# Yes, Literally, In My Backyard: The Effect of "Gently" Upzoning Single-Family Neighborhoods

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March 2023

**Abstract**

Single-family zoning protects the preferences of local residents but limits housing supply, driving up home and rent prices. I study an increasingly popular middle ground approach: allowing homeowners to build accessory dwelling units (ADUs) on their properties. In 2016, the state of California legalized ADUs on most single-family lots in the state, overriding local regulations. Exploiting variation in treatment between single- and two- or three-family zones, I find upzoning had a significant effect on ADU construction. A single-family zone experienced .04 to .05 more ADUs permitted than a two- or three-family zone. Furthermore, I find that supply constraints strongly predict ADU construction, suggesting ADUs are filling gaps in rental supply. However, a linear panel model shows that ADUs are insufficient to decrease rent. Using variation in distance to a constructed ADU, I find no evidence that an ADU has a nuisance effect on nearby property values. My confidence interval excludes effects larger than a three percent reduction in property values, qualifying previous literature.

*I am grateful to Professor Jesse Shapiro, whose advising and support has been invaluable. I also thank Natalka Bowley, Matej Cerman, Slavik Sheremirov, Lucas Szwarcberg, Aurash Vatan, Ariana Vlad, and Andy Wang for their feedback and support. Professors Edward Glaeser, Andrei Shleifer, and Elie Tamer provided helpful comments. I also thank the field experts with whom I corresponded, with particular thanks to Professor Karen Chapple, Adelaide Deley, David Hamilton, Francisco Montes, and State Senator Robert Wieckowski. All errors are my own. E-mail: ishanbhatt42@gmail.com

# 1 Introduction

Many desirable cities in the United States face a housing affordability crisis. To buy a home in Miami, the median household must part ways with 85.6% of their monthly income, while those in Los Angeles must use 83% and New York 78% (Realty Hop, 2022). As the economic consensus builds that this is an issue of supply, with one estimate placing the national shortage at 6.5 million homes, increased attention is directed to local land use regulations (Glaeser and Gyourko, 2002; CNN, 2023). Land use regulations, particularly single-family zoning, protect the preferences of local homeowners but seriously constrain housing supply. However, reforming land use regulation is especially difficult, as local residents are often concerned about congestion, privacy, and, of course, property values.

I study a middle ground policy: allowing homeowners to build Accessory Dwelling Units (ADUs), which are self-contained residential units on a lot with a primary residential unit. Interest in ADUs continues to grow. ADU permits in Portland increased by almost 250% from 2019 to 2022, British Columbia's provincial budget has allocated 91 million dollars over three years towards encouraging homeowners to build ADUs as long-term rentals, and the White House held an event on how to make it easier to build ADUs (Ionescu, 2023; Depner, 2023; The White House, 2022). The popularity of ADUs as new housing supply underscores the importance of an economic analysis of their effects.

In 2016, the state of California established a right to build an ADU on a single-family home, overriding local regulations against such construction. This "gentle" approach to increased density has the goal of increasing housing supply without drastically changing the landscape of single-family neighborhoods (Simpson, 2019; Baca et al., 2019). Proponents hope that ADUs can provide affordable housing to alleviate the state's affordability crisis (Garcia, 2017; Chapple et al., 2018, 2021). However, it is not clear whether individual homeowners can close the gap in housing supply. Glaeser and Tarki (2023) make the case to rely on corporate developers as opposed to individual ADUs, since developers are much more efficient. Furthermore, the central compromise of ADUs, that they pose minimal nuisance effects on local residents, is not well investigated.

Studying the effect of zoning deregulation is difficult because we do not know the counterfactual. ADUs are growing in popularity nationally, and, over the last seven years, California passed numerous pro-ADU policies at the state-level. This makes it difficult to analyze the degree to which zoning deregulation specifically contributed to ADU construction. The other primary challenge to studying the effect of ADUs is that where ADUs are built is non-random. One is likelier to build an ADU where one would profit, and thus ADUs may be correlated with increased rent. Similarly, this non-random placement of ADUs is a barrier to studying their effects on nearby property values since ADUs may be built where housing density is increasing.

In this paper, I study whether zoning deregulation caused a significant increase in ADU construction, where ADUs are built, what effect supply from ADUs may have on rent, and whether ADUs impose a nuisance effect on neighboring property values. To overcome the challenges to this, I compare the effect of California's policies between single- and two- or three-family zones. I then use this variation, coupled with economic theory, to estimate the effect of ADUs on rent prices. Finally, I exploit variation in distance to a constructed ADU and the timing of constructions to estimate a nuisance effect.

I start by presenting a theoretical model of ADU construction in a housing market where developers build apartments, renters demand rental housing, and single-family homeowners are given the choice to build an ADU. The model yields three key results. First, homeowners under local coordination will coordinate to build no ADUs while homeowners without local coordination will build ADUs in the presence of supply constraints on rental housing. Second, the effect of increased supply from ADUs on price can be estimated from the size of the supply increase. Third, the value of a property near versus slightly further away from an ADU differs only in the negative spillovers of density on nearby properties.

I then investigate the effect of zoning deregulation on ADU permitting. California's zoning and permitting reforms differentially affected single-family zones. Since two/three family zones did not experience zoning reform in 2016, but did experience most other pro-ADU forces in the state, they serve as a natural comparison group to single-family zones. Therefore, I use this variation to estimate the effect of zoning regulation on housing construction. I collect and merge building permit data from Los Angeles, San Diego, and San Francisco to create a dataset of all ADU permits issued within those cities. Using a difference-in-difference analysis at the zone-level, interacting whether the zone is single-family with the year, I find that zoning-related deregulation had a significant effect on ADUs permitted in a zone, on the order of .04-.05 ADUs per zone. Single-family zones, on average, permit nearly double the ADUs of two/three family zones. Using the ratio of home values to home replacement costs as a measure of supply constraints, I find that the effect of upzoning is particularly high in supply constrained areas.

To study rent prices, I use rent price data from the American Community Survey, combining this with ADU construction data from the building permits. I first use the results from my economic model to forecast the effect of the quantity increase in housing due to ADUs on rent prices. I find that the plausible range of reduction in rent prices is below three percent. I then construct a tract-level measure of treatment exposure to ADUs by determining what percent of a primarily residential census tract is single-family zoned. Using a linear panel model, I find a directionally consistent but not economically or statistically significant effect on log rent prices, which lines up with the forecast from the model.

Lastly, I study whether ADU construction harms nearby property values. My estimation strategy is motivated by my theoretical framework, which describes how the nuisance effect from an ADU changes in distance to that ADU. Empirically, I estimate whether the relationship of a property's value to its distance from the site of an ADU construction changes before and after the ADU is constructed, akin to Linden and Rockoff (2008) and Diamond and McQuade (2019). I find no effect on nearby property values and am able to exclude negative effects larger than three percent.

This paper contributes to the economic literature in two central ways.

First, this paper extends a robust economic literature on zoning to the context of "gently" upzoning, which allows homeowners to add units. Previous literature establishes that large scale upzoning increases housing supply (Büchler and Lutz, 2021; Greenaway-McGrevy and Phillips, 2022). Extending this literature, I show that 'gently' upzoning also has a significant effect on homeowner-driven construction of rental housing. Furthermore, my findings underscore the degree to which land use regulation constrains rental supply. Glaeser and Gyourko (2002) establish theory and evidence for why regulations inhibit home construction in the U.S., specifically that regulations drive a mismatch between the cost of constructing a new home and the home's price. Gyourko and Molloy (2015) review several studies underscoring the finding that areas with high regulations have low housing construction, and Diamond et al. (2019) find the same effect in the context of rent control policies. This paper extends on these results by showing that homeowners build ADUs in the presence of supply constraints on rental housing.

Second, this paper contributes to the literature on the effects of new housing construction, both on rents and nearby property values. This paper is the first to study the effect of ADUs on rent, contributing to previous literature on the effect of large apartment buildings (Li, 2019; Asquith et al., 2023). There is previous literature on the nuisance effect of ADUs, as Davidoff et al. (2022) estimate a 3.8 reduction in transaction price using a cross-sectional estimation strategy that compares variation newly built homes with ADUs to newly built homes without. My paper has the advantage of exploiting both cross-sectional and temporal variance in ADU construction. My confidence interval excludes the previous estimates, and contributes to the literature on the nuisance effects of density.

This paper's findings also are of interest to policymakers. To the best of my knowledge, this paper is the first to comprehensively review the last seven to ten years of ADU policy change in California. This paper establishes that while deregulation is successful in driving up housing supply, the size of the supply increase from ADUs is insufficient to lower rents. Similarly, the construction of ADUs had little effect on nearby property values. Throughout, my analysis on the policy is supplemented with original qualitative research on ADUs in California. I motivate and interpret a number of my results with interviews of field experts in residential development and contracting. I also interview State Senator Robert Wieckowski, who authored many of California's policy changes studied in this paper.

The rest of this paper proceeds as follows. Section 2 provides further background on the Californian context and Section 3 reviews data sources used. Section 4 then introduces a simple economic model that aides in my empirical estimation. Then, Section 5 studies the deregulation of ADUs, providing evidence that upzoning affected single-family zones differentially. Section 6 covers the estimation of ADUs on rent prices and Section 7 investigates whether ADUs harm the property values of their neighbors. Section 8 concludes.

## 2 Background

This section provides background on accessory dwelling units and California's legislative changes.

### The Accessory Dwelling Unit

An accessory dwelling unit is a self-contained residential unit on a lot with a primary residential unit. The primary residential unit may be of any type: a single-family home, a duplex, a fourplex, or even an apartment building. In a single-family home or duplex with a large backyard, an ADU might be a detached structure. With less backyard space, constructing an ADU might involve adding a new room on top of one's garage. An ADU could be built in the basement garage of an apartment building that sees little need for extra parking spaces. An ADU can be detached or attached to the primary unit, may have its own pathway and porch, or may simply be an extra bedroom converted into a studio apartment. Crucially, the ADU must be an independent housing unit. This is distinct from renting out one's guest bedroom – an ADU generally must have its own entrance, accessible without entering the primary residential unit. Figure 1 depicts example detached ADUs, built in California homeowners' backyards.

A crucial and attractive characteristic of ADUs is that they can infill unused land. That is, backyard space, an unused garage, or space in the basement can be converted into a housing unit. In areas with high rental demand, it is likely that such rental units illicitly appear (Wegmann and Chapple, 2014). Therefore, California's approach to formalizing such housing could be appropriate given the prevalence of single-family homes in California and the need for increased housing supply. Indeed, State Senator Wieckowski suggested that adding a unit in a backyard is much easier than getting a large "acre-and-a-half" new housing development.

Beginning in 2016, California's state government lifted prohibitive local regulations. In California, local regulatory authorities have strong power over the rules around housing construction in their jurisdiction. California's actions were a preemption of local authority that have clearly generated results. Figure 2

**Figure 1: Example ADUs in California.** This figure shows example detached ADUs built in backyards (California Department of Housing and Community Development, 2023).

displays the total number of issued ADU permits in Los Angeles, San Diego, and San Francisco – the ADU hotspots of the state. It is clear that issued permits rose immediately in response to legislation in 2016 and 2020. Prior to 2016, permits were rarely issued in these cities.

What were the reforms in that increased ADU permits? The following paragraphs detail the relevant reforms, drawing from California Department of Housing and Community Development (2023). The 2016 reforms, primarily SB 1069 and AB 2299, addressed the two of the most significant barriers to permitting.

First, the 2016 reforms made an ADU permit ministerial or by-right on zones with single-family homes. Prior to reforms, a local permitting authority's judgement on an ADU was discretionary. A local authority could object to the specifics of one's design, add onerous requirements, or simply outright outlaw extra units in certain zones. Local jurisdictions, if they did not want to explicitly prohibit ADUs but still wanted to discourage them, would add requirements such as a 10-foot wide passageway between the street and an ADU. In my conversation with a field expert who worked in an ADU-specializing contractor office, they mentioned that they regularly expected the process of approval to take months. Furthermore, it was standard for a permit to be rejected at least once so that some update to the design must be made.

The 2016 reforms established that a single-family home could add one ADU "by-right." Also referred

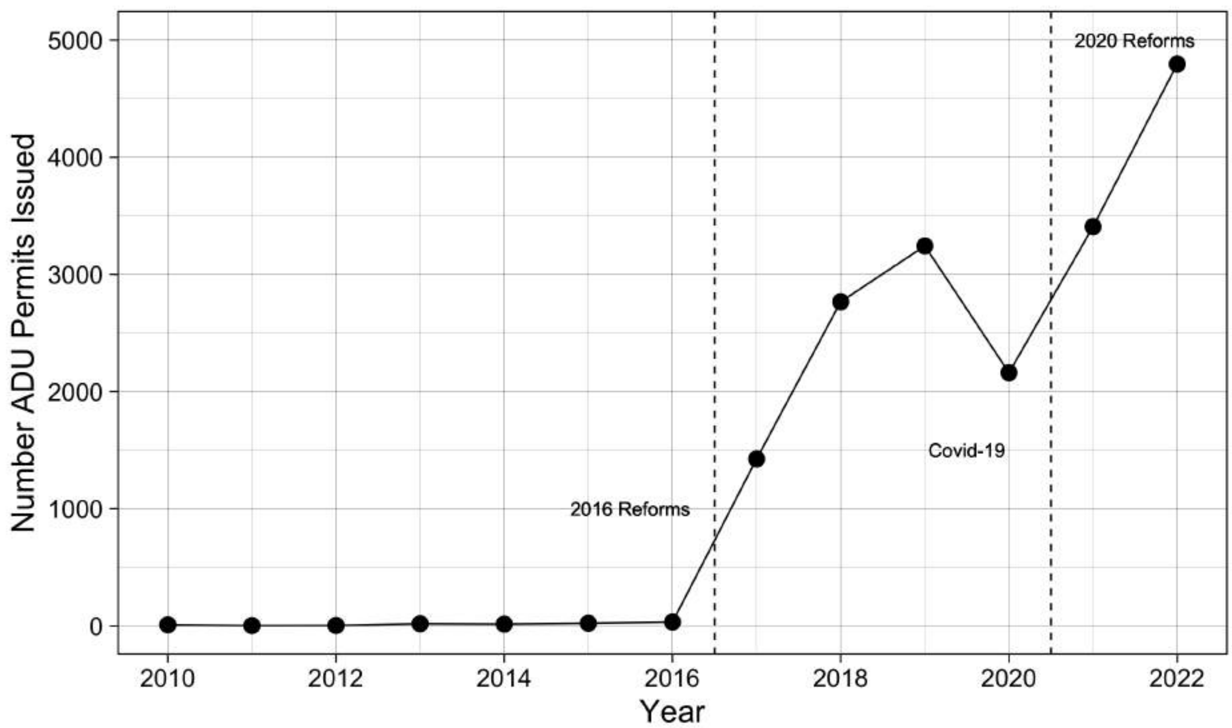



**Figure 2: ADUs Permitted Over Time.** This figure plots the number of ADUs permitted in Los Angeles, San Diego, and San Francisco since 2010. *Data Sources: Building Permit Data*

to as ministerial permitting, this policy meant that an ADU must be permitted if it met certain guidelines set by the state. Those guidelines capped the maximum size of a detached ADU to 1200 square feet, and an attached ADU to the lesser of 1200 square feet or half of the primary unit's floor area. Note crucially that the *by-right* permitting reform only applied to single-family homes. All other reforms in 2016 were, by and large, equally applied to all types of primary residential units. Specifically, the legislation reads:

> [...] every local agency shall ministerially approve the creation of an accessory dwelling unit if the accessory dwelling unit complies with all of the following: [...] (C) The lot contains an existing single-family dwelling.
>
> Legislation text accessed from California Legislative Information (2016).

Second, the 2016 reforms waived parking requirements for all ADUs within half a mile of a transit stop. Parking requirements could be, at maximum, one space per unit added. In Los Angeles, a city with plenty of bus stops, the removal of the requirement to find parking space in addition to space for the ADU, was impactful. Additionally, the legislation lifted the 10-foot passageway requirement. Requiring a passageway was a prohibitive regulation given that most single-family homes are not built such that ten-foot wide path between the sidewalk and their backyard is simple to add. Another costly regulation –

the requirement of a setback, the open space around a residential structure – was also waived.

The law set a requirement that if a local authority's ADU ordinance was not in line with state requirements, it would be in violation of state law. The preemption of local zoning authorities is worth mentioning. Localities in California can be resistant to housing and can express this preference through a byzantine array of local regulations[1]. A legislative aide in the office of State Senator Wieckowski described the process of removing barriers to ADU construction as a 'cat and mouse' game with local authorities. In our conversation, Senator Wieckowski described the preemptive nature of the policy - voiding local regulations – as one of the best aspects of the bill.

The 2020 reforms consisted primarily of AB 68, AB 881, and SB 13. The two largest regulatory changes were the banning of owner-occupancy requirements[2] and the lifting of impact fees. An impact fee is a fee imposed by local authorities for adding residential density to the area. Given that a fire department, police department, DMV, or school's costs increase if more people move in, adding a new unit of residential housing would often incur thousands of dollars in extra fees for the owner. The motivation for the fee stems from the addition of people, not housing, so these fees would often be similar in magnitude to the ones incurred for building a primary residential structure. The 2020 laws waived impact fees for ADUs under 750 square feet and significantly reduced other impact fees by requiring them to be proportional to ADU size. Furthermore, the wait time for approval of an ADU permit was reduced from 120 days to 60 days, with an ADU considered as automatically approved if a response was not issued in that time.

Finally, the 2020 laws extended the by-right capacity established in 2016. Homeowners now had by-right permitting access to one ADU and one JADU[3] on their property. Crucially, the by-right reform was also extended to two/three-family properties. Therefore, duplexes and triplexes also gained the ability to add ADUs.

Table 1 summarizes the main points of the above exposition.

A reform mentioned in the table but not extensively studied in this paper is SB 9. Passed in 2021 and taking effect in 2022, SB 9 allows for lot splits – which allow an owner to take a single-family lot and split it into two residential lots. This "duplex-es" single-family lots. Some argue that this, coupled with the ADU reforms, could theoretically result in a "four-plexing" of single-family homes in California, as the owner could first duplex the house and then build an ADU for each primary unit in the duplex (Metcalf et al., 2021). Such a change could transform single-family zones in California into two/three/four-family

[1]The City of Sonoma, for example, responded to state efforts to promote duplexes by requiring that a duplex lot must contain three mature trees.

[2]The owner-occupancy requirement essentially prevented ADUs from serving as true rental housing stock.

[3]A Junior Accessory Dwelling Unit (JADU) is an ADU built within the existing structure of the primary unit, and must be less than 500 square feet. These have less stringent requirements regarding their independence – they may share central housing systems, bathrooms, etc. with the primary unit.

| Summary of Reforms | | |
|---|---|---|
| Year | Main Bills | Summary of Reforms |
| 2016 | SB 1069, AB 2299, AB 2406 | By-right permitting, reduced parking requirements, streamlined conversion. *Ministerial permitting only applied to single-family homes*. |
| 2020 | AB 68, AB 881, SB 13 | No owner-occpancy requirement, 60 days to respond to permit, banned misc. restrictions, reduced impact fees. Establishes two by-right ADUs (1 ADU, 1 JADU) on single-family properties and a by-right ADU on multi-family properties. |
| 2021 | SB 9 | Lot split and duplexes. |

**Table 1: Summary of ADU Reforms.** This table summarizes legislative changes that occurred with regard to ADUs in California. The list of bills and reforms is not exhaustive. The main focus of this paper is the reforms of 2016 and 2020, as more time is needed to study the 2022 reforms.

zones. However, given the length of construction and the availability of rental data, the study of SB 9 is out of the scope of this paper. Similar analyses to this paper could be conducted one or two more year after SB 9's passage.

## ADUs as Affordable Housing Supply

The California Department of Housing and Community Development cites numerous benefits to building an ADU: that they are cost-effective, provide extra space for extended family, and serve as housing for the elderly. However, the state's primary hope for ADUs is increased affordable housing supply. The Government Code Section 65852.150 of the California legislature lays out the state's motivations:

> (4) Allowing accessory dwelling units in single-family or multifamily residential zones provides additional rental housing stock [...]
>
> (7) Accessory dwelling units offer lower cost housing to meet the needs of existing and future residents within existing neighborhoods, while respecting architectural character.
>
> Legislation text accessed from (California Legislature, 2017).

Therefore, it is useful to briefly review some facts about the rental characteristics of ADUs.

First, ADUs are frequently rented out. Chapple et al. (2021) conducted an n=823 survey of California homeowners who had constructed ADUs. They find fifty-one percent of ADUs serve as long-term rental units, and a further sixteen percent of ADUs house a relative of the primary homeowner at no cost. Relatively few (eight percent) of ADUs serve as short term rentals. Eighty-six percent of ADUs are occupied by one or two people, as families are unlikely to be able to live in such a small space. Furthermore, the median rent of ADUs in San Francisco was \$2200, \$2150 in San Diego, and \$2000 in Los Angeles. This is generally affordable to the median-income two-person household in these areas.

Second, proponents of ADUs suggest that they contribute to affordable housing supply. Since ADUs "do not require paying for land, major new infrastructure, structured parking, or elevators," they can naturally serve as low to mid-range rental units for individuals looking for permanent housing (California Department of Housing and Community Development, 2023).

Third, proponents of ADUs emphasize the ability of ADUs to infill empty space (e.g. backyards) in single-family parcels. Estimates from Wegmann and Chapple (2014) argue that in the Bay Area "Flatlands,[4]" an ADU-centered strategy could infill a comparable amount of housing as a strategy that prioritizes building denser multi-family units. Their analysis also points out that ADUs unlock single-family parcels previously off-limits for rental housing. Hence, ADUs are a setting in which to not just study zoning's effect on housing supply but also the subsequent potential supply effect on rent prices.

## 3 Data

This section describes the data sources used in this paper.

### Building Permit Data

Los Angeles, San Diego, and San Francisco regularly publish building permit data, which I access (Los Angeles Department of Building and Safety, 2023; San Diego Development Services Department, 2023; San Francisco Department of Building Inspection, 2023). Each observation contains a permit identification number, the date submitted, the block and lot, coordinates, a street address, the status, and a description of the permit. Example descriptions from San Francisco's October 2022 permits read: "bakyard landscape and front porch remodel [sic]," "remodel of (e) duplex: add a new garage, kitchen and bathroom remoel, add new deck, [sic]" and "detached garage: convert to adu. 1 story vertical addition with one bedroom and bathroom." It is through this description field that I determine whether a permit is for the construction of an ADU. I filter for ADU-related language, including terms relating to ADUs or the relevant ordinances and state bills. I then use other variables, such as a permit category variable, to filter for whether the permit is constructing a new ADU or merely updating its wiring. From there, I determine whether an ADU was converted from an already-existing room or was a new detatched construction.

Table 2 presents summary statistics for the relevant variables. The permit data, unfortunately, does not have latitude and longitude information for each observation, which is what is necessary to merge

[4] The Flatlands is a geographic area adjacent to, but not contained in, the areas of San Francisco studied in this paper.

a permit with its zoning information and the characteristics of its area. In particular, Los Angeles has a lower rate of geocoding observations than the other cities. Furthermore, the rate of geolocation declines over time, with 2022 only having latitude and longitude for about half of the permits created.

| Year | ADUs Permitted | ADUs Constructed | Pct Converted | Pct Geolocated |
|---|---|---|---|---|
| 2010 | 10 | 8 | 0.10 | 1.00 |
| 2011 | 3 | 2 | 0.00 | 1.00 |
| 2012 | 4 | 4 | 0.25 | 1.00 |
| 2013 | 19 | 16 | 0.16 | 1.00 |
| 2014 | 16 | 12 | 0.19 | 0.94 |
| 2015 | 23 | 19 | 0.09 | 1.00 |
| 2016 | 33 | 27 | 0.18 | 1.00 |
| 2017 | 1425 | 1138 | 0.63 | 0.70 |
| 2018 | 2766 | 2203 | 0.59 | 0.63 |
| 2019 | 3243 | 2476 | 0.52 | 0.68 |
| 2020 | 2161 | 1540 | 0.54 | 0.73 |
| 2021 | 3407 | 1743 | 0.46 | 0.60 |
| 2022 | 4795 | 558 | 0.41 | 0.47 |

**Table 2: Summary Statistics of ADU Permitting Data.** This figure reports summary statistics for the building permit data in Los Angeles, San Diego, and San Francisco from 2010-2022. The variable converted refers to whether the ADU was a new construction or a conversion of an already built structure, such as garage. Geolocated indicates whether the observation has latitude and longtitude information. *Data Sources: Building Permit Data*

## Zoning Data

For each of Los Angeles, San Diego, and San Francisco, I access shapefiles of their zones and regulation information (Los Angeles Department of City Planning, 2021; City of San Diego, 2023; San Francisco Open Data, 2022). These maps contain polygons of each zone, with feature information such as the type of zone, the office responsible for regulating the zone, and the zones' neighborhood. I then spatially merge this with the building permit data by mapping the latitude/longitude of each permit to inside a zone's polygon. The unit of analysis in this dataset is the zone, and for each year from 2010 to 2022, I use the Building Permit data to calculate how many ADUs were permitted and constructed in a particular zone. There are about 25,000 zones each year, over twelve years. Furthermore, about half of the zones in my sample are single-family zones.

## American Community Survey

I get census tract-level data from the American Community Survey (ACS), a yearly U.S. Census survey covering a broad range of social and economic information. I use ACS 5-year estimates of median income, population, median rent prices, number of rental units, and percent of households married. The tract-level data serve two main purposes. First, they supplement the first question in my paper, the effect of upzoning at the zone-level, as covariates. Second, tracts are the observational unit in studying rent prices, as the ACS data is the most granular measure of rent available to me.

To achieve the second purpose, I merge the ACS data with both the building permit and zoning data. I conduct this merge spatially. I map each permit to its corresponding census tract using the coordinates of the permit and the spatial polygon of the tract. From there, I can create a tract-level measure on how many ADUs were permitted and constructed each year. I can similarly map each zone to its census tract, and thus can know how many single family zones a tract may have versus multi-family zones. The resulting dataset of census tracts with ADU and zoning information in Los Angeles, San Diego, and San Francisco covers approximately 660 census tracts over six years.

Table 3 reports summary statistics for the ACS data, combined with the building permit and zoning data. This table reports summary statistics at the tract-year level.

| | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Population (Thousands) | 3969 | 4.15 | 1.25 | 0.00 | 10.23 |
| Income (Thousands) | 3955 | 70.92 | 34.99 | 11.21 | 247.03 |
| Rent | 3949 | 1553.77 | 489.18 | 267.00 | 3501.00 |
| Units Rented | 3969 | 817.30 | 420.48 | 0.00 | 2264.00 |
| Pct Married | 3961 | 41.55 | 12.85 | 0.00 | 94.00 |
| ADUs Constructed | 3969 | 0.50 | 1.17 | 0.00 | 13.00 |

**Table 3: Summary Statistics of ACS Data.** This figure reports summary statistics for ACS data combined with building permit data in Los Angeles, San Diego, and San Francisco from 2010-2022. *Data Sources: Building Permit Data, ACS*

## Los Angeles Property Value Data

I construct a novel dataset of Los Angeles property values using the Los Angeles Property Assessment Information Map (Los Angeles County Assessor, 2023). This service allows a user to search for property information, including nearby sales in the last two years.

From the Building Permit Data, I take the parcel number and construction date for every ADU constructed in Los Angeles from 2021 to 2022. Using the service, I build a script using the Python packages Selenium and Beautiful Soup that iteratively enters each ADU-containing property into the service and records the transacted properties within a quarter-mile of it. Figure 17 in the appendix depicts an example property search using the service. Therefore, I acquire all property sales from 2021 to 2022 in a quarter mile around every ADU constructed in 2021 or 2022. I remove transactions of the property containing the ADU. In addition, I am able to scrape the number of bedrooms, bathrooms, lot size, square footage, and year built for most of the sales. I get 38,523 property transactions after removing the outliers below the .01

quantile and above the .99 quantile. I also only keep a sale price if it is within a year on either side of its corresponding ADU construction. This leaves 17,656 sale prices.

### San Francisco Assessed Property Value Data

In San Francisco, I am unable to acquire adequate real sale price data. Instead, I use assessed home value data from the San Francisco assessor office (San Francisco Assessor, 2021). San Francisco's assessor makes their assessed value calculations available for each property from the fiscal years 2010-2019, where the year listed represents the first calendar year in the fiscal year's span[5].

I then determine whether assessed values precisely reflect property sale values, which is not always the case with assessors. However, San Francisco's assessor office's website indicates it used property sale prices to update their assessed values. This is initial evidence that these data contain relevant variation, and to verify this, I compiled true sale price data as follows. For a property within the assessed value dataset, I entered its parcel identification number into San Francisco's Assessor Map, a web service offered by the Assessor Office that takes in an address or property identification number and returns information on that property, including sales (San Francisco Assessor, 2023). From there, I scraped the sale price and date of sale. The Assessor Map is finicky and inconsistent in its function, and so I was able to eventually pull on the order of 3500 observations of property sales.

In Appendix Figures 20, 21, and 22, I plot the property sale data in each year against that property's assessed value in a particular year. It is visually immediate that there is a strong relationship between the sale price and assessed value that breaks immediately if the assessed value is recorded prior to the sale date. It appears as if assessed values are being updated directly as equal to the sale prices of homes. Therefore, I only keep assessed values such that the property being assessed was sold in the previous year. This substantially reduces the size of my dataset but provides much more accuracy in measuring property value.

### BuildZoom Value to Replacement Cost

Romem (2017) at BuildZoom, an online marketplace for contractors, constructs an index for the home value to replacement costs of a home. The author builds this index at the zip code level, drawing on data from the American Community Survey, Federal Housing Finance Agency, and the Census Building Permit Survey. They use data from 2011-2015 to construct a value of the ratio in 2016. I combine this data with ADU constructions across the state of California from 2018-2020, which are available from Chapple (2021)

[5]Here, 2019 means the fiscal year spanning 2019-2020.

and were generously provided through email correspondence with the author.

# 4 Theory

This section builds a simple model of a rental housing market with ADUs. The model describes the relationship between single-family homeowners, housing developers, and renters. The purpose of the model is twofold. First, I characterize where and when ADUs will be built. In particular, I show that ADUs are built in the absence of local control and in the presence of supply constraints on rental housing from developers. Second, I derive tools to estimate the supply effect of ADUs on rent prices and the nuisance effect on nearby property values. This section first reviews the model, discusses implications, and concludes by addressing assumptions and limitations. Proofs are in Appendix A.

## 4.1 A Housing Market with ADUs

I study $1, \ldots, C$ independent housing markets. In a market $c$, there are three types of agents: renters, homeowners, and developers. There are two residential areas, one where homeowners live in single-family homes and one where renters live in apartment buildings. I do not consider tenure choice in this model. No individual can switch from homeowner to renter, or vice versa. Let $\ell_s > 0$ be the land allocated to single-family homeowners and $\ell_r > 0$ be the land allocated to rental housing.

#### Developers

Developers build apartments on $\ell_r$, according to a production function $F_r(\delta) = \delta \ell_r$. Here, $\delta \in \mathbb{R}_{\geq 0}$ is an intensity of housing production and can be thought of as how densely the developers build apartments. Similarly, developers build single-family homes on $\ell_s$ according to a production function $F_s$, which is specified by a choice of $\phi$. Here, $\phi$ is constrained in the unit interval since single-family homes are not built on top of each other. Developers face convex cost functions $C_r(\delta) = \sigma_r \frac{\delta^2}{2} \ell_r, C_s(\phi) = \sigma_s \frac{\phi^2}{2} \ell_s$ for rental and single-family housing respectively, where $\sigma_r, \sigma_s$ are exogenous construction cost parameters. Construction costs include physical costs of materials and labor, but can also include the cost of potential government supply constraints or regulation. The choice to model exogenous supply constraints as increased cost is akin to the model of zoning restrictions as a tax in Glaeser and Gyourko (2002). Developers solve

$$\max_{\delta, \phi} \left[ p_r \delta \ell_r - \sigma_r \frac{\delta^2}{2} \ell_r + p_s \phi \ell_s - \sigma_s \frac{\phi^2}{2} \ell_s \right]$$

where $p_r$ and $p_s$ are the price of rental housing and single-family housing, respectively.

**Renters**

The renter derives utility from a numeraire good $g_r$ and rental housing consumed $h_r$. I assume the renter's utility in housing is additively separable from the utility from the numeraire, and the utility from housing is of an isoelastic form[6]: $u(h_r, g_r) = \frac{h_r^{1+\eta}}{1+\eta} + g_r$, where $\eta \in \mathbb{R}_{<0} \setminus \{-1\}$.

The renter's budget constraint is $h_r p_r + g_r \leq w_r$, where $p_r$ is the rent price and $w_r$ is the renter's wage. Since the utility function is monotonically increasing in consumption of housing and $g_r$, the renter satisfies the budget constraint with equality. The renter solves

$$\max_{h_r, g_r} \left[ \frac{h_r^{1+\eta}}{1+\eta} + g_r \right] \text{ such that } h_r p_r + g_r = w_r$$

**Homeowners**

There are $H_c$ homeowners in market $c$. The homeowner is allocated $\frac{\ell_s}{H_c}$ land upon which to build an ADU as rental housing. The homeowner has an ADU production function $F_h(\alpha) = \alpha \frac{\ell_s}{H_c}$, where $\alpha \in [0, 1]$. Recall that the developers could build rental housing at any intensity level $\delta$ since they build apartments. However, the homeowner's production intensity is bounded in the unit interval since only one ADU may be constructed on a unit of land. The homeowner faces cost $C_h(\alpha) = \sigma_a \frac{\alpha^2}{2} \frac{\ell_s}{H_c}$, where $\sigma_a > 1$ is an exogenous cost parameter[7].

The homeowner derives utility $v(g_h, h_s)$, which is a function of a numeraire good $g_h$ and housing $h_s$. I again assume the utility is additively separable and isoelastic in housing consumption:

$$v(g_h, h_s) = \frac{1}{\tilde{D}} \frac{h_s^{1+\gamma}}{1+\gamma} + g_h$$

where $\gamma \in (-1, 0)$ and $\tilde{D}$ represents disutility from residential density, specifically from the presence of renters on $\ell_s$. For a homeowner $i$, I assume $\tilde{D}$ is given by:

$$\tilde{D} = o(\bar{\alpha}) \cdot \prod_{j \neq i} n(\alpha_j)^{1-d_j}$$

where $\bar{\alpha} := \sum_{j \neq i} \alpha_j$ is the total intensity of ADU production and $d_j$ is the distance of neighbor $j$ to homeowner $i$ normalized to the unit interval. Note $\tilde{D}$ consists of two effects: $o(\cdot)$ from overcrowding and $n(\cdot)$

[6]The typical parameterization uses the form $\frac{h^{1-\eta}}{1-\eta}$ where $\eta$ is positive, but my formulation is equivalent. I write it this way to interpret $\eta$ as the inverse price elasticity of demand in later analysis.

[7]Here, $\sigma_a$ is different from the cost parameter for developer rental housing $\sigma_r$. While the cost of materials might be similar, $\sigma_a$ could reflect that homeowners now must spend time marketing their ADU or learning how to rent out a unit, thus trading off with consumption of the numeraire good. It could reflect distaste from the presence of a renter in your backyard. Regardless, the assumption that homeowners face a different cost to becoming landlords that professional developers is a natural one.

from the nuisance of new neighbors. Both $o$ and $n$ have non-negative first and second derivative, and $o(0) = n(0) = 1$. The homeowner faces budget constraint

$$\underbrace{\sigma_a \frac{\alpha^2}{2} \frac{\ell_s}{H_c}}_{\text{ADU Cost}} + p_s h_s + g_h \leq w_h + \underbrace{p_r \alpha \frac{\ell_s}{H_c}}_{\text{ADU Income}}$$

where $w_h$ is the homeowner's wage. Since utility is monotonically increasing in the numeraire good, homeowners satisfy the budget constraint with equality. Thus, the homeowner solves

$$\max_{h_s, g_h, \alpha} \left[ \frac{1}{\tilde{D}} \frac{h_s^{1+\gamma}}{1+\gamma} + g_h \right] \text{ such that } \sigma_a \frac{\alpha^2}{2} \frac{\ell_s}{H_c} + p_s h_s + g_h = w_h + p_r \alpha \frac{\ell_s}{H_c}$$

**Equilibrium Conditions**

I solve the model under two different equilibrium conditions for homeowners, modelling homeowner choices under zoning regulations and state-level preemption. Under both equilibria, renters and developers optimize taking prices and the others' choices as given, and markets clear.

**1. Collective Equilibrium**. The first is the *collective equilibrium*, reflecting local homeowner zoning. Often, zoning can be explained by the responsiveness of local governments to the homeowners[8] within their jurisdiction as opposed to renters who do not yet live there (Fischel, 2004; Glaeser, 2017). Prior to state-level intervention, local homeowners of a Californian community would set their own level of ADU intensity *collectively*. Therefore, the first equilibrium focuses on what happens if homeowners are able to coordinate their preferred level of ADU production. Formally, the homeowner optimizes over $\alpha$ for all homeowners, taking housing consumption as given[9] and then subsequently optimize housing consumption taking ADU production as given. Note $\tilde{D}$ is a function of $\alpha$, and the homeowner does not take rental price as given since they collectively determine the rental supply from ADUs.

**2. Individual Equilibrium**. Second is the *individual equilibrium*. After state-level intervention, homeowners were given by-right ADU construction ability and could no longer coordinate at the local level. Therefore, homeowners would build ADUs, only taking into account their own utilities and ignoring spillover effects of those ADUs onto neighbors. Formally, the homeowner simultaneously optimizes over housing consumption and their personal level of ADU production.

[8] The development of zoning as an expression of homeowner preferences is not limited to a distaste for renters. Indeed, zoning in the United States also has a history of racial disparity, as documented by Shertzer et al. (2016).

[9] This reflects a collective decision-making process amongst the homeowners already living in market $c$, which could take the form of a referendum or a political game between politicians and voters as in Calabrese et al. (2007).

## 4.2 Model Implications

**When and Where Are ADUs Built?**

In the first proposition, I show why homeowners, under collective optimization, would not produce ADUs.

**Proposition 1** (Collective Equilibrium). *Consider the collective equilibrium. Let $p_r^*(\alpha)$ denote the equilibrium price of rental housing if the homeowner chooses $\alpha$ as the collective level of ADU production. If*

*A1. For all homeowners $i$, $\sum_{j \neq i} 1 - d_j > 0$.*

*A2. The magnitude of the marginal disutility from overcrowding and the nuisance effect is strictly greater than the magnitude of marginal profits from increased ADU production:*

$$\forall \alpha > 0, \ \| \frac{h_s^{1+\gamma}}{1+\gamma} \frac{d}{d\alpha} \left( \frac{1}{\tilde{D}(\alpha)} \right) \| > \| \frac{\ell_s}{H_c} \left( p_r^*(\alpha) - \sigma_a \alpha \right) \| \tag{1}$$

*Then, the homeowner sets $\alpha = 0$.*

The assumptions of the proposition are reasonable in many scenarios. First, A1 is mild and only exists to ensure that people have some neighbors. An infinitely sparse neighborhood would not experience any disutility from density. Second, A2 relates the marginal impact of ADU construction on utility from housing to the profit of an ADU. This assumption is akin to a community deciding that the average profits from an ADU do not outweigh the disutility they would experience from an ADU next door. Prior to 2016, this was the decision often made by many local communities in California, which indicates many communities of homeowners found the marginal disutility from increased density to be greater than the profits from an ADU.

In the next proposition, I have the homeowner choose a $\alpha$ for only their own level of ADU production, disregarding the spillover impact on their neighbors.

**Proposition 2** (Individual Equilibrium). *If the homeowner optimizes over their individual $\alpha$, the supply curve of total rental housing is given by:*

$$\textit{Rental housing at } p_r = \ell_r \frac{p_r}{\sigma_r} + \ell_s \frac{p_r}{\sigma_a} \tag{2}$$

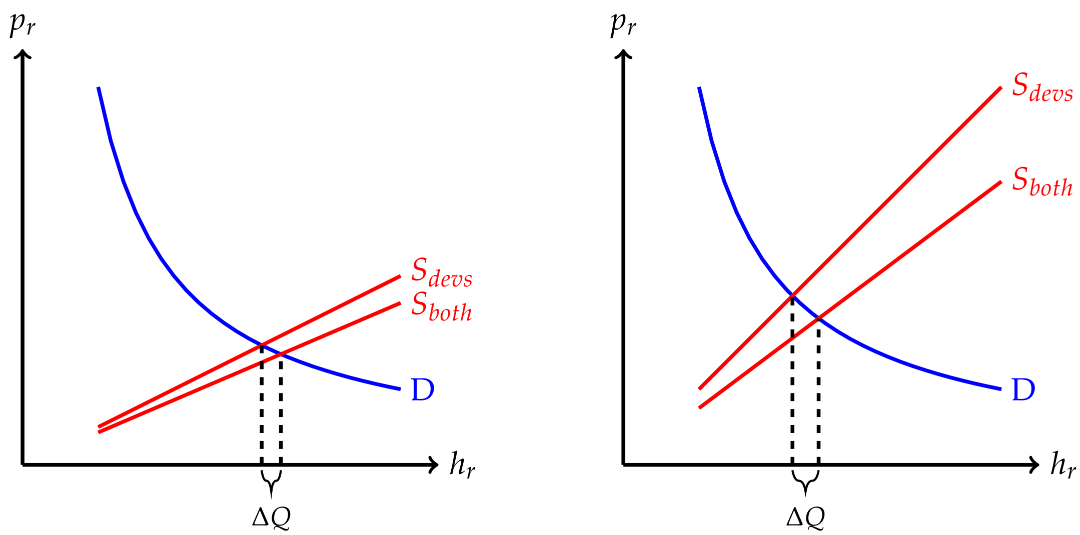
This proposition characterizes supply from developers $\ell_r \frac{p_r}{\sigma_r}$ and supply from ADUs $\ell_s \frac{p_r}{\sigma_a}$. A natural question is where we will see more supply from ADUs in the rental market. The next proposition answers what conditions will drive ADU production.

**Proposition 3** (Supply Constraints). *In the individual equilibrium, areas with rental supply constraints will see more ADU production. Formally, the ratio of rental housing in individual equilibrium to rental housing in collective* *equilibrium is given by*

$$\left(1+\frac{\ell_s\sigma_r}{\ell_r\sigma_a}\right)^{\frac{1}{1-\eta}} \tag{3}$$

Since $\eta$ is negative, the above value is increasing in $\ell_s, \sigma_r$ and decreasing in $\ell_r, \sigma_a$. This aligns with intuition: more land for rental housing or higher costs for ADUs lowers ADU production, and higher cost for rental housing and more land for single-family housing increases ADU production. This is magnified when $|\eta|$ is small, which again lines up with intuition since $\eta$ is the inverse price elasticity of demand.

The main qualitative prediction of this proposition is that if developers are "efficient enough" at building housing, then fewer ADUs will appear in the market. In Figure 3, I plot two hypothetical scenarios, one with a low $\sigma_r$ developer and one with a high $\sigma_r$ developer, holding all other parameters constant. I plot the supply curves in collective equilibrium (where just developers supply rental housing) and in individual equilibrium (where both developers and homeowners supply rental housing). In the first scenario, homeowners produce few ADUs. In the second, homeowners produce many ADUs since $\sigma_r$ is high.




**(a)** Low $\sigma_r$, Few ADUs Built

**(b)** High $\sigma_r$, Many ADUs Built

**Figure 3: Supply Constraints on Developers and ADU Production.** This figure plots supply curves from developers and from both developers and homeowners. I hold $\ell_r = \ell_s = 1$, $\sigma_a = 3$, and use a dummy demand curve specified by $h_r = 5p_r$. In (a), $\sigma_r = 1/2$ and in (b), $\sigma_r = 1$. This is a toy example of the results in Proposition 2 and Proposition 3.

Why is it that more ADUs are likely due to high $\sigma_r$ from supply constraints? Note that my qualitative prediction that *supply constraints* are associated with ADUs is not strictly equivalent to the theoretical result in Proposition 3. The result only says that high $\sigma_r, \ell_s$ and low $\sigma_a, \ell_r$ can determine whether ADUs are produced. In particular, a high $\sigma_r$ is not necessarily due to supply constraints. The cost of materials could also potentially increase, although that should also increase $\sigma_a$ on the bottom of the ratio. Qualitatively, I am interpreting supply constraints as a high $\sigma_r$ relative to $\sigma_a$. My hypothesis is that this is that zoning regulation on developers is the most likely scenario in which we see a high ratio of $\sigma_r$ to $\sigma_a$. Otherwise, there are not many reasons why the cost parameter for developers should be higher than the cost parameter for single-family homeowners, since homeowners lack expertise[10]. This prediction is important given the Californian context because it demonstrates that ADUs fill in for constrained rental supply. I will test this prediction empirically in section 5.

#### Estimating the Supply Effect and the Nuisance Effect

Next, I derive two propositions to estimate the supply effect and the nuisance effect of ADUs.

**Proposition 4.** *Let $p_r^*$ be the equilibrium price between renters and developers, i.e. when the supply curve is $\ell_r \frac{p_r}{\sigma}$. Let $h_r^*$ be the equilibrium quantity of rental housing. Let $p_r'^*$ be the equilibrium price when homeowners may produce ADUs, i.e. when the supply curve is given by Equation 2 in Proposition 2. Let $h_r'^*$ be the equilibrium quantity of rental housing. Then,*

$$\log(p_r'^*) - \log(p_r^*) = \eta \left(\log(h_r'^*) - \log(h_r^*)\right) \tag{4}$$

Intuitively, Equation 4 says that the percent change in housing price is proportional to the percent change in housing supply.[11] Economically, a supply shift's effect on the price can be recovered by tracing out the demand curve.

**Proposition 5.** *The nuisance effect of ADUs on property values can be estimated by comparing properties within the same market $c$ but different distances from neighboring ADUs. Formally, the equilibrium price of single-family housing in individual equilibrium can be written as*

$$\log(p_s^*) = \frac{\gamma}{\gamma-1}\log(\sigma_s) - \frac{\gamma}{\gamma-1}\log(\ell_s) + \frac{1}{\gamma-1}\log(o(\bar{\alpha}^*)) + \sum_{j\neq i}\frac{1-d_j}{\gamma-1}\log(n(\alpha_j^*)) \tag{5}$$

*where $\alpha^*$ refers to the individual equilibrium intensity of ADU production.*

The expression in this proposition lines up with intuition. Since $\gamma$ is negative, we have home prices increasing in construction costs, decreasing in availability of land, decreasing in density, and decreasing in nuisance from neighbors. Proposition 5 shows that differences in distance to an additional density from ADUs can yield estimates of the nuisance effect. In particular, between two properties in the same market $c$, the overall overcrowding effect they experience, $o(\bar{\alpha})$, is the same. However, the distance coefficients on

[10] Another zoning-related interpretation is that homeowners produce ADUs when $\ell_s$ is high relative to $\ell_r$. In communities that have given very little land for renters in the first place, ADU production is likely.

[11] The logarithm here approximates percent changes because $\frac{Q'-Q}{Q} = \frac{Q'}{Q} - 1 \approx \log\left(\frac{Q'}{Q} - 1 + 1\right) = \log(Q') - \log(Q)$ using the fact that $\log(x+1) \approx x$ for small $x$.

the nuisance effect will differ. Furthermore, I assume $\sigma_s$, the cost of constructing single-family housing, subsumes all additional differences in property characteristics (i.e. year built, square footage, etc.). Then, the equation derived in this proposition motivates my empirical strategy to estimate $n(\cdot)$ in section 7 since I compare property values very near to ADUs to those slightly further away.

### 4.3 Model Limitations

This model is intentionally simple and restrictive, as I abstract away much besides the homeowner's choice to build an ADU. Notable limitations include the following.

1. I consider the markets $1, \ldots, C$ to be independent of each other and ignore general equilibrium effects. In particular, if people move between markets, then new supply in one market should drive down the rent price in other markets. In my empirical analysis, I take $c$ to be a census tract, and it is plausible that people move between census tracts in response to rent prices. This is a limitation does not affect analysis on localized impacts like ADU production or nuisance effects.

2. I ignore most of the complexities of housing production. In particular, I make a functional form assumption on both developers' and homeowners' production and cost functions. This abstracts away many relevant distinctions between how developers and homeowners might produce housing units, and the relative qualities of said housing units.

3. I assume that all housing units and all land are homogenous. In particular, I include very little spatial richness in the model, which is prevalent in many other models of housing markets with zoning such as the mono-centric city model adapted by Büchler and Lutz (2021).

## 5 The Effect of Deregulation

This section estimates the causal effect of zoning deregulation on ADU permitting using a difference-in-difference design. I then test a prediction of my model, that the presence of supply constraints predicts ADU construction. Finally, I review some evidence of continuing regulatory barriers.

### 5.1 Upzoning's Effect on ADU Permits Issued

Comparing single-family zones to two- or three- family zones presents a natural setting to study the causal effect of removing zoning restrictions on housing supply. While the process of building an ADU became easier on two- or three-family zones as well, these zones didn't experience the same *by-right legalization* that single-family zones experienced. Hence, these two groups could be used to study the effect of upzoning on ADU construction. In Figure 4, I plot ADUs permitted from 2010 through 2022 by the zone type.

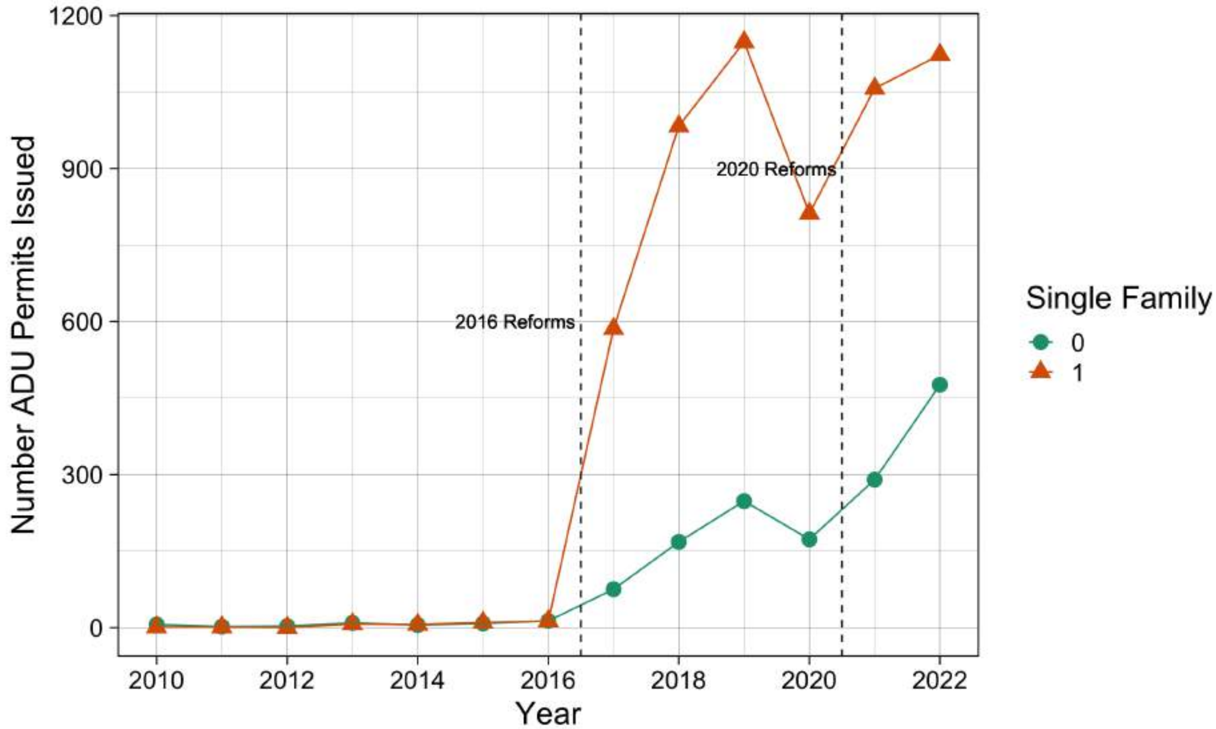



**Figure 4: ADUs Permitted By Zone.** This figure plots the number of permits issued each year over time by the zone type. There are very few permits issued each year before 2017. *Data Sources: Building Permit Data, Zoning Data*

Clearly, single-family zones experience a higher number of ADUs permitted after 2016. The orange line moves much farther up, much more quickly. It is noteworthy that the legislative changes passed in 2020 also appear to have a significant effect on ADU permitting, but one that is far less differentiated by zone type. That is, the 2016 changes drive a sharper increase in ADU permitting in single-family zones, but the slope of the upward line caused by the 2020 reforms looks roughly similar between the two types of zones. This result lines up with the legislative changes as single-family zones were differentially treated in 2016 but not in 2020. Therefore, this is initial evidence that I can exploit this variation in single and two- or three-family zones.

### Methodology

I compare outcomes in a single-family zones versus outcomes in a two- or three- family zone over time. This is a difference-in-difference strategy, a canonical example of which is Card and Krueger (1993). Let a zone $i$ be considered treated if it is a single-family zone. Let $t$ denote time and define $\mathbb{I}\left[\text{Post } 2016\right]_t$ to be an indicator of whether $t$ is greater than 2016. The primary outcome of interest is the number of ADU permits issued in a zone at some time, $Y_{i,t}$. As an initial specification, I estimate the following

$$\begin{aligned}\overbrace{Y_{i,t}}^{\text{ADUs Permitted}} &= \beta_0 + \beta_1 \mathbb{I}\left[\text{Single Family}\right]_i + \beta_2 \mathbb{I}\left[\text{Post 2016}\right]_t \\ &\quad + \underbrace{\beta_3 \mathbb{I}\left[\text{Single Family}\right]_i * \mathbb{I}\left[\text{Post 2016}\right]_t}_{\text{difference-in-difference term}} + \underbrace{x_{i,t}^T \vec{\eta}}_{\text{covariates}} + \underbrace{\epsilon_{i,t}}_{\text{centered error}} \end{aligned} \tag{6}$$

and interpret $\beta_3$ as the causal effect of deregulation on ADU permitting. In this specification, it is crucial that parallel trends in housing supply hold between the treated and non-treated zones in the population. Formally, this means that, absent the treatment, single-family zones and multi-family zones would have a constant difference in ADUs permitted. In visual terms, it means the orange line in Figure 4 would move like the green line had the treatment not occurred. Indeed, if other ADU or housing supply related policies were updated at local levels, this could affect the estimate of $\beta_3$. I will discuss the validity of the parallel trends assumption at length later in this section.

I add covariates that relate to housing construction, which I acquire at the census tract level from ACS data. For each zone $i$ at time $t$, I control for median income, population, and percent of households married. Since these characteristics typically influence the decision to build additional housing, I attempt to isolate the effect of the treatment that is unrelated to these covariates.

Additionally, it could be the case that the treatment effect grows over time, as more people find out about the option of adding more units to their property and decide whether it is economically viable. Furthermore, given that there were two broad rounds of deregulation, one in 2016 and one in 2020, it is useful to study time-dependent coefficients. Therefore, I estimate a dynamic version of the model, specified as

$$\begin{aligned}\overbrace{Y_{i,t}}^{\text{ADUs Permitted}} &= \beta_0 + \beta_1 \mathbb{I}\left[\text{Single Family}\right]_i + \overbrace{\sum_{j=-T}^{T} \beta_j \mathbb{I}\left[\text{Single Family}\right]_i * \mathbb{I}\left[t = j\right]_t}^{\text{dynamic difference-in-differences}} \\ &\quad + \underbrace{x_{i,t}^T \vec{\eta}}_{\text{covariates}} + \underbrace{\psi_i}_{\text{zone FE}} + \underbrace{\gamma_t}_{\text{time FE}} + \underbrace{\epsilon_{i,t}}_{\text{centered error}} \end{aligned} \tag{7}$$

Here, the policy has potentially different effects in each year, where $\beta_j$ represents the effect in year $j$ and the covariates are the same as in the first specification. For conciseness, I will only estimate this regression from 2014 through 2022.

**Results**

My analysis suggests that zoning deregulation has a causal effect on ADU permitting in single-family zones, with an effect that is consistent in sign and magnitude across a range of specifications. I estimate that a single-family zone experienced a $.04 - .05$ increase in the number of ADUs permitted relative to two/three-family zones.

In Table 4, I report the specification defined in Equation 6, where I use a simple difference-in-difference analysis. Column (1) reports the outcome of the a simple regression without covariates. The coefficient of interest is positive and significant at the one percent level. Note that the coefficient on Post-2016 is also positive and significant. This suggests that the number of ADUs permitted is rising overall, but does not negate the conclusion that single-family zones experienced a sharp differential treatment effect. In particular, the magnitude on both the interaction term and the Post-2016 term are of the same order.

However, it's feasible that single-family zones simply reflect a richer underlying population, or occur in less populated areas where new construction is intrinsically easier. My analysis demonstrates that these factors do not explain the entire rise of ADU construction California has seen. Rather, the easing of zoning regulations had a causal effect on ADU construction.

Column (2) adds time-varying covariates that could also explain the rise in ADU permits. Median household income, population, and percent households married are introduced as covariates and do not diminish the sign or magnitude of the treatment effect. The coefficient on population is as expected. More populous places built more ADUs.

It is notable that a higher proportion of married households is negatively correlated with the outcome. Perhaps this can be explained by the fact that areas with high numbers of married individuals have stricter homeowners associations or might already be entirely settled and unlikely to significantly alter their house. In addition, they could be less likely to want a renter close by.

Furthermore, it is highly likely the treatment effect varies with time. Therefore, I estimate Equation 7 and report the results in the Appendix Table 7. In it, all significant effects of the interaction of a single-family zone and the year are positive effects after 2016 and on the order of magnitude of my previous estimates. Both the size and the magnitude of the coefficient of interest are robust to adding controls and fixed effects. A test of the hypothesis that all coefficients are equal has a p-value much less than .001, which is displayed on the plot.

Figure 5 plots the coefficients from the specification in Equation 7. Significant, positive coefficients are seen in 2017 and onwards, when the effect begins to take shape. The size of the coefficients is largest in 2018 and 2019, which could be because ADUs took time to become popular amongst homeowners. Given

| | ADUs Permitted | |
|---|---|---|
| | (1) | (2) |
| Single Family | $-0.0003$ | 0.0004 |
| | (0.0015) | (0.0013) |
| Post | $0.0244^{***}$ | $0.0192^{***}$ |
| | (0.0017) | (0.0015) |
| Median Income (Thousands) | | $-0.00001$ |
| | | (0.00002) |
| Total Population (Thousands) | | $0.0011^{**}$ |
| | | (0.0004) |
| Pct Households Married | | $-0.0001^{*}$ |
| | | (0.00004) |
| Single Family x Post | $0.0453^{***}$ | $0.0494^{***}$ |
| | (0.0022) | (0.0020) |
| Constant | 0.0007 | $-0.0003$ |
| | (0.0012) | (0.0024) |
| *N* | 299,988 | 233,187 |
| $R^2$ | 0.0098 | 0.0153 |
| Adjusted $R^2$ | 0.0098 | 0.0153 |

$^{***}$Significant at the 1 percent level.
$^{**}$Significant at the 5 percent level.
$^{*}$Significant at the 10 percent level.

**Table 4: Difference in Difference on ADUs Permitted Between Single vs Two/Three Family Zones.** This table presents regressions from the specification in Equation 6, which is a simple difference-in-difference on the ADUs permitted between single-family and multi-family zones. Column (1) presents the regression without controls, while column (2) adds controls for median income, population, and percent households married. *Data Sources: Building Permit Data, Zoning Data, ACS*

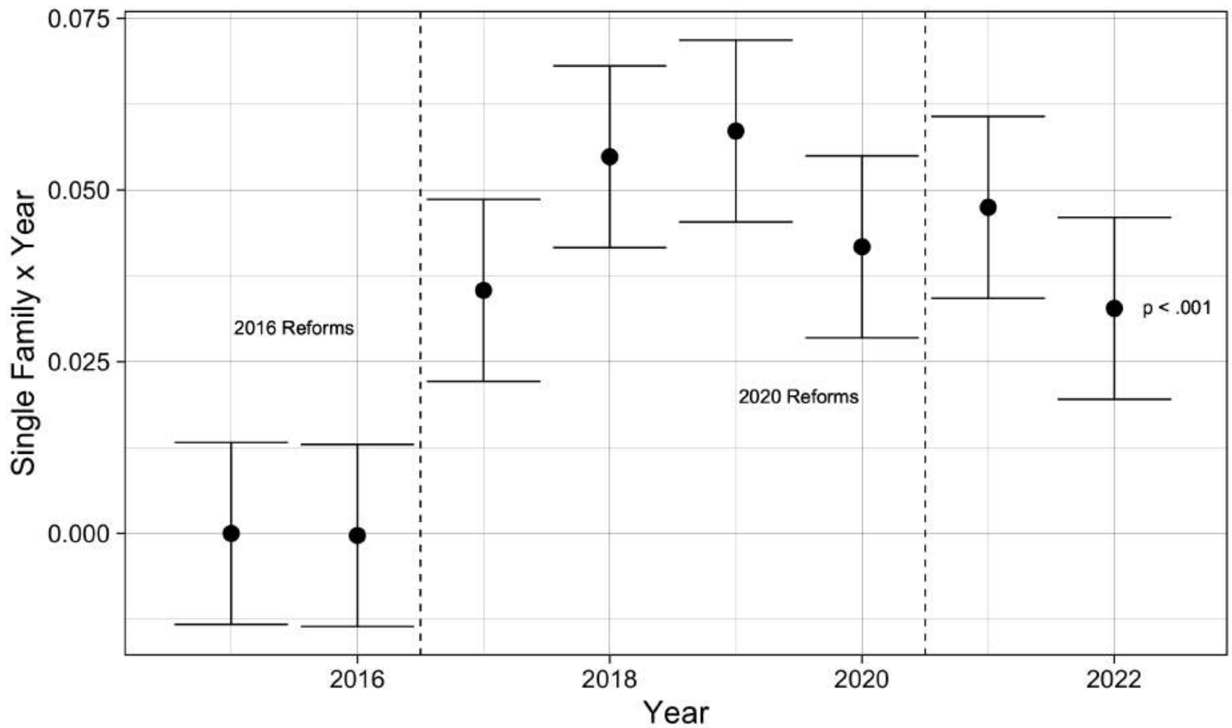



**Figure 5: Coefficients from Difference in Difference on ADUs Permitted.** This figure plots the coefficients from specification (1) in Table 7, which is Equation 7 without covariates since the ACS covariate data extends to only 2021 and I include a 2022 coefficient. The confidence intervals are at the 95 percent level. The p-value on the right-hand side is a joint test of whether all the coefficients are equal. *Data Sources: Building Permit Data, Zoning Data*

that an ADU is a significant change to one's single family home, it is reasonable that many homeowners waited until other homeowners had seen success with their ADUs. The state of California also engaged in significant information campaigns regarding ADUs, so increased awareness could also explain the growth in effect. A test of the hypothesis that all post-treatment coefficients are equal rejects the hypothesis at $p = 0.00025$, which suggests that the dynamic effects model is valuable.

However, I would note that it is not precise to attribute the magnitude of the coefficients to reflect the effect of solely the reform their time period corresponds to. It is feasible that some main barriers were actually lifted in 2020, but it also the case that the reforms in 2016 have a cumulative effect over time, so what we are seeing in the later years is the cumulative effect of both rounds of reforms.

**Assessing the Parallel Trends Assumption**

The empirical strategy of this paper rests on a foundational assumption: that, absent the treatment, the difference of ADUs permitted between single-family and two and three family zones would remain constant differences. I assume that the trends of ADU approval between these two categories of zones move in parallel after the treatment period if the treatment had not occurred.

My goal is to investigate whether upzoning causally increased the number of ADUs permitted. I want to disentangle this effect from other regulatory improvements in the ADU permitting process and thus compare two groups that were deferentially treated by the 2016 reforms. However, if there were other policies that affected the groups differently, or perhaps changing characteristics that make single-family zones more conducive to ADUs, this would threaten my analysis.

To show that my assumption is plausible, I plot ADUs permitted prior to the policy in Figure 6. This is the 2010 - 2016 portion of Figure 4, in which the scale of ADUs permitted post-policy dwarfed pre-policy ADUs. ADUs permitted moved roughly in parallel between single and two- or three-family zones prior to the treatment. This lends credibility to the parallel trends assumption, as it reasonable to assume this would have continued absent the policy in 2016.

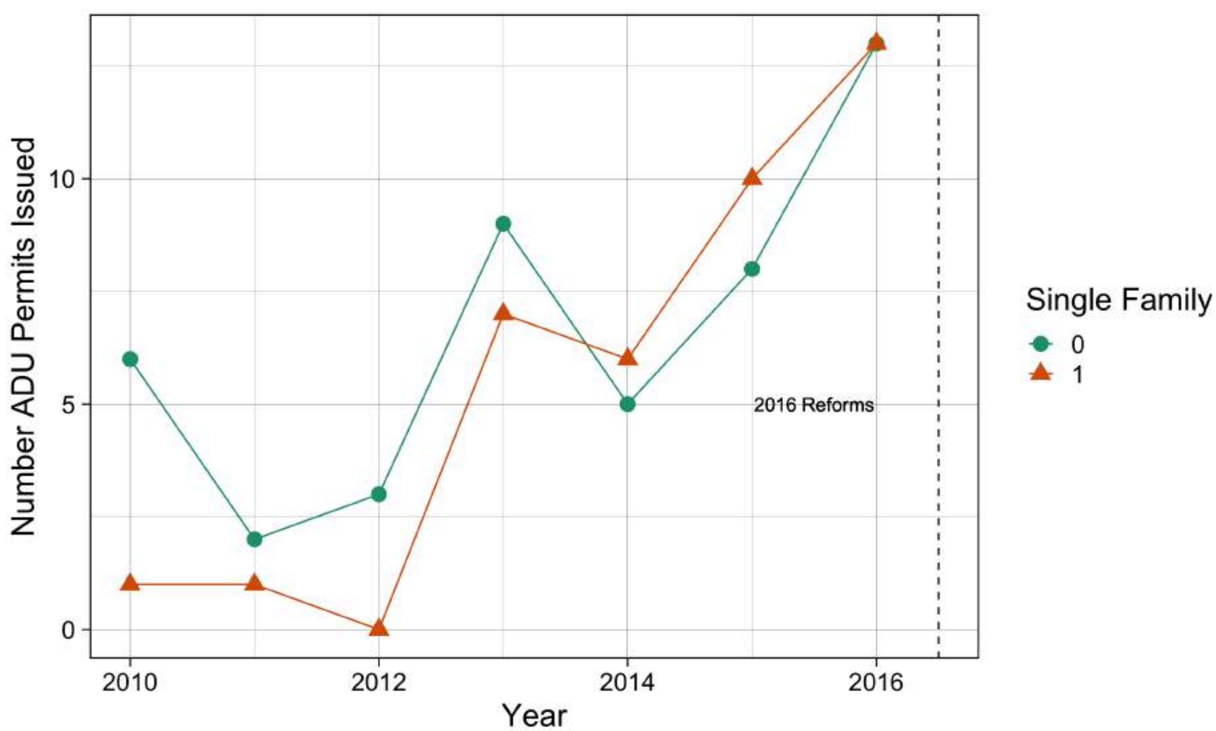



**Figure 6: Pre-Period ADUs Permitted by Zone.** This figure plots the number of permits issued from 2010 to 2016. There are very few permits over these years, and thousands starting in 2017, so years after 2016 are excluded from the plot. *Data Sources: Building Permit Data, Zoning Data*

Therefore, I conclude that upzoning significantly increased in the number of ADU permits, and that this effect is on the order of .04-.05. The vast majority of the effect is not driven by factors such as the increase in popularity of ADUs over time or desire for new units, as the comparison to two- or three-family zones demonstrates.

## 5.2 Do Supply Constraints Predict ADUs?

Next, I test Proposition 3, which predicts that ADUs will be constructed in the presence of supply constraints. To proxy for supply constraints, I follow Glaeser and Gyourko (2018), who use the ratio of home values to construction costs as a measure of the presence of binding regulatory supply constraints. I use a similar measure at the zip code level: the ratio of home values to replacement costs (henceforth, V/R). The intuition is the same: in efficient markets, a home's value should be equal to the cost of replacing said home. If Proposition 3 is correct, then areas with a high V/R ratio will see high levels of ADU construction. In Figure 7, I plot the ADUs permitted in single and two- or three-family zones by their quantile value of the value to replacement ratio.

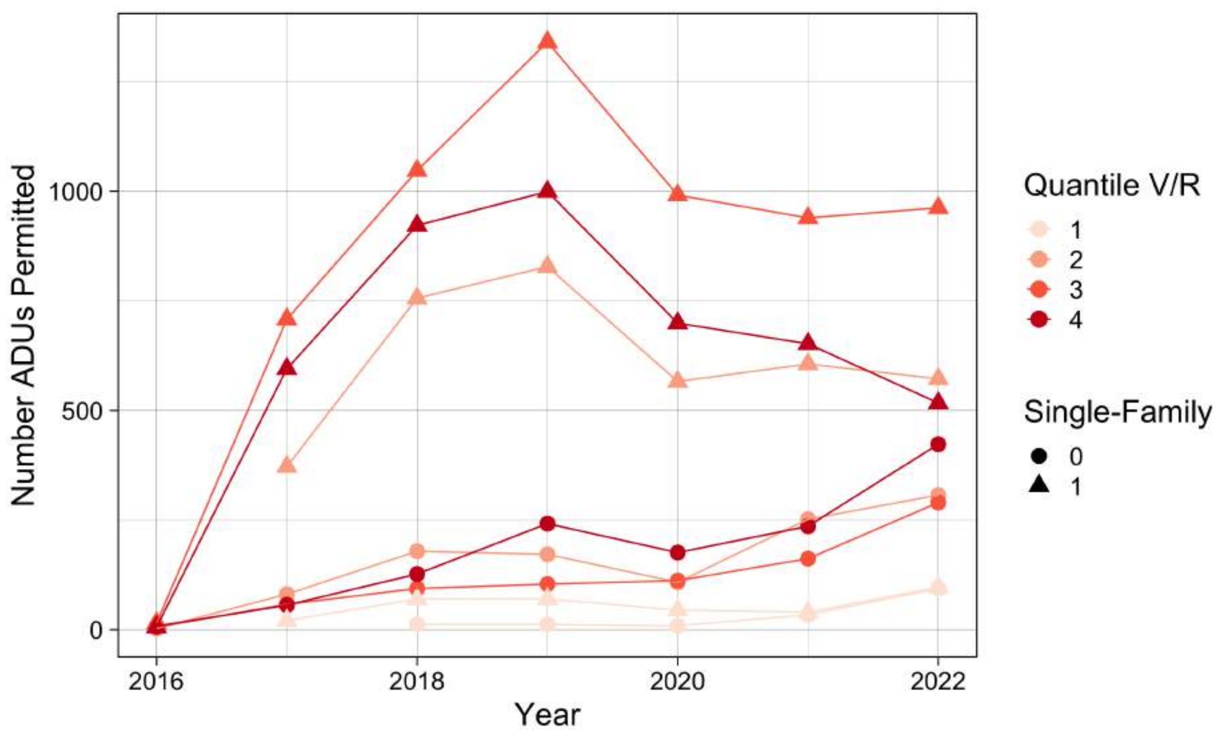



**Figure 7: ADUs Permitted by Zone and Value to Replacement Ratio.** This figure plots the number of ADUs permitted in single and two/three family zones over time by the quantile of the value to replacement cost ratio. *Data Sources: Building Permit Data, Zoning Data, BuildZoom Data*

Clearly, the value to replacement ratio is positively associated with ADU construction, verifying the prediction in the proposition. While ADUs are constructed primarily in single-family zones, the V/R value can explain differing quantities of ADU construction.

There are two key takeaways from this figure. First, the vast majority of ADUs permitted are coming from the second, third, and fourth quantiles of the value to replacement ratio. The areas in the first quantile produce no ADUs, and single and multi-family zones basically behave the same way. The second, third, and fourth quantiles groups of multi-family zones produce more ADUs than the first quantile of single-family zones. This validates the predictions of my model in Propositions 2 and 3, that both local regulations must be removed, and $\sigma_r$ must be high.

Second, the third quantile of the value to replacement ratio produces more than the fourth quantile. This is likely because the most supply constrained areas like the ones in the fourth quantile are also places where there is already significant wealth and aversion to renters. Simply put, no one is renting out a backyard unit in Beverly Hills. Therefore, the presence of these areas with extremely high value to replacement ratios causes the third quantile to produce more than the fourth.

To show the correlation directly, Appendix Figure 23 plots a binscatter of the ADUs constructed from 2018-2022 in a zip-code by the V/R value in the zip-code. As a further robustness check, I test whether the value to replacement ratio is only picking up on ADU construction due to a spurious correlation with other characteristics. Table 9 in the appendix regresses ADUs constructed on the value to replacement ratio. The relationship is positive and significant at the one percent level, even after controlling for income, population, age, and percent of households married. Furthermore, the effect persists after the inclusion of metro area fixed effects. Therefore, the effect is not just due to more ADUs being built in the expensive metros more than anywhere else.

## 5.3 Evidence of Continuing Regulatory Barriers

### Bunching in Floor Area Limits

First, I investigate whether there is bunching at the floor size limits under which state preemption applies. A JADU (a "junior" ADU, smaller and with fewer requirements) that is subject to the state guidelines may be at a maximum of 500 square feet, and an ADU may be a maximum of 1200 square feet. Local jurisdictions have discretion on ADUs that surpass these size limits. In Figure 8, I plot a histogram of the floor size of ADUs permitted in Los Angeles.[12] There is clear visual evidence of bunching at the limits described above. This provides some evidence that ADU owners are keen to be subject to state regulations, as opposed to local discretionary authority.

Several alternative explanations are available. First, a local jurisdiction can be permissive, but homeowners may simply prefer the certainty of the state ADU ordinance, as they know that their unit is certainly by-right. Second, the state ordinances automatically apply if local ordinances are not up to scratch. Therefore, local jurisdictions may have simply opted to not modify the state legislation. However, it is clear that homeowners desire to build larger ADUs.

[12]Only the Los Angeles permits contained usable floor size data.

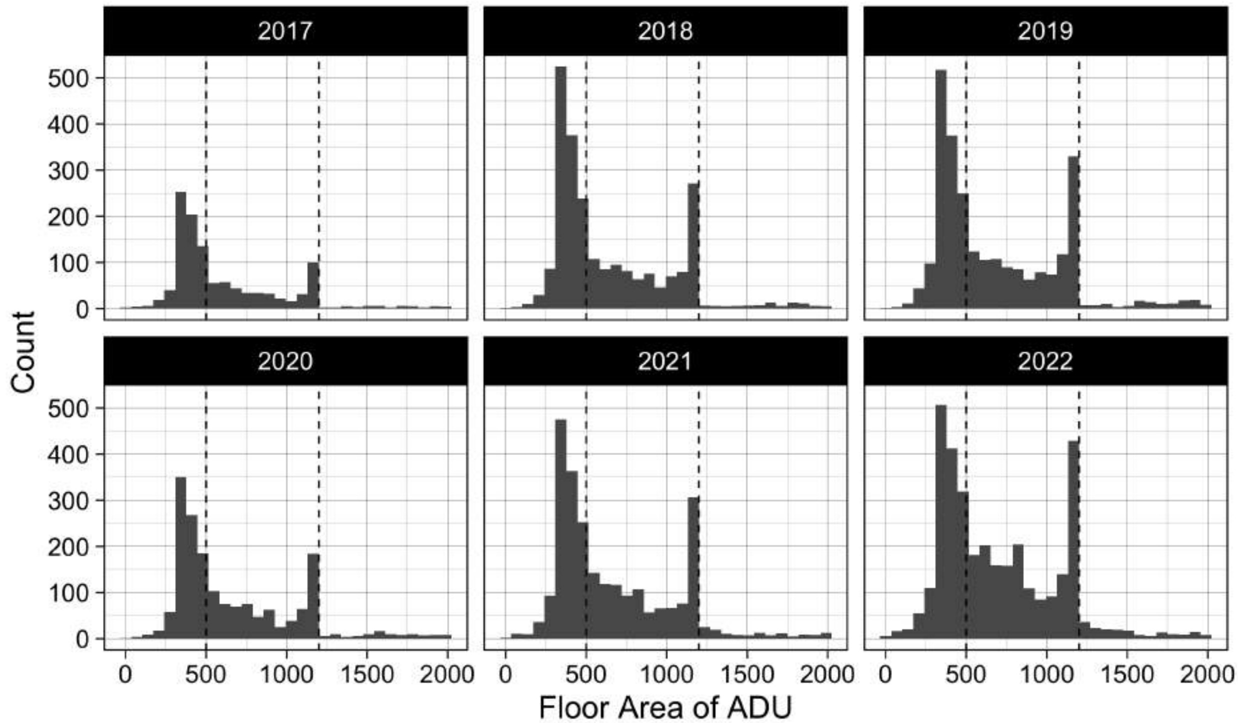



**Figure 8: Histogram of Floor Area by Year.** This figure plots a histogram of the floor area of each ADU permitted in Los Angeles (the only city of the three where floor area data was available) by year. The vertical lines are at 500 and 1200 square feet, which are the state-set floor area limits for a JADU and ADU respectively such that the state legislation protects a permit from local regulations. *Data Sources: Building Permit Data*

**Potential Circumvention of Permitting Time Regulations**

In 2020, California required ADU permits to be approved within 60 days. Anecdotal evidence suggests that this order was not followed. Figure 9 plots a histogram of the days between when a permit was approved and when it was submitted. Clearly, the 60-day limit is regularly exceeded by permitting authorities.

My conversations with David Hamilton, a subject-matter expert in contracting and residential development at the Harvard Graduate School of Design, indicated that these excessive waiting times could be occurring completely legally. Local permitting authorities could, after the passage of 59 or so days, ask the petitioner to make some update to their permit or to correct some error. This phenomenon would manifest as a substantial number of permits being approved in a multiple of 60 days. In Figure 9, I add vertical lines at multiples of 60.

It is unclear whether this phenomenon is present in ADU permitting. While there are some spikes, especially at 120 and 180 in 2021 and 180 in 2022, the evidence is not visually clear[13].

[13] I attempted statistical tests at detecting bunching, but there is not enough data between each multiple of 60 to accurately deal with several bunching points.

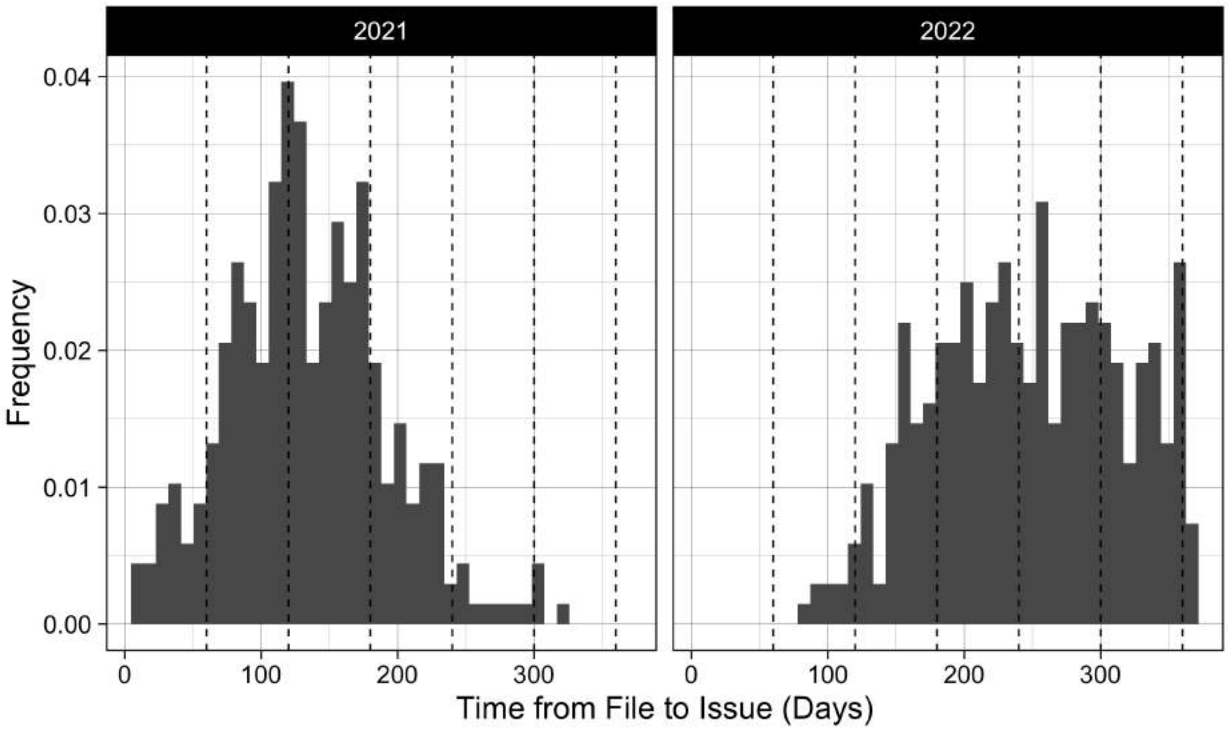



**Figure 9: Histogram of Waiting Time for Permit Approval.** This figure plots of the time waited in days between submitting a permit and recieving approval. This only contains data from San Francisco and San Diego, since Los Angeles data did not include the date a permit was originally submitted. I choose to include 2021 and 2022 since the other years do not have enough data to have informative histograms. The vertical lines are at multiples of 60 days. *Data Sources: Building Permit Data*

There could be numerous regulatory barriers still at play and specific laws that must be preempted. However, my conversation with State Senator Wieckowski suggested that the current legislative language is enough and what must be done now is for the state to follow up in voiding local regulations in court. Indeed, the California Attorney General filed a lawsuit in early March 2023 against Huntington Beach for illegal barriers to ADU and duplex production.

Both theory and evidence suggest that local coordination constrains housing supply, and this section establishes that California's preemption is a successful model for the removal of local regulations.

# 6 The Effect on Rent Prices

This section estimates the effect of ADU construction on rent prices, exploiting the variation in ADU construction between single and two/three-family zones. The observational unit is a Census Tract and the outcome is its log rent price. I review my empirical strategy and construction of a tract-level measure of treatment exposure. I estimate the supply effect from my economic theory and then report the results of my main regression.

## 6.1 Empirical Strategy

For a Census Tract $c$, I spatially merge $c$ with the residential zones contained within it from the zoning dataset. Then, I calculate how much of the area of the tract is single, two, or three family zoned. I then define a percent "in-sample" variable as the total area that is single, two, or three family zoned divided by the total area of the tract[14]. I exclude tracts with lower than fifty percent "in-sample," only keeping tracts that are sufficiently residential. Finally, I define the percent single-family zoned $Z_c$ as

$$Z_c := \frac{\text{area in tract } c \text{ that is single-family zoned}}{\text{area in tract } c \text{ that is single or two- or three-family zoned}}$$

In Figure 10, I plot the density of $Z_c$. This is evidence that my treatment variable well approximates the indicator of a zone being single family used in the previous section. In particular, the bimodal nature of the density plot indicates that my variable functionally captures a yes/no of "was this tract exposed to ADU-related upzoning". In Appendix Figure 24 I plot the density of the "in-sample" variable, which looks approximately uniform.

Therefore, using $Z_c$ as a measure of exposure to ADU deregulation, I estimate:

$$\overbrace{\ln(P_{c,t})}^{\text{Log Rent Price}} = \beta_0 + \beta_1 Z_c + \overbrace{\sum_{j=-T}^{T} \beta_j Z_c * \mathbb{I}\left[t=j\right]_t}^{\text{dynamic difference-in-differences}} + \underbrace{x_{c,t}^T \vec{\eta}}_{\text{covariates}} + \overbrace{\psi_c}^{\text{tract FE}} + \overbrace{\gamma_t}^{\text{time FE}} + \underbrace{\epsilon_{c,t}}_{\text{centered error}} \tag{8}$$

I briefly verify that $Z_c$ does in fact capture exposure to the policy. I regress the number of ADUs constructed on an interaction term between $Z_c$ and the year. That is, I estimate Equation 8, but with number of ADUs constructed as the outcome variable. I plot the coefficients in Figure 11. The coefficients indicate that the treatment variable defined picks up on the variation in ADU construction needed to estimate the effect of ADUs on rent prices.

I also report the regression in Table 8 in the appendix, which verifies that the effect is significant at the one percent level and robust to changes in specification. There appears to be a delay in the effect of the policy, with the most significant effects beginning in 2018. Note that the magnitude of the coefficient is larger than the second section. Here, the coefficient ranges from .7-1.5, which makes sense since the tract is a larger unit than the zone. The results in this table are largely consistent with the results from the

[14] The area is unitless and calculated from the spatial polygon itself. Given that I am simply interested in the relative measure of area that is zoned a particular way, it is not necessary to use a particular unit.


**Figure 10: Density of Percent Single-Family Zoned in In-Sample Tracts.** This figure plots the density of $Z_c$, which is calculated as the proportion of the in-sample area that is single-family zoned. Estimation is done with a kernel density estimator with Gaussian kernel and nrdo bandwidth selection. *Data Sources: ACS, Zoning Data*

zone-level specification in the previous section.

## 6.2 A Plausible Range of the Impact of ADUs on Rent

Drawing from the economic theory developed in section 4, I use the result of Proposition 4 to estimate a plausible range for $\beta_j$. Using ACS data, I start with the true amount of rental supply and the median rent price in each census tract in my sample in 2015. For each subsequent year, I use a range of estimates for the price elasticity of demand of rental housing from the economic literature and the true number of ADUs constructed to estimate a trajectory of rent prices. The goal of the simulation is to construct a dataset where the rent price variable is solely affected by supply shocks from ADUs. Fitting Equation 8 on this dataset, given that the assumption for that regression is that it only picks up on the effect of ADU deregulation, yields plausible estimates for $\beta_j$.

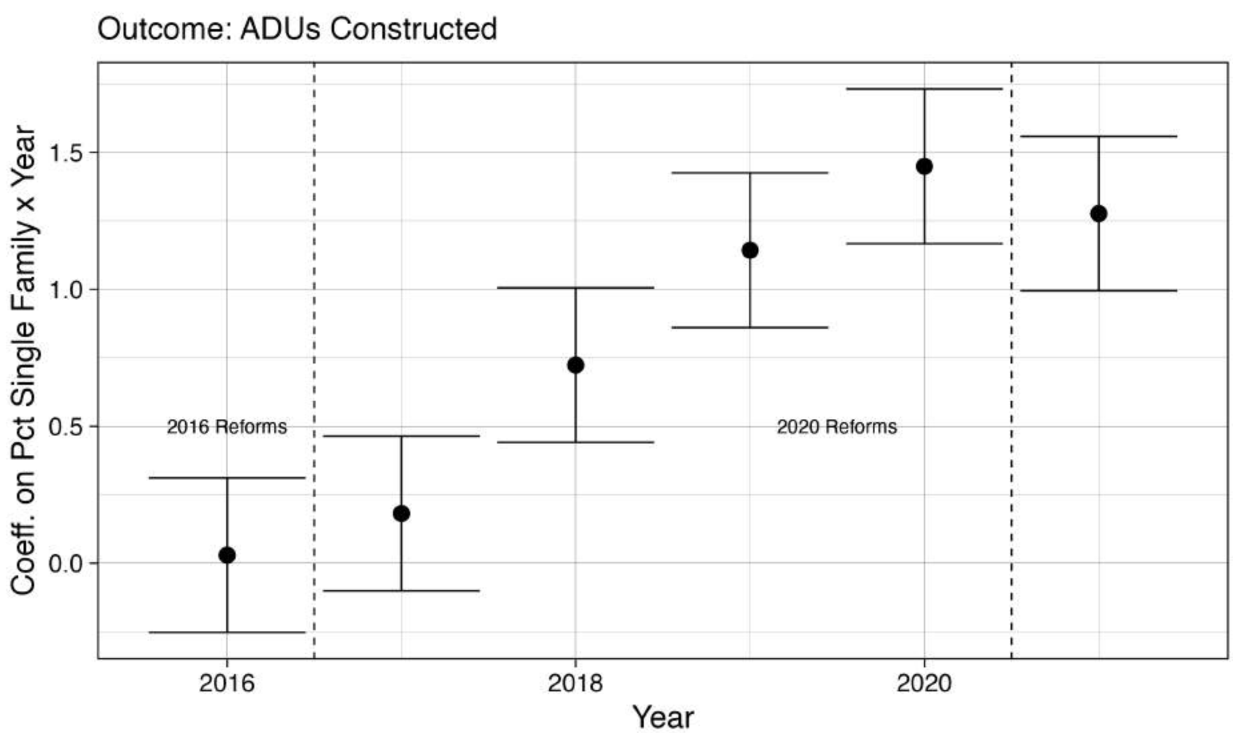



**Figure 11: Tract-Level Difference in Difference on ADUs Constructed.** This figure plots the coefficients from the first stage regression of Percent Single Family Zoned $\times$ Year on the number of ADUs constructed. The specification plotted is with covariates and city fixed effects. *Data Sources: ACS, Zoning Data, Building Permit Data*

Denote the number of ADUs constructed in tract $c$ at time $t$ as $A_{c,t}$. Denote the synthetic number of rental units as $Q_{c,t}$ and the synthetic rental price $P_{c,t}$. Finally, denote the price elasticity of demand for rental housing as $\eta$.

By Proposition 4, I can estimate the change in log rent price from a supply shock as:

$$\ln(P_{c,t}) - \ln(P_{c,t-1}) = \eta \left[\ln(Q_{c,t}) - \ln(Q_{c,t-1})\right] \tag{9}$$

The assumption that allows the use of the proposition is that $Q_{c,t}$ and $P_{c,t}$ are equilibrium price and quantity, and the change from $Q_{c,t-1}$ to $Q_{c,t}$ comes from the shift in the supply curve due to ADUs. Under these assumptions, I take $Q_{c,t}$ to be equal to $Q_{c,t-1} + A_{c,t-1}$. That is, quantity in a tract evolves only with respect to constructed ADUs. I set $Q_{c,2015}$ and $P_{c,2015}$ equal to the true number of rental units and rent price respectively. Then, I estimate this model forward for $t \in \{2016, 2017, 2018, 2019, 2020, 2021\}$. At each step, I derive $Q_{c,t+1}$ and use Equation 9 to estimate the change in log rent price. I then update $P_{c,t+1}$ with this change. In this simulation, each tract's rent price trajectory is constructed as it would be if the *only change* was the construction of ADUs.

My estimates for the inverse price elasticity of rental housing demand $\eta$ come from Mayo (1981), which comprehensively reviews estimations of housing demand in the economics literature. Table 1 in this paper reviews prominent estimations of the price elasticity of demand in log-linear models, collecting the estimates from 16 papers. I estimate my synthetic dataset across $\frac{1}{\eta} \in \{-1.28, -.71, -.56, -.17\}$. This set covers the smallest and largest estimates of elasticity in the paper and two less extreme estimates. I acknowledge that these estimates are old but their wide range means that my analysis would still capture the result from a more modern estimate.

My overall strategy makes two somewhat unrealistic assumptions. First, this assumes that all ADUs will contribute to rental stock. This is a generous assumption, but since I am interested in lower bounding the coefficients of interest from Equation 8, I accept assumptions that grant more credence to ADUs. Second, the synthetic price variable only reflects a supply shift. It could be the case that demand shifted rightward in California, and that other exogenous events affected rent prices in a way that differentially affected single-family zones. For example, single- and two- or three-family zones were likely affected differently by Covid-19 due to the composition of residents.

However, my strategy will be to estimate an analog of Equation 8 on the synthetic data. Therefore, to the extent that my treatment variable picks up on the effect of ADU deregulation, which is the assumption that my empirical strategy itself requires, the coefficients in the synthetic price regression should accurately reflect what the coefficient would be in the regression with true data.

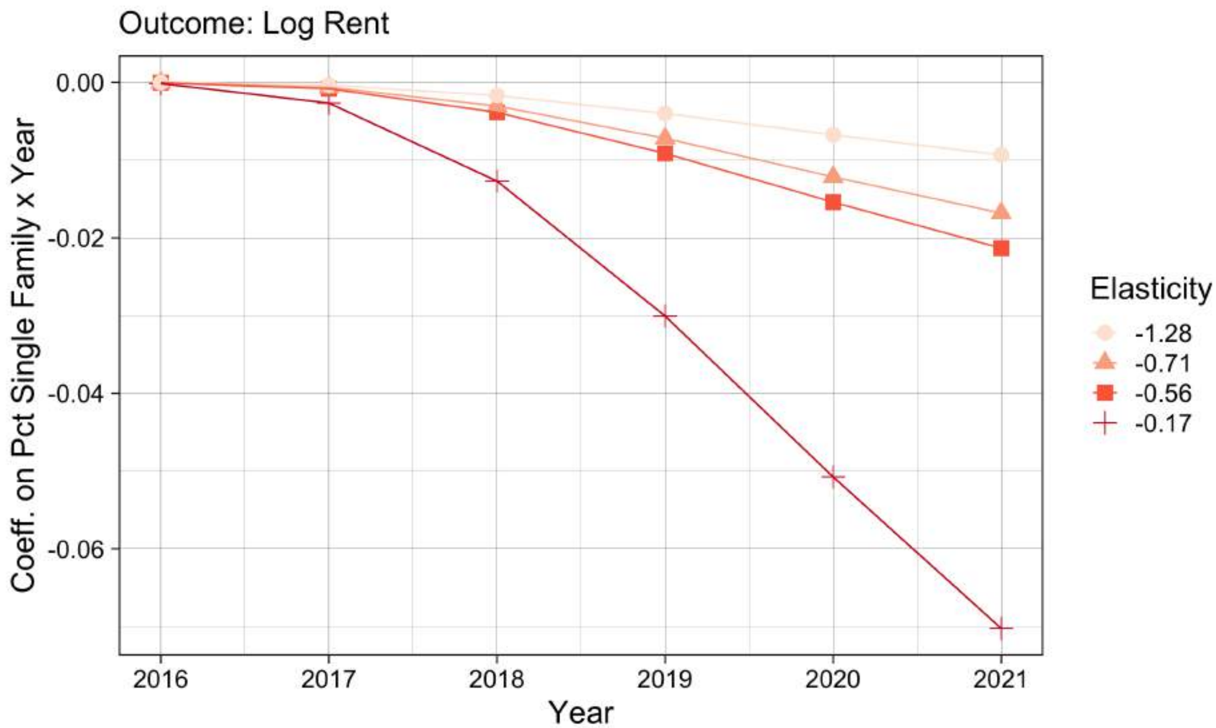



**Figure 12: Tract-Level Difference in Difference on Simulated Rent.** This figure plots the coefficients from Equation 10 on synthetic datasets constructed across four specifications of the price elasticity of rental housing demand. *Data Sources: ACS, Zoning Data, Building Permit Data*

Formally, I estimate

$$\overbrace{\log(P_{c,t})}^{\text{Synthetic Price}} = \beta_0 + \beta_1 Z_c + \overbrace{\sum_{j=-T}^{T} \beta_j^S Z_c * \mathbb{I}\left[t=j\right]_t}^{\text{dynamic difference-in-differences}} + \overbrace{\gamma_t}^{\text{time FE}} + \overbrace{\psi_c}^{\text{tract FE}} + \underbrace{\epsilon_{c,t}}_{\text{centered error}} \tag{10}$$

where $B_j^S$ are the coefficients of interest.

In Figure 12, I plot the coefficients across each elasticity specification. In Table 10 in the appendix, I report the estimates for Equation 10 for each value of $\eta$. Naturally, the estimates are larger for smaller elasticity, but the middle estimates for $-.56, -.71$ already suggest that the effect on rent prices is less than two percent. Rental housing in California is likely more inelastic than not, and thus I find the range of estimates for $\frac{1}{\eta} = -.56$ most plausible. In the next section, I compare my simulated coefficients to the true ones.

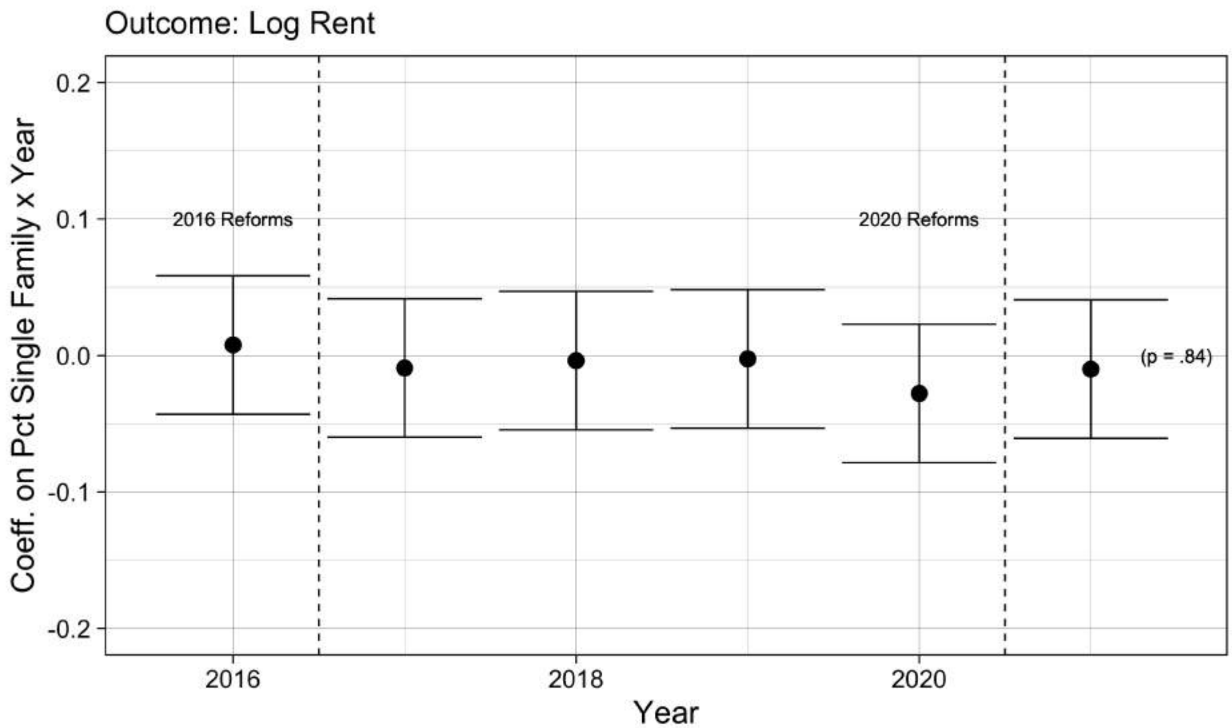



**Figure 13: Tract-Level Difference in Difference on Log Rent.** This figure plots the coefficients from Column (3) in Table 5, which is a difference in difference on log rent with covariates and city fixed effects. The confidence interavls are at the 95% level. The p-value on the right-hand side is from a test of the hypothesis that all coefficients are equal. *Data Sources: ACS, Zoning Data, Building Permit Data*

## 6.3 Linear Panel Model Estimation of Rent Price Effect

I find that there is no statistically detectable effect of ADU construction on rent prices. In Table 5, I report the estimates from Equation 8. In Column (1), I report the simple regression without covariates. In (2), I add covariates of median income, population, and percent of households married. The sign and significance of the coefficients on the covariates is expected. The coefficients on population and median income are likely very small due to the scale and units of those variables.

The size of my coefficients of interest ranges from .001-.01 and the standard error is typically an order of magnitude larger. This suggests that the effects are indistinguishable from zero.

As shown in Figure 13, the confidence intervals do not exclude zero. The p-value of .84 on the plot is from a hypothesis test of whether all the coefficients are equal to each other, which is additional evidence of no effect on rent prices. Curiously, the 2020 coefficient is substantially more negative across all specifications, whereas the size of the coefficients in 2017-2019 diminish as the specification becomes more robust. I believe that the regression is picking up on Covid-19, and that the pandemic must have had a differential effect on rent prices in single-family tracts, which is plausible.

| | Log Rent | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Pct Single Family | 0.066** | −0.019 | −0.018 |
| | (0.030) | (0.019) | (0.019) |
| Median Income | | 0.006*** | 0.007*** |
| | | (0.0001) | (0.0001) |
| Population | | −0.00000 | −0.00000** |
| | | (0.00000) | (0.00000) |
| Pct Married | | 0.002*** | 0.001*** |
| | | (0.0002) | (0.0003) |
| Pct Single Family x 2016 | −0.001 | 0.008 | 0.008 |
| | (0.042) | (0.026) | (0.026) |
| Pct Single Family x 2017 | −0.016 | −0.009 | −0.009 |
| | (0.042) | (0.026) | (0.026) |
| Pct Single Family x 2018 | −0.013 | −0.003 | −0.004 |
| | (0.042) | (0.026) | (0.026) |
| Pct Single Family x 2019 | −0.017 | −0.003 | −0.002 |
| | (0.042) | (0.026) | (0.026) |
| Pct Single Family x 2020 | −0.041 | −0.028 | −0.028 |
| | (0.042) | (0.026) | (0.026) |
| Pct Single Family x 2021 | −0.016 | −0.011 | −0.010 |
| | (0.042) | (0.026) | (0.026) |
| Constant | 7.140*** | 6.730*** | 6.750*** |
| | (0.021) | (0.018) | (0.018) |
| *N* | 3,949 | 3,949 | 3,949 |
| $R^2$ | 0.100 | 0.649 | 0.663 |
| Adjusted $R^2$ | 0.097 | 0.647 | 0.661 |
| *Notes:* | ***Significant at the 1 percent level. | | |
| | **Significant at the 5 percent level. | | |
| | *Significant at the 10 percent level. | | |

**Table 5: Tract-Level Linear Panel Model on Log Rent.** This figure presents estimates from the regressions specified in Equation 8, which uses the percentage of a census tract that is single-family zoned as a scalar treatment variable. Column (1) is just fitted on the interaction between years and the treatment variable. Column (2) adds controls for median income, population, and percent households married and (3) adds city fixed effects. The base year is 2015. *Data Sources: Zoning Data, ACS*

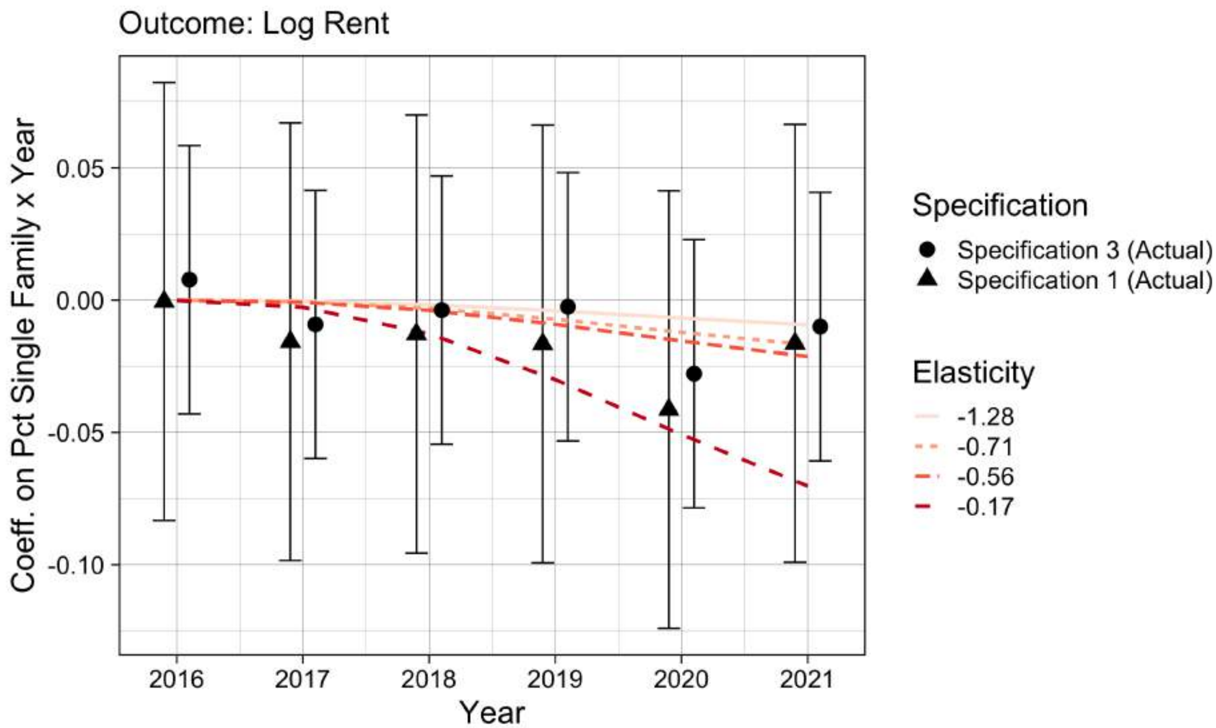



**Figure 14: Comparison of Coefficents from Simulated vs True Tract-Level Difference in Difference.** This figure plots the coefficients on $Z_c \times$ Year for the elasticity regressions in Equation 10 and specifications (1) and (3) from Table 5. *Data Sources: ACS, Zoning Data, Building Permit Data*

In Figure 14, I plot the coefficients from Column (1) and (3) against the simulated coefficients from my back-of-the-envelope calculation. I use the specification from (1) since it exactly matches the regression I fit on the synthetic data. I use (3) since the covariates and fixed effects diminish the size of the coefficients, and thus I am interested in whether they fall into the simulated range.

First, the confidence intervals from my empirical specification contain the estimates from the elasticity-based estimation. The only departure is the estimates for $-.17$, which is a fairly low elasticity to begin with, so this is not too surprising. The elasticity estimates for $-.56$ line up with the point estimates, but the confidence intervals here are much more important.

Additionally, the Covid-19 bump in 2020 suggests that my treatment variable $Z_c$ is not solely picking up on ADU construction in single-family zones. If the preferences of renters changed such that they no longer prefer rental units in single-family tracts over the course of 2016-2021, then this could also explain the size and sign of my coefficients.

A more charitable explanation is that my simulation solely picks up on the supply effect, but the true impact of ADUs on rent stems from a supply effect plus a nuisance effect, where ADUs simply lower the quality of the single-family neighborhood. This is plausible, given that members of a single-family neighborhood clearly pay for lower density and their own privacy and space. However, as section 7 will demonstrate, the nuisance effect is quite small. Therefore, it is unlikely that my coefficients are more negative than the simulated ones due to a nuisance effect.

Therefore, I conclude that ADUs deregulation is not driving any meaningful reduction in rent prices. This provides some evidence that reliance on single-family parcels is not an effective strategy to reduce rents. Furthermore, the more plausible estimates from Proposition 4 suggest that any potential reduction in rent prices is between zero and two percent.

# 7 The Nuisance Effect on Neighbors

This section estimates a nuisance effect from ADUs.

## 7.1 Empirical Strategy

The challenge to estimating the nuisance effect is that ADU construction is non-random. ADUs might be built in areas with less valuable single-family homes or areas about to experience increased presence of renters. The first could be measured, but the second is impossible. Indeed, if the channel by which ADUs impose a nuisance is through the presence of renters, then this second problem poses a serious roadblock to cross-sectional estimation of the nuisance effect. To overcome this, I compare the property values close to the ADU over time to property values just slightly farther way over time. My strategy to use variation in distance from an event site to overcome the non-random placement of events draws from Linden and Rockoff (2008) and Diamond and McQuade (2019).

This strategy also draws on the economic theory shown in Proposition 5. Under the assumptions of my model, a home being slightly closer or slightly further away from an ADU only affects its property value through the nuisance effect. Furthermore, the effect of being closer enters log-linearly. Taking this to the context of ADUs, I limit my analysis to property sales with a certain distance $d$ of a constructed ADU. For property $i$ and time $t$, let $ADU(i)$ denote the ADU that property $i$ is less than $d$ distance away from. I estimate

$$\overbrace{\log(P_{i,t})}^{\text{Log Sale Price}} = \beta_0 + \beta_1 \mathbb{I}\left[\text{After ADU Constructed}\right]_{i,t} + \underbrace{\beta_2 \mathbb{I}\left[\text{Within } d/2 \text{ of ADU}\right]_i \times \mathbb{I}\left[\text{After ADU Constructed}\right]_{i,t}}_{\text{Interaction Term}} + \underbrace{\gamma_t}_{\text{time FE}} + \underbrace{\psi_i}_{ADU(i)\text{ FE}} + \underbrace{\epsilon_{i,t}}_{\text{centered error}} + \underbrace{x_{i,t}^T \vec{\eta}}_{\text{covariates}} \tag{11}$$

where $\beta_2$ is the coefficient of interest. There are two more qualifying notes on this regression. First, I am intentionally ambiguous about the nature or units of $d$. This is because $d$ varies between my estimation of this equation in Los Angeles and San Francisco, due to data constraints.

Second, I use the "ring method" of Linden and Rockoff (2008), where I consider a unit to be treated if it is within $d/2$ of the constructed ADU and as not treated otherwise. The intuition behind this strategy is that units closer to the ADU should experience a higher nuisance effect. However, Diamond and McQuade (2019) use a non-parametric strategy, where they allow for property values in an area around an event of interest to be some function of distance from that event. They are able to estimate the empirical derivatives of this function, and thus make fewer assumptions on how distance affects property values. However, due to sample size constraints, I am unable to use the "empirical derivatives" method and use the "ring method" instead.

## 7.2 Results

### Results from Los Angeles

In this section, I use property values from Los Angeles near ADUs constructed in 2021 and 2022. Given the constraints of the Los Angeles data, I only have observations one year on each side of a constructed ADU. In this estimation, I take $d$ to be 1000 feet. This is a reasonable choice for two reasons. First, this sets the treatment range to be within 500 feet. Qualitatively, it is unlikely that a small backyard unit imposes a significant nuisance to homes that are not its immediate neighbors. The preferred specification Davidoff et al. (2022) uses immediate neighbors. Second, Los Angeles is a city with many geographic discontinuities. Two neighborhoods, across the road from each other, can be extremely different. Therefore, my constraint of 1000 feet ensures that the control units are as similar as possible to the treatment units.

Before estimating the regression, I investigate some visual evidence. Figure 15 plots a binscatter of the distance from the construction site and log sale price before and after the ADU was constructed. An advantage of this initial visual evidence is that it makes fewer parametric assumptions on the relationship between distance to an ADU and the property value than the regression analysis. Hence, even if the effect was not log linear as I assume or if the specification of $d$ in the "ring" analysis was incorrect, the binscatter would still show a potential nuisance effect. In the presence of a nuisance affect, the after line should gain a clear upward slope compared to the before line, as being further away from the event site increases property values. However, the relationship remains nearly identical before and after the construction. Indeed, the uniform confidence bands in the figure basically lie on top of each other. This is strong visual evidence that there is no economically significant nuisance effect.

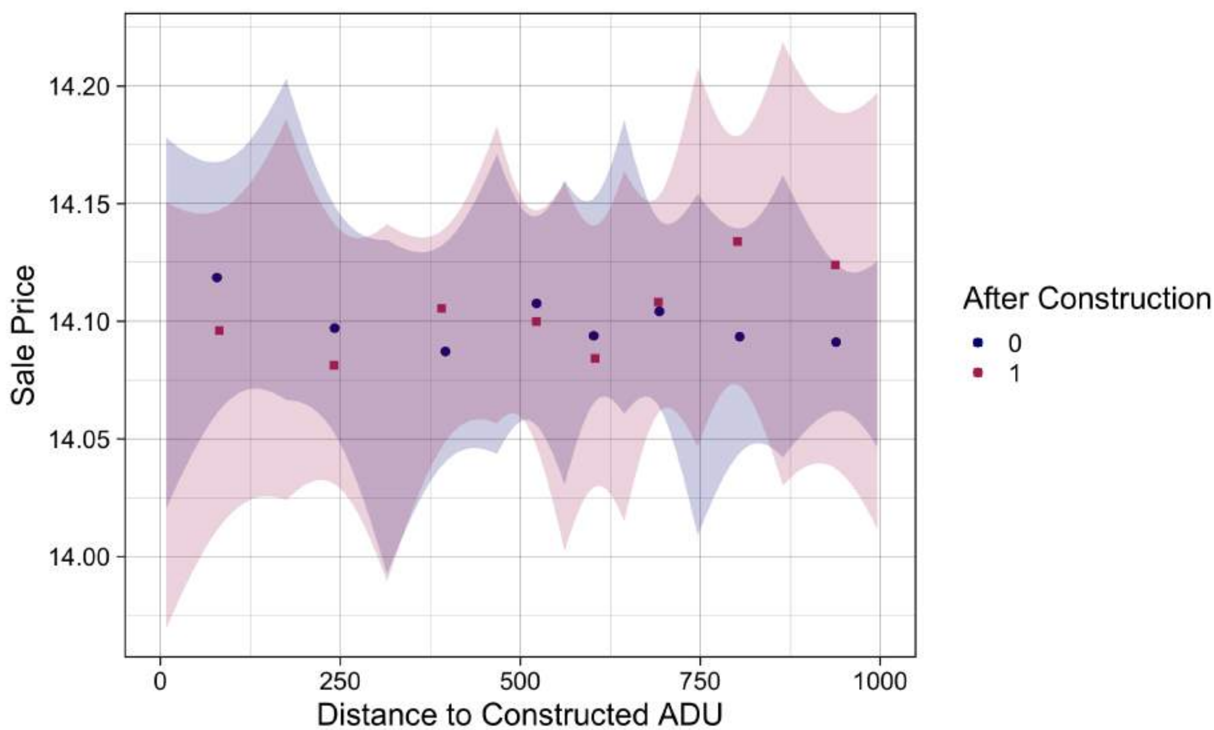



**Figure 15: Log Value by Distance Before and After ADU Construction in Los Angeles.** This figure plots a binscatter of property values by distance from an ADU construction site before and after the ADU was built. A one degree piecewise polynomial with smoothness one is used to construct uniform confidence bands. Bins are selected through IMSE-optimal direct plug-in rule. *Data Sources: Building Permit Data, Los Angeles Property Value Data*

In Table 6, I report the results from the regression specified by Equation 11. Column (1) runs a bare bones regression without controls. Column (2) adds controls, and (3) adds fixed effects for the time of the sale and $ADU(i)$. The coefficients of interest are all indistinguishable from zero. More notably, the confidence interval excludes estimates larger than a three percent reduction in rent prices due to the nuisance effect.

It could, however, be the case that some other confounder also changes with distance, nullifying the

| | Log Sale Price | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| After ADU Built | 0.017 | 0.037*** | −0.001 |
| | (0.011) | (0.010) | (0.012) |
| Within 500 Feet | −0.018 | −0.001 | 0.003 |
| | (0.013) | (0.012) | (0.009) |
| Lot Area | | 0.0002*** | 0.0002*** |
| | | (0.00001) | (0.00001) |
| Number of Beds | | −0.040*** | −0.012*** |
| | | (0.004) | (0.004) |
| Year Built | | 0.0002*** | 0.0003*** |
| | | (0.00004) | (0.00004) |
| Valuation of ADU | | 0.00000*** | 0.00001 |
| | | (0.00000) | (0.00005) |
| After ADU Built x Within 500 Feet | 0.007 | 0.005 | 0.00000 |
| | (0.019) | (0.017) | (0.013) |
| Constant | 14.396*** | 13.622*** | 13.272*** |
| | (0.007) | (0.087) | (0.711) |
| *N* | 5,603 | 5,603 | 5,603 |
| $R^2$ | 0.001 | 0.220 | 0.601 |
| Adjusted $R^2$ | 0.001 | 0.219 | 0.573 |
| *Notes:* | ***Significant at the 1 percent level. | | |
| | **Significant at the 5 percent level. | | |
| | *Significant at the 10 percent level. | | |

**Table 6: Difference-in-Difference on Sale Price Between Properties Near and Far from ADU Construction in Los Angeles.** This table reports the results of estimating Equation 11 in Los Angeles. Here, $d$ is taken to be 1000 feet, and thus units within 500 feet are considered treated. Column (1) is the bare-bones regression. Column (2) adds controls, and (3) adds $ADU(i)$ fixed effects. *Data Sources: Los Angeles Property Sales Data, Building Permit Data*

assumption that property values close to vs further away would have moved similarly if not for the construction of the ADU. In the appendix, I report several balancing tests in Figure 25, which show that relevant property characteristics are not changing in time. In particular, I show that the relationship of distance to number of beds, year property is built, and square footage of a house is not changing over time. This shows that the assumptions of my strategy are plausible.

This estimation qualifies previous cross-sectional estimates from the literature. It excludes the $-3.8\%$ estimate from Davidoff et al. (2022) and has the distinct advantage of being able to exploit cross-sectional and temporal variation to overcome the issue of non-random ADU construction.

**Results from San Francisco**

Next, I use assessed value data in San Francisco coupled with geolocated data on constructed ADUs. I use ADUs constructed in 2016 and 2017. I remove observations that are closer to an ADU that was built outside my period of interest (e.g. ADUs constructed in 2018 or 2019). I filter for observations within two years on either side of an ADU construction. In this estimation, which has fewer observations than Los Angeles, I set $d$ to 500 meters and thus compare units within 250 meters of an ADU to units further away.

Figure 16 plots a binscatter of distance on log value before and after the ADUs are constructed. Again, the uniform confidence bands lay entirely on top of each other.

I report the estimates from the regression specified by Equation 11 in Table 11 in the appendix. The point estimates on the interaction term are consistent in sign but are indistinguishable from zero, confirming the visual evidence in Figure 16. Additionally, the balancing tests are reported in Figure 25 in the appendix.

The standard errors in the San Francisco estimation are larger than the Los Angeles estimation. The sample size is low due to the numerous constraints I placed on the dataset. This yields an insufficient amount of data with which to map the relationship between distance and property value. In particular, I lack enough observations with 50 or so meters of the ADU, where the nuisance effect would be the strongest. If a nuisance effect were to exist, it is plausible that it ought to only affect the closest units to an ADU. Furthermore, the Los Angeles estimation is able to rely on true property sales data, which is still better than the assessed values used here. Therefore, the estimates from Los Angeles are preferable to San Francisco.

This section provides guidance for future research into the spillover effects of density. My theoretical model predicts that homeowners will coordinate to prevent new construction if the marginal disutility of increased density is greater than the potential profits. The estimation in this section shows that the

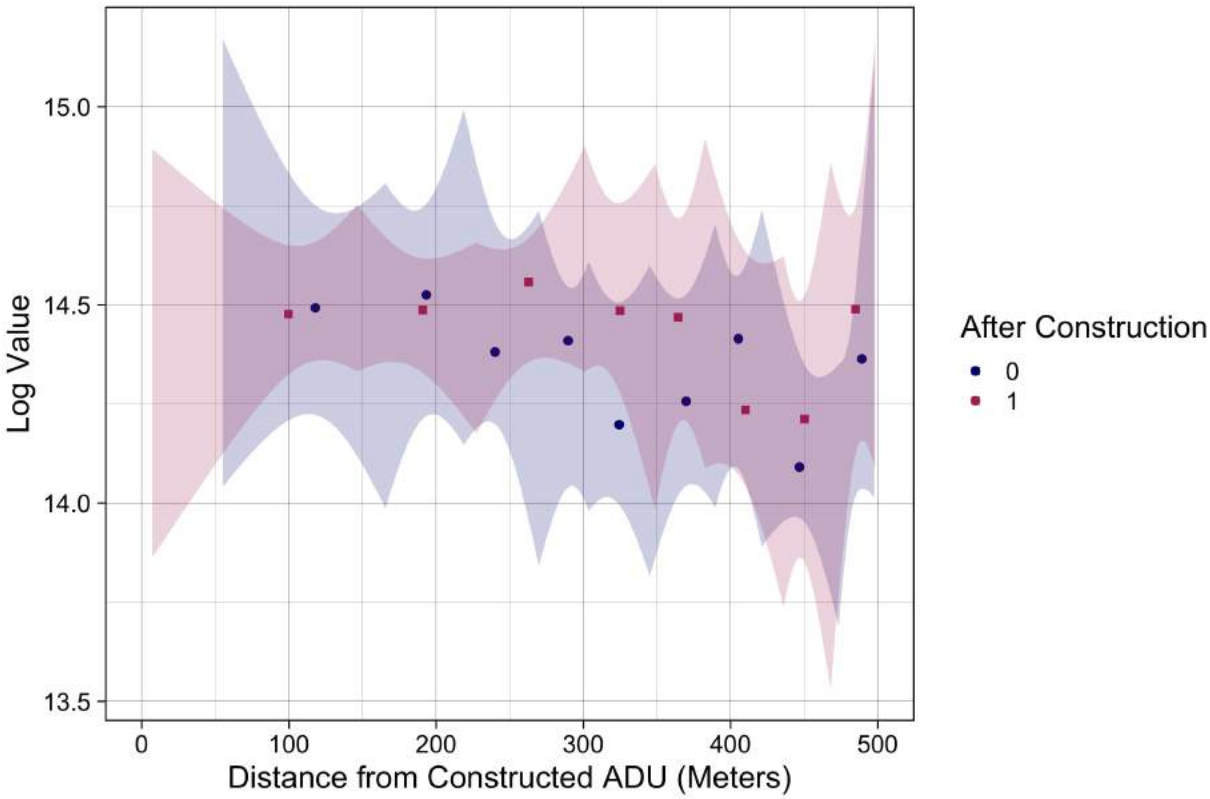



**Figure 16: Log Value by Distance Before and After ADU Construction in San Francisco.** This figure plots a binscatter of property values by distance from an ADU construction site before and after the ADU was built. A one degree piecewise polynomial with smoothness one is used to construct uniform confidence bands. Bins are selected through IMSE-optimal direct plug-in rule. *Data Sources: Building Permit Data, San Francisco Assessed Value Data*

distance-dependent nuisance effect is likely small in the context of ADUs, which suggests that homeowners were primarily worried about the overall increase congestion in their neighborhood. This finding is reflected in the content of many of the regulations that the state lifted: requirements for parking, impact fees, and requirements for setbacks. Hence, future research on single-family zones can focus on measuring disutility from the congestion effect, which is not in the scope of this paper.

# 8 Conclusion

This paper studies a land use regulation reform focused on accessory dwelling units. I find that upzoning has a causal effect on housing supply, which is in line with this paper's theoretical prediction that local homeowner-driven control will result in strong limits on local construction and that lifting that control will increase the production of ADUs. Exploiting variation between single- and two- or three-family zones, I find a single-family zone experienced .04-.05 more ADUs than a two- or three-family zone. Furthermore, I assess whether ADUs can ease rent prices. I first estimate the supply effect of ADUs using economic theory and then estimate the effect of ADUs in a linear panel model. The effect is statistically indistinguishable from zero, and my theoretical analysis argues that a plausible effect is no larger than a two to three percent reduction in rent prices. Finally, I find that ADUs do not impose a nuisance effect on neighbors. My confidence interval excludes effects larger than a three percent reduction in home values.

These findings contribute to the growing body of literature suggesting that land use regulations are a major barrier to housing construction. California's policy relied on individual homeowners adding units, and upzoning still caused an increase in housing supply. Furthermore, my findings on the nuisance effect contribute to the literature on the effects of new construction by studying these issues in the context of "gently" upzoned single-family neighborhoods.

Policymakers should note California's successful state-level preemption of local regulations. By establishing a right to construction, California was largely successful in removing local barriers, in whatever form they appeared. However, if policymakers want address housing shortages, they should be skeptical of ADUs as housing supply. Housing infill on single-family zones through ADUs is an inadequate strategy to ease rising house and rent prices, and perhaps stronger upzoning measures should be considered.

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# A Proofs

## Proof of Proposition 1

*Proof.* Homeowners take their housing consumption and the price of housing as given. They are then given the choice to collectively set $\alpha$. Note that when homeowners collectively choose $\alpha$, they are no longer price takers for rental housing, so $p_r$ will depend on $\alpha$. Let $p_r^*(\alpha)$ denote the equilibrium rent price for a given choice of $\alpha$. Substituting the budget constraint into the homeowner's objective function yields the following maximization problem:

$$\max_{\alpha}\left[\frac{1}{\tilde{D}(\alpha)}\frac{h_s^{1+\gamma}}{1+\gamma}+w_h+p_r^*(\alpha)\alpha\frac{\ell_s}{H_c}-\sigma_a\frac{\alpha^2}{2}\frac{\ell_s}{H_c}-p_sh_s\right]$$

Differentiating with respect to $\alpha$ yields

$$\frac{d}{d\alpha}\left(\frac{1}{\tilde{D}(\alpha)}\right)\frac{h_s^{1+\gamma}}{1+\gamma}+\frac{dp_r^*(\alpha)}{d\alpha}\alpha\frac{\ell_s}{H_c}+\frac{\ell_s}{H_c}p_r^*(\alpha)-\sigma_a\alpha\frac{\ell_s}{H_c}$$

The goal of this proof is to show that this derivative is negative. Rearranging this expression yields

$$\overbrace{\frac{h_s^{1+\gamma}}{1+\gamma}\frac{d}{d\alpha}\left(\frac{1}{\tilde{D}(\alpha)}\right)+\frac{\ell_s}{H_c}\left(p_r^*(\alpha)-\sigma_a\alpha\right)}^{(A)}+\overbrace{\frac{dp_r^*(\alpha)}{d\alpha}\alpha\frac{\ell_s}{H_c}}^{(B)}$$

where showing that (A) and (B) are negative completes the proof.

1. $(B) < 0$. Starting with (B), we must characterize $p_r^*(\alpha)$. Demand for rental housing is given by the first order condition of the renter's problem: $h_r^\eta - p_r = 0$. The second order condition is met since $\eta h_r^{\eta-1} < 0$ since $\eta < 0$. Therefore, the demand for rental housing at $p_r$ is $p_r^{\frac{1}{\eta}}$. The first order condition of the developer's problem is given by $p_r \ell_r - \delta \sigma_r \ell_r = 0$, which implies $\delta^* = \frac{p_r}{\sigma_r}$. The second order condition is met since $-\sigma_r \ell_r$ is negative. The supply of apartments is $\ell_r \frac{p_r}{\sigma_r}$. Hence, the overall supply of rental housing is given by $\alpha \ell_s + \frac{p_r}{\sigma_r} \ell_r$ and the demand for rental housing is $p_r^{1/\eta}$. Since markets clear, we have

$$\alpha \ell_s + \frac{p_r}{\sigma_r} \ell_r = p_r^{1/\eta}$$

A closed form expression for $p_r$ is not feasible, but let $p_r^*(\alpha)$ denote the solution to the above expression. Then, we have that

$$p_r^*(\alpha)^{\frac{1}{\eta}} - \frac{\ell_r}{\sigma_r} p_r^*(\alpha) - \alpha \ell_s = 0$$

From the implicit function theorem, it follows that

$$\frac{1}{\eta} p_r^*(\alpha)^{\frac{1}{\eta}-1} \frac{dp_r^*(\alpha)}{d\alpha} - \frac{\ell_r}{\sigma_r} \frac{dp_r^*(\alpha)}{d\alpha} - \ell_s = 0 \implies \frac{dp_r^*(\alpha)}{d\alpha} = \ell_s \left( \frac{1}{\eta} p_r^*(\alpha)^{\frac{1}{\eta}-1} - \frac{\ell_s}{\sigma_r} \right)^{-1}$$

Note that $\eta$ is negative, $p_r^*(\alpha)$ is non-negative, and $\ell_s, \sigma_r$ are positive. Hence, we have that $\frac{dp_r^*(\alpha)}{d\alpha} < 0$.

2. $(A) < 0$. Note the left-hand term is negative since, by the chain rule, it equals

$$\frac{-1}{\tilde{D}(\alpha)^2} \frac{d\tilde{D}(\alpha)}{d\alpha} \frac{h_s^{1+\gamma}}{1+\gamma} < 0$$

and $\tilde{D}$ is increasing in $\alpha$, housing consumption is positive, and $\gamma > -1$ in the setup of the homeowner's problem. By A2, (A) is therefore negative since the magnitude of the left-hand term of (A) exceeds the magnitude of the right-hand term. □

## Proof of Proposition 2

*Proof.* In the individual equilibrium, substituting the budget constraint into the objective function, the homeowner solves

$$\max_{h_s, \alpha} \left[ \frac{1}{\tilde{D}} \frac{h_s^{1+\gamma}}{1+\gamma} + w_h + p_r \alpha \frac{\ell_s}{H_c} - \sigma_a \frac{\alpha^2}{2} \frac{\ell_s}{H_c} - p_s h_s \right]$$

The first order condition with respect to $\alpha$ is

$$p_r \frac{\ell_s}{H_c} - \sigma_a \frac{\ell_s}{H_c} \alpha = 0$$

Since $\frac{\ell_s}{H_c} > 0$ by construction, we may divide by it and rearrange to get that $\alpha^* = \frac{p_r}{\sigma_a}$. Hence, the supply of ADUs is given by $\ell_s \frac{p_r}{\sigma_a}$. The optimal $h_s$ and the second order conditions are checked in the proof of Proposition 5. From the proof of Proposition 1, we have that the supply of apartments is $\ell_r \frac{p_r}{\sigma_r}$. Hence, the overall supply of rental housing is as desired. □

## Proof of Proposition 3

*Proof.* From the proof of Proposition 1, we have that the supply of rental housing is $\ell_r \frac{p_r}{\sigma_r}$ and rental demand is $h_r = p_r^{\frac{1}{\eta}}$ in collective equilibrium. From the market clearing condition, we have that equilibrium price is:

$$p_r^{1/\eta} = \ell_r \frac{p_r}{\sigma_r} \implies p_r^* = \left(\frac{\ell_r}{\sigma_r}\right)^{\frac{\eta}{1-\eta}}$$

Plugging back into the rental demand curve yields that collective equilibrium rental housing supply is:

$$h_r^* = \left(\frac{\ell_r}{\sigma_r}\right)^{\frac{1}{1-\eta}}$$

In individual equilibrium, the supply curve is given as in Proposition 2 and the demand curve remains unchanged. The same algebra as above yields that equilibrium rental housing supply is:

$$h_r'^* = \left(\frac{\ell_r}{\sigma_r} + \frac{\ell_s}{\sigma_a}\right)^{\frac{1}{1-\eta}}$$

Then, the ratio of housing in individual equilibrium to housing in collective equilibrium is given by

$$\begin{aligned}
\frac{h_r'^*}{h_r^*} &= \frac{\left(\frac{\ell_r}{\sigma_r} + \frac{\ell_s}{\sigma_a}\right)^{\frac{1}{1-\eta}}}{\left(\frac{\ell_r}{\sigma_r}\right)^{\frac{1}{1-\eta}}} \\
&= \left(\frac{\frac{\ell_r}{\sigma_r} + \frac{\ell_s}{\sigma_a}}{\frac{\ell_r}{\sigma_r}}\right)^{\frac{1}{1-\eta}} \\
&= \left(1 + \frac{\ell_s \sigma_r}{\ell_r \sigma_a}\right)^{\frac{1}{1-\eta}}
\end{aligned}$$

which is the desired equation. □

## Proof of Proposition 4

*Proof.* The equilibrium price is given by $p_r^* = h_r^{*\eta}$ by rearranging the market clearing condition. Next, assume homeowners individually optimize and produce ADUs. Denote the equilibrium supply curve as $h_r'^*$ and note that the rental demand curve remains unchanged as $p_r^{\frac{1}{\eta}}$. Then, equilibrium price $p_r'^* = h_r'^{*\eta}$ by the market clearing condition again. It follows that $\frac{p_r'^*}{p_r^*} = \left(\frac{h_r'^*}{h_r^*}\right)^{\eta}$, where taking the log on both sides yields the desired equation. □

## Proof of Proposition 5

*Proof.* Developers provide single family homes with supply curve $\ell_s \frac{p_s}{\sigma_s}$, adapting the solution to the developer's problem in the proof of Proposition 1. Turning to the homeowner's problem, from the proof of Proposition 2, we have that the homeowner's problem is:

$$\max_{h_s,\alpha} \left[ \frac{1}{\tilde{D}} \frac{h_s^{1+\gamma}}{1+\gamma} + w_h + p_r \alpha \frac{\ell_s}{H_c} - \sigma_a \frac{\alpha^2}{2} \frac{\ell_s}{H_c} - p_s h_s \right]$$

We know $\alpha^* = \frac{p_r}{\sigma_a}$. Differentiating with respect to $h_s$ yields first order condition

$$\frac{h_s^{\gamma}}{\tilde{D}} - p_s = 0 \implies h_s^* = (p_s \tilde{D})^{1/\gamma}$$

Verifying the second order conditions, we have that

$$\frac{\partial}{\partial \alpha^2} = -\sigma_a h_s \text{ and } \frac{\partial}{\partial h_s^2} = \gamma \frac{h_s^{\gamma-1}}{\tilde{D}}$$

These are both negative at $h_s^*$ since $h_s^*$ is positive. The cross partial is zero. Hence, the second order condition is satisfied. Setting home supply equal to demand yields

$$\frac{\ell_s}{\sigma_s} p_s = (p_s \tilde{D})^{1/\gamma} \implies p_s^* = \left(\frac{\ell_s}{\sigma_s}\right)^{\frac{\gamma}{1-\gamma}} \frac{1}{\tilde{D}}^{\frac{1}{1-\gamma}}$$

Taking logs,

$$\log(p_s^*) = \frac{\gamma}{\gamma-1} \log(\sigma_s) - \frac{\gamma}{\gamma-1} \log(\ell_s) + \frac{1}{\gamma-1} \log(o(\bar{\alpha}^*)) + \sum_{j \neq i} \frac{1-d_j}{\gamma-1} \log(n(\alpha_j^*))$$

□

# B Additional Tables

# C Additional Figures

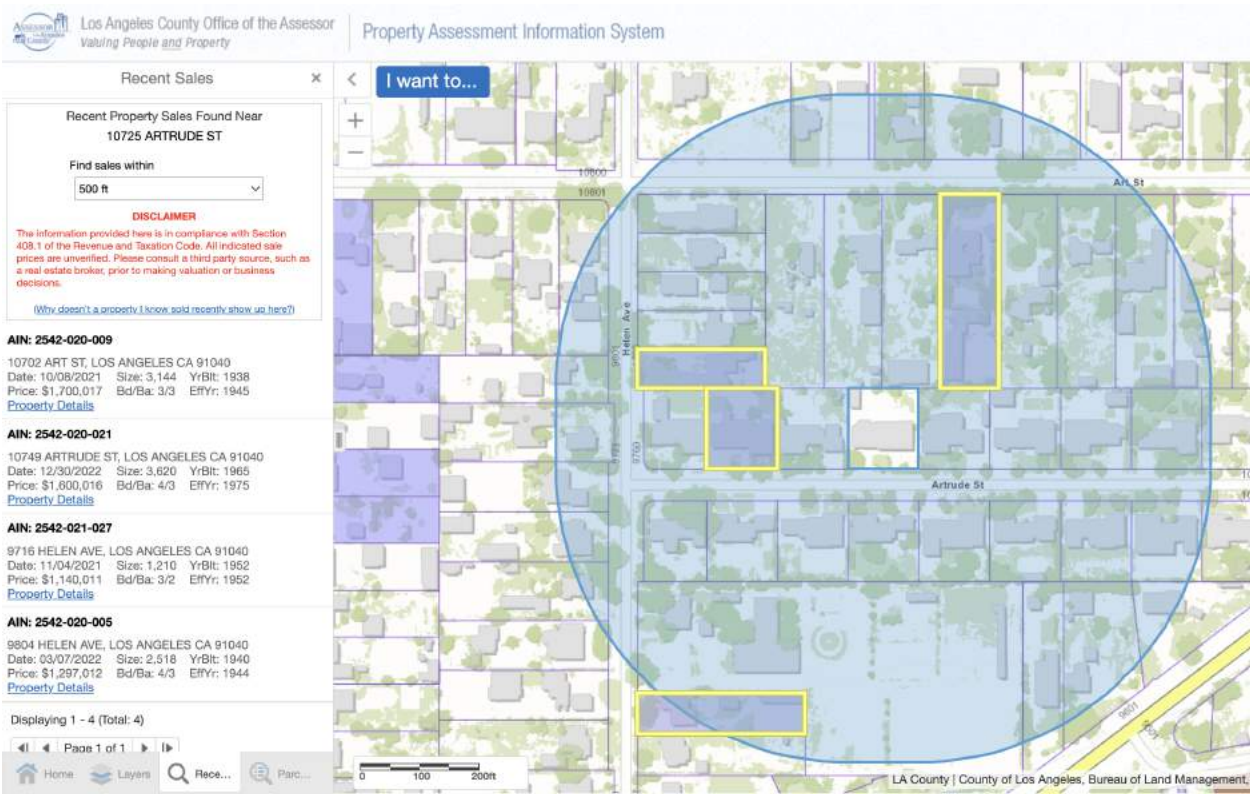



**Figure 17: Example of Los Angeles Property Assessment Information Map.** This figure shows searching for a house that has had added an ADU and the nearby property transactions.

| | ADUs Permitted | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Single Family | $-0.0001$ | 0.0012 | $0.0109^{**}$ |
| | (0.0048) | (0.0041) | (0.0043) |
| Median Income (Thousands) | | $-0.00005^{**}$ | $0.0002^{**}$ |
| | | (0.00002) | (0.0001) |
| Population (Thousands) | | $0.0015^{**}$ | 0.0016 |
| | | (0.0006) | (0.0030) |
| Pct Married | | $-0.0001$ | $-0.0004^{**}$ |
| | | (0.0001) | (0.0002) |
| Single Family x 2015 | $-0.00002$ | $-0.0001$ | $-0.0001$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2016 | $-0.0003$ | $-0.0001$ | $-0.0002$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2017 | $0.0354^{***}$ | $0.0352^{***}$ | $0.0350^{***}$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2018 | $0.0548^{***}$ | $0.0567^{***}$ | $0.0565^{***}$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2019 | $0.0586^{***}$ | $0.0605^{***}$ | $0.0602^{***}$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2020 | $0.0417^{***}$ | $0.0429^{***}$ | $0.0426^{***}$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2021 | $0.0475^{***}$ | $0.0504^{***}$ | $0.0499^{***}$ |
| | (0.0068) | (0.0058) | (0.0056) |
| Single Family x 2022 | $0.0328^{***}$ | | |
| | (0.0068) | | |
| Constant | 0.0005 | 0.0001 | $-0.0393$ |
| | (0.0037) | (0.0045) | (0.0699) |
| *N* | 207,684 | 155,478 | 155,478 |
| $R^2$ | 0.0080 | 0.0127 | 0.0692 |
| Adjusted $R^2$ | 0.0079 | 0.0126 | 0.0623 |
| *Notes:* | $^{***}$Significant at the 1 percent level. | | |
| | $^{**}$Significant at the 5 percent level. | | |
| | $^{*}$Significant at the 10 percent level. | | |

**Table 7: Dynamic Difference in Difference on ADUs Permitted Between Single vs Two/Three Family Zones.** This table presents regressions from the specification in Equation 7, which is a dynamic difference-in- difference on the ADUs permitted between single-family and two/three-family zones. Column (1) presents the regression without controls, while column (2) adds controls for median income, population, and percent households married and (3) adds zone fixed effects. The 2022 coefficient is missing in (2) and (3) since the ACS data used for the control variables is not available in 2022. *Data Sources: Building Permit Data, Zoning Data, ACS*

| | ADUs Constructed | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Pct Single Family | $-0.019$ | $-0.001$ | $-0.171^{*}$ |
| | (0.106) | (0.107) | (0.103) |
| Median Income | | $-0.001^{***}$ | $0.001^{**}$ |
| | | (0.001) | (0.001) |
| Population | | 0.00001 | $0.0001^{***}$ |
| | | (0.00001) | (0.00001) |
| Pct Married | | $-0.0005$ | $0.003^{**}$ |
| | | (0.001) | (0.001) |
| Pct Single Family x 2016 | 0.023 | 0.021 | 0.029 |
| | (0.150) | (0.150) | (0.144) |
| Pct Single Family x 2017 | 0.173 | 0.173 | 0.181 |
| | (0.150) | (0.150) | (0.144) |
| Pct Single Family x 2018 | $0.709^{***}$ | $0.714^{***}$ | $0.723^{***}$ |
| | (0.150) | (0.150) | (0.144) |
| Pct Single Family x 2019 | $1.123^{***}$ | $1.133^{***}$ | $1.143^{***}$ |
| | (0.150) | (0.150) | (0.144) |
| Pct Single Family x 2020 | $1.426^{***}$ | $1.438^{***}$ | $1.449^{***}$ |
| | (0.150) | (0.150) | (0.144) |
| Pct Single Family x 2021 | $1.260^{***}$ | $1.274^{***}$ | $1.277^{***}$ |
| | (0.150) | (0.150) | (0.144) |
| Constant | 0.018 | 0.083 | $-0.168^{*}$ |
| | (0.074) | (0.101) | (0.098) |
| *N* | 3,969 | 3,955 | 3,955 |
| $R^2$ | 0.231 | 0.235 | 0.296 |
| Adjusted $R^2$ | 0.228 | 0.232 | 0.292 |

*Notes:* $^{***}$Significant at the 1 percent level.
$^{**}$Significant at the 5 percent level.
$^{*}$Significant at the 10 percent level.

**Table 8: Tract-Level Linear Panel Model on ADUs Constructed.** This table estimates a first-stage to the census tracts regression, with the outcome as number of ADUs constructed. The treatment variable is the percentage of a census tract that is single-family zoned as a scalar treatment variable. Column (1) is just fitted on the interaction between years and the treatment variable. Column (2) adds controls for median income, population, and percent households married and (3) adds city fixed effects. The base year is 2015. *Data Sources: Building Permit Data, Zoning Data, ACS*

| | ADUs Constructed | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Value to Replacement Ratio | 1.750*** | 2.052*** | 1.015** |
| | (0.226) | (0.292) | (0.407) |
| Median Income | | −0.027*** | −0.041*** |
| | | (0.009) | (0.012) |
| Population | | 0.170*** | 0.147*** |
| | | (0.012) | (0.012) |
| Median Age | | 0.208*** | 0.164*** |
| | | (0.043) | (0.044) |
| Pct Households Married | | −0.101*** | −0.023 |
| | | (0.017) | (0.026) |
| Constant | 1.464*** | −5.279*** | −10.209*** |
| | (0.543) | (1.890) | (2.739) |
| *N* | 2,952 | 2,952 | 2,952 |
| $R^2$ | 0.020 | 0.100 | 0.162 |
| Adjusted $R^2$ | 0.020 | 0.098 | 0.154 |

*Notes:* ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

**Table 9: ADU Construction and Ratio of Home Value to Replacement Cost.** This table regresses the number of ADUs constructed on the ratio of home value to construction costs. This is done at the zip-code level. Column (1) is just a univariate regression, (2) adds controls for income, popoluation, age, and percent of households married. Column (3) adds year and metro area fixed effects. *Data Sources: BuildZoom Data*

| | Synthetic Log Rent | | | |
|---|---|---|---|---|
| | $\frac{1}{\eta} = -1.28$ | -.71 | -.56 | -.17 |
| Pct Single Family | 0.065536** | 0.065536** | 0.065536** | 0.065536** |
| | (0.029247) | (0.029236) | (0.029231) | (0.029308) |
| Pct Single Family x 2016 | −0.000018 | −0.000033 | −0.000042 | −0.000138 |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Pct Single Family x 2017 | −0.000354 | −0.000638 | −0.000809 | −0.002666 |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Pct Single Family x 2018 | −0.001686 | −0.003039 | −0.003854 | −0.012694 |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Pct Single Family x 2019 | −0.003992 | −0.007196 | −0.009124 | −0.030056 |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Pct Single Family x 2020 | −0.006742 | −0.012154 | −0.015410 | −0.050761 |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Pct Single Family x 2021 | −0.009330 | −0.016820 | −0.021325 | −0.070249* |
| | (0.041361) | (0.041345) | (0.041339) | (0.041447) |
| Constant | 7.140059*** | 7.140059*** | 7.140059*** | 7.140059*** |
| | (0.020273) | (0.020266) | (0.020263) | (0.020316) |
| *N* | 3,941 | 3,941 | 3,941 | 3,941 |
| $R^2$ | 0.008112 | 0.007636 | 0.007404 | 0.007508 |
| Adjusted $R^2$ | 0.004828 | 0.004351 | 0.004118 | 0.004223 |

*Notes:* ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

**Table 10: Tract-Level Linear Panel Model on Simulated Log Rent.** This table reports the results of a regression that uses percentage of a census tract that is single-family zoned as a scalar treatment variable. I regress a simulated log rent price on the treatment variable interacted that with year indicators. Each column uses a different construction of the simulated log rent price using a different elasticity value $\frac{1}{\eta}$.

| | Log Value | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| After ADU Built | 0.1191* | 0.0903 | 0.0404 |
| | (0.0612) | (0.0582) | (0.0505) |
| Within 250 Meters | 0.1913** | 0.1999** | 0.1295* |
| | (0.0813) | (0.0775) | (0.0673) |
| Lot Area | | 0.0002*** | 0.0002*** |
| | | (0.00003) | (0.00002) |
| Year Built | | −0.0006 | 0.0007 |
| | | (0.0010) | (0.0009) |
| Number of Beds | | 0.0598*** | 0.0403*** |
| | | (0.0134) | (0.0116) |
| After ADU Built x Within 250 Feet | −0.1334 | −0.1125 | −0.0633 |
| | (0.1110) | (0.1057) | (0.0918) |
| Constant | 14.2899*** | 14.8261*** | 12.2301*** |
| | (0.0449) | (1.8633) | (1.6641) |
| *N* | 447 | 444 | 444 |
| $R^2$ | 0.0188 | 0.1398 | 0.3653 |
| Adjusted $R^2$ | 0.0121 | 0.1280 | 0.3507 |

*Notes:* ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

**Table 11: Difference-in-Difference on Assessed Value Between Properties Near and Far from ADU Construction in San Francisco.** This table reports the results of estimating Equation 11 in San Francisco. Here, $d$ is taken to be 500 meters, and thus units within 250 meters are considered treated. Column (1) is the bare-bones regression. Column (2) adds controls, and (3) adds $ADU(i)$ fixed effects. *Data Sources: San Francisco Assessed Value Data, Building Permit Data*

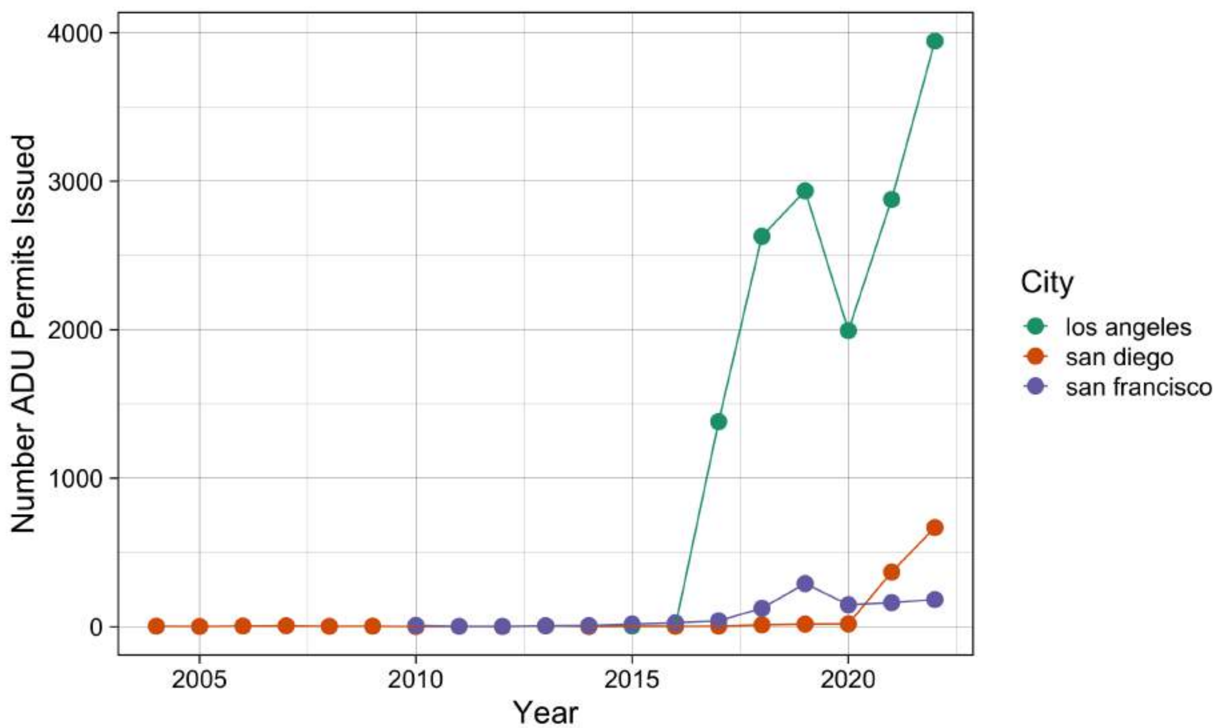
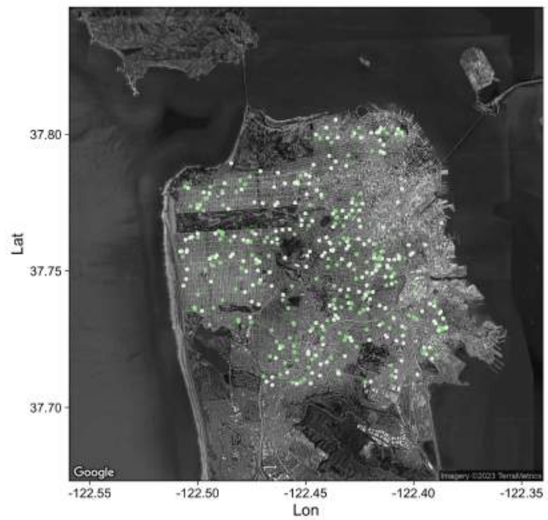
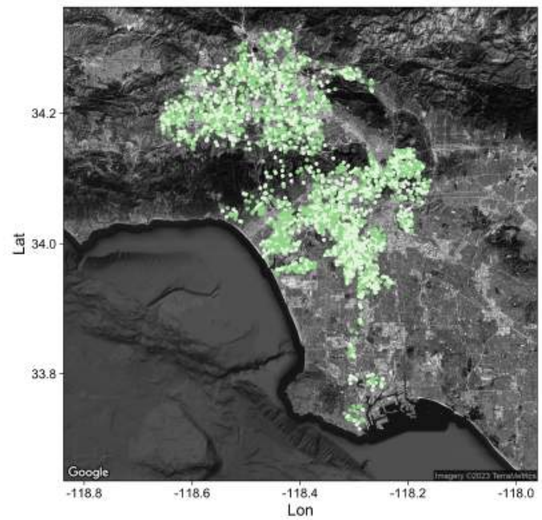


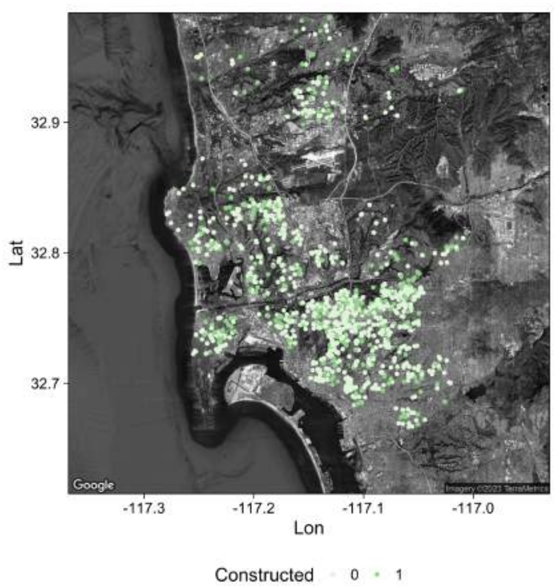

**Figure 18: Number of ADU Permits over Time by City.** This figure plots the number of permits issued each year over time, but separates the data by the cities in the sample. There are less than 5 permits issued each year before 2017, and the years without dots represents no permits issued. *Data Sources: Building Permit Data*




**(a)** San Francisco




**(b)** Los Angeles




**(c)** San Diego

**Figure 19: Map of ADU Permits.** This figure plots each of the issued ADU permits from 2010-2022 in each city. The darker green dots represent the permitted ADUs that have been constructed. *Data Sources: Building Permit Data, Google Maps Static Images*

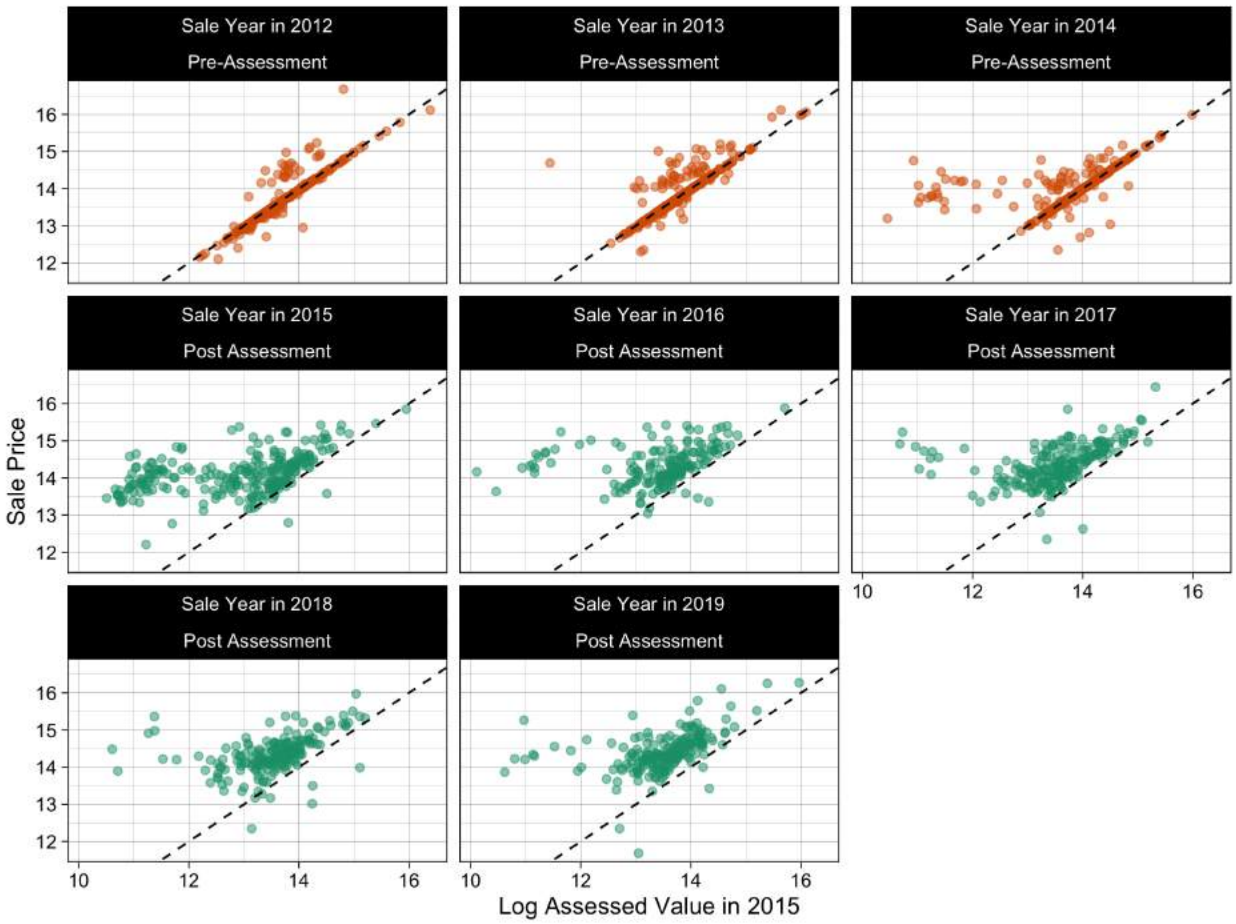
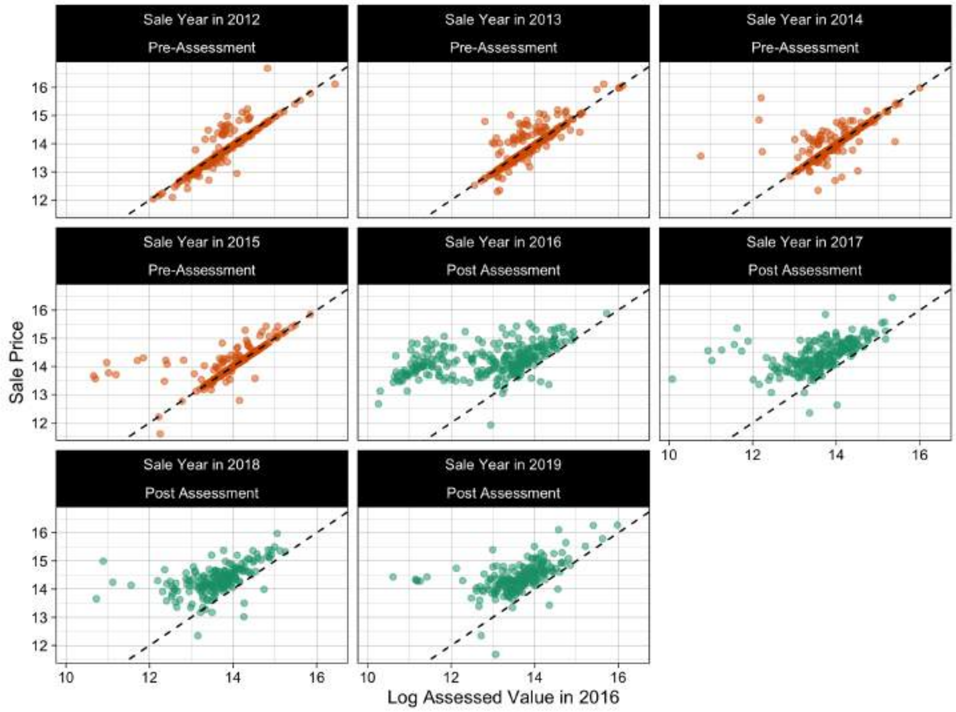
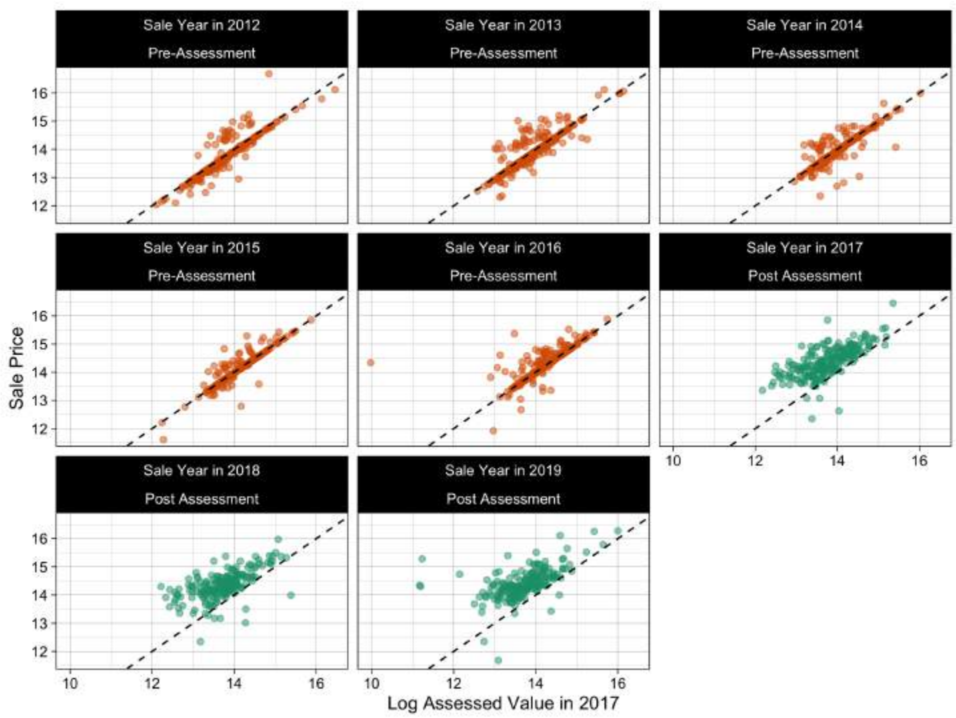



**Figure 20: Comparison of Assessed Values in 2015 to Sale Prices.** This figure plots properties' assessed values in 2015 against the last sale price of that property. This is indexed by year of sale since some properties have different years of last sale. *Data Sources: Assessed Value Data*

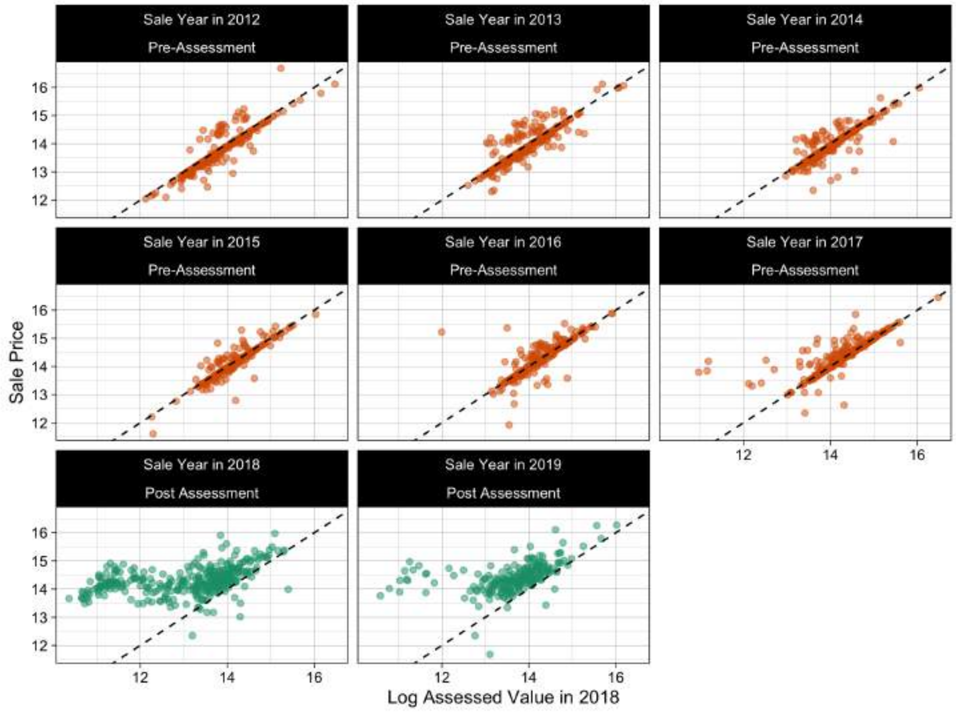



**(a)** 2016

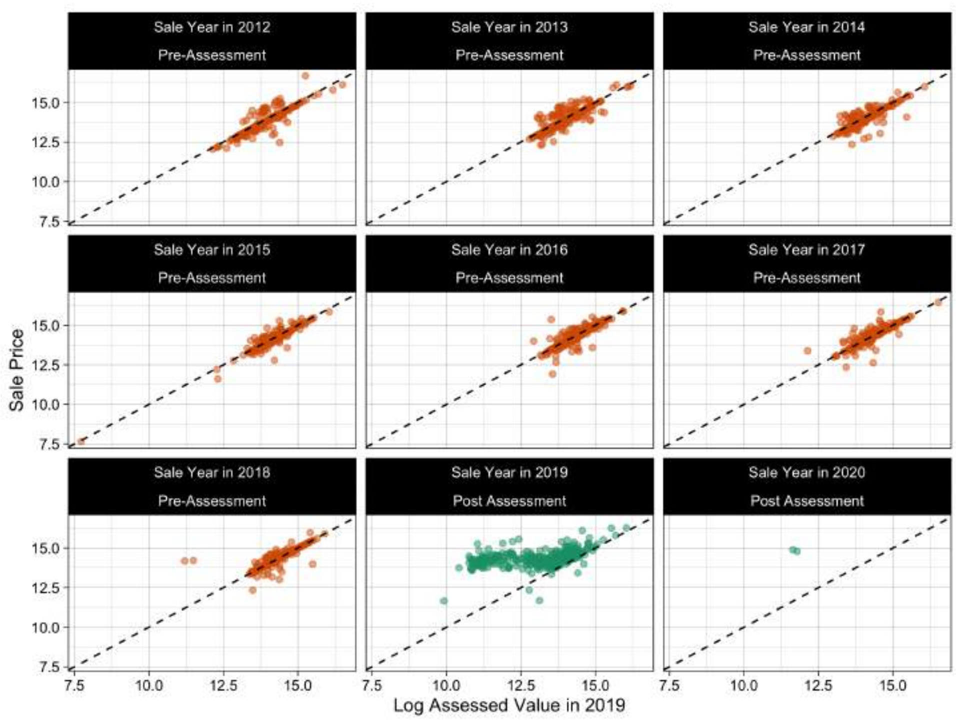



**(b)** 2017

**Figure 21: Comparison of Assessed Values to Sale Prices, 2016 and 2017.** Each subfigure plots properties' assessed values in a particular year against the last sale price of that property. In each subfigure, an observation in the scatterplot is a property with an assessed value recorded in some year on the x-axis and the sale price on the y-axis. This is indexed by year of sale since some properties have different years of last sale. This plot covers 2016 and 2017 assessed values. *Data Sources: Assessed Value Data*




**(a)** 2018




**(b)** 2019

**Figure 22: Comparison of Assessed Values to Sale Prices, 2018 and 2019.** Each subfigure plots properties' assessed values in a particular year against the last sale price of that property. In each subfigure, an observation in the scatterplot is a property with an assessed value recorded in some year on the x-axis and the sale price on the y-axis. This is indexed by year of sale since some properties have different years of last sale. This plot covers 2018 and 2019 assessed values. *Data Sources: Assessed Value Data*

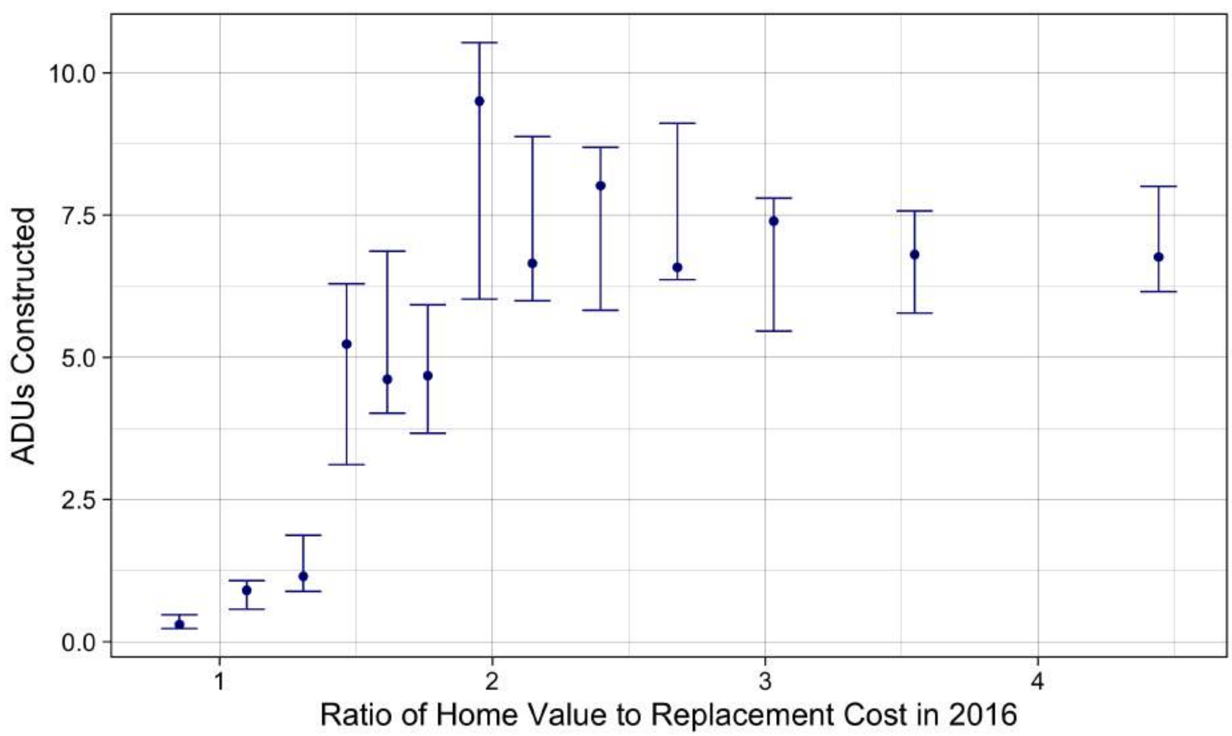



**Figure 23: Binscatter of ADUs Constructed on Value to Replacement Ratio.** This figure plots a binscatter of the number of ADUs constructed in a zip-code in California from 2018-2020 by the value to replacement ratio of the zip-code in 2016. *Data Sources: California ADU Data, BuildZoom Data*

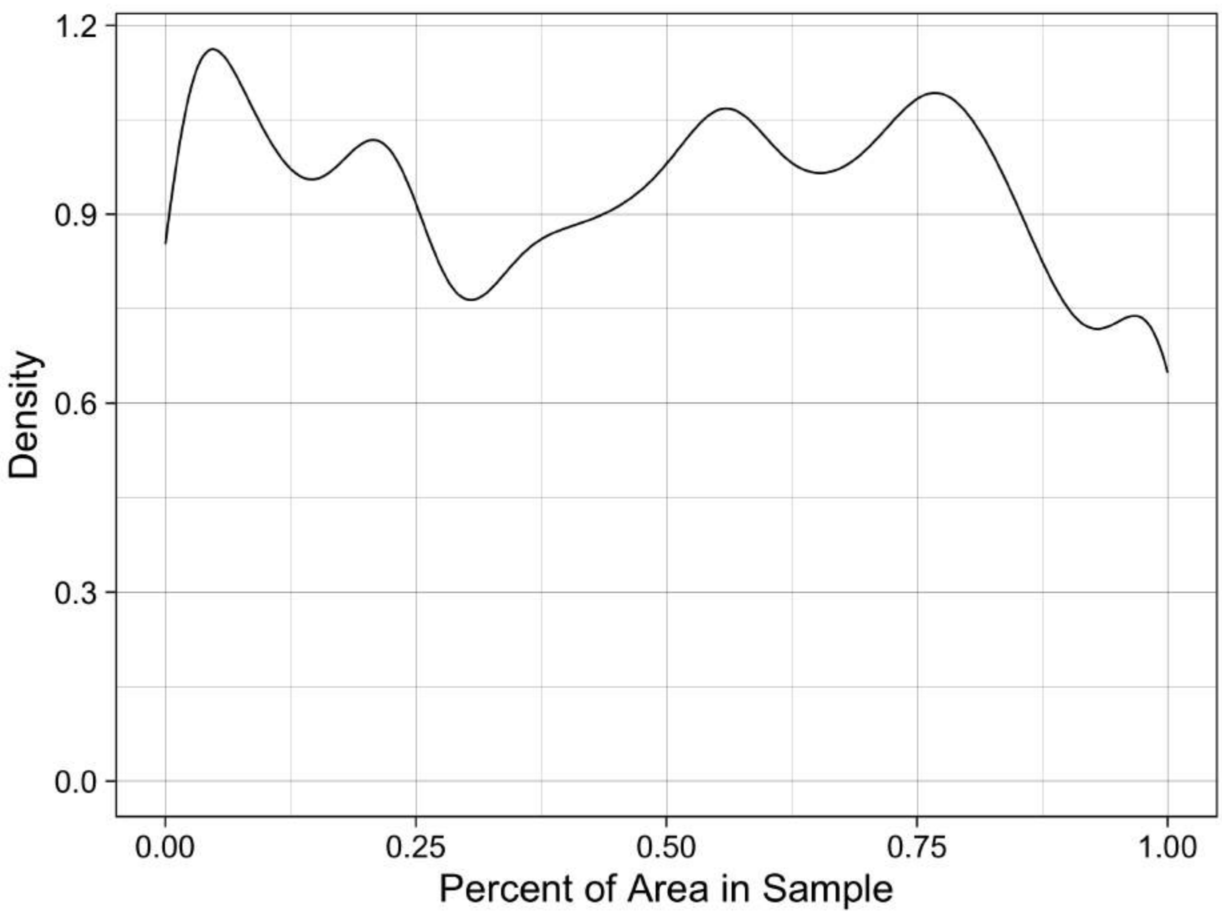
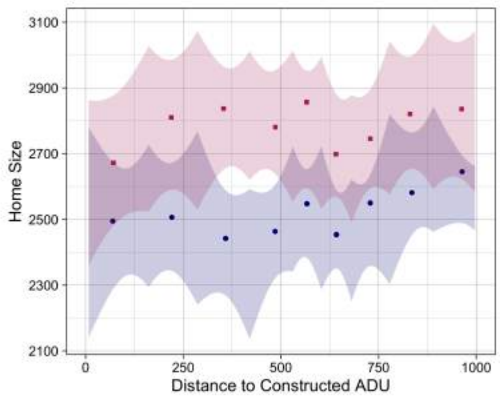
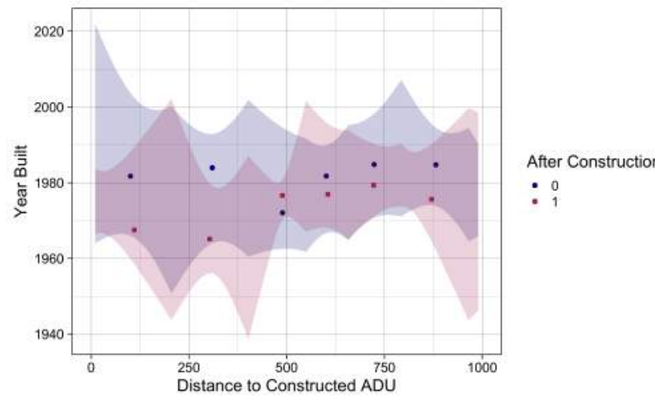


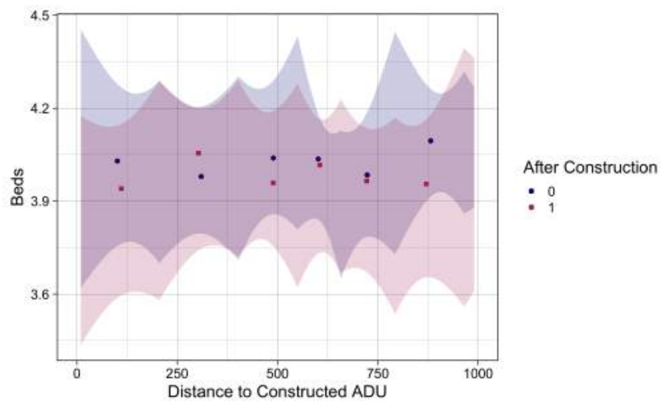

**Figure 24: Density of Percent of Tract in Sample** This figure plots the density of the proportion of the area of the tract that is residentially zoned (ie single, two, or three family zoned). I refer to this as "in-sample" since I compare single family zones to two/three family zones. Estimation is done with a kernel density estimator with Gaussian kernel and nrdo bandwidth selection. *Data Sources: ACS, Zoning Data*




**(a)** Floor Area

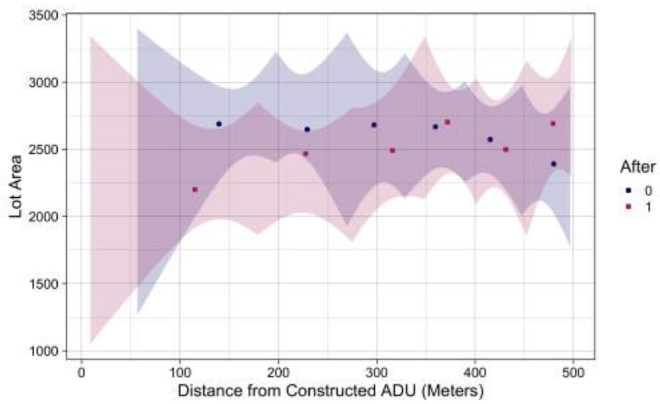



**(b)** Year Property Built

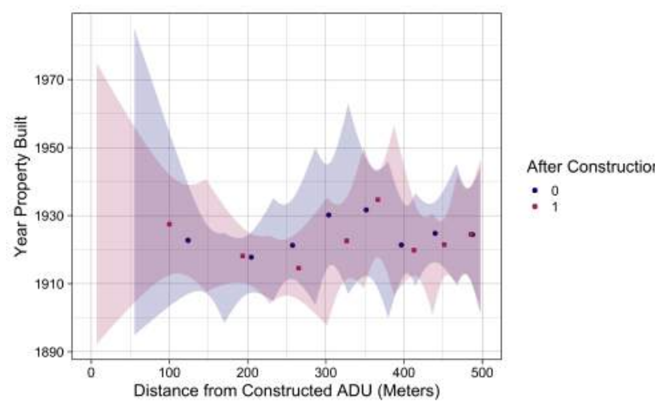



**(c)** Beds

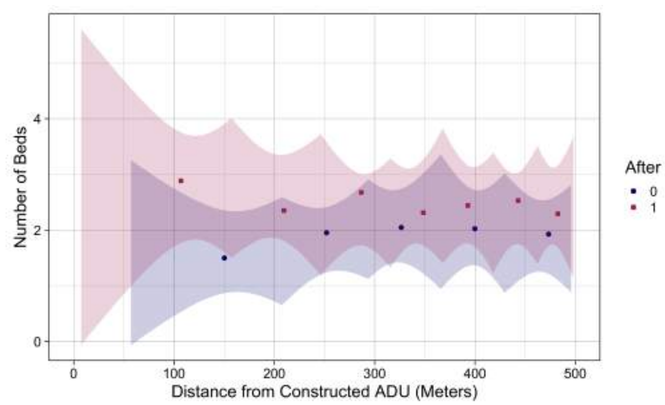
**Figure 25: Balancing Tests with Areas around ADUs in Los Angeles.** This figure reports the characteristics of assessed properties plotted against distance from the location of constructed ADUs two years before and after the ADU's construction. These are coupled with uniform confidence bands on the points. *Data Sources: Building Permit Data, Los Angeles Property Value Data*




**(a)** Floor Area




**(b)** Year Property Built




**(c)** Beds

**Figure 26: Balancing Tests with Areas Around ADUs in San Francisco.** This figure reports the characteristics of assessed properties plotted against distance from the location of constructed ADUs two years before and after the ADU's construction. These are coupled with uniform confidence bands on the points. *Data Sources: Building Permit Data, San Francisco Assessed Value Data*