes towards existing STR listings, and report issues related to these listings. This could make the STR business environment more challenging in those regions.



(a) Existing Listings

(b) Change in Average Number of Reservations of All Active Listings

Appendix Figure B.14: Number of Active Existing Listings and Average Number of Reservations