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Overseeing Infill

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Title: Overseeing Infill: How State Agencies Can More Effectively Monitor Local Land-Use Administration

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Problem, Research Strategy, and Findings: Several US states with high housing costs have recently adopted laws intended to promote infill development. These new laws expand state agencies' supervisory responsibilities to ensure that local governments comply with state mandates. Effective administration of these laws will require state agencies to accurately estimate the amount of new housing that might be created, and to target review to the jurisdictions that are failing to meet the relevant requirements. This article presents quantitative tools both for prioritizing review of local plans and zoning ordinances and for estimating future housing development. We apply the tools to the implementation of California laws requiring local governments to amend their zoning ordinances to allow accessory dwelling units on parcels zoned for detached single-family housing development. We provide computer code, written in the open-source statistical computing language R, that implements these tools. Although we present off-the-shelf tools, our proposed tools should supplement other regulatory techniques rather than serving as a substitute.

Takeaway for Practice: Requirements for local governments to allow infill development should be accompanied by mandates for data collection. With good data, state agencies can use open-source statistical software to create quantitative measures that can help to estimate future housing production and set priorities for reviewing local plans and zoning ordinances.

Keywords: Zoning; land-use planning; regulation; infill development; housing

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Introduction

Since the mid-2010s, several US states with high housing costs have adopted significant laws intended to promote infill development (Infranca, 2019; Schuetz, 2022; Wegmann, 2020). The relevant laws include those requiring local governments to plan and zone for multifamily housing and authorizing the development of accessory dwelling units (ADUs) and duplexes on parcels zoned for detached single-family development. All of these laws are intended to boost the supply (and reduce the cost) of market-rate housing in already developed areas, and some of them also attempt to increase the supply of below-market-rate housing.

Under these new laws, described below, zoning and land use regulation remain predominantly local activities, but state agencies have expanded supervisory responsibilities to ensure that local plans and zoning ordinances comply with the state mandates. In some cases, the state agencies must also forecast housing production or review cities’ forecasts.

This article introduces two models to help with these tasks. The first model is designed to help state oversight agencies set enforcement and technical assistance priorities. With limited staffing and many competing responsibilities, the state agencies charged with oversight simply cannot provide an exhaustive review of every local implementation ordinance. We propose that state agencies prioritize review of cities whose past housing production has been especially low relative to potential. In order to identify significant differences (if any) between local governments in realizing this potential, this first model assesses the raw potential for new housing within a jurisdiction, given market conditions and parcel characteristics.

The first model intentionally omits characteristics that may affect the politics of housing-development approvals. Instead, it treats local governments as black boxes—the model indicates *whether* a city has previously fallen short of its potential, in comparison to other jurisdictions, not *why*. The second model cracks open the black box, incorporating jurisdiction-level features (such as the density of homeowners' associations) that may influence the politics of housing approvals, and could therefore affect the number of units permitted. This second model also enables regulators to account for the availability of additional sites suitable for different types of development.

We apply these two models to the implementation of California laws requiring local governments to allow ADUs on parcels zoned for detached single-family housing development. As we explain below, the specific case of ADUs generalizes to oversight strategies for a variety of other state-level reforms adopted in states such as California, Oregon, Washington, and Massachusetts, as well as reforms that have been proposed in states such as New York and Colorado. The computer code, which is written in the open-source statistical computing language R, is publicly available (Marantz et al., 2023).

The article proceeds as follows: First, we describe the general structure and features of recent state laws requiring state agency review of local planning and zoning ordinances, and we briefly describe the challenge of regulatory oversight. Second, we present the pertinent details of an important example of the new state laws: California's efforts to facilitate ADU permitting on single-family parcels. Third, we apply our models and explain how the California state agency charged with reviewing local plans and zoning ordinances could use these models. Fourth, we discuss other potential applications of the tools introduced in this article, as well as the broader implications: Requirements for local governments to allow infill development should be accompanied by data collection, because – with good data – state agencies can create quantitative measures to estimate future development and to set priorities for reviewing local plans and zoning ordinances.

The new state laws

The regulation of land-use and housing development has traditionally been a local affair. Although the underlying authority derives from states’ police power, i.e., the “general power of governing, possessed by the States but not by the Federal Government” (*Nat’l Fed’n of Indep. Bus. v. Sebelius*, 2012, p. 536), states in the early 20th century adopted laws delegating their land-use authority to local governments. Many states relied on model legislation published by the US Department of Commerce (Knack et al., 1996).

In recent years, however, some states have sought to curb local authority in order to address the twin crises of climate change and rapidly escalating housing costs by promoting infill development. The impetus for this shift is continued localized resistance to infill development, particularly in neighborhoods where existing laws allow only detached single-family housing (Manville et al., 2019; Wegmann, 2020). It is widely recognized that infill development is an important strategy for reducing per-capita vehicle miles traveled, thereby curbing greenhouse gas emissions (Ewing & Cervero, 2017). Constraints on housing supply, including limitations on increased density in existing residential neighborhoods, are a major driver of high housing costs in many metropolitan areas (Glaeser & Gyourko, 2018). Moreover, focusing residential construction in places with substantial existing development could reduce the risks from wildfires in the western US, because such risks are significantly larger for communities at and beyond the urban fringe.

The new state reforms that we describe below *do not* replace local planning and zoning with a statewide zoning map. Instead, the new laws set standards for local plans and zoning ordinances, task local governments with revising their plans and ordinances accordingly, and in some cases piggyback on local zoning by stipulating that if a city has zoned a parcel for one type of use (e.g., single-family homes) then it must allow certain other uses too (e.g., ADUs).

There are good reasons for states to deploy this form of regulatory design, but it introduces substantial challenges for state oversight. As a practical matter, local officials may be best situated – by virtue of proximity – to determine appropriate uses for any particular parcel of land. Moreover, complete state preemption could magnify the already substantial political opposition to the relevant reforms. On the other hand, reforms are necessary precisely because local governments have long resisted accommodating infill development. Thus, states need some strategy for reviewing the adoption and implementation of local plans and zoning ordinances.

In the remainder of this section, we describe two types of recently adopted laws. The first type relates to planning and zoning for multifamily housing. The second type relates to the liberalization of local laws governing the development of ADUs, duplexes, triplexes, and quadplexes on parcels zoned for detached single-family development. For each set of laws, we explain how state governments are attempting to oversee implementation. We then briefly describe the challenges of regulatory oversight.

Planning and zoning for multifamily housing

Several states have adopted laws that either require or encourage local governments in jobs-accessible areas to allow denser housing development. Some such laws draw on longstanding requirements for governments to adopt plans and then ensure consistency between the plan and their zoning, but others do not. As an example of the latter, in 2020 Massachusetts required 175 transit-accessible Boston-area jurisdictions to adopt "a zoning ordinance or by-law that provides for at least 1 district of reasonable size in which multi-family housing is permitted as of right" (An Act Enabling Partnerships for Growth, 2020, sec. 18). These municipalities need not adopt a separate land-use plan, but – in order to be eligible for certain state funds – they must adopt a zoning ordinance that complies with guidelines promulgated by the state's Department of Housing & Community Development. In January 2023, New York State's governor proposed legislation modeled on the Massachusetts law, with an even more stringent enforcement mechanism that would have authorized the state's attorney general to sue noncompliant municipalities (New York State, Division of the Budget, 2023, pt. G), although the bill was not adopted.

By contrast, states such as California and Oregon have long required local governments to adopt land-use plans. Recent revisions to these states' laws strengthen the requirements for local governments to plan for more housing and compel greater alignment between zoning and planning (Elmendorf, 2020). Although these laws are not exclusively concerned with multifamily housing, they are the principal regulatory lever for ensuring that municipalities plan and zone for such housing. In California, the state's Department of Housing & Community Development (HCD) determines regional housing allocations (typically for multi-county areas), and then a regional organization (often a council of governments) assigns portions of the allocation to individual jurisdictions. Although these allocations were widely viewed as meaningless for many decades (Dillon, 2017; Lewis, 2003), revisions to California law between 2017 and 2019 empowered HCD to ensure that local governments accommodate their allocations (Elmendorf et al., 2020). After receiving their allocations, localities must revise their plans to accommodate the allocated units and amend their zoning ordinances to ensure consistency with their plans. By default, about 40% of a city's housing target must be accommodated on land zoned for multifamily housing,[1] but cities may substitute "projected ADU production" for multifamily zoning if they can show that the projection is reasonable and that ADUs would be affordable to lower-income households (HCD, 2020a, pp. 30-31). These allocation and plan-revision processes occur over multi-year cycles (eight years in the most populous parts of California). Municipalities must submit their housing plans to HCD for pre-enactment review, and HCD may conduct additional reviews during the cycle. In 2021, the Oregon legislature adopted a law designed to create a statewide housing allocation system similar to that of California (Oregon Department of Land Conservation and Development & Oregon Housing and Community Services, 2022).

In short, both in states where planning is optional (such as Massachusetts) and in states where planning is a required precursor to zoning (such as California and Oregon), state agencies must review a very large number of local plans and ordinances. The relevant agencies need some way to prioritize their review. In addition, when determining regional housing allocations in states such as California and Oregon, state agencies should be able to assess the realism of local plans and to account for the substantial uncertainties associated with housing development.

Authorizing **gentle density**

Since roughly 2016, a growing number of state and local governments across the US have adopted laws intended to promote forms of *gentle density* or *missing-middle* housing, which is denser than detached single-family units but less dense than conventional apartment buildings. Relevant housing types include duplexes, triplexes, quadplexes, and ADUs. Although some municipalities, such as Minneapolis, MN, have adopted gentle density requirements of their own accord (Kuhlmann, 2021), in several cases the relevant mandates have come from state governments. Oregon and California both adopted laws requiring local governments to allow ADUs and other forms of gentle density, such as duplexes, in areas zoned for detached single-family development (Adams-Schoen & Sullivan, 2021; Alameldin & Garcia, 2022; Infranca, 2019). The Oregon and California statutes served as models for a law adopted by Washington State in May 2023 (State of Washington, 2023), as well as for proposed legislation in Colorado that failed to pass (Paul & Wenzler, 2023).[2]

These laws do not directly preempt local zoning by creating a statewide map, statewide zoning district designations, or statewide zoning administration procedures. Rather, they provide guidelines for local zoning and for subsequent review of revised zoning ordinances by a state agency. Although such state review can help to ensure local compliance, opportunities remain for municipalities to evade state requirements. For example, Oregon cities designated by state law as “Medium” or “Large” must allow a duplex on all residentially zoned parcels where detached single-family development is authorized (Applicability of Middle Housing in Medium Cities, 2020; Applicability of Middle Housing in Large Cities, 2020). Notwithstanding this requirement, however, cities “may regulate siting and design … provided that the regulations do not, individually or cumulatively, discourage the development of [duplexes] … through unreasonable costs or delay” (Development of Middle Housing, 2023, sec. 5). A state agency is charged with determining whether local regulations impose improper constraints on duplex development and, when necessary, requiring a revision of the zoning ordinance (Enforcement of Planning Requirements, 2022).[3] Similarly, as discussed below, California charges a state agency with reviewing local ordinances and, when necessary, referring recalcitrant jurisdictions to the state attorney general.

The challenge of oversight

It is difficult for state agencies to create effective strategies for reviewing local plans and ordinances. In general, the laws described above seem to call for a form of monitoring described by political scientists McCubbins and Schwartz (1984, p. 166) as “police-patrol” oversight, which requires the regulator aim to identify and address non-compliance with legislative aims, thereby deterring violations. State agencies are charged with reviewing *every* city's housing plan, ADU ordinance, missing-middle ordinance, etc. The problem with police-patrol oversight in the domain of land-use regulation is that municipalities can impede development through a myriad of regulatory channels, including parking mandates, height restrictions, and development fees. Even if state law constrains a city's authority to impose one restriction, a city can make another restriction more stringent to maintain the status quo in the built environment (Monkkonen and Manville, 2020). State regulators can attempt to reduce the options for such substitutions, but they cannot foresee all the loopholes that officials in housing-averse jurisdictions will devise. Nor can they identify all potential obstacles to implementation, even for cities that are relatively open to new housing. As a result, the challenges for state-level bureaucrats reviewing local plans or zoning ordinances for impediments to infill development are significant, and effectively assessing the text of a land-use plan or zoning ordinance will require substantial resources.

Given their limited resources, agencies need some way to set priorities, to decide which jurisdictions' plans will be closely scrutinized and which will receive light-touch or delayed reviews. They could prioritize review by relying on "fire alarms" (McCubbins & Schwartz, 1984, p. 166), that is, complaints from homeowners, developers, and other interested parties. But it is hard to know without substantial investigation whether a complaint reflects a serious problem, an anomalous incident, or a disgruntled complainer. Another approach – simply counting the number of relevant building permits that a municipality has issued – may not effectively target review, because municipalities do not control many of the factors that drive demand for housing. As a result, production – standing alone – may be a poor proxy for compliance with state laws mandating local regulatory reforms. Below, we provide a method for state regulators to account for such factors using statistical models. We illustrate the proposed approach using data on ADU permits with parcel-level identifiers, which local governments in California have been required to report to the state since 2018.

Legalizing accessory dwelling units in California

California's ADU laws are an important example of the new state laws described above, and they provide a valuable opportunity to demonstrate how state regulators can use statistical models to evaluate local plans and ordinances. Although California law has encouraged local governments to permit ADUs for decades, the relevant state laws proved largely ineffective until very recently (Brinig & Garnett, 2013; Volker & Handy, 2023). Beginning in 2016, the state legislature adopted a series of laws intended to liberalize ADU permitting. The revisions capped the fees local governments could impose on ADUs, set dimensional standards (such as setback requirements), and established a stringent timeline for reviews of applications (California Senate Bill [Cal. SB] 1069, 2015-2016; California Assembly Bill [Cal. AB] 2299, 2015-2016; Cal. AB 494, 2017-2018; Cal. SB 229, 2017-2018). Moreover, these laws strictly limited (and in many cases eliminated) the authority of local governments to impose parking requirements on ADUs. In 2019, the legislature shortened the approval timeline, prohibited municipalities from restricting the right to build ADUs to owner-occupiers, tightened dimensional standards (e.g., by establishing minimum and maximum square footage requirements for ADUs), and prohibited the imposition of fees on ADUs of less than 750 square feet (Cal. SB 13, 2019-2020). The Legislature also barred homeowners' associations (HOAs) from applying any covenant, condition, or restriction that either "effectively prohibits or unreasonably restricts the construction or use of an accessory dwelling unit ... on a lot zoned for single-family residential use" (Cal. AB 670, 2019-2020, §2), and, in 2020, prevented HOAs from restricting the rental of ADUs (Cal. AB 3182, 2019-2020).

In sum, as of 2020, ADUs should essentially have been allowed as-of-right on single-family lots, provided that they were under 800 square feet, no more than 16 feet tall, and had 4-foot setbacks. The available evidence suggests that these changes have spurred a large increase in ADU permitting. While California did not collect data on ADU production prior to 2018, a study of seven major California cities found a more than tenfold increase in ADU applications from 2015 to 2017 (Garcia, 2017).

Despite these recent changes, a 2020 survey of ADU owners indicated that securing municipal approval was the main impediment to building an ADU, and some surveyed homeowners contended that their local governments had failed to comply with the requirements of the new state ADU laws (Chapple et al., 2021). The state legislature has attempted to address these remaining hurdles by requiring local governments to submit their ADU ordinances to HCD (California Government Code, §65852.2(h)). Based on its review, HCD provides guidance to local governments by suggesting amendments. If HCD finds that an ordinance does not comply with state law and the municipality fails to revise the ordinance to HCD's satisfaction, the agency may refer the locality to the state's attorney general for enforcement. Because HCD and the Attorney General have many other responsibilities, they need some way to determine which ordinances to review most closely and whether to sue an intransigent city.

Between October 2018 and October 2022, HCD reviewed ordinances for 35 jurisdictions (33 municipalities and 2 counties) (HCD, 2023). There are 482 municipalities and 58 counties in California. Thus, at its current average rate of 8.75 ordinances per year, HCD will finish reviewing all city and county ordinances sometime around 2080. Clearly, HCD must somehow prioritize its review, but the relevant statute does not provide criteria for priority-setting.

Cities' ADU potential also matters for administering California's regional housing planning framework, also known as the Housing Element Law (California Government Code, tit. 7, div. 1, ch. 3, art. 10.6). As discussed above, this law requires cities to periodically adopt multi-year plans, called housing elements, for accommodating their assigned share of a regional housing-production target. Each city must show through its housing element that it has enough realistic zoned capacity to accommodate its quota, or else commit to the requisite amount of upzoning (i.e., allowing higher densities). However, a city may also claim credit toward its target for projected ADU production and thereby reduce the amount of land it must zone for multifamily housing. In the current planning cycle, HCD invited cities to use the rule of thumb that future ADU annual production would equal (1) the city's average annualized rate of production since 2018, when reforms to the state ADU law took effect, or (2) five times the city's annualized rate of production before 2018. HCD characterizes these numbers as presumptively valid "safe harbor[s]" (HCD, 2020a, p. 31).

Rather than assuming that future ADU production will equal a city's past production, HCD could use predictions from a statistical model to project ADU production as a function of the characteristics of parcels that do not yet have an ADU, after controlling for the city in which a parcel is located. Because such a model would account for the characteristics of ADU-less parcels in the jurisdiction, it would be less prone to over-crediting jurisdictions that performed well in the past but have few remaining parcels with high ADU potential. Moreover, such a model would provide state regulators with a principled way to assess the uncertainty inherent in predicting housing development.

Modeling local permitting performance to guide state oversight

In order to illustrate how state agencies can use our modeling tools, we used a sample of all parcels zoned for detached single-family development in the nine-county San Francisco Bay Area and five southern California counties (Los Angeles, Orange, Riverside, San Bernardino, and Ventura). Collectively, these counties represent 67% of the state's population, and 82% of the parcels receiving ADU permits during our study period (2018-2021). We restricted the analysis to parcels zoned for single-family development, because these were the parcels that the California legislature targeted for regulatory relief. Our sample, which consists of over 3.5 million parcel-level observations, was dictated by the areas for which we have the relevant zoning data, as described in the Technical Appendix. Our ability to analyze millions of observations demonstrates that the software tools we provide can handle very large datasets on the kinds of computers that are widely available to state agency personnel.

We undertook two modeling exercises. First, we assessed the probability that a parcel received an ADU permit from 2018 through 2021 as a function of parcel and tract characteristics and an indicator variable denoting the jurisdiction in which a parcel is located. By assessing past performance, this model can help HCD (or similarly situated agencies) to prioritize review of municipalities that are permitting fewer ADUs (or other types of housing) than expected, after controlling for real estate market fundamentals. Second, we applied a regression model that identifies the city-level correlates of ADU permitting performance, and we used this model to predict future ADU permitting as a function of parcel, tract, and city-level characteristics. As noted above, in addition to reviewing ADU ordinances, HCD must also assess local housing elements, which include projections of future ADU production. Currently, cities’ obligation to plan and zone for other types of housing (e.g., multifamily housing) is reduced by the amount of their projected

ADU development, which cities can predict with a simple rule of thumb. A statistical model can better account for the fact that the number of appropriate parcels will decrease over time, and it also reveals the uncertainty inherent in such predictions, giving state regulators a more realistic metric by which to gauge cities' projections.

Assessing past performance

We assessed cities' past performance in ADU permitting with a parcel-level regression model, detailed in the Technical Appendix, in which the probability that a single-family parcel received an ADU permit from 2018-2021 is a function of (1) the median gross rent in the census tract where the parcel is located (both as a continuous variable and binned into quintiles); (2) the proportion of the census tract consisting of vacant land; (3) the area of the parcel; (4) the number of buildings on the parcel; (5) whether the parcel contains slopes exceeding 15%; and (6) the municipality where the parcel is located. Median gross rent serves as a proxy for housing demand; the proportion of vacant land in a census tract indicates availability of substitutes for ADU development (i.e., detached single-family houses); a parcel's buildable area indicates the amount of unbuilt land available for an ADU; and parcels with more existing structures may more readily accommodate an ADU in one of those structures. Slopes exceeding 15% can render development economically infeasible (Saiz, 2010). We included a fixed effect for each municipality, which captures the residual effect on ADU permitting of a parcel's location in a particular municipality, after controlling for the other variables. This approach is superior to simply counting the proportion of single-family parcels receiving an ADU permit, because the latter strategy would not account for parcel-level and neighborhood-level attributes that are largely outside the control of local governments.

Our model does not establish a normative standard for the appropriate amount of ADU permitting. It simply provides a means of comparing historic permitting patterns among cities that adjusts for factors that are largely beyond a city’s control.

Figure 1 illustrates the application of this model to municipalities in Los Angeles County.[4] The dots illustrate the city-level fixed effect coefficient, which is equivalent to the probability of a typical parcel, with typical tract-level characteristics (rents and vacant land), receiving an ADU permit if the parcel and tract were located in that city. The horizontal black lines on either side indicate the 95% confidence interval around the point estimate. The vertical line indicates the median of the fixed effects (i.e., a reference jurisdiction at the middle of the distribution). Thus, for example, the fixed effect coefficient for the City of San Fernando (where 8% of single-family parcels had ADUs permitted from 2018 through 2021), indicates that a typical parcel in a typical tract would have a 6.9% higher probability of receiving a permit for an ADU if it were located in San Fernando, relative to the median jurisdiction.

Figure 1 also includes the location quotient for ADU production in parenthesis next to each jurisdiction’s name, which indicates each city’s ADU share relative to the share of ADUs in the entire study area, providing a sense of the range of activity being modeled. The location quotient is calculated as follows: $(\frac{ADU\_PARCEL_C}{SF\_PARCEL_C})/(\frac{ADU\_PARCEL_{SA}}{SF\_PARCEL_{SA}})$, where ADU_PARCEL_C is the number of single-family parcels with at least one ADU permit in city C, SF_PARCEL_C is the total number of single-family parcels in city C, and ADU_PARCEL_{SA} and SF_PARCEL_{SA} are the corresponding statistics for the entire study area.

If all jurisdictions were equally likely to permit ADUs, after controlling for parcel- and tract-level characteristics, then we would expect 95% of the fixed effects to be statistically indistinguishable (with 95% confidence intervals) from the median jurisdiction. The fact that the median is within the 95% confidence interval for only 29% of the jurisdictions in Los Angeles County (and 32% of the jurisdictions in our full sample) suggests that additional city-level factors continue to affect ADU production.[5]

One factor HCD should consider in setting review priorities is whether a jurisdiction's fixed effect is significantly smaller than the median fixed effect. Such municipalities are permitting fewer ADUs than expected, given the attributes of extant parcels and neighborhoods. As Figure 1 illustrates, there are twenty-one such outliers in Los Angeles County. Notably, only three of these twenty-one jurisdictions had been reviewed as of October 2022 (HCD, 2023).

To be sure, other factors should figure into priority setting too, such as jobs accessibility and the number of parcels in a jurisdiction that are prime candidates for adding an ADU. Of the above-mentioned poor performers in Los Angeles County, sixteen of the eighteen unreviewed jurisdictions are in the top quartile of jobs accessibility among cities statewide, and eleven are in the top decile. (The measure of jobs accessibility is detailed in the Technical Appendix.)

Notably, the demographics of the sixteen unreviewed jobs-accessible jurisdictions vary significantly (Table 1), suggesting that HCD might tailor its responses based on the needs of different jurisdictions. For example, the median annual household income in these jurisdictions ranges from $47,050 (in Cudahy) to $181,591 (in La Habra Heights), and homeownership rates in these two cities are, respectively, 14% and 92%. A low-resourced city, such as Cudahy, where renters predominate, may face different challenges in accommodating ADUs as compared with a high-resourced city, such as La Habra Heights. Our model can thus be used for prioritizing technical assistance (and, where necessary, making referrals to the state attorney general) by identifying underperformers.

Identifying the attributes of under-performing jurisdictions and predicting future performance

A second model identifies the attributes of underperforming jurisdictions and predicts the number of ADUs that will be permitted in a city over the next eight years, based on parcel-, tract-, and city-level characteristics. This is important, because – as discussed above – HCD relies on cities' representations concerning future ADU development when evaluating local housing plans. We included city-level characteristics in this model because, in contrast to the fixed effects model, the goal is not to identify poor performers but to predict future production. If a city has a characteristic that is strongly correlated with ADU production across all cities in the sample, incorporating that information into the model should improve its prediction of future ADU production in the city.

In order to provide point estimates and prediction intervals, we first modeled the likelihood of ADU permitting on a parcel from 2018-2021. Whereas the model used to generate city fixed effects did not include any city-level variables (apart from an indicator variable for each city), our second model does include city-level attributes, including population size, the proportion of mortgaged housing units that are part of an HOA, and the proportion of residences that are owner-occupied. The coefficients on these variables provide state regulators with insights regarding the city-level characteristics associated with more or less ADU permitting and increase the precision of our predictions. As detailed in the Technical Appendix, population size and the proportion of housing that is owner occupied appear generally unrelated to ADU permitting, but ADU permitting is much less likely in cities with a higher proportion of units belonging to an HOA, when controlling for parcel-, tract-, and city-level attributes.

After modeling the likelihood that each parcel received an ADU permit from 2018 through 2021, we restricted the sample to parcels that *did not* receive an ADU permit during this period.

Although this sample may include a handful of parcels that received an ADU permit prior to 2018, this is the best available estimate of parcels without ADUs, given the slow pace of ADU permitting prior to 2018. Using this sample, we took the fitted regression model and predicted the probability of future permitting on the sample of ADU-less parcels over the next four years. We then aggregated the probability estimates to the city level and multiplied by two (since the relevant planning period is eight years), thereby generating a point estimate for city-level ADU production. In order to provide prediction intervals, as detailed in the Technical Appendix, we generated simulations based on the model parameters that account for uncertainty in the coefficient estimates and in the parcel-level and city-level error terms.

Figure 2 illustrates the predicted number of ADUs on single-family lots over an eight-year period. The y-axis is on the $\log_{10}$ scale to account for the differences between large cities (e.g., Los Angeles, population 3.9 million) and small cities (e.g., La Habra Heights, population 5,651). Notably, the predictions derived from the regression model (the red dots in Figure 2) are very close to those derived based on HCD’s safe harbor rule averaging the annual rate of production from 2018-2021 (the blue dots in Figure 2). Both in Los Angeles County and statewide, the median difference between the regression model-based prediction and the safe harbor rule of thumb prediction is one ADU over the eight-year planning period.

In general, where the two predictions differ substantially, the regression-based prediction is lower than the rule of thumb estimates in jurisdictions with high ADU permitting performance (i.e., those closer to the right of Figure 1) and higher than the rule of thumb estimates in jurisdictions with low ADU permitting performance (i.e., those closer to the left of Figure 1). Since some of the highest-potential sites have already been developed in the high-performing jurisdictions, a model that accounts for the availability of remaining sites could predict fewer new units than a model (such as HCD's rule of thumb) that does not. In addition, as discussed in the Technical Appendix, the regression model introduces shrinkage toward the mean across jurisdictions, because it pools information across jurisdictions. Because many unmodeled factors affect annual ADU permitting, it makes sense – for the purpose of prediction – to incorporate information from other jurisdictions, rather than assuming that a small jurisdiction that had a few very good (or very bad) years of ADU production will necessarily continue to have similarly good (or bad) years.

Perhaps the main advantage of a regression-based prediction model is its capacity to represent the inherent uncertainty about future housing development. Although the housing planning laws adopted in states such as California and Oregon rely on highly uncertain predictions about future development, current approaches to oversight in these states do not clearly take that uncertainty into account. The regression-based approach that we provide here would be an important step towards incorporating uncertainty.

As described in the Technical Appendix, we used simulation methods to create the range of plausible estimates for each jurisdiction depicted by the horizontal red lines in Figure 2. Such methods are widely used in transportation planning, because they enable planners to model some of the uncertainties inherent in long-range planning. By incorporating these simulations into housing planning, state agencies can create a more realistic picture of the range of potential outcomes associated with the kinds of enforceable local plans that are cornerstones of the housing planning process in Oregon and California. For example, in a large jurisdiction, such as the City of Los Angeles, the 95% prediction interval ranges from 4,149 to 185,580 newly permitted ADUs over an eight-year period. In a small city, such as La Habra Heights, the range is zero to thirty-one.

With access to this information, officials might choose to credit cities and counties with the mean or median modeled prediction of ADU production, or they might reasonably stick with the existing simple rule of thumb. The advantage of the current rule of thumb is that it provides high-powered incentives for local governments to permit ADUs. If a city does very well with ADUs in one planning period, its obligations to zone for multifamily housing will be reduced in the next period. But the downside of the rule of thumb is that cities—especially small cities—may do well or poorly during a given period owing to chance factors beyond their control (say, an idiosyncratic spurt of interest, or lack of interest, in ADU development on the part of homeowners in the city). Also, as the number of sites with high ADU potential decreases (because ADUs have been developed on those sites), the regression-based projections will appropriately decrease for cities that have been permissive of ADU development. On balance, the regression approach is likely to provide a more accurate projection than the rule of thumb, but at the price of somewhat weaker incentives for permissive ADU policies.

Whether or not officials use the regression-based estimates for regulatory purposes, better understanding the uncertainties associated with the relevant projections will provide a more realistic base of information for state regulators to evaluate local performance. Given the large amount of uncertainty in the forecasts, state regulators should not expect most jurisdictions to produce a quantity of ADUs that is close to the forecasted point estimate. Instead, if the aggregate forecasted quantity of ADUs is to be produced, some jurisdictions will probably need to “overshoot” by a large amount even as others underperform.

A data- and model-driven approach to enforcement and planning for infill housing

Efforts to promote infill development via state oversight of local planning and zoning hold promise, provided that – as has occurred in California – the relevant laws include requirements governing data collection and enforcement. While good data and enforcement provisions may be necessary to promote infill housing development, they may also be insufficient, because the agencies responsible for oversight and enforcement must effectively use the data to set priorities. Explicit, publicly available models, such as those presented in this article, can help state agencies to prioritize their review of local plans and ordinances.

Beyond what they tell us about whether any given city is a high or low performer conditional on parcel characteristics, and about the expected "ADU yield" of all the parcels in a city during the next planning period, the models also shed some light on jurisdiction-level features that are associated with ADU production. Our main finding in this regard is that cities with a high density of HOAs have lower ADU production, after controlling for a variety of other factors. Homeowners in these cities may well have an easier time organizing to block housing, even when state law purports to make the type of housing in question developable as of right. The legislature might consider fully preempting HOAs' authority to apply HOA restrictions to ADUs, rather than (as is currently the case) allowing HOAs to apply restrictions so long as they do not "effectively prohibit[] or unreasonably restrict[] the construction or use of an accessory dwelling unit" (California Civil Code, §4751(a)).

Our example application involves California's ADU laws, but the modeling techniques that we use are not restricted to ADUs or to California. For example, although California's Department of Housing and Community Development does not currently require cities to project non-ADU production as part of their housing element, some cities have elected to do so for multifamily-zoned sites (City of Los Angeles, 2022; San Francisco Planning Department, 2023). With suitable data, cities could extend this approach using a two-stage model that first estimates the probability of development activity on a parcel and then, conditional on development, the type of development. The model would concurrently estimate the probabilities that a single-family home will be augmented with an ADU, redeveloped as a new or renovated single-family home, or replaced with multifamily housing. Such a two-stage modeling strategy would be broadly useful in any state which has mandated that more than one type of densification be allowed on a class of parcels. (It would, of course, be necessary to account for state environmental or other laws that may limit which parcels are eligible for densification.)

We emphasize that our fixed effects model should be used only as a screening tool to alert state agencies about jurisdictions that might benefit from technical assistance or require enforcement actions. It does not indicate which form of intervention is appropriate. As the comparison of the cities of Cudahy and La Habra Heights illustrates, a variety of unmodeled factors may account for the modeled underperformance. Regulators should consider these factors in deciding on appropriate actions. For example, lower-resource cities may benefit from additional technical assistance, whereas enforcement actions may be required to improve permitting performance in wealthier cities. The state might also prioritize enforcement in larger jurisdictions and jurisdictions near centers of employment, where the societal payoff from better ADU permitting would be greater.

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[1] This follows from two provisions of state law. First, regional housing need is subdivided into different levels of affordability, with "housing for lower income households" defined as housing that is affordable to households earning up to 80% of the area median income (California Government Code, §65584(f); California Health and Safety Code, §50079.5). Such households typically comprise about 40% of the total (see, e.g., California Department of Housing & Community Development, 2020b, Attachment 1; 2020c, Attachment, 1). Second, the sites through which cities accommodate their "lower income" housing target must be zoned at densities that allow for multifamily housing (California Government Code, §65583.2).

[2] In 2023, Montana also adopted laws enhancing planning requirements and requiring certain jurisdictions to allow duplexes in areas zoned for single-family development, but these laws do not require state administrative review of local ordinances (State of Montana, 2023a; 2023b).
[3] If an Oregon city fails to adopt a compliant, state-certified missing-middle zoning ordinance, it eventually becomes subject to a default state-promulgated missing-middle code (Oregon House Bill 2001, § 3, 2019).
[4] Although there are 88 cities in Los Angeles County, our sample includes only 85. Two cities, Industry and Vernon, have no single-family zoning, and we were unable to match building footprint data for Avalon, the only incorporated area on the otherwise largely uninhabited Santa Catalina Island.
[5] It is also possible that our results could reflect unobserved parcel- or tract-level characteristics that affect ADU production and that are more common in some cities than others.

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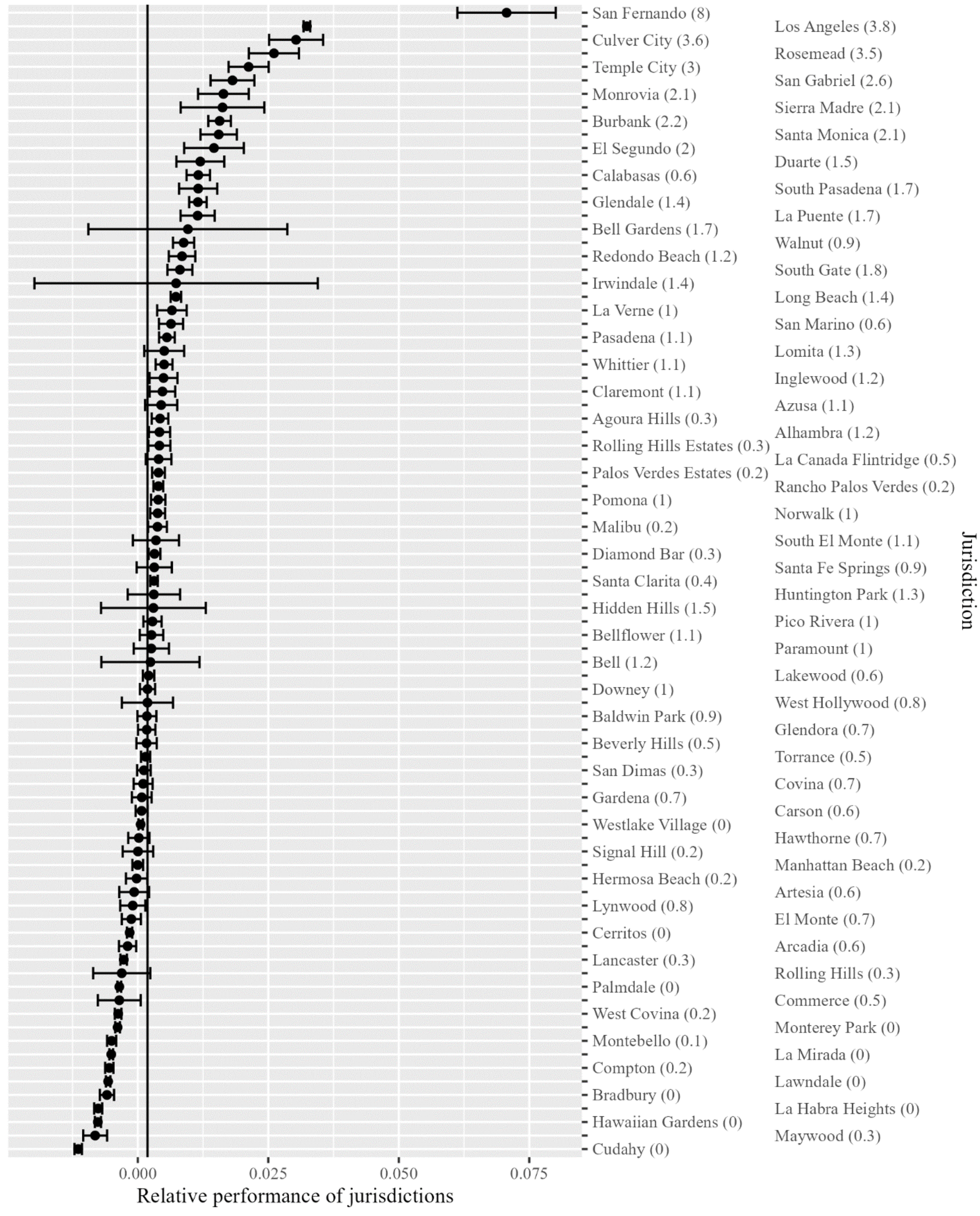
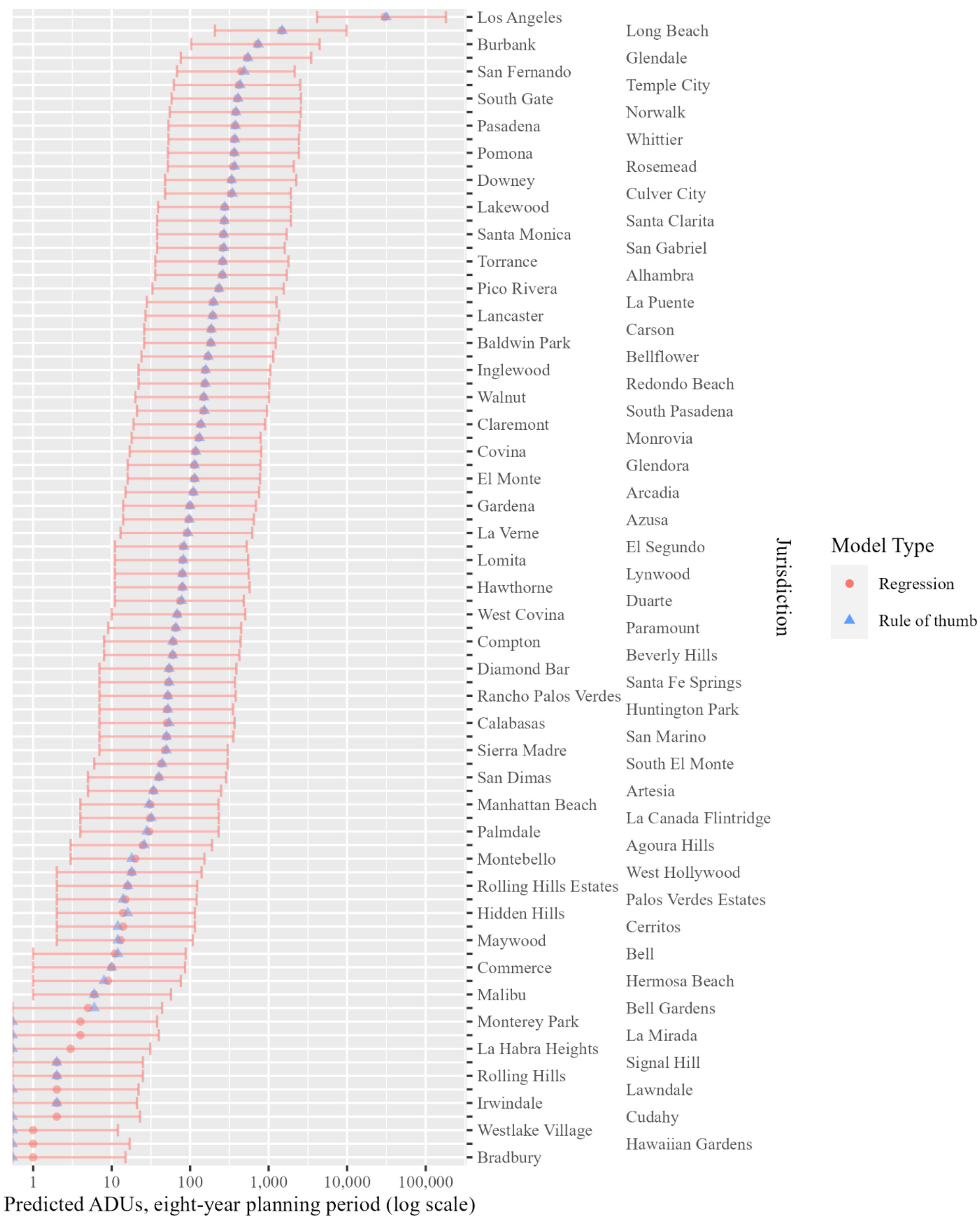
Figure 1: ADU permitting performance estimates for cities in Los Angeles County



Note: Location quotients in parentheses following jurisdiction names; relative performance of jurisdictions measured as the fixed effect from a linear probability model; the vertical line indicates the median fixed effect for the entire study area; error bars indicate 95% confidence interval, based on HC2 standard errors.

Marantz, N.J., Elmendorf, C.S., & Kim, Y.B. “Overseeing Infill.” Accepted Manuscript. Version of Record: *Journal of the American Planning Association*, https://doi.org/10.1080/01944363.2023.2255580

Figure 2: ADU production predictions for Los Angeles County, with 95% prediction intervals



Marantz, N.J., Elmendorf, C.S., & Kim, Y.B. “Overseeing Infill.” Accepted Manuscript. Version of Record: *Journal of the American Planning Association*, https://doi.org/10.1080/01944363.2023.2255580

Table 1: Characteristics of unreviewed, under-performing, jobs-accessible cities in Los Angeles County

	Arcadia	Bradbury	Cerritos	Commerce	Compton	Cudahy	Hawaiian Gardens	Hermosa Beach	La Habra Heights	La Mirada	Lawndale	Lynwood	Manhattan Beach	Maywood	Montebello	Monterey Park
Population																
Total	56,697	760	49,630	12,459	96,083	23,003	14,178	19,787	5,651	47,957	32,035	67,497	35,585	25,477	62,828	61,153
% Asian	57	39	58	1	1	0	11	7	20	21	11	1	15	1	13	65
% Black or African American	2	1	8	1	27	1	2	1	0	2	7	8	1	0	1	1
% Hispanic or Latino	15	14	15	95	69	96	78	12	20	44	65	88	8	97	80	27
% non-Hispanic white	21	43	13	3	1	2	8	72	50	30	15	2	71	1	6	6
% foreign born	46	32	42	36	29	43	38	12	28	26	40	38	13	48	37	52
% below poverty line	9	6	5	15	17	29	17	5	2	6	10	16	3	21	11	11
Med. household income	99,588	171,964	115,600	58,226	62,297	47,050	66,578	144,388	181,591	97,672	72,246	61,612	169,586	54,535	66,584	68,497
Housing																
Total units	19,189	267	15,582	3,466	24,921	5,775	3,733	8,926	1,970	14,679	9,726	15,100	13,422	6,332	19,119	20,318
% detached single-family	58	97	81	66	65	43	48	44	98	79	56	53	70	54	49	56
% owner occupied	60	83	76	58	57	14	46	51	92	77	39	48	68	27	44	51
Median gross rent	1,801	NA	2,482	1,136	1,329	1,443	1,584	2,498	NA	1,774	1,672	1,355	2,893	1,227	1,543	1,627
Median value	1,152,200	1,750,000	764,200	455,700	423,000	434,200	439,900	1,674,500	945,800	629,900	587,900	449,300	2,000,001	481,800	557,400	667,300

Source: 2017-2021 American Community Survey
Note: Jurisdictions unreviewed as of October 2022

Technical Appendix

Data assembly

Our data on ADU permitting comes from the annual progress reports (APRs) compiled by the California Department of Housing & Community Development (HCD) (2022). Each city's APR should include the current assessor parcel number (APN) and street address for every reported development project. A city's APR must also report the type of project, based on a list that includes ADUs. A single project may appear multiple times in the compiled APR dataset if, for example, the project receives a building permit in one year and a certificate of occupancy in a subsequent year. In addition, HCD does not validate the APR data, and – as a result – the dataset includes some erroneous APNs.

In order to generate an unduplicated count of parcels on which at least one ADU was approved from 2018 through 2021, we first filtered the compiled APR data from HCD to include only ADUs in the study counties. We then selected rows that are uniquely identified by jurisdiction, APN, and street address. We merged this dataset with parcel data from the Southern California Association of Governments (SCAG) (2021) and Boundary Solutions (2022), which maintains a proprietary database of digitized parcel boundaries. The SCAG parcel data includes consistent information on zoning and land use as of 2016, but the Boundary Solutions data (which covers the Bay Area) does not. For the Bay Area, we combined geodata compiled by the Othering & Belonging Institute (Menendian et al., 2020), which indicates single-family residential zoning as of 2020.[1]

We restrict the regression sample to single-family parcels, because the relevant revisions to state law impose uniform maximum standards that municipalities may use “to evaluate a proposed accessory dwelling unit on a lot that includes a proposed or existing single-family

[1] We expect that very little land shifted from single-family to multi-family (or vice versa) between 2016 and 2020. Such rezonings are rare and, if they happen at all, would be most likely to occur in the wake of housing element revisions. Within our study area, these revisions occur in eight-year cycles, and the cycles have been timed fortuitously for our purposes. For the fifth cycle, housing need determinations were established for the Bay Area in 2012 and our southern California study area in 2011 (California Department of Housing & Community Development, 2016). The Council of Governments (COG) for the Bay Area adopted its final fifth cycle regional housing need plan in 2013, and local housing plans were required to by certified as compliant by HCD as of January 31, 2015 (Association of Bay Area Governments, 2023; California Department of Housing & Community Development, 2016). The COG for the southern California study area adopted its final fifth cycle housing plan in 2012, and jurisdictions in the region were required to adopt compliant housing plans by Oct. 15, 2013 (California Department of Housing & Community Development, 2016; Southern California Association of Governments, 2012). Due to low housing targets and lax standards for compliance, few jurisdictions in the Bay Area or Los Angeles region had to do any rezoning (Elmendorf et al., 2022).

dwelling" (California Government Code, § 65852.2(a)(8)(A)). We further restrict the sample to urbanized areas (as defined by the Census Bureau), because California's ADU legislation is intended to promote infill development. We focus on cities, rather than unincorporated areas because (1) cities generally have significantly better jobs accessibility than unincorporated areas; (2) the large majority of ADU development has occurred in cities; and (3) the politics of land-use regulation may differ significantly between cities and unincorporated areas, where counties regulate land-use and may take a hands-off approach (Anderson, 2012; Chase, 2015). We also drop parcels of less than 1,000 square feet and more than two acres, as well as parcels with more than four structures. Table A - 1 reports summary statistics of the unstandardized regression model variables.

Table A - 1: Summary statistics for regression model variables

	Variable	N	Mean	SD	Min	Max
(1)	ADU Parcel (2018)	7,500	NA	NA	NA	NA
(2)	ADU Parcel (2019)	8,380	NA	NA	NA	NA
(3)	ADU Parcel (2020)	8,245	NA	NA	NA	NA
(4)	ADU Parcel (2021)	10,654	NA	NA	NA	NA
(5)	ADU Parcel (2018-2021)	34,779	NA	NA	NA	NA
(6)	Parcel contains steep slope	672,076	NA	NA	NA	NA
(7)	Parcel sq. ft. (2016)	3,569,148	8,437	6,552	1,000	87,119
(8)	Structures on parcel (N)	3,569,148	1.31	0.55	1.00	4.00
(9)	Vacant land as proportion of tract land area (2011)	3,569,148	0.13	0.23	0.00	0.99
(10)	Tract median gross rent ($) (2012-2016)	3,569,148	1,723	567	276	4,096
(11)	City population (N) (2012-2016)	3,569,148	633,174	1,238,281	954	3,918,872
(12)	City owner-occupied residences (%) (2012-2016)	3,569,148	55.9	13.2	14.9	96.5
(13)	City HOA intensity (%) (2016)	3,569,148	9.5	13.1	0.0	70.3

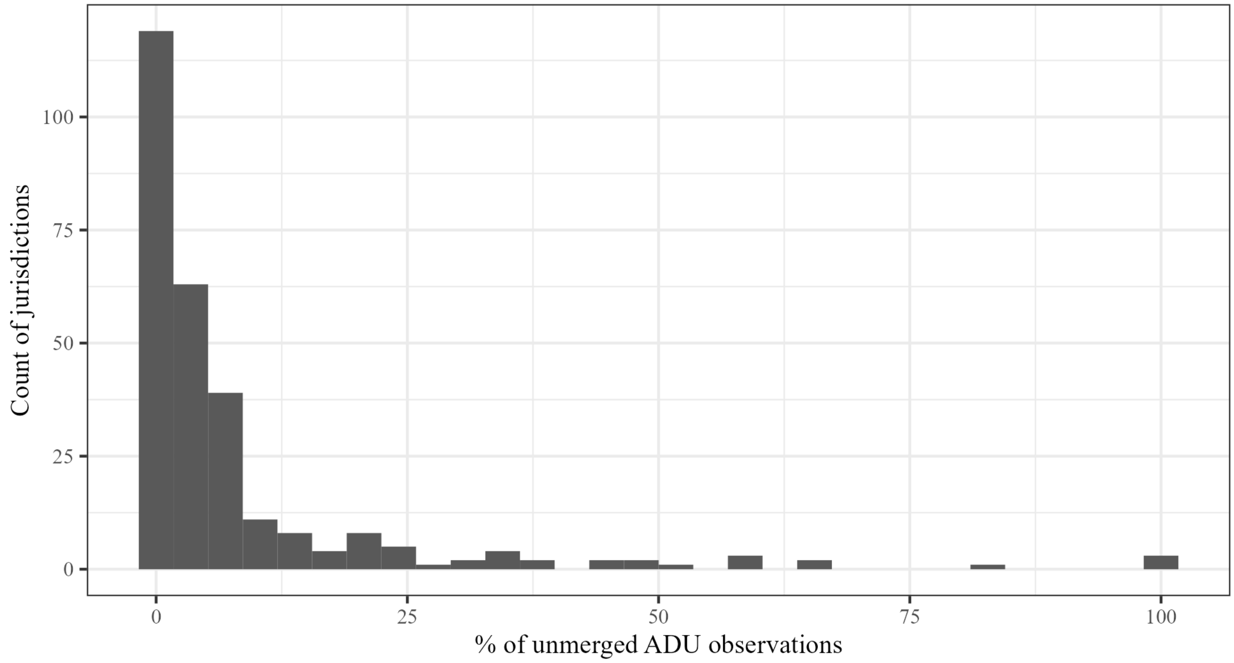
Notes: For the dichotomous variables ((1)-(6)), N is the number of observations for which the variable equals one. The vintage for each variable is given in parenthesis. For variable (8), the precise vintage was not available but, as discussed in the text below, predates 2018.

Sources: (1)-(5), California Department of Housing & Community Development (2022); (6) U.S. Geological Survey (2020); (7) Southern California Association of Governments (2021) and Boundary Solutions (2022); (8) Microsoft (2018); (9) Manson et al. (2022); (10)-(12) American Community Survey, 2012-2016; (13) CoreLogic.

We merged ADU permit observations from the APR data with the parcel geodata from SCAG and Boundary Solutions based on APN and jurisdiction. HCD does not validate APNs, so there are inconsistent APN formats in the dataset. To improve the merge rate, we created a consistent format for APNs in the APR data by, for example, dropping leading zeros and removing all punctuation marks. For jurisdictions that have high rates of unmerged observations even after this standardization process, we conducted additional inspection to determine, for example, whether these jurisdictions added customized suffixes or prefixes to their APNs. After further harmonizing the APNs based on this analysis and validating our harmonization by comparing street names in the APR data and the parcel geodata (where available), we were able to merge 52,480 (96%) of the 54,584 ADU observations from the APR data. We created a unique ID for each parcel and reduced the dataset to one observation per unique ID, generating an unduplicated count of 43,160 parcels with at least one ADU permit. We then further restricted the sample to single-family parcels in urbanized areas, as described above.

Merge rates vary significantly across jurisdictions (Figure A - 1). Thirty-two percent of jurisdictions in our sample have no unmerged observations. Of the remaining 70% of the sample, a relatively small number of jurisdictions have a large number of missing observations. For example, of the 280 jurisdictions in the sample, twenty-four jurisdictions (ranging in population from 2,991 to 246,992) have more than 25% of their reported ADUs unmerged. In many cases, the APR is missing crucial data, such as APNs and street names for the relevant observations. In other cases, the APNs reported in the APR are clearly erroneous. For the purpose of evaluation, it is appropriate to ignore these unmerged observations. If HCD does not credit jurisdictions for unmatchable ADUs, then the agency will provide jurisdictions with an incentive to properly report their data.

Figure A - 1: Merge rates by jurisdiction



After merging the ADU permit data with the parcel geodata, we added tract- and jurisdiction-level demographic data. The demographic data comes from the 2012-2016 American Community Survey (ACS) and predates our first year of ADU data (2018), mitigating concerns about endogeneity. Data on homeowners' associations comes from CoreLogic, a firm that aggregates data from county assessors and recorders. For each property in its mortgage dataset (including properties mortgaged as of 2016), CoreLogic indicates whether a condominium rider or a planned unit development rider was recorded. We initially planned to use these indicators to create a parcel-level variable identifying whether a property is covered by an HOA's covenants, conditions, and restrictions (CCRs), following Clarke and Freedman (2019), but analysis of the data suggests a high probability of false negatives. Since the recordation of riders does not appear to vary systematically by county (i.e., our concerns about undercounting apply to all counties in our sample), we created a jurisdiction-level measure of the proportion of mortgaged properties with a relevant rider, providing a relative measure of the extent to which potential ADU sites in a jurisdiction are encumbered by an HOA's CCRs.

We also added parcel-level data indicating the number of structures on each parcel and whether the parcel includes steeply sloped terrain. We generated the number of structures from footprint data provided by Microsoft Maps, which derives building footprints by applying computer vision algorithms to satellite raster imagery. Microsoft's publicly available building footprint data is periodically updated, so – in order to ensure that the building footprints predate our study period – we obtained archival data from archive.org, which Microsoft posted to GitHub on June 13, 2018 (Microsoft, 2018). Although the archived dataset does not include the capture date for the footprints, we believe that most (if not all) were captured prior to 2018, both because the data were posted in 2018 and because as of March 2021, a Microsoft employee indicated that the average vintage was roughly 2012 (Trifunović, 2021). For each parcel in the sample, we used 1/3rd arc-second digital elevation models from the U.S. Geological Survey (2020) to generate a dichotomous variable indicating whether the parcel contains terrain with a slope greater than 15%. Such steep slopes can inhibit housing development (Saiz, 2010).

We generated our measure of jobs accessibility by calculating the distance-weighted sum of jobs within 50 miles of block group centroids. We used a linear decay function, following Salon (2014, p. 18), who notes that weighting by inverse distance squared "quickly renders jobs beyond 10 miles to have little effect on the [jobs accessibility] variable," which is problematic in the California context. The census tract and block group distances come from the National Bureau of Economic Research (NBER) (2014), and the job counts come from the 2016 vintage of the Workplace Area Characteristics dataset from the Longitudinal Employer-Household Dynamics database (U.S. Census Bureau, n.d.). To select the jurisdictions for Table 1 in the main text, we aggregated the jobs accessibility to the city level by weighting each block group in a city by the proportion of the city's population aged 18-64 living in the block group and summing the weighted values by city. Block group *BG* is assigned to city *C* if more than 50% of the population of *BG* lives in *C*.[2]

Regression models

For the purpose of identifying cities for priority review, we used a fixed effects regression model, which assigns coefficients and standard errors to each city, enabling us to compare city performance after controlling for parcel-level characteristics that may affect ADU development. Our fixed effects model takes the following form:

[2] We are unable to generate values for eleven small cities that consist exclusively of block groups in which 50% or less of the population lives in the city. Because the NBER dataset is based on 2010 vintage census data, we are also unable to generate values for two cities that incorporated after the 2010 Census.

$$y_{i,j} = \beta^{\mathrm{P}} * \mathrm{P}_{i,j} + \beta^{\mathrm{FE}} * \mathrm{FE}_j + \epsilon_{i,j},$$
$$\epsilon_{i,j} \sim \mathrm{N}(0, \sigma^2),$$

where $y_{i,j}$ is the probability of an ADU being permitted on parcel i in city j during the study period, β^{P} and β^{FE} are row vectors of coefficients, $\mathrm{P}_{i,j}$ is a column vector of parcel-level characteristics, FE_j is a column vector of fixed effects equal to one if parcel i is in city j and zero otherwise, and $\epsilon_{i,j}$ is a vector of errors. We pooled the permitting data over the four-year study period to limit the influence of any single year on the evaluation of municipal permitting performance. We used a linear probability model with HC2 standard errors (rather than a logit model) because the coefficients of interest (FE_j) are more readily interpretable and because our focus is on assessing relative performance instead of predicted values (Hellevik, 2009; Gomila, 2021).

To predict future ADU permitting, we estimated a random effects model, in which the city-level variables are given a model which is estimated simultaneously with the parcel-level regression. Our random effects model takes the following form:

$$\Pr(\mathrm{ADU}_{i,j} = 1) = \mathrm{logit}^{-1}(\beta^0 + \beta^{\mathrm{P}} * \mathrm{P}_{i,j} + \alpha_j + \epsilon_{i,j}),$$
$$\alpha_j \sim \mathrm{N}(\beta^{\mathrm{C}} * \mathrm{C}_j, \sigma^2),$$

where $\Pr(\mathrm{ADU}_{i,j} = 1)$ is the probability of an ADU being permitted on parcel i in city j during the study period, $\mathrm{P}_{i,j}$ is a column vector of parcel-level characteristics, α_j is determined through a group-level model based on a vector of attributes C for city j, and $\epsilon_{i,j}$ is a vector of errors. The random effects model estimates variation within and between cities, producing a weighted average for C_j that pulls the value closer to the population mean for cities with relatively few parcels (see Gelman & Hill, 2007, Chapter 12). We obtained approximations of the variance parameters by using the *lme4* package in R.

As indicated in Table A - 1, the parcel-level characteristics in our models include parcel area, the number of existing structures, a dichotomous variable indicating the presence of steep slopes, the median gross rent for the tract (measured both as a continuous variable and divided into quintiles), and the proportion of land in the tract that is vacant. For our random effects models, we added three city-level variables: the log of population, the percentage of housing units that are owner-occupied, and the intensity of homeowners' associations. We standardized all right-hand-side variables (other than the count of structures and the dichotomous steep slope indicator) both for ease of interpretation and to facilitate model fitting.

One potential concern about the interpretation of our models is that some ADUs permitted from 2018 through 2021 were probably built illegally prior to that period. We are unable to distinguish ADUs that went through the permitting process after being built from ADUs that were permitted prior to construction. We expect, however, that applications for ADU amnesty would be more common in the year or two immediately following the relevant reforms, and we therefore ran regression models for each year, removing from the sample parcels on which an ADU was permitted in a prior year.

Table A-2 displays the results of our fixed effects regression model. All coefficients are in the expected direction, the magnitudes are sensible (given the low probability that any given parcel will receive an ADU permit), and all results are statistically significant. We discuss the interpretation of coefficients below in the context of our random effects model. Measuring model fit for linear probability models is a challenge. R^2, the standard measure of model fit for ordinary least squares, is an inappropriate measure of model fit for linear probability models because – even if the model were perfect – the observed data cannot lie on the regression line. A variety of pseudo-R^2 statistics enable researchers to compare a given binary outcome model to other models estimated using the same data. In order to assess goodness-of-fit and reliability, we therefore estimated logit models on the same variables included in the linear probability model, as well as two subsets of those variables. Table A-3 presents the resulting goodness-of-fit and reliability measures for three logit specifications: (1) no fixed effects but all other right-hand-side variables in Model 1, (2) fixed effects only, and (3) all variables used in Model 1. Specification (3) improves all measures of goodness-of-fit over specifications (1) and (2).

Table A - 2: Fixed effects linear probability regression model

Parcel sq. ft. (std)	0.002***
	(0.0001)
Structures on parcel	0.004***
	(0.0001)
Parcel contains steep slope	-0.007***
	(0.0001)
Tract median gross rent (std)	-0.002***
	(0.0001)
Tract proportion vacant (std)	-0.001***
	(0.0000)
Num.Obs.	3,569,148

* p < 0.05, ** p < 0.01, *** p < 0.001
Model includes city fixed effects; Standard errors in parentheses.

Note: The dependent variable is a dichotomous variable equal to 1 if an ADU was permitted on a parcel from 2018-2021 and 0 otherwise.

Table A - 3: Goodness of fit and reliability measures for fixed effects logit model

	AIC	BIC	McFadden	Cox-Snell	Cragg-Uhler (Nagelkerke)	AUC
(1)	499,100	499,200	-0.275	-0.031	-0.295	0.500
(2)	349,800	353,500	0.108	0.012	0.113	0.794
(3)	344,900	348,700	0.120	0.013	0.126	0.812

Note: This table displays goodness-of-fit and reliability measures for three logit specifications. Specification (1) includes all variables included in the linear probability model, except the jurisdiction fixed effects; Specification (2) includes only the jurisdiction fixed effects; Specification (3) includes all right-hand-side variables in the linear probability model. Smaller values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) indicate a better model fit, after accounting for model complexity. Larger values of the McFadden, Cox-Snell, and Cragg-Uhler (Nagelkerke) statistics indicate better model fit. Larger values of the AUC statistic (area under the receiver operating characteristic curve) indicate greater reliability.

Table A - 4 displays the results from our random effects logit model, which enables us to assess whether different city-, tract-, and parcel-level attributes are related to ADU permitting. The pooled specifications combine all four years of the study period, but as noted above, we also analyzed each year separately. To facilitate interpretation, we estimated marginal effects for a one-unit change for each statistically significant variable, holding other variables equal to their sample means (in the case of continuous variables) or sample medians (in the case of dichotomous, factor, and count variables). The mean predicted value (i.e., probability that a parcel receives an ADU permit) is 0.01, and the median is 0.005. (The mean is consistent with the observed proportion of parcels with ADU permits in our sample, which is also 0.01.) In pooled model (2), a standard deviation increase in lot size from the sample mean is associated with an increase in the probability that a parcel receives an ADU from 0.003 to 0.004, as is an increase from one to two structures on a parcel.[3] A standard deviation decrease in the proportion of vacant land in a tract is associated with an increase in the probability that a parcel receives an ADU from 0.003 to 0.004. The presence of steeply sloped terrain decreases the probability that a parcel receives an ADU from 0.003 to 0.002.

On average, tract-level gross rents are negatively related to ADU permitting – a standard deviation increase in median rent (i.e., $567) is associated with a small decrease in the probability that a parcel receives an ADU, but this average negative relationship masks non-linearities, as illustrated by dividing rents into quintiles. In the pooled model, the odds of an ADU being permitted increase from 0.003 for parcels in first quintile tracts (with median rents of $276 - $1,230) to 0.004 in second quintile tracts (with median rents of $1,231 - $1,483). As Figure A-2 illustrates, the predicted probability that a parcel will receive an ADU declines in each quintile from the third to the fifth.

[3] The baseline predicted probability of 0.003 in the marginal effects estimation is lower than either the sample mean (0.01) or median (0.005). We attribute this anomaly to the sparseness of the sample in the relevant range. Specifically, there are zero observations in the sample for which (a) all continuous variables are within +/- 0.1 standard deviation of the sample mean and (b) the count and dichotomous variables are equal to the sample median.

Table A - 4: Random effects logit regression model

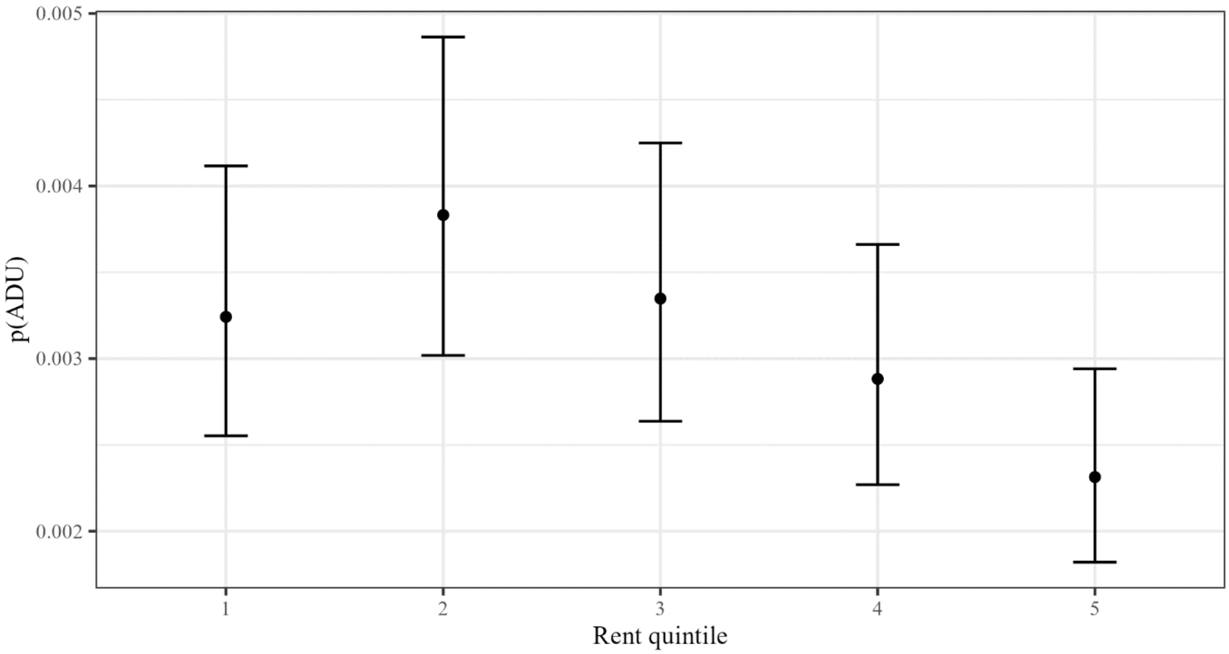
	Pooled				2018				2019			
	(1)		(2)		(1)		(2)		(1)		(2)	
Characteristic	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]
Parcel sq. ft. (std)	1.21***	0.006	1.21***	0.006	1.21***	0.012	1.20***	0.012	1.22***	0.012	1.21***	0.012
Structures on parcel	1.30***	0.011	1.30***	0.011	1.38***	0.024	1.39***	0.024	1.29***	0.022	1.30***	0.022
Parcel contains steep slope	0.52***	0.010	0.52***	0.010	0.52***	0.021	0.52***	0.021	0.53***	0.021	0.53***	0.020
Tract median gross rent (std)	0.87***	0.006			0.88***	0.013			0.89***	0.013		
Median rent quintile												
1			—	—			—	—			—	—
2			1.18***	0.020			1.35***	0.046			1.26***	0.041
3			1.03	0.018			1.19***	0.044			1.10**	0.038
4			0.89***	0.018			0.99	0.041			0.99	0.039
5			0.71***	0.015			0.77***	0.035			0.76***	0.032
Tract proportion vacant (std)	0.82***	0.010	0.82***	0.010	0.79***	0.021	0.80***	0.021	0.81***	0.020	0.81***	0.020
Log city population (std)	0.84	0.099	0.84	0.095	0.63**	0.108	0.63**	0.105	0.76	0.115	0.76	0.113
City owner-occupied residences (std)	0.98	0.081	0.98	0.079	0.91	0.108	0.92	0.108	0.92	0.096	0.92	0.095
City HOA intensity (std)	0.65***	0.053	0.65***	0.052	0.63***	0.077	0.63***	0.076	0.62***	0.066	0.62***	0.065
No. Obs.	3,569,148		3,569,148		3,569,148		3,569,148		3,561,648		3,561,648	

	2020				2021			
	(1)		(2)		(1)		(2)	
Characteristic	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]	**OR**[1,2]	**SE**[2]
Parcel sq. ft. (std)	1.18***	0.012	1.18***	0.012	1.21***	0.011	1.20***	0.011
Structures on parcel	1.26***	0.022	1.26***	0.022	1.26***	0.019	1.26***	0.019
Parcel contains steep slope	0.56***	0.022	0.56***	0.022	0.51***	0.018	0.51***	0.018
Tract median gross rent (std)	0.85***	0.013			0.87***	0.012		
Median rent quintile								
1			—	—			—	—
2			1.10**	0.037			1.09**	0.032
3			0.96	0.035			0.96	0.031
4			0.78***	0.033			0.87***	0.031
5			0.67***	0.030			0.71***	0.028
Tract proportion vacant (std)	0.83***	0.019	0.83***	0.019	0.82***	0.017	0.82***	0.017
Log city population (std)	0.81	0.108	0.81	0.107	0.91	0.120	0.91	0.119
City owner-occupied residences (std)	0.90	0.082	0.90	0.081	1.03	0.094	1.03	0.093
City HOA intensity (std)	0.66***	0.060	0.66***	0.060	0.69***	0.062	0.69***	0.061
No. Obs.	3,553,268		3,553,268		3,545,023		3,545,023	

[1]*p<0.05; **p<0.01; ***p<0.001
[2]OR = Odds Ratio, SE = Standard Error

Among the city-level variables, only HOA intensity (which is only moderately correlated with owner-occupancy) is consistently statistically significant. In pooled model (2), a standard deviation increase in HOA intensity (13.3 percentage points) from the mean decreases the probability that a parcel receives an ADU from 0.003 to 0.002. Notably, California preempted HOA restrictions on ADU development as of 2019 and preempted HOA restrictions on ADU rentals as of 2020. After controlling for steep slopes, the relationship between HOA intensity and ADU production diminished moderately over the course of the four-year study period, suggesting that these reforms may be having some effect. Nevertheless, the continued strong negative relationship may also suggest that HOAs have found extra-legal ways to thwart ADU production notwithstanding the changes in state law. Or maybe homeowners and investors are not yet aware of their right to build and rent an ADU in derogation of HOA rules.

Figure A - 2: Predicted p(ADU) by quintile of tract-level median gross rent



Note: 95% confidence intervals shown.

The proportion of owner-occupied residences is negatively associated with ADU permitting, but this relationship is not statistically significant in any specification. The log of population is negatively associated with the odds of a parcel receiving an ADU permit, but the association is statistically significant only in the 2018 specification, indicating that the relationship (to the extent that it exists at all after controlling for the other variables) varies by year.

In order to generate predictions for the eight-year planning period, we took the fitted random effects model and estimated parcel-level outcomes only for parcels that have not yet received an ADU permit. We aggregated the parcel-level probability estimates by jurisdiction and multiplied by two, since the random effects model includes four years of data and we are projecting over an eight-year period. We generated prediction intervals with the *predictInterval* function from the *merTools* R package, which we used to simulate 500 draws from a distribution, estimate fitted values across each distribution, and then pool the draws to generate the prediction intervals displayed in Figure 2 of the main text.

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