Regulatory Hurdles and Costly Delay in Housing Development*

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Abstract

This paper quantifies the supply effects of discretionary permit review, a common but understudied regulatory friction that delays and adds uncertainty to housing development. Using the universe of permit applications in Seattle, Washington, during a period when a unit count threshold for undergoing discretionary permit review was in place, I show that undergoing discretionary review increased permit review time by 4 to 5 months, and that developers reduced unit counts and increased average unit size in order to avoid discretionary review. I then propose a novel extension of prevailing housing production models to multifamily developments that accounts for both the intensive and extensive margins of development. Using data that is freely and publicly available in most jurisdictions, I estimate the model and find that removing discretionary permit review would have increased the number of new units constructed by 5.5% while reducing the average size of new developments by nearly 2%. The estimated change comes largely from the intensive margin, as, in expectation, only two additional parcels would be redeveloped absent discretionary review.

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> "In the St. Aidan's case, as in many similar episodes across the country, a developer... tried to increase the density of housing in a desirable location. A group of motivated neighborhood defenders participated in the development process and raised a varierty of concerns about the project. They used every regulatory tool at their disposal to slow down, alter, and stop the development. While they ultimately were unable to stop the development, their participation had a dramatic impact on the housing produced. The project ultimately took eleven years to complete, and the final version included nearly 60 percent fewer housing units than the original proposal."
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> —Einstein, Glick, and Palmer (2019, p. 25)

Over the last decade, housing prices and rents have rapidly increased nation-wide, directing the attention of voters and public officials to policies that promote housing affordability. One set of policy solutions aims to increase the supply of new housing, particularly in the urban core of large cities, which have seen the largest increases in housing costs since the financial crisis. In most U.S. cities, multifamily housing developments (i.e., apartment buildings) undergo a discretionary public hearing process (in this paper, referred to as "design review"), typically when they cross a given size threshold. The economics literature has established both an empirical and theoretical link between density regulations and the multifamily housing supply, but despite evidence from political science research that burdensome permitting processes inhibit new apartment development, the effect of design review has garnered little attention within the economics literature. In this paper, I study one typical example of discretionary permit approval—design review in Seattle, Washington—to quantify the link between permitting delays and reductions in the development of new multifamily housing units.

In Seattle, apartment buildings that satisfy certain criteria must obtain a land use permit and undergo a process referred to as design review in order for development to proceed. From 2011 to 2018, developments in most multifamily-zoned parcels were subject to design review if they exceeded eight dwelling units. When a development undergoes design review, the developer must pay additional fees, hold public meetings, respond to public comments, and receive a recommendation from a design review board before the land use permit can be approved, at which point the approval may be appealed to an administrative judge. Using data on apartment permits, I show that undergoing design review increases the delay from permit application to issuance by over four months, from a baseline of 14 months. I document evidence of bunching at the design review threshold, that developers alter their housing supply decision to avoid this delay: At the threshold, there is a discontinuity in average unit size.[1]

Development patterns indicate heterogenous costs of undergoing design review. Although the observed bunching patterns are consistent with a relatively high cost of exceeding the 8-unit design review threshold, there are multiple developments at unit counts just above the threshold. I show that permit approval times for the developments with 9 to 17 units are consistent with the permitting delays of developments with 8 and fewer units, despite the developments

1. I do not apply a bunching estimator similar to that in, among others, Kleven (2016). As described in greater detail in section 2, this setting presents major challenges to doing so, but the structural estimation that I pursue can be considered a bunching estimator similar to Brueckner, Leather, and Zerecero (2024) in that I impose structural assumptions that allow me to exploit the existence of bunching in order to recover the cost of design review.

with 9 to 17 units requiring design review and obtaining an additional permit. As unit counts increase above 17 units, permitting delays increase substantially. These patterns are consistent with developments that would be optimally constructed just above the 8-unit threshold only doing so if the expected cost from undergoing design review is low, while those that would face a high cost instead reduce their unit counts or altogether choose not to proceed with the apartment development. Developments with optimal unit counts well above the design review threshold garner enough variable profit to cover even high permit approval costs.

Motivated by these empirical facts, I construct a model of housing production for apartment development that extends the frameworks of Epple, Gordon, and Sieg (2010), Ahlfeldt and McMillen (2014), Combes, Duranton, and Gobillon (2021), and Baum-Snow and Han (2024) to incorporate multifamily development by modeling developers' simultaneous choice between unit count and development size. Following these papers, I assume Cobb-Douglas production for housing services. In addition to land and non-land factors (proxied by parcel size and square feet of development, respectively), the number of dwelling units is a production scale factor, and the developer optimizes on development size and unit counts, taking lot size as given. By inverting the model-derived optimization conditions, I identify, for each observed development in the sample, a set of rationalizable combinations of marginal unit costs and design review costs. These set of rationalizable costs for 8-unit developments and those for developments with more than 8 units jointly identify the parameters of the design review cost distribution.

Using the estimated parameters from the model, I simulate the development outcomes for every parcel in the sample assuming that there was no design review during the sample period. Absent design review, I find that approximately 137 many more apartment units would have been built, a 5.5% increase in new units constructed. However, the increase in floor space is more modest: as developers substitute between units and floor space, I find that absent design review, these marginal units would be 2% smaller, so the increase in housing supply, as measured by floor space, is smaller (under 5%). Consistent with the reduced form evidence on bunching and unit size patterns, unit count increases come almost entirely from the "missing middle" of small-to-medium apartment building, those with 9 to 17 units. The effects are concentrated almost entirely within the intensive margin of development, i.e., lots that were developed in the baseline scenario with 8-unit apartment buildings were instead developed with larger buildings. In expectation, 2 additional parcels would be redeveloped that were not redeveloped in the baseline scenario.

The counterfactual increases in unit counts under the elimination of design review are not evenly distributed across space. Unit count gains concentrate in the racially diverse and medium-density neighborhoods of the Central Area and Rainier Valley, as well as the wealthy and less diverse neighborhood of Ballard. This suggests that the costs of design review are themselves also not distributed equally across space. The smallest gains would be seen in the inner suburbs of Northwest Seattle and the already-dense neighborhoods of Capitol Hill and the University District. Land value increases would be the highest in neighborhoods with the most developments above 8 units, which include Queen Anne, Cascade (which includes South Lake Union), and Capitol Hill.

Related Literature

Although this study is narrowly focused on the housing supply effects of permitting delays, the literature on land use regulations is broad and finds effects on a variety of economic outcomes. Macroeconomic studies of the costs of zoning restrictions find that these restrictions have large negative effects on economic growth and productivity, from 3.7% to nearly 8% of U.S. GDP, depending on the methodology used (Herkenhoff, Ohanian, and Prescott, 2018; Herkenhoff, Ohanian, and Prescott, 2018; Duranton and Puga, 2023). The growth-inhibiting effects of land use regulations are driven first by restricting the labor supply in high-productivity cities and second by reducing endogenous productivity growth through agglomeration economies. Additionally, Albouy and Stuart (2020) find that land use restrictions also reduce aggregate quality of life by limiting access to high-amenity cities, and they measure the increase in amenity value from relaxing land use restrictions nation-wide at 0.6% of U.S. GDP.

The relationship between land use or other regulations and the housing supply is well-studied in the economics literature (see Gyourko and Molloy (2015) for a comprehensive review of this literature). Land use restrictions have been shown to reduce new supply and increase housing costs (Glaeser and Gyourko, 2002; Glaeser, Gyourko, and Saks, 2005; Gyourko, Saiz, and Summers, 2008; Glaeser and Ward, 2009; Stacy et al., 2023; Büchler and Lutz, 2024; Song, 2025; Kulka, Sood, and Chiumenti, 2025). These effects are particularly concentrated at the lower end of the income distribution (Ma, 2025; Bartik, Gupta, and Milo, 2025) and exacerbate segregation by race and class (Kulka, 2019; Trounstine, 2020; Bartik, Gupta, and Milo, 2025). The overwhelming focus of these studies is on exclusionary zoning as a barrier to development. One of the few papers that evaluates the effect of land use regulations on multifamily development is Glaeser, Gyourko, and Saks (2005) who show that, in Manhattan, the price of a new unit of housing greatly exceeds the marginal cost of constructing additional housing units, and that the ratio of prices to construction costs rose substantially, from 1.2 in 1996 to over 2.0 in 2002. They do not, however, attempt to explain the source of this gap. More recently, D'Amico et al. (2024) model the multifamily housing construction sector in order to evaluate the evolution of its productivity over time. They find that land use restrictions which limit the size of building projects also reduced the size of construction firms in equilibrium, which in turn reduced the productivity of the sector.

Many housing regulation papers rely on the Wharton Residential Land Use Regulation Index (WRLURI) developed most recently by Gyourko, Hartley, and Krimmel (2019) to measure the restrictiveness of land use regulations in a given city. Among the measures of restrictiveness is the average approval time for new construction permits. Using an early version of these data, Mayer and Somerville (2000) estimate that each month of delay in subdivision approvals reduced single-family home permits by 9-13% across 44 MSAs and partial MSAs.[2] Caldera and Johansson (2013) found that this relationship holds for the overall housing supply across countries. They report that the U.S. has both

2. Partial MSAs are used for MSAs that include multiple central cities, such as New York–Newark or San Francisco–Oakland.

the most elastic housing supply among OECD nations as well as the shortest building permit delays, which is consistent with an overall negative relationship they find between permit delays and housing supply elasticity. However, as Gyourko, Saiz, and Summers (2008) show, each measure of land use restrictiveness is highly correlated with the others, making it difficult to isolate the effect of any one measure when comparing across jurisdictions. Additionally, regulatory land use restrictions are endogenous to other physical and economic determinants of development, such as the parcel's (often unobserved to the econometrician) development desirability (Rolleston, 1987, McMillen and McDonald, 1991, Pogodzinski and Sass, 1994, Fu and Somerville, 2001, Gabbe, 2018). By holding the jurisdiction constant and exploiting variation over time and across a within-building margin of adjustment, this study overcomes these endogeneity concerns. Manville et al. (2023) use a sample of multifamily developments in Los Angeles to study the delay effect of discretionary permitting and find that discretionary permitting times were both longer and more variable than by-right permitting times.

As the approach in this study requires the estimation of a production function for housing services, it also contributes to the literature on the supply of housing services. This literature is as old as the field of urban economics but its most recent era was spearheaded by Epple, Gordon, and Sieg (2010), who exploit the duality of the supply function and an assumption of constant returns to scale to flexibly and non-parametrically estimate the housing production function using land value assessments. They find that the production function is well-estimated by the traditional Cobb-Douglas functional form in land and non-land (proxied by capital) factors, and that the capital share of output is nearly constant at 0.856. Ahlfeldt and McMillen (2014) compare this methodology to older alternatives to estimating the capital-land substitution, and their results also suggest that Cobb-Douglas is the best functional form for the housing production function by estimating the elasticity of substitution between land and non-land factors to be very close to one. Combes, Duranton, and Gobillon (2021) exploit the zero-profit condition and profit maximization conditions to calculate latent housing services for a sample of single family homes in France, which they use to non-parametrically estimate the housing production function. They confirm that Cobb-Douglas is a strong approximation of the housing production function and reject the assumption of constant returns to scale in favor of slightly decreasing returns to scale. Critically, these studies exclusively rely on single-family home data, which may not generalize to multifamily housing production.[3] Eriksen and Orlando (2022) model the production function for multifamily buildings specifically in order to estimate the impact of building height on marginal development cost but abstract away from the unit count decision. These studies are relevant to my decision to model the production function for housing services as

3. Explicitly studying multifamily housing development rather than relying on evidence from existing research on single-family development is critical due to the nature of supply in each market. Among the many critical differences are the regulatory regimes, which treat multifamily developments more like commercial real estate than residential real estate, and the development lags and demand for multifamily housing. Single-family homes are relatively inexpensive to build and take at most a year to construct. Multifamily developments require large commercial mortgages and upfront private investments and multiple years from initial the initial planning stage to leasing. Thus, multifamily development decisions are more sensitive to dynamic considerations. Finally, single-family homes are much more likely to be owner-occupied than multifamily units—according to the 2021 American Housing Survey, 64% of detached, single-family homes in the U.S. were owner-occupied, compared to 9.5% of units in buildings with 5 or more units.

Cobb-Douglas in land, capital, and unit count.[4]

This study also contributes to the broad literature on the redevelopment of urban real property stocks, which generally focuses on residential development and was pioneered by Wheaton (1982), who was the first to develop a model of urban residential density patterns with renewable capital. My findings suggest that the permitting environment, rather than purely economic frictions such as capital durability, may be an important determinant of redevelopment patterns, consistent with Siodla (2015), who exploits the exogenous destruction of parts of San Francisco's real property stock in the early 20th century to determine that legal restrictions in addition to capital durability pose strong and persistent barriers to the renewal of the city's housing stock. This paper's findings suggest that the permitting environment may be one such source of friction rather than merely economic barriers such as capital durability. Although I do not model the decision between renovation and redevelopment explicitly, it stands to reason that increasing permitting frictions for new-build developments but not for renovations would lead to relatively greater renovation activity, consistent with Schuetz (2020). A number of other studies further investigate the determinants of which lots in an urban environment are redeveloped first, and at what level of density.[5]

This study differs from the extant literature on regulatory barriers to the housing supply by estimating the effect of additional permitting frictions on multifamily redevelopment within a city rather than qualitatively evaluating them, quantifying the effect of single-family home regulations, quantifying the overall regulatory tax on multifamily development, or by comparing across cities with very different demand shocks and regulatory environments. In doing so, I establish a direct link between permitting frictions and unit count decisions. Moreover, I show that developers adapt to the costs of design review by substituting floor space for dwelling units. This motivates an extension of the standard housing production function to multifamily housing, with parameters that I identify with a novel identification strategy that exploits observed bunching patterns at regulatory thresholds.

The paper proceeds as follows. Section 1 describes the regulatory environment for apartment buildings in Seattle. Section 2 describes the data and presents descriptive statistics and analyses. Section 3 presents a model of developers' production of housing services. Section 4 presents the estimation approach for recovering the model's parameters, with results presented in section 5. Section 6 uses the estimated model parameters to consider the consequences of Seattle's design review policy, and section 7 concludes.

4. As described in Section 3, the model may be interpreted as either having unit count as a third factor of production or as a scale adjustment to housing services produced using only land and capital.

5. For example, Bar-Ilan and Strange (1996) model the property owner's redevelopment decision under uncertainty in the income stream as well as lags between the development decision and the income stream. They find that sufficiently large development lags can induce "leapfrog" development, as opposed to more moderate increases in density over multiple redevelopments. Bulan, Mayer, and Somerville (2009) empirically support this result using condo development data in Vancouver, B.C., to show that increases in both idiosyncratic and systematic risk delay redevelopment by as much as 13%. Finally, Dye and McMillen (2007) use redevelopment data from Chicago to show that density-increasing redevelopment occurs first in lots that are closer to public transit and commercial centers that have older and smaller existing land uses.

1 Policy Background

1.1 Multifamily Zoning in Seattle

In Seattle, multifamily development is restricted to parcels based on their zoning designation, and these zoning designations influence how design review is applied.[6] Figure 1 shows the zoning designations in the City of Seattle as of 2011, the first year of the sample period.[7] The multifamily-specific zoning designations of low rise (LR), mid rise (MR), and high rise (HR) heavily limit non-residential use. Commercial (C), neighborhood commercial (NC), and Seattle Mixed (SM) designations allow for apartments with a wider range of commercial uses. Mixed-use and downtown designations (DOC, DRC, DMC, DMR, PSM, IDM, IDR, DH, and PMM) allow for a wide range of uses but face unique land use restrictions and guidance, including those related to design review. Although some of these zoning designations refer to types of buildings that are associated with density levels, it is not necessarily the case that all residential structures developed in lots under each designation could be referred to according to that designation. For example, a low rise building (e.g., with eight units and two stories) could be built on a lot that is zoned HR for high rise development, and a large apartment building may be permitted on a sufficiently large lot that is designated as LR for low rise development.

As Figure 1 shows, the overwhelming majority of land designated for residential development is designated for detached, single-family homes, and the overwhelming majority of land designated for multifamily residential development is designated as low rise. Low rise–designated parcels are spread throughout the city but primarily concentrated along major transportation routes and near commercial centers. Mid rise–designated parcels are scattered throughout clusters of low rise parcels, closer in to commercial centers, and the handful of high rise–designated parcels are concentrated just outside of the central business district.

1.2 Design Review

In Seattle, design review is the city's discretionary review process for approving housing development permits. All developments are required to obtain a building permit, which is reviewed solely through a clerical process administered by the Seattle Department of Construction and Inspections (SDCI) and is approved if the proposed development meets the requirements of Seattle's building code. However, if a development meets certain criteria, the developer must also obtain a land use permit, also referred to as a master use permit, which can only be approved following a process referred to as design review.

If a development is required to undergo design review, then the developer must pay additional fees, hold additional meetings with SDCI staff, post public notices, hold public meetings, and receive public comments about the devel-

6. See Title 23 of the Seattle Municipal Code for more information on zoning designations and related land use regulations.
7. For reference, all LINK 1 light rail stations are displayed. However, all stations north of downtown opened in 2016 or later.

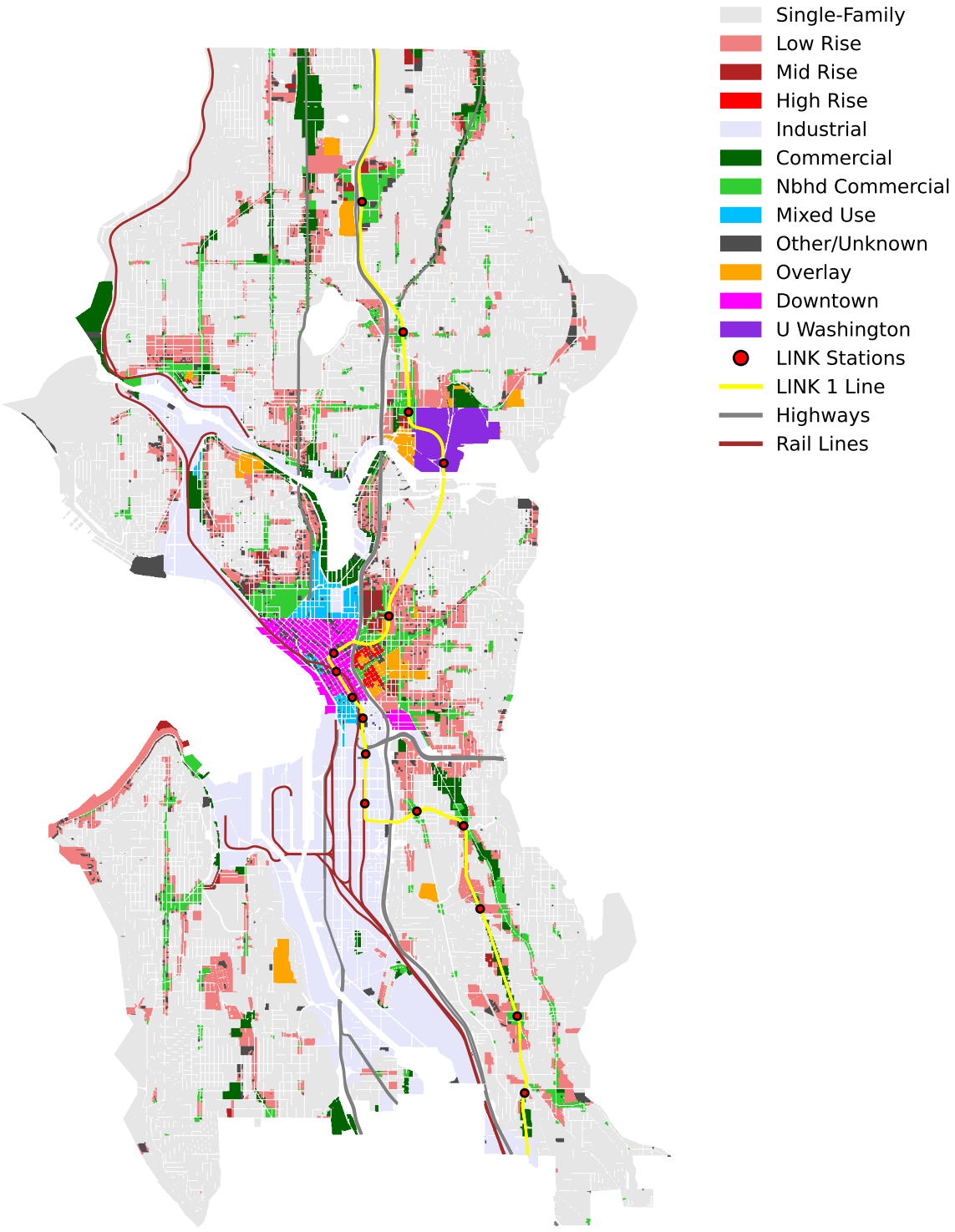


Figure 1: Map of Parcel-level Zoning Designations as of 2011 and Key Transportation Features in the City of Seattle

opment. The meetings are held by the local design review board, which is composed of local residents and design professionals, who are volunteers.[8] At the conclusion of the design review process, the design review board makes a recommendation to the director of the SDCI about whether the land use permit application for the development should be approved. Once the SDCI director approves or rejects the application, the decision may be appealed to an administrative judge, referred to as a hearing examiner, by "any person significantly affected by or interested in the permit".[9] The hearing examiner may accept, reject, or modify the SDCI director's decision, including by imposing additional conditions on the development's approval. This examiner's decision is final and may only be appealed through the state's court system.

Prior to May 2008, design review was required in most parcels that allowed multifamily zones if the proposed development exceeded subjective, ad-hoc thresholds laid out in the State Environmental Policy Act (SEPA). Beginning on May 30th, 2008, design review was required based on the unit count of the proposed development, which was determined by the zoning designation of the lot.[10] The thresholds were 8 units for low-rise designations, 20 units for mid-rise and high-rise designations, 4 units for commercial and neighborhood commercial designations, and 20 units (plus a square footage threshold that depends on specific designation) for downtown and Seattle mixed designations.

On July 1st, 2018, the thresholds were substantially overhauled.[11] Two new design review types, administrative and streamlined design review, were introduced, and the unit count thresholds were removed in favor of thresholds for the gross square footage of development (i.e., floor area of the building). In zones outside of downtown, streamlined design review applies only to certain lots and to developments between 8,000 and 15,000 square feet. Administrative design review applies to developments greater than 15,000 square feet (or 8,000 square feet in lots where streamlined design review does not apply) but below 35,000 square feet. Full design review applies to developments above 35,000 square feet. Streamlined design review is an administrative process similar to the process for construction permits, and the SDCI director's approval decision cannot be appealed. Administrative design review is more-or-less identical to full design review except that the approval recommendation is made by SDCI staff rather than by the design review board.

2 Data and Reduced-Form Evidence

Most of the data were obtained through the Seattle Department of Construction and Inspections (SDCI), either through direct download from the Seattle Open Data Portal, or via public disclosure request. These data include all permit applications for new residential developments in Seattle beginning in 2005–2006, including the dates of application, issuance, and completion, the building type, square footage, design review status, geographic coordinates, and units

8. See A.1 for more information on the design review board.
9. Seattle Municipal Code §23.76.022(C)2.
10. Seattle Ordinance 122670.
11. Seattle Ordinance 125429.

proposed.[12] A parcel shapefile as of 2011, contemporaneous zoning codes, and lot sizes come from the Seattle Office of Planning and Community Development through a public disclosure request and direct data download. Data from the King County Assessor's Office provide parcel characteristics relevant for assessed property value (e.g., traffic noise and quality of view). I use CoreLogic data for assessed values from 2008 onward.[13]

As described in Section 1, from 2008 to 2018, the design review threshold was a unit count that depended on the zoning designation of the lot. Table A1 displays the number of parcels and the number of new apartment developments by zoning designation and policy period for parcels that are zoned for multifamily residential use.[14] The overwhelming majority of both parcels and redevelopments are in low-rise (LR) zones, which have a threshold of 8 units and are distributed throughout the city, primarily along or just off of major arterials or outside of commercial clusters. To control for endogenous zoning designations and to avoid mis-specification by not accounting for non-residential considerations in mixed-use zones, the data are restricted solely to applications in low-rise-designated lots.

As shown in Appendix Table A1, the number of lots that are redeveloped during the sample period is small relative to the number of lots that are not redeveloped: of the 24,368 low-rise-designated lots in Seattle as of 2011, only 112 (0.46%) were redeveloped into apartments from 2011 to 2018 and 62 were redeveloped from 2018 to 2025. This is not surprising, as redevelopment is a rare event for any given parcel (Rollet, 2025). However, this creates a challenge for any estimation strategy that, like the one presented in Section 4, explicitly models the "entry" (i.e., redevelopment) of parcels: If the sample of parcels that do not undergo redevelopment or indeed are outside of developers' consideration set is more than two orders of magnitude larger than the universe of parcels that do enter, estimation becomes inefficient at best and computationally infeasible at worst. Later in this section, I describe how I address this challenge by selecting a subset of non-redeveloped parcels that were likely in the consideration set for redevelopment.

Table 1 compares the mean and inter-quartile range of parcel characteristics between low rise–designated lots that were and were not redeveloped into apartments during the sample period. The first three columns display the statistics for all low-rise-designated lots that were not redeveloped into apartments during the sample period, while final three columns display the statistics for low-rise-designated lots that were redeveloped into apartments during the sample period. Lots that were redeveloped into apartments were larger, more valuable overall, had more valuable land that was a larger share of the total value, and were closer to downtown, the University of Washington campus, and light rail stations. The three biggest differences between redeveloped and non-redeveloped lots are lot size, land value, and land value as a share of total value. This is consistent with the findings from the option value literature that suggests that

12. The exact start date is not clear, as the city began moving to a new system for documenting permits in 2005 and concluded the transition sometime in 2006. Some permits from before the transition have been digitized and are thus included in the sample, but not all. As the sample period begins in 2011, this uncertainty is not a concern for the analysis presented here.

13. These data are also available from the King County Assessor's Office. As such, the full data set could be constructed entirely using publicly available sources at no or merely nominal cost.

14. Throughout the paper, "redevelopment" and "new apartment development" are used interchangeably to refer to the construction of a new apartment building. The lot may have been previously vacent, used for a different purpose, or previously contained an apartment building that was demolished.

	Not Redeveloped								
	Full Sample			Selected			Redeveloped		
	p25	mean	p75	p25	mean	p75	p25	mean	p75
Lot Sqft ('000, L_i)	1.39	4.50	5.00	3.96	8.57	7.02	4.12	8.55	7.12
Assessed Value at Acquisition ('000)	408	768	712	531	1,361	1,269	655	1,633	1,371
Assessed Land Value	141	443	456	366	947	932	454	1,026	1,084
Land Value, % Total Value	31.99	53.73	72.51	56.17	74.85	99.70	56.60	76.92	99.83
Assessed Land Value per Lot Sqft	74	105	134	82	120	155	91	135	161
Dist. CBD (mi)	1.23	2.97	4.15	0.65	2.59	3.83	0.62	2.29	3.36
Dist. UW (mi)	2.06	3.73	4.57	1.65	3.11	4.02	1.08	2.52	3.18
Dist. LRT (mi)	0.63	1.64	2.58	0.44	1.14	1.54	0.34	0.96	1.15
Dist. Commercial Dist. (mi)	0.08	0.34	0.46	0.06	0.32	0.48	0.05	0.33	0.49

Table 1: Summary statistics for parcel characteristics

lots are more likely to be redeveloped when the land value share of a lot exceeds 50% (Lee, Chung, and Kim, 2005).

Using these observed differences in the parcel characteristics of lots that were and were not redeveloped into apartments during the sample period, I derive a propensity score for redevelopment for each parcel in the sample to select a set of non-redeveloped parcels that were likely in the consideration set for redevelopment. To do so, I estimate a probit model on a sample excluding lots that were redeveloped after 2018, where the dependent variable is an indicator for whether a parcel was redeveloped into apartments during the 2011–2018 policy period, and the independent variables are neighborhood fixed effects and parcel characteristics displayed in Table 1:[15]

$$\Pr\left(\text{Redeveloped}_i\right) = \Phi\left(\alpha_{N(i)} + \alpha_{Z(i)} + X_i'\right) \tag{1}$$

Where Φ is a mean-zero cumulative normal distribution function with variance σ^2. The model parameters are estimated via maximum likelihood. The results from equation 1 are displayed in Appendix Table A2. To account for non-linearities in the relationship between the probability of redevelopment and lot size and land value share, lot size is included non-parametrically and land value share is included with quadratic and cubic terms. Every variable is statistically significant at the 10% level except for the interaction between land value and lot size and the distance to the nearest commercial district, consistent with the differences in means displayed in Table 1.

The median estimated probability of development for lots that were redeveloped during the sample period is 3.44% and the median for undeveloped lots is 0.24%. Lots that were not redeveloped during the sample period were dropped from the sample if their estimated probability of redevelopment was below the 10th percentile for lots that were redeveloped during the sample period, 0.006%. The middle three columns of 1 display the mean and interquartile range of parcel characteristics for the set of non-redeveloped parcels that were selected using the propensity scores from the probit estimation. The parcel characteristics of these selected lots are much closer to those of the

15. Also included is a dummy indicator for whether the parcel is zoned for low-rise 3 (LR3) as opposed to low-rise 2 (LR). Higher LR designations have higher floor area ratio maximums. While most of the parcels in the sample are zoned LR2, a non-trivial share are zoned LR3.

redeveloped lots than the full set of non-redeveloped lots, suggesting that this an effective mechanism for reducing the dimensionality of the parcel selection problem, creating a set of parcels that were likely in the consideration set for redevelopment.

The sample is further restricted to exclude special cases. Any parcel was excluded that was redeveloped into townhomes or rowhomes, was dissolved or rezoned during the sample period, was a special tax parcel for an existing condo development, was developed into government-owned or -subsidized housing, was purchased by the government, was developed into congregate housing, or was developed into an apartment but had a special design review case, i.e., was subject to design review despite being below the unit count threshold or was exempt from design review despite being above the unit count threshold. Each individual sample restriction and resulting sample sizes are displayed in Appendix Table A3.

The final sample includes 6,005 parcels, of which 174 were redeveloped into apartments from 2011 onward, and 112 were developed during the 2008–2018 policy period when an 8-unit design review threshold was in place.[16] The locations of in-sample parcels within the City of Seattle are displayed in Figure 2. Parcels that were not redeveloped into apartments during the sample period are displayed in red, while parcels that were redeveloped into apartments are displayed in blue. Neighborhoods with in-sample parcels are labeled.[17] There are large clusters of parcels in Capitol Hill near the boundary with the central business district, the north and west ends of the University District, and in Cascade (more commonly known as South Lake Union) on the eastern shore of Lake Union. Ballard, Queen Anne, and the Central Area (made up primarily of the Central District neighborhood) are also well-represented in the sample. Most in-sample parcels in the Northwest and Northgate neighborhoods are located along State Route 99, better known as Aurora Avenue North. The remaining parcels are scattered throughout the southern neighborhoods of the city, particularly Beacon Hill and Rainier Valley, which are divided by Martin Luther King Jr. Way South and the light rail line that runs through its median until the northern ends of the neighborhoods.

Appendix Table A4 provides summary statistics for developments in low-rise-designated lots during and after the sample period. Over half of the developments were applied for during the 2008–2018 policy period, when the 8-unit design review threshold was in place, and the median development includes 24 units with a little over 500 square feet per unit. There is a long upper tail in development size (by both square footage and unit count), though these developments are dropped when the sample is restricted to lots smaller than 10,000 square feet. 146 (84%) of the 174 developments in the sample include an observed acquisition cost, i.e., the purchase price of the lot(s) prior to redevelopment. For developments that do not include an observed acquisition cost, the assessed value of the lot(s) in the year of permit issuance is used as a proxy. Figure A3 displays the relationship between acquisition price and

16. For estimation purposes, lots that are larger than 10,000 square feet are excluded, as only 14 in-sample developments were on lots larger than this size, and the variance of lot sizes increases substantially above this threshold, creating estimation challenges.

17. The more recognizable neighborhood designations known to locals are much more granular than those that are used for this study, which relies on a coarser classification used by the city's Office of Planning and Community Development due to the sample's relatively small size.

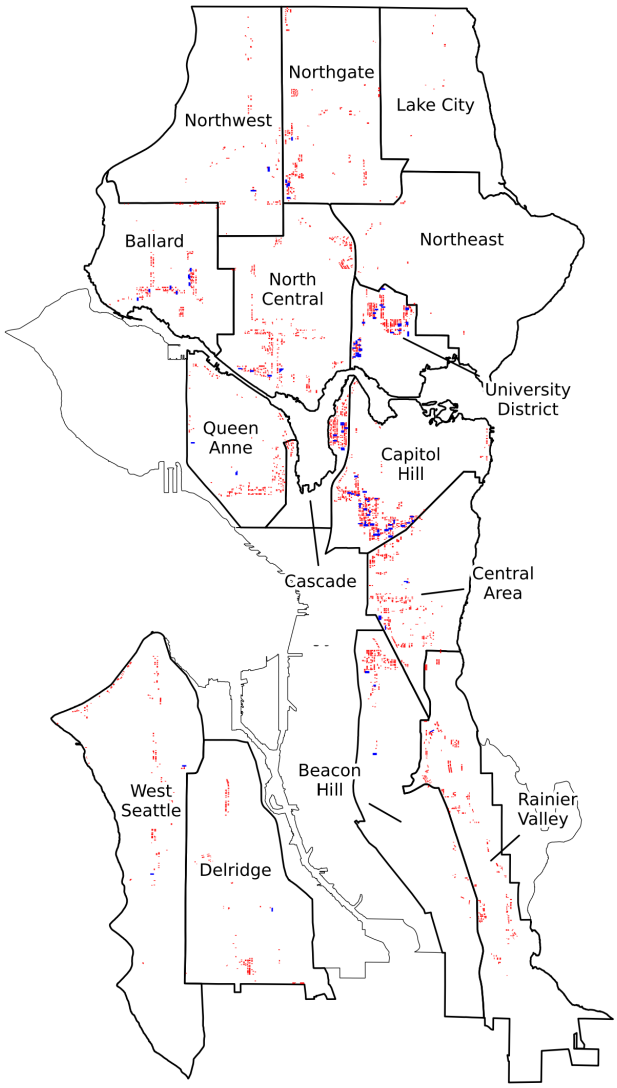


Figure 2: Neighborhoods and parcels in the estimation sample

Notes: The map displays the locations of parcels in the estimation sample, with parcels that were redeveloped into apartments during the sample period displayed in blue and parcels that were not redeveloped into apartments during the sample period displayed in red. Neighborhood boundaries group together smaller neighborhoods and are as defined by the Seattle Office of Planning and Community Development.

assessed value in the year of acquisition, in logs, for the 146 developments in low-rise designated lots with observed acquisition costs. Also displayed is a linear fit line and the 45-degree line, which heavily overlap. A regression of log acquisition price on log assessed value fails to reject a slope of 1 (p-value $= 0.0605$), but rejects an intercept of 0 (p-value $= 0.0335$).

2.1 Reduced-form Analysis of Design Review Costs

The primary mechanism by which design review imposes costs on developers is through delays in the permitting process. To test the extent to which design review delays the permitting process, delay in months is regressed on (log) unit count with year and neighborhood fixed effects according to the following specification:[18]

$$\text{Delay}_i = \alpha_{t(i)} + \alpha_{N(i)} + \beta_1 \mathbb{1}\{\text{DesignReview}_i\} + \beta_2 \log(\text{Units}_i) + \epsilon_i \tag{2}$$

Where $\alpha_{t(i)}$ is a fixed effect for the year in which the first permit application was submitted, $\alpha_{N(i)}$ is a fixed effect for the neighborhood in which parcel i is located, and $\mathbb{1}\{\text{DesignReview}_i\}$ is an indicator variable for whether the development proposed on parcel i was subject to design review. The number of units proposed is included as a control to account for the possibility that larger developments are more complex and thus require longer application reviews. The results from equation 2 are displayed in Table 2. The first three columns show the results including parcels of all multifamily zoning designations, while the last three columns show the results for low-rise-designated lots only. On average, controlling for year and neighborhood fixed effects, design review increases permitting delay by three and a half to six months, and the size of the effect is stable across specifications with unit count controls. The average delay from application to issuance is 14 to 15 months, indicating that design review increases the delay by roughly one-third.

The sample on which this estimation is conducted includes only development permits that were applied for and eventually issued. Because developers may adjust their development plans to avoid design review or even choose not to develop at all due to anticipated long delays, the estimates from Table 2 may understate the true effect of design review on permitting delay. Thus, these estimates should be interpreted as lower bounds on the effect of design review on permitting delay.

Since developers may avoid the additional delay imposed by design review by reducing the size of their developments to fall below the design review threshold, another indicator of the cost of design review is whether developments are "bunched" at the design review threshold. Figure 3 displays a histogram of the number of units proposed during the during the 2011-2018 sample period, when the design review threshold was 8 units for low-rise-designated lots.

The density of developments increases up to the 8-unit threshold, where there is a large spike in the number of developments, and then drops off sharply after the threshold. However, the mass of developments just above the threshold is still nonzero. The existence of apparent bunching with positive mass on both sides of the threshold implies

18. The delay is measured as the number of months from when the first permit application was submitted to when the last permit was issued. In cases with design review, the first permit application is typically for a land use permit, and the last permit issued is typically for a construction permit. In cases without design review, the first permit applied for and last permit issued are typically both construction permits. Some parcels have multiple construction associated with them, with the developer sequencing the construction permits such that the second permit is applied for only after the construction for the initial permit is complete. As such, the delay analysis is conducted on a permit-level sample, whereas all other analyses are conducted on a development-level (i.e., parcel-level) sample. The sample is restricted to permits that were issued and eventually completed to align with restrictions in the development-level sample.

	LR, MR, HR Zones			LR Zones Only		
	(1)	(2)	(3)	(4)	(5)	(6)
1(Design Review)	5.732***	3.902**	3.517**	5.306***	4.467***	4.170**
	(0.692)	(1.360)	(1.552)	(1.005)	(1.301)	(1.480)
log(No. Units)		1.266	1.547		0.729	0.962
		(0.884)	(0.978)		(0.707)	(0.902)
Mean Delay	14.6	14.6	14.6	13.9	13.9	14.0
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	No	No	Yes	No	No	Yes
R^2	0.179	0.199	0.221	0.222	0.228	0.251
Clusters	13	13	12	13	13	12
Obs.	296	296	295	223	223	222

Jackknife standard errors, clustered by neighborhood, in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Regression results for permit delay in months by design review status

Notes: The table displays OLS regression results for permit delay in months on an indicator for whether the development was subject to design review and log units proposed, with fixed effects for neighborhood of development and year of application submission. Standard errors, clustered by neighborhood, are displayed in parentheses and estimated via jackknife to account for the small number of clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

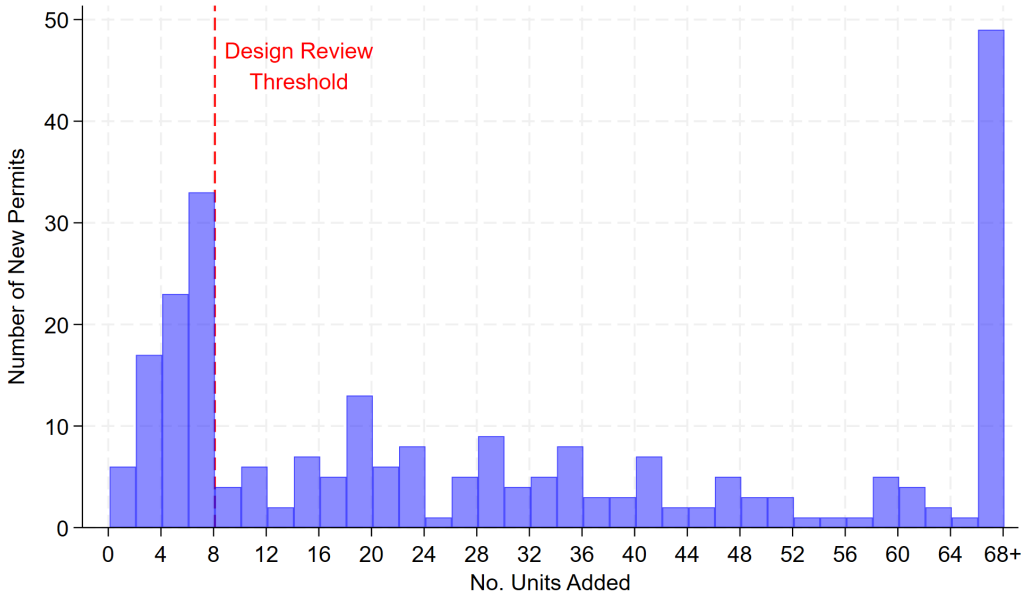


Figure 3: Histogram of units proposed by during the sample period

that the cost of design review is not constant across all parcels, which is consistent with design review cost depending on parcel and/or neighborhood characteristics.

No such bunching is apparent in the post-2018 period, when the design review threshold was a square footage threshold that was rarely binding.[19] However, the mass of development proposals well below 8 units is reduced as

19. Figure A4 in appendix A.2 displays a histogram of unit counts for developments proposed during the post-2018 period.

well, indicating that either the set of parcels that were developed into apartments during the post-2018 period were more favorable to larger developments, or that demand factors induced developers to build larger developments during this period, or both. In appendix A.2, evidence is presented in favor of the former explanation.[20]

The existence of bunching at discrete policy thresholds such as that displayed in Figure 3 provides variation that may be used to identify key parameters. In the tax literature, such bunching is often used to estimate the income elasticity of labor (Saez, 2010, Kleven and Waseem, 2013, Kleven, 2016). However, this approach cannot be used to recover the elasticity of unit counts with respect to regulatory costs, as, contrary to the tax case, the cost of design review is neither constant nor fully observable to the econometrician. Despite facing a similar set of challenges, Brueckner, Leather, and Zerecero (2024) exploit bunching at floor area ratio (FAR) maximums in New York City to estimate the unobserved cost of obtaining FAR exemptions. However, in order to do so, the authors impose a set of functional form assumptions on the housing production function and developers' optimal floor area as a function of the latent local price of housing services. As Brueckner, Leather, and Zerecero abstract away from the choice of unit counts and adopt a constant returns to scale assumption between floor area and land, inverting the relationship between the developer's sole continuous choice variable (development size) and the latent price variable is straightforward. The application in this paper is complicated by the existence of two choice variables, with the policy threshold of interest applying to a discrete choice variable.[21] Instead, the existence of bunching provides variation that may be used to identify structural parameters in the model presented in Section 3. As the existence of bunching with mass above the threshold is a sufficient condition for the identification of the structural policy parameters, the estimation used in this paper can be considered an application of the bunching estimation methodology similar to Brueckner, Leather, and Zerecero (2024).

Since developers have two primary choice variables when designing an apartment building—the number of units and the size of those units—it stands to reason that, when developers reduce the number of units in a new apartment building to avoid design review, they may compensate by increasing the size of those units. This is consistent with Proposition 1, which is defined in Section 3 and proven in Appendix A.9, which uses a parsimonious set of production function assumptions to show that any non-negligible cost of design review with a discrete unit count threshold will lead to bunching at the threshold, with bunched developments having larger average unit sizes than developments just below the threshold. To test this proposition empirically, I compare the floor area of developments above and below the unit count threshold during the pre-2018 policy period, where an often-binding unit count threshold was in place, to those proposed during the post-2018 policy period, when a rarely-binding square footage threshold was in place.

20. In particular, development patterns are consistent with townhouses becoming more attractive relative to small apartment buildings during the post-2018 period, consistent with policy changes unrelated to design review in the ordinance that established the new design review threshold.

21. Additionally, Brueckner, Leather, and Zerecero (2024) are unable to separately identify the capital production share and the marginal floor area cost. The authors thus rely on the capital production share estimate from Combes, Duranton, and Gobillon (2021) to identify the cost of exceeding FAR limits. The extant housing production literature does not provide estimates for the production share of both capital and land, which would be required for identification of the production function in a model that includes a unit count input, as is the case in this setting.

Figure 4 displays a linear regression discontinuity design (RDD) plot between square footage and units proposed by policy period, in logs. Next to the dashed line in each plot that indicates the 8-unit design review threshold that was in place during the pre-2018 period, the bias-corrected linear RDD estimate is displayed.[22] As predicted by the model and proposition above, there exists a discontinuity in the relationship between square footage and units proposed in the pre-2018 period at the 8-unit threshold, but no such discontinuity exists in the post-2018 period. The RDD estimate in the pre-2018 period implies a 0.9 log-point reduction in square footage at the 8-unit threshold, which is statistically significant at the 10% level. Appendix Table A5 displays the results of regressions testing the same relationship:

$$\log\left(DevSqft_i\right) = \beta_0 + \beta_1 \log\left(Units_i\right) + \beta_2 \mathbb{1}\left\{\text{Units}_i > 8\right\} + \beta_3 \mathbb{1}\left\{\text{Units}_i > 8\right\} \times \log\left(Units_i\right) + \epsilon_i. \tag{3}$$

Using only observations from the pre-2018 period, the coefficients on the dummy variable and its interaction with log units are large (in absolute terms) and statistically significant at the 1% level. In the same specification using only observations from the post-2018 period, the coefficients are small and statistically insignificant at conventional levels.

When developers simulateously choose the number of units and the total development size, the relationship between these two variables implicitly determines average unit size, which more directly relates to the quantity of housing services produced. Figure 5 displays the same RDD plots as Figure 4, but a quadratic fit and with square footage per unit on the vertical axis and units counts in levels on the horizontal axis. The right panel, which displays the relationship for developments proposed during the post-2018 period, shows a smooth quadratic relationship between square footage per unit and units proposed, with no apparent discontinuity at 8 units. The left panel, which displays the relationship for developments proposed during the pre-2018 period, shows a sharp decline in average unit size for developments that undergo design review. The RDD estimate implies a decrease of 670 square feet per unit, statistically significant at the 1% level. While this decrease is very large, the post-2018 plot shows that some of this decline would have occurred even in the absence of design review. This is in part due to the fact that the y-axis displays *gross* square footage per unit, which includes common areas and amenities such as hallways, parking garages, lobbies, and laundry rooms, which do not scale one-to-one with unit count.

Finally, to test whether the interpretation of delay as the primary cost of design review and this cost as being stochastic is consistent with the data, the relationship between delay and the size of developments is examined. Figure 6 displays a binscatter of permit delay in months against units proposed for apartment development permits in low rise-designated lots from 2011 to 2018. Below the design review threshold of 8 units, permit delays are stable at around 10 months. Between 9 units and 18 units, permitting delays remain low but increase slightly, reflecting increased

22. The estimate provided uses the bias-corrected RDD method described by Calonico, Cattaneo, and Titiunik (2014), using a triangular kernel and optimal bandwidth selection, which minimizes mean squared error and uses the same bandwidth on either side of the threshold.

As the number of total observations in each period is small, the running variable (units proposed) is discrete, and there are several ranges along the running variable with no observations, the RDD estimates should be interpreted with caution. Appendix A.2 displays the scatter plots for each RDD plot included in this section.

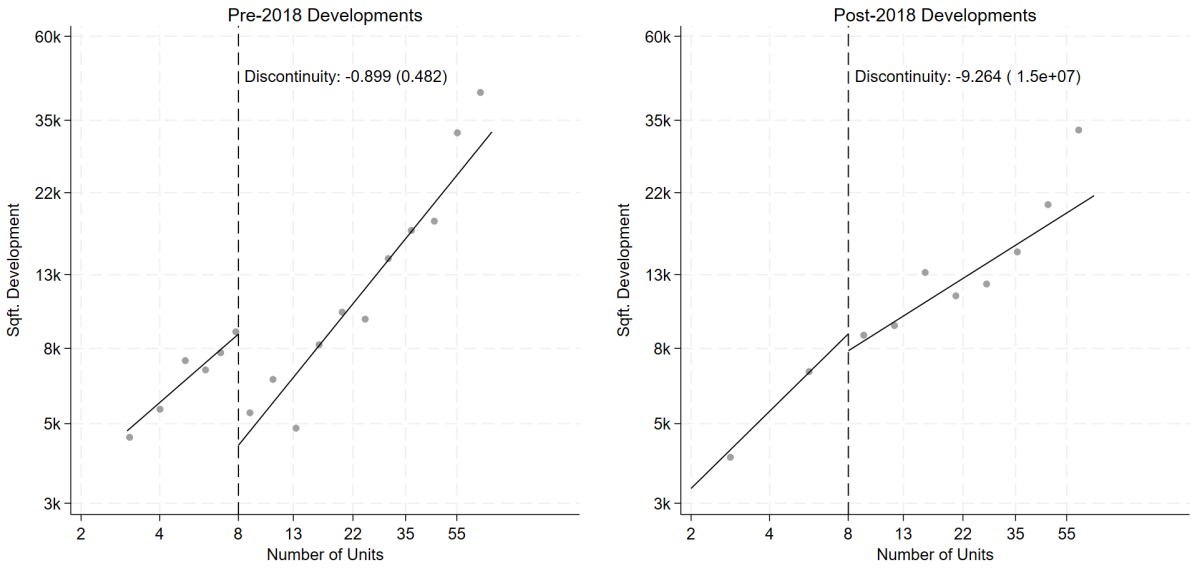


Figure 4: Regression discontinuity for square footage and units proposed by policy period

Notes: The left panel displays the relationship between gross square footage and units proposed for new apartment developments during the 2008-2018 period, when an 8-unit design review threshold was in place, and the right panel displays the same relationship during the post-2018 period, when a 35,000 square footage threshold was in place. Axis labels are in levels but the regression is estimated in logs. The discontinuity displayed is estimated using the bias-corrected local linear regression discontinuity method described in Calonico, Cattaneo, and Titiunik (2014) with a triangular kernel and optimal bandwidth selection.

but low permitting delay from exceeding the design review threshold. At around 20 units, permitting delay becomes substantially more variable but consistently above the average for permits that were not subject to design review.

In summary, the reduced-form analyses presented in this section demonstrate that design review increases permitting delays, resulting in developers reducing the size of their developments to avoid design review, and that developers who do so build larger units than they otherwise would have. The developments that are built just above the design review threshold appear to suffer only negligible delays relative to those built 10 or more units above the threshold, suggesting that the cost of design review is stochastic, directly related to permitting delay, and at least somewhat observable to developers prior to permit application.

3 Model

A given city is divided into a set of developable parcels $\mathcal{I}$. Each parcel $i \in \mathcal{I}$ has exogenous characteristics X_i and lot size L_i. For each parcel i, a large number of identical developers observe the price of housing services p_i, marginal unit cost c_i, and cost of obtaining a land use permit ω_i before deciding whether to acquire the parcel at price q_i and develop it into an apartment development during the current period. It is assumed that developers are profit maximizing and

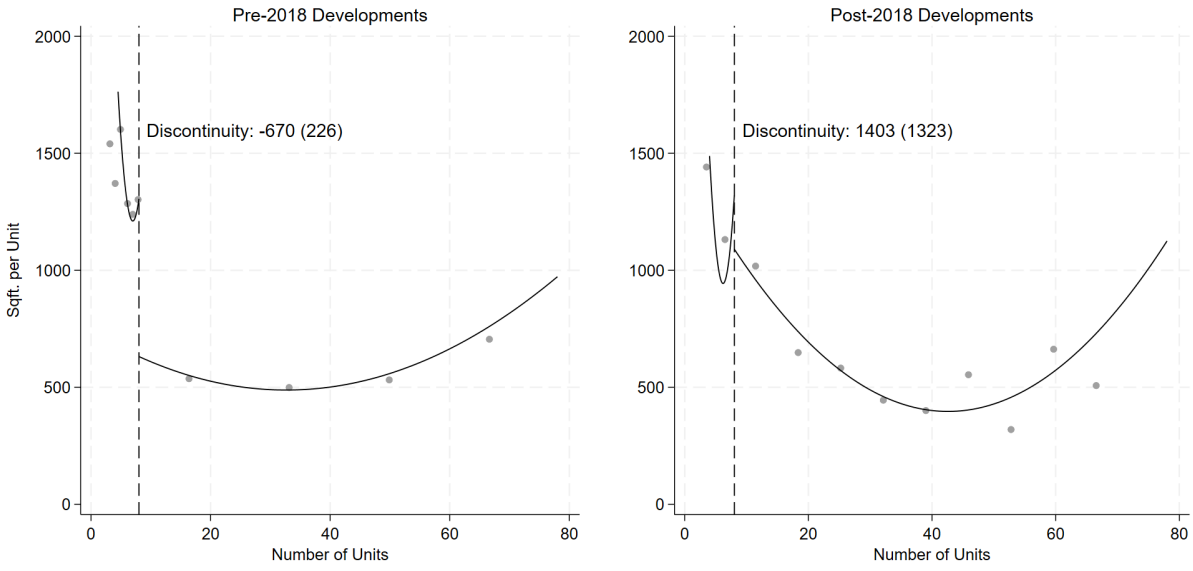


Figure 5: Regression discontinuity for square footage per unit and units proposed by policy period

Notes: The left panel displays the relationship between gross square feet per unit and units proposed for new apartment developments during the 2008-2018 period, when an 8-unit design review threshold was in place, and the right panel displays the same relationship during the post-2018 period, when a 35,000 square footage threshold was in place. Axis labels are in levels but the regression is estimated in logs. The discontinuity displayed is estimated using the bias-corrected local quadratic regression discontinuity method described in Calonico, Cattaneo, and Titiunik (2014) with a triangular kernel and optimal bandwidth selection.

price takers in both input and output markets.

Each apartment delivers H_i housing services to u_i households, where u_i is the number of units in the development. Consistent with the extant housing production literature, housing services are assumed latent, homogenous, and produced by a production function with capital, K_i, measured in square footage of development, and land, L_i, measured in square footage of the lot, as inputs. Additionally assume that the production function is strictly increasing in both inputs and in unit count. Given this parsimonious set of assumptions, the existence of bunching with a behavioral response at a discrete threshold can be proven given a sufficiently high cost of design review, as shown in Appendix A.9:

Proposition 1 *For a sufficiently high cost of design review, there are marginal lots that will redevelop below the threshold at a lower level of capital than they otherwise would have.*

Corollary: *Marginal lots will develop at higher levels of capital than inframarginal lots due to the higher price of housing services on marginal lots.*

The implication of this proposition is that, in the presence of design review with a non-zero compliance cost, there will be a mass of developments at the design review threshold that would otherwise have developed at a higher number of

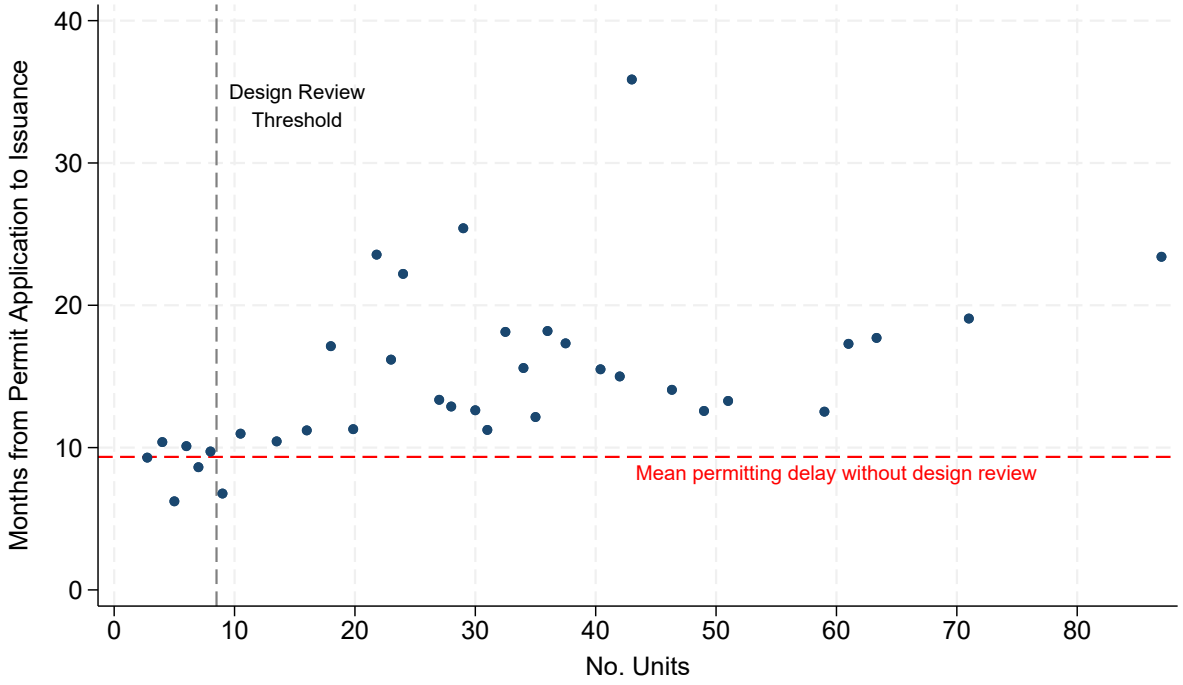


Figure 6: Binscatter of the relationship between permit delay and units proposed

Notes: Observations are grouped into 50 equally-sized bins by units proposed. Only permits that were applied for prior to the 2018 policy change are included. The vertical axis displays the time in months from the first permit application to the last permit issuance. The red, dashed horizontal line indicates the average delay for permits that were not subject to design review (i.e., those proposing 8 or fewer units).

units, and these developments will be larger (in terms of square footage) than those that would have developed at the threshold regardless of design review.

For the full structural model, I follow the existing housing production literature in assuming a Cobb-Douglas functional form and that each of the u_i dwelling units in the development has the same square footage and that the land on the lot is shared equally across all units. The production function is thus given by

$$H_i = \sum_{j=1}^{u_i} A(K_i/u_i)^{\alpha_K}(L_i/u_i)^{\alpha_\ell} \tag{4}$$

where α_ℓ and α_K are the strictly positive output shares of capital and land with $\alpha_\ell + \alpha_K < 1$. A is a constant, universal productivity scalar. Without loss of generality, it is assumed that $A = 1$.[23] Simplifying this expression yields the following:

$$H_i = u_i^{1-\alpha_K-\alpha_\ell} K_i^{\alpha_K} L_i^{\alpha_\ell}. \tag{5}$$

23. As the estimation only relies on equations derived from the profit function, the scale parameter of the price function cannot be separately identified from the scale parameter of the production function. Thus, either the productivity or price scale parameter must be normalized.

This specification implies either a three-factor model with constant returns to scale or a two-factor model with only capital and land as inputs, but with decreasing returns to scale for those inputs. The implications of each of these interpretations are discussed in Appendix A.8.

Although housing services are assumed to be homogenous, demand for them varies across parcels due to both observed and unobserved exogenous characteristics such as location, neighborhood amenities, and access to employment opportunities. Let p_i be the (unobserved) price of housing services on parcel i and q_i be the price of parcel i (including any improvements). Assume that the marginal costs of capital is given by r and is fixed and constant throughout the city. Furthermore, let ω_i be the fixed cost of obtaining a land use permit, which is only required for developments that exceed the unit count threshold, $\overline{u}$. Then, the profit function for a development on parcel i is given by

$$V_i(K_i, u_i; c_i, \omega_i) = p_i u_i^{1-\alpha_\ell-\alpha_K} K_i^{\alpha_\ell} L_i^{\alpha_K} - rK_i - c_i u_i - \omega_i \mathbb{1}\{u_i > \overline{u}\} - q_i. \tag{6}$$

The developer chooses to enter if the profit from developing parcel i exceeds their outside option, π_i^0, which represents the best alternative to developing lot i into an apartment during the period. π_i^0 includes the option value of waiting to develop the parcel into an apartment in a future period as well as the value of any alternative uses of the parcel, such as redevelopment into attached or detached single-family housing. Let D_i be an indicator variable that equals 1 if the developer chooses to develop parcel i into an apartment building during the period and 0 otherwise. Then, the developer's entry decision is characterized by

$$D_i = \mathbb{1}\left\{\max_{K_i,u_i} \pi_i \geq \pi_i^0\right\}. \tag{7}$$

Lots that remain undeveloped at the end of the time period are assumed to have sufficiently high option values such that the profit from developing them during the period at the profit-maximizing intensity would be negative. In other words, the lowest price that the current lot owner would be willing to accept for the lot is greater than what any developer would be willing to pay to acquire the lot.

3.1 Solution

The developer's problem can be solved in two stages. First, the developer decides whether to acquire and develop parcel i. Conditional on choosing to develop parcel i, the developer chooses the optimal capital stock, K_i, and number of units, u_i, to maximize profit. In the first stage, the land owner chooses a price of q_i to extract all economic profit from the development:

$$q_i = \max_{K_i,u_i} p_i u_i^{1-\alpha_\ell-\alpha_K} K_i^{\alpha_\ell} L_i^{\alpha_K} - rK_i - c_i u_i - \omega_i \mathbb{1}\{u_i > \overline{u}\} - \pi_i^0. \tag{8}$$

This zero-profit condition follows from the developer lacking market power and the number of parcels being fixed and finite.

The intensive margin (i.e., the choice of capital and number of units) is determined by the first-order conditions of the profit function with respect to K_i and u_i. As capital is a continuous variable, its profit-maximizing value, conditional on unit count, is solved with the first order condition of profit with respect to K_i:

$$K_i^*(u) = \left(\frac{\alpha_K p_i}{r} u^{1-\alpha_\ell-\alpha_K} L_i^{\alpha_\ell}\right)^{\frac{1}{1-\alpha_K}}. \tag{9}$$

Two factors complicate the solution for the number of units. First, the number of units is a discrete variable, which implies a set of rationalizable parameter vectors for each u_i. Second, the cost of obtaining a land use permit, ω_i, introduces a discontinuity in the marginal cost of adding a unit at $u_i = \overline{u}$. To solve for the optimal number of units, first substitute the optimal capital choice from 9 into the profit function to obtain reduced-form profit as a function of unit count, conditional on marginal unit cost c and design review cost, ω:

$$\tilde{V}_i(u; c, \omega) = \left(p_i u^{1-\alpha_K-\alpha_\ell} L_i^{\alpha_\ell}\right)^{\frac{1}{1-\alpha_K}} \left(\frac{\alpha_K}{r}\right)^{\frac{\alpha_K}{1-\alpha_K}} (1-\alpha_K) - cu - \omega \mathbb{1}\{u > \overline{u}\} - q_i. \tag{10}$$

Denote with $\tilde{u}_i^*$ the unit count that maximizes $\tilde{V}_i(u; c, 0)$, which is the floor of the solution to the continuous first-order condition of equation 10 with $\omega = 0$:

$$\tilde{u}_i^* = \left\lfloor \left[\left(\frac{1-\alpha_K-\alpha_\ell}{c_i}\right)\frac{\alpha_K}{r}\right]^{\frac{1-\alpha_K}{\alpha_\ell}} p_i^{\frac{1}{\alpha_\ell}} L_i \right\rfloor. \tag{11}$$

That is, $\tilde{u}_i^*$ is the profit-maximizing unit count assuming that the development does not undergo design review. Then, the optimal unit count is given by

$$u_i^* = \begin{cases} \tilde{u}_i^* & \text{if } \tilde{V}_i(\tilde{u}_i^*; c, \omega_i) \geq \tilde{V}_i(\overline{u}; c, \omega_i) \\ \overline{u} & \text{if } \tilde{V}_i(\tilde{u}_i^*; c, \omega_i) < \tilde{V}_i(\overline{u}; c, \omega_i) \end{cases}, \tag{12}$$

where the first case corresponds to developments that either do not trigger design review or do trigger design review but for which developing at $\tilde{u}_i^*$ is more profitable than developing at $\overline{u}$. The second case corresponds to developments that would prefer to develop at $\tilde{u}_i^*$ absent design review but choose to develop at the threshold $\overline{u}$ because the cost of design review, ω_i, exceeds the marginal profit from developing at $\tilde{u}_i^*$.

4 Identification & Estimation

4.1 Identification

The model includes four sources of unobserved heterogeneity: the price of housing services, p_i, the marginal cost of adding a unit, c_i, the outside option, π_i^0, and the cost of design review, ω_i. To identify the model, first assume that the value of the outside option is equal to the sum of the assessed value of the parcel, q_i^0, and unobserved value ϕ_i, which represents both assessor error and any fixed costs associated with apartment development.[24] For parcels that were redeveloped during the sample period, the assessed value is observed in the year of permit issuance. For parcels that were not redeveloped, the assessed value is observed in 2011, the first year of the sample period.

For each parcel that is developed into an apartment during the sample period, the price of housing services, p_i, is point-identified by the first-order condition for capital, by solving equation 9 for p_i:

$$p_i = \frac{r}{\alpha_K} K_i^{1-\alpha_K} u_i^{-(1-\alpha_K-\alpha_\ell)} L_i^{-\alpha_\ell}. \tag{13}$$

Given a value for marginal unit cost c_i and cost of design review ω_i, there exists a unique fixed cost shock ϕ_i by inverting the zero-profit condition in equation 8, after substituting equation 13 for p_i in 8:

$$\phi_i(c,\omega) = r\left(\frac{1-\alpha_K}{\alpha_K}\right) K_i - cu_i - \omega \mathbb{1}\{u_i > \overline{u}\} + q_i^0 - q_i. \tag{14}$$

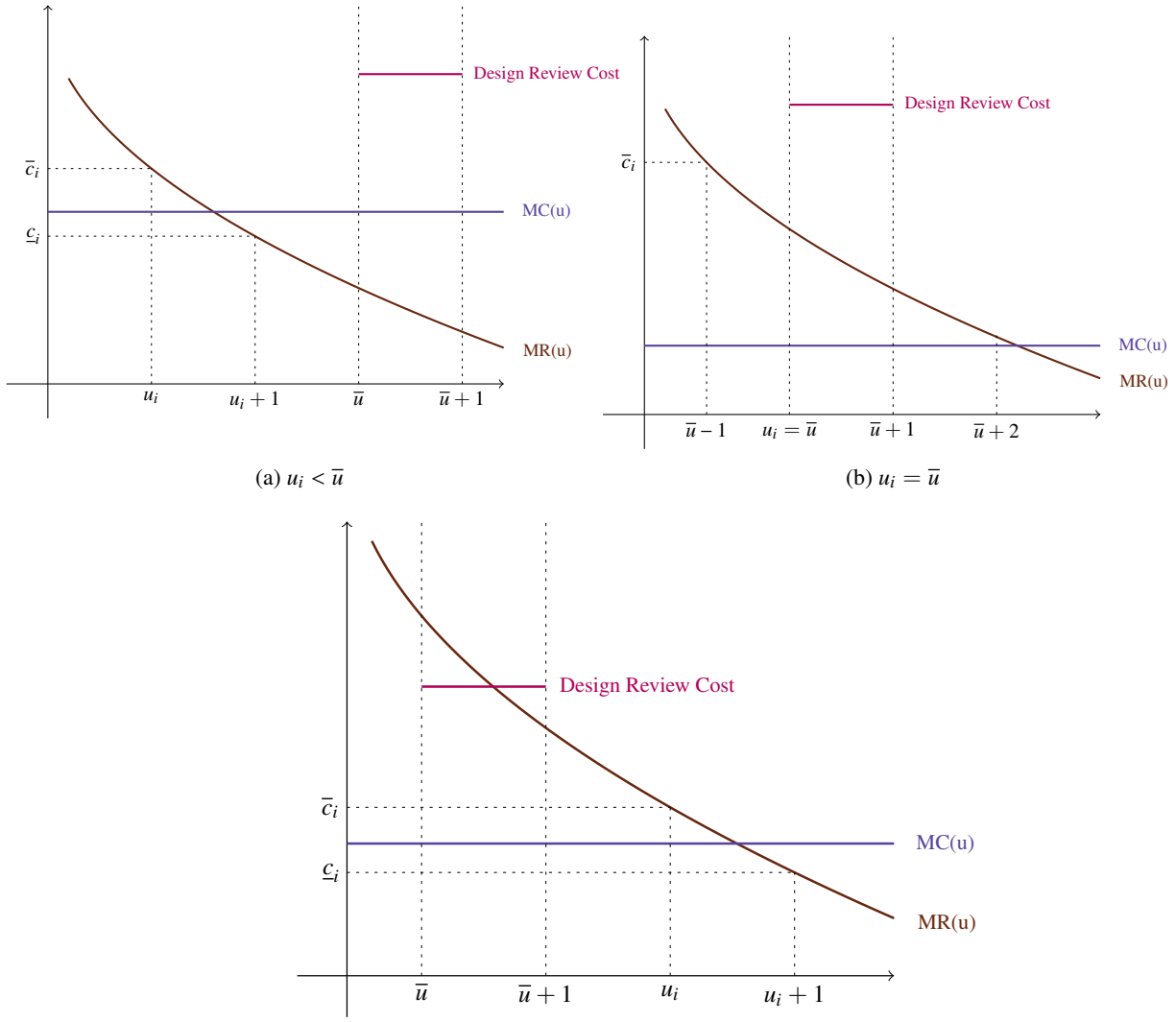
For each developed parcel, a set of rationalizable values of c_i and ω_i are identified by the first-order condition for unit count. The bounds of the set have closed-form solutions that are a piecewise function of u_i relative to the design review threshold, $\overline{u}$. In particular, there are three cases: $u_i < \overline{u}$, $u_i = \overline{u}$, and $u_i > \overline{u}$. For each case, the stylized relationship between the marginal cost and marginal benefit of adding a unit as well as the cost of undergoing design review is illustrated in Figure 7. For developments with observed unit counts strictly below the design review threshold ($u_i < \overline{u}$), a unit interval of rationalizable marginal costs is identified by the first-order condition for unit count, as shown in panel 7a. In this case, the cost of design review exists but is irrelevant to unit choice, and the bounds of the marginal cost interval are determined by the indifference conditions for adding or removing a unit:

$$\tilde{V}_i(u_i+1 \,|\, \underline{c}_i, \omega_i, u_i < \overline{u}) - \tilde{V}_i(u_i \,|\, \underline{c}_i, \omega_i, u_i < \overline{u}) = 0 \tag{15}$$

$$\tilde{V}_i(u_i \,|\, \overline{c}_i, \omega_i, u_i < \overline{u}) - \tilde{V}_i(u_i-1 \,|\, \overline{c}_i, \omega_i, u_i < \overline{u}) = 0. \tag{16}$$

Where $\tilde{V}_i(\cdot)$ is the indirect utility function defined in equation 10.

24. I show in Appendix A.10 that applying a fixed cost to the profit function and an additive error to the assessor's valuation of the parcel results in the sum of the two being identified as a single error term.



(a) $u_i < \overline{u}$

(b) $u_i = \overline{u}$

(c) $u_i > \overline{u}$

Figure 7: Relationship between the optimal unit count, marginal cost, and cost of design review for each unit count choice

The plot for developments with observed unit counts exactly equal to the design review threshold ($u_i = \overline{u}$) is displayed in panel 7b. There exists an unobserved optimal unit count determined by the intersection of the curves for the marginal cost and marginal benefit of adding a unit. However, the additional profit from exceeding the design review threshold to construct a development at this unobserved optimal unit count is less than the cost of design review, so the developer chooses to build at the threshold. The upper bound of the marginal unit cost is defined by the indifference condition for removing a unit, as in the previous case, but any marginal unit cost below the upper bound

is rationalizable by a sufficiently high cost of design review:

$$\tilde{V}_i(\overline{u} \,|\, \overline{c}_i, \omega_i, u_i = \overline{u}) - \tilde{V}_i(\overline{u} - 1 \,|\, \overline{c}_i, \omega_i, u_i = \overline{u}) = 0 \tag{17}$$

$$\max_u \tilde{V}_i(u \,|\, c, 0, u_i = \overline{u}) - \tilde{V}_i(\overline{u} \,|\, c, 0, u_i = \overline{u}) = \underline{\omega}_i(c). \tag{18}$$

Where $\underline{\omega}_i(c)$ is the minimum cost of design review, given marginal unit cost c, that would rationalize a unit count of $\overline{u}$.

Finally, the plot for developments with observed unit counts strictly above the design review threshold ($u_i > \overline{u}$) is displayed in panel 7c. A unit interval of rationalizable marginal costs is identified by the first-order condition for unit count, as in the case when $u_i < \overline{u}$. However, because the unit count exceeds the design review threshold, the cost of design review must be sufficiently low to rationalize this choice: the profit from exceeding the design review threshold must be greater than the cost of design review. For each marginal unit cost within the interval of rationalizable marginal unit costs, there exists a maximum cost of design review, $\overline{\omega}_i(c)$, at which the developer is indifferent between u_i and $\overline{u}$:

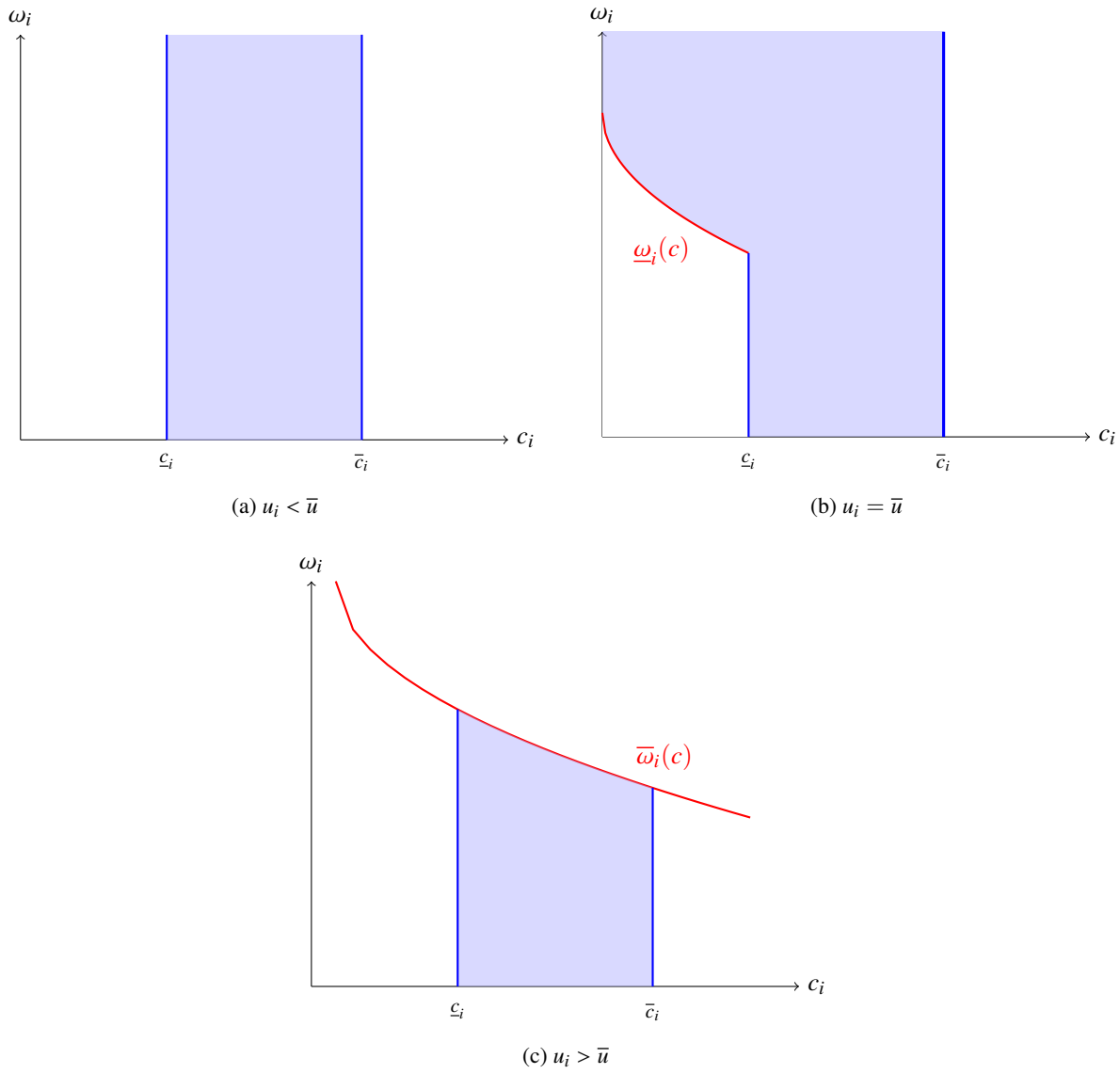
$$\tilde{V}_i(u_i + 1 \,|\, \underline{c}_i, \omega_i, u_i > \overline{u}) - \tilde{V}_i(u_i \,|\, \underline{c}_i, \omega_i, u_i > \overline{u}) = 0 \tag{19}$$

$$\tilde{V}_i(u_i \,|\, \overline{c}_i, \omega_i, u_i > \overline{u}) - \tilde{V}_i(u_i - 1 \,|\, \overline{c}_i, \omega_i, u_i > \overline{u}) = 0 \tag{20}$$

$$\tilde{V}_i(u_i \,|\, c, 0, u_i > \overline{u}) - \tilde{V}_i(\overline{u} \,|\, c, 0, u_i > \overline{u}) = \overline{\omega}_i(c). \tag{21}$$

Figure 8 displays the set of rationalizable marginal unit cost–design review cost vectors (c_i, ω_i) for each of the three cases. These plots also represent the identification of the structural error terms for marginal unit cost and the cost of design review.

Given the discrete outcome variables of unit count (u_i) and entry (D_i) and the set identification of the structural errors c_i and ω_i, the identification strategy proceeds with distributional assumptions on the structural errors. Three of the model's error terms—price, marginal unit cost, and cost of design review—are bounded below by zero and are thus assumed to be log-normally distributed. The final error term, fixed cost shock ϕ_i, is unbounded and is thus assumed to be normally distributed. Additionally, the price of housing services on lot i is assumed to vary by neighborhood, $N(i)$, and by distance to the city center, light rail stations, commercial centers, and to the University of Washington, all of which are included in the vector X_i. No assumptions are made regarding the covariance between each of the structural error terms with the exception of the cost of design review, which is assumed to be uncorrelated with all other error



(a) $u_i < \overline{u}$

(b) $u_i = \overline{u}$

(c) $u_i > \overline{u}$

Figure 8: Marginal Cost and Design Review Identification Cases

Notes: Each panel displays the set of rationalizable marginal unit cost–design review cost vectors (c_i, ω_i) for each of the three unit count cases. The shaded region represents the set of rationalizable values, while the solid lines represent the bounds of the set. In panel (a), the developer's optimal unit count choice is unaffected by the cost of design review, since it lies strictly below the design review threshold, $\overline{u}$. In panel (b), the developer's optimal unit count choice is the design review threshold, $\overline{u}$, but it may have been higher if the cost of design review were sufficiently low. Thus, each marginal unit cost c_i that would, absent design review costs, induce the developer to choose a unit count above $\overline{u}$ is rationalizable by a sufficiently high cost of design review, ω_i. In panel (c), the developer's optimal unit count choice is above the design review threshold, $\overline{u}$, and thus the cost of design review must be sufficiently low to rationalize this choice.

terms.[25] The joint distribution of the model's error terms is thus given by

$$\begin{pmatrix} \log(p_i) \\ \log(c_i) \\ \phi_i \\ \log(\omega_i) \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} \overline{p} + d_{N(i)} + X_i'\gamma \\ \overline{c} \\ \overline{\phi} \\ \overline{\omega} \end{pmatrix}, \begin{pmatrix} \sigma_p^2 & \sigma_{pc} & \sigma_{p\phi} & 0 \\ \sigma_{pc} & \sigma_c^2 & \sigma_{c\phi} & 0 \\ \sigma_{p\phi} & \sigma_{c\phi} & \sigma_\phi^2 & 0 \\ 0 & 0 & 0 & \sigma_\omega^2 \end{pmatrix} \right). \tag{22}$$

Estimation proceeds via maximum likelihood. For each observation, the price shock, p_i, is point-identified using equation 13, while the marginal unit cost, c_i, and cost of design review, ω_i, are set-identified using the bounds described above and displayed in Figure 8. The likelihood contribution for each observation is derived by integrating the joint distribution shown in equation 22 at p_i over the rationalizable values of c_i and ω_i. At each vector (c_i, ω_i), the fixed cost shock, ϕ_i, is point-identified using equation 14. The likelihood function is described in detail below in Section 4.2.

4.2 Likelihood Function

The model includes four outcome variables, (K_i, u_i, q_i, D_i), of which only D_i is observed for all parcels, where the remaining outcome variables are only observed for parcels that are developed into apartments during the sample period ($D_i = 1$). For each of the parcels in the sample that were developed into apartments, the likelihood contribution depends on whether the observed unit count is strictly below, exactly equal to, or strictly above the design review threshold, $\overline{u}$, as described in the previous section. The likelihood function is therefore a piecewise function of the three cases described above, as well as the case of the parcel not being developed during the sample period ($D_i = 0$):

$$\ell(D_i \mid \theta, L_i, X_i) = \begin{cases} \ell(K_i, u_i, q_i \mid \theta, L_i, X_i, u_i < \overline{u}) & \text{if } D_i = 1, u_i < \overline{u} \\ \ell(K_i, u_i, q_i \mid \theta, L_i, X_i, u_i = \overline{u}) & \text{if } D_i = 1, u_i = \overline{u} \\ \ell(K_i, u_i, q_i \mid \theta, L_i, X_i, u_i > \overline{u}) & \text{if } D_i = 1, u_i > \overline{u} \\ \ell(D_i \mid \theta, L_i, X_i) & \text{if } D_i = 0 \end{cases}. \tag{23}$$

The likelihood contribution for parcels that were not developed during the sample period ($D_i = 0$) is the probability that the profit from developing the parcel is less than the outside option:

$$\ell(D_i \mid \theta, L_i, X_i, D_i = 0) = \int_{\pi_i < \pi_i^0} f(\varepsilon \mid \theta) d\varepsilon \tag{24}$$

25. This assumption is made because the correlation parameters between the cost of design review and the other error terms are not identified by the model and data. More information about the identification of the design review cost parameters is provided in Section 4.3.

Where $f(\varepsilon \mid \theta)$ is the joint distribution of the model's error terms and $\varepsilon = (\log(p_i), \log(c_i), \phi_i, \log(\omega_i))$ is the vector of error terms. This integral is calculated using quasi-Monte Carlo integration with 1,024 Sobol draws.

Case 1: $u_i < \overline{u}$. The optimal unit count is below the design review threshold, so all values of the design review cost, ω_i, are rationalizable, and a unit interval of rationalizable marginal unit costs is identified by the first-order condition for unit count:

$$\ell_i^1(K_i, u_i, q_i \mid \theta, L_i, X_i, D_i = 1) = \int_0^{\infty} \int_{\underline{c}_i}^{\overline{c}_i} f(p_{it}, c, \phi_i, \omega \mid \theta)(1-\alpha_K) dc d\omega. \tag{25}$$

$$\underline{c}_{it} = r\left(\frac{1-\alpha_K}{\alpha_K}\right) K_i \left[\left(\frac{u_i+1}{u_i}\right)^{1-\alpha_K-\alpha_\ell} - 1\right] \qquad \overline{c}_{it} = r\left(\frac{1-\alpha_K}{\alpha_K}\right) K_i \left[1 - \left(\frac{u_i-1}{u_i}\right)^{1-\alpha_K-\alpha_\ell}\right] \tag{26}$$

Where $1-\alpha_K$ is the Jacobian term of the joint distribution, calculated as $\partial \log(p_i) / \partial K_i$, which is the absolute value of the determinant of the Jacobian matrix of $f(p_i, c_i, \phi_i, \omega_i)$.

Case 2: $u_i = \overline{u}$. The marginal cost of adding the last unit was constant at c_i, but adding the next unit would incur a cost of ω_i. Since the marginal cost of adding a unit is bounded below by zero and the cost of design review is unbounded above, for every marginal unit cost below $\underline{c}_i$ (at which point the developer would choose $\overline{u}+1$ if $\omega_i = 0$), there exists an optimal unit count, $u_i^*(c)$, that the developer would have chosen if the cost of design review were zero. Furthermore, for each optimal unit count $u_i^*(c)$, there exists a cost of design review, $\underline{\omega}_i(c)$, such that the developer is indifferent between $\overline{u}$ and $u_i^*(c)$. These bounds comprise the integration base for the likelihood contribution when $u_i = \overline{u}$:

$$\begin{aligned} \ell_i^2(K_i, u_i, q_i \mid \theta, L_i, X_i, D_i = 1) = &\int_0^{\infty} \int_{\underline{c}_i}^{\overline{c}_i} f(p_{it}, c, \phi_i, \omega \mid \theta)(1-\alpha_K) dc d\omega \\ &+ \int_0^{\overline{c}_i} \int_{\underline{\omega}_i(c)}^{\infty} \phi(p_{it}, c, \phi_i, \omega \mid \theta)(1-\alpha_K) d\omega dc \end{aligned} \tag{27}$$

$$\underline{\omega}_i(c) = r\left(\frac{1-\alpha_K}{\alpha_K}\right) K_i \left[\left(\frac{u^*(c)}{\overline{u}}\right)^{\frac{1-\alpha_\ell-\alpha_K}{1-\alpha_K}} - 1\right] - c\left(u^*(c) - \overline{u}\right) \tag{28}$$

$$u_i^*(c) = \left\lfloor \left(\frac{r(1-\alpha_K-\alpha_\ell)}{\alpha_K c} \frac{K_i}{u_i}\right)^{\frac{1-\alpha_K}{\alpha_\ell}} u_i \right\rfloor. \tag{29}$$

Case 3: $u_i > \overline{u}$. The marginal cost of adding the last unit and the next unit is constant at c_i, but for every marginal unit cost c, there exists a cost of design review, $\underline{\omega}_i(c)$, such that the developer is indifferent between u_i and $\overline{u}$. All other rationalizable values of ω_i are below this threshold, as any value above this threshold would induce the developer to

choose $u_i = \overline{u}$.

$$\ell_i^3(K_i, u_i, q_i \,|\, \theta, L_i, X_i, D_i = 1) = \int_{\underline{c}_i}^{\overline{c}_i} \int_0^{\underline{\omega}_i(c)} f(p_i, c, \phi_i, \omega \,|\, \theta)(1 - \alpha_K) d\omega dc \tag{30}$$

$$\underline{\omega}_i(c) = r\left(\frac{1-\alpha_K}{\alpha_K}\right) K_i \left[1 - \left(\frac{\overline{u}}{u_i}\right)^{\frac{1-\alpha_\ell-\alpha_K}{1-\alpha_K}}\right] - c(u_i - \overline{u}). \tag{31}$$

Let $j(i) = \{1, 2, 3\}$ be determined by the unit count of observation i and represent which of the three cases above. Then the log-likelihood function is given by:

$$L_n(\theta) = \sum_{i=1}^{N} (1 - D_i) \log\left(\ell(D_i = 0 \,|\, \theta, L_i, X_i, D_i = 0)\right) + D_i \log\left(\ell_i^{j(i)}(K_i, u_i, q_i | \theta)\right). \tag{32}$$

Optimization proceeds by maximizing $L_n(\theta)$, with respect to the parameter vector,

$$\theta = (\alpha_K, \alpha_\ell, r, \overline{p}, \overline{c}, \overline{\phi}, \overline{\omega}, \gamma, \{\tilde{d}_{N(i)}\}, \sigma_p^2, \sigma_c^2, \sigma_\phi^2, \sigma_\omega^2, \sigma_{p,c}, \sigma_{p,\phi}, \sigma_{c,\phi}). \tag{33}$$

One key parameter constraint, $\alpha_K + \alpha_\ell \in (0, 1)$, is required to derive a likelihood value, since the domain of the log function is violated if this constraint is not met. As a result, α_K and the composite parameter $1 - \alpha_K - \alpha_\ell$ are estimated, rather than α_K and α_ℓ separately, and each is estimated with a change of variables that maps its domain to the real line. Similarly, to avoid imposing additional non-negativity or equation constraints, the log of the variance parameters and the inverse hyperbolic tangent of the partial correlation parameters are estimated. Standard errors for parameters estimated with transformations are calculated using the delta method.

4.3 Parameter Identification

Each parameter of the model is identified either directly or through a composite parameter via covariances between observed variables or the scale of outcome variables, with the exception of the marginal cost of capital, r, and the distributional parameters of the cost of design review, $(\overline{\omega}, \sigma_\omega^2)$. The marginal cost of capital and the capital share parameter, α_K, are jointly identified through their ratio. Thus, identification is achieved by assuming a value for the marginal cost of capital, r, using industry reports and existing literature, which vary from \$120 per square foot to \$200 per square foot. A marginal capital cost of \$175 per square foot is assumed, which is near the upper range of the results found by Eriksen and Orlando (2022), who calculate marginal floor area costs in multifamily housing from a sample of cities in 2018. A cost at the upper end of the range is used to account for increasing costs from 2018 to 2025 and the fact that Seattle is a relatively high-cost city.

The distribution of the cost of design review, ω_i, is identified by the unit count choice in cases 2 and 3, outlined

above. The likelihood contribution of developments with $u_i = \overline{u}$ increases monotonically in the mean of the design review cost distribution, $\overline{\omega}$, as higher values of $\overline{\omega}$ increase the likelihood of a parcel being developed with $u_i = \overline{u}$, holding all other parameters and observable characteristics constant. The likelihood contribution of developments with $u_i > \overline{u}$ decreases monotonically in the mean of the design review cost distribution, $\overline{\omega}$, by the inverse logic: such observations can only be rationalized by sufficiently low values of ω_i such that incurring the cost of design review is profit-maximizing. The variance of the design review cost distribution, σ^2_ω, is identified by the relative frequency of developments that require high costs of design review to be rationalized to developments that require low costs of design review to be rationalized. Thus, developments with $u_i = \overline{u}$ and $u_i > \overline{u}$ are both required to identify the distribution of ω_i.

5 Results

5.1 Parameter Estimates

Parameter estimates from the full model, including neighborhood fixed effects, are displayed in Table 3. The mean of the unit cost distribution ($\overline{c}$) implies a median marginal unit cost of around $\$108,000$. This cost includes the physical costs of dividing existing units into smaller units and adding the relevant amenities, such as appliances. Publicly-available estimates of this cost typically provide the *average* unit cost, which includes fixed costs and assumes a corresponding increase in square footage.

To compare the results of the estimation to these outside estimates, the implied variable cost per unit of an 8-unit development with an average unit size of 700 square feet at the median unit cost is about \$230k with a variable cost per square foot of \$329. This is around the lower range of industry estimates of total cost per square foot for a small (below 4 stories) apartment building. By interpreting ϕ_i as a fixed cost shock and using its median, estimated construction costs per unit and per square foot for an 8-unit development with an average unit size of 700 square feet are about \$568k and \$811, respectively.

To compare the production parameter estimates with the existing literature that relies on data from single-family home production, interpret the production function as a two-factor model with land and capital where each dwelling unit is equally-sized.[26] The estimate for capital production share, α_K, varies by methodology and sample in the literature. Combes, Duranton, and Gobillon (2021) estimate a value of 0.601 using observed land prices and capital choices and 0.767 using predicted data to account for measurement error. Epple, Gordon, and Sieg (2010) estimate an implied value of 0.856 using a non-parametric approach that fails to reject a Cobb-Douglas functional form. The estimate in

26. In addition to the imperfections in the comparison between these results and those from the literature that arise from production differences between single-family and multifamily housing, the estimates from the literature are generally based on K being measured as "non-land factors" as opposed to floor space of development, as in the model presented here. As such, comparisons should be taken with caution.

Parameter	Estimate	SE
α_k	0.411	(0.0020)
α_ℓ	0.245	(0.0030)
$\overline{p}$	8.477	(0.3438)
$\overline{c}$	11.586	(0.2554)
$\overline{\phi}$	2.699	(0.0494)
$\overline{\omega}$	9.715	(0.0318)
log(CBD dist.)	0.013	(0.0093)
log(UW dist.)	-0.018	(0.0108)
log(LRT dist.)	-0.021	(0.0295)
log(Comm. dist.)	-0.000	(0.0098)
σ_p	0.250	(0.0106)
σ_c	0.590	(0.0061)
σ_ϕ	1.372	(0.3772)
σ_ω	1.693	(0.0066)
$\rho_{p,c}$	0.895	(0.0039)
$\rho_{\phi,p}$	0.217	(0.0087)
$\rho_{\phi,c}$	0.177	(0.0081)
Log-likelihood	-2267	
r	175	
Observations	5512	

Table 3: Parameter estimates for the full model

this paper of 0.411 is lower than estimates from the literature that are generally estimated using single-family home transfers and (with the exception of Combes, Duranton, and Gobillon, 2021) assuming two-factor constant returns to scale.

Epple, Gordon, and Sieg (2010) impose a constant returns to scale (CRS) assumption, while Combes, Duranton, and Gobillon (2021) do not but only identify a land share parameter under the assumption of CRS. As such, land share α_ℓ is estimated simply as $1 - \alpha_K$ in these papers. This suggests estimates of 0.144, 0.233, and 0.399, depending on methodology. The estimated land share in this paper is well within this range at 0.245.

The estimates in Table 3 imply decreasing returns to scale in floor area and land, with $\alpha_K + \alpha_\ell = 0.656$. Thus, to make a more direct comparison of capital and land production shares with the literature, each factor's production share is divided by $\alpha_K + \alpha_\ell$ to account for decreasing returns to scale. By this measure, capital production share is 0.627, aligning much more closely with the measurement error–corrected estimate from Combes, Duranton, and Gobillon (2021).

Consistent with the number of developments proposed at both the unit count threshold and just above it, the estimated spread parameter for the cost of design review, σ_ω, is relatively large, at 1.693. Though the mean of the distribution is estimated below that of the marginal unit cost, implying a median design review cost of \$17k, the high variance of design review costs results in about 15% of lots facing design review costs above the median marginal unit cost. Figure 9 displays the dollar cost of design review by quantile, starting in the second quartile. Also displayed

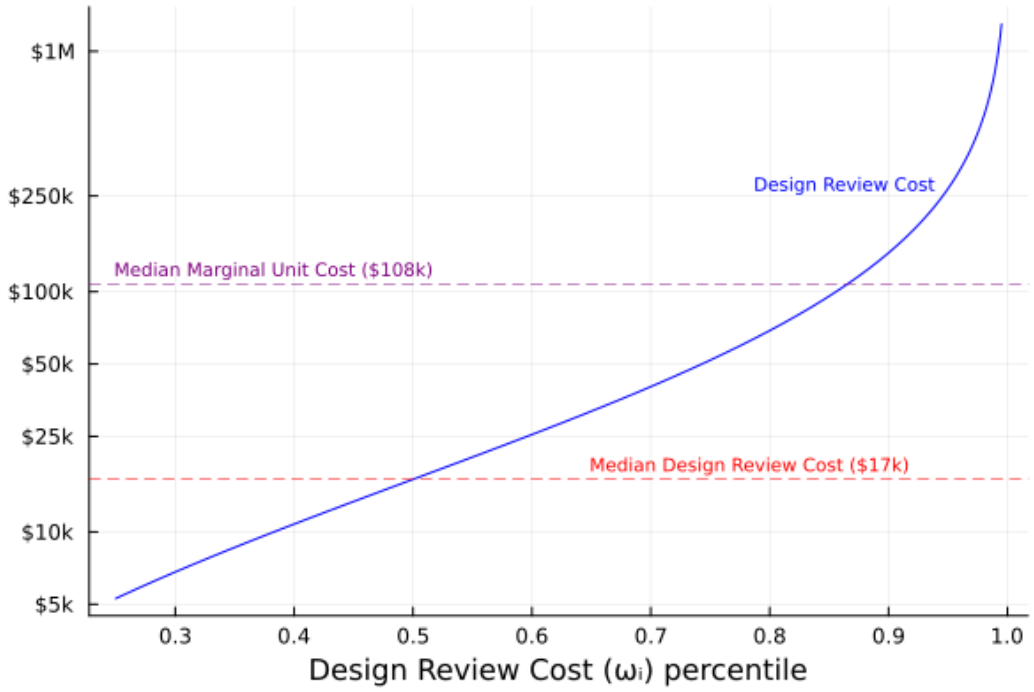


Figure 9: Design review cost by percentile

are the median marginal unit cost and the median design review cost. Although 85% of developments face a design review cost below the median marginal unit cost, the upper tail of developments face a prohibitive cost. These costs at the extreme of the distribution should not necessarily be interpreted literally, but rather as an anticipated rejection, as the only mechanism in the model for a permit rejection is through design review costs.

A design review cost distribution with high variance is consistent with design review costs being determined by (mostly) unobservable lot characteristics. An empty lot in an already relatively dense neighborhood is unlikely to receive any opposition that would be taken seriously by the design review board, the SDCI director, or an administrative judge (in the event of an appeal of permit approval). However, a large development in a low-density residential neighborhood that requires the demolition of a beloved property that is considered historic by locals though lacks historic designation is likely to face significant opposition. Between these two extremes are a range of cases that result in a range of opposition and corresponding design review costs.

5.2 Model Fit

5.2.1 Simulated Developments

Given the estimated model parameters, it is possible to simulate the unit count, square footage, and acquisition cost for each lot that was proposed for development during the sample period. Additionally, each simulation of the set of sample parcels generates a predicted development rate through each parcel's development decision, D_i. For each

observation i (which includes a parcel and development year) and simulation s, four shocks are drawn from the joint distribution whose mean and covariance matrix were estimated in the previous section: $p_{i,s}$, $c_{i,s}$, $\phi_{i,s}$, and $\omega_{i,s}$. The price, marginal unit cost, fixed cost, and design review cost shocks are then used to calculate the optimal unit count, which determines the optimal square footage per unit conditional on unit count. Without considering the cost of design review, the optimal unit count is given by the first-order condition of the value function after replacing the capital choice with its optimal value, as in equation 11, then comparing the value function at this unit count to the value function at the design review threshold, $\overline{u}$. After calculating the optimal unit count, the optimal square footage is calculated using the capital first-order condition of the value function given in equation 9, and acquisition cost is calculated using the zero profit condition. Finally, entry is determined by whether the acquisition cost, q_i, is weakly greater than the sum of the fixed cost shock, ϕ_i, and the assessed value, q_i^0.

5.2.2 Comparison to Observed Developments

To compare model predictions to observed developments, each development in the city is simulated 5,000 times via the process described in the previous section. Figure 10 displays the observed and modeled means of each of the four response variables: unit count, square footage, acquisition cost, and entry (i.e., whether a lot is developed into an apartment building during the sample period). The simulated data fit the observed data well for unit count, floor area, and lot development rate, with the simulated means within 3 units, 3,000 square feet, and 0.2 percentage points of the observed means, respectively. The model over-predicts acquisition cost by about $200k, relative to an observed mean of $980k.

The first two bars in Figure A7 compare the mean unit counts of developments between the observed and simulated data, and panel (a) of Figure 11 displays the distribution of unit counts for both the observed and simulated data. The share of developments that develop at the design review threshold is higher in the simulated data than in the observed data, though the mass of developments at 6 units is not replicated in the simulated data.[27] The model predicts that the reduction in mass above the design review threshold wanes by 14 units, while the observed data are more consistent with a mass reduction that persists until about 20 units.

The next two bars in Figure A7 compare the means for the square footage of developments between the observed and simulated data, and Panel (b) of Figure 11 displays the two distributions. The simulated moments generally adhere to the observed ones, though the simulated data predict the existence of developments that are too small to exist in the real world.. The final two bars of Figure A7 compare the acquisition cost—how much developers pay to acquire the parcel—between the observed and simulated data. Simulated acquisition costs are higher than observed acquisition

27. A shortcoming of the model is that the assumption of constant marginal costs in both unit count and square footage are inconsistent with discontinuous jumps in cost from increasing building height, as shown in Eriksen and Orlando (2022). The mass of developments at 6 units is likely due to bunching from developments with optimal unit counts above 8 units with higher profits from 6 unit development than an 8 unit development due to nonlinearities in costs and profits induced by the building height choice.

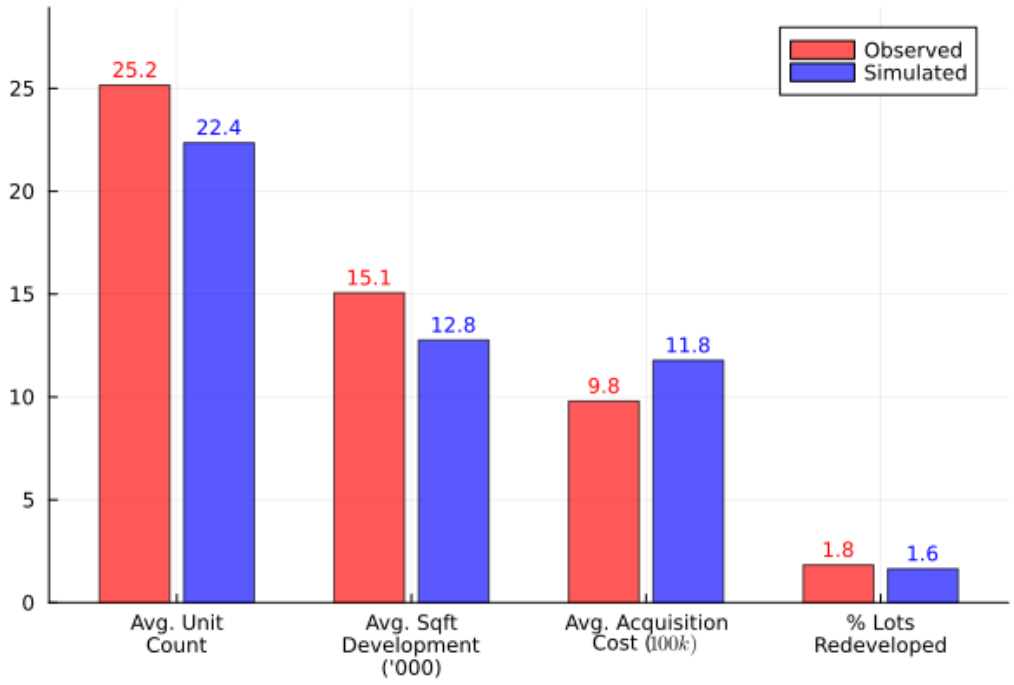
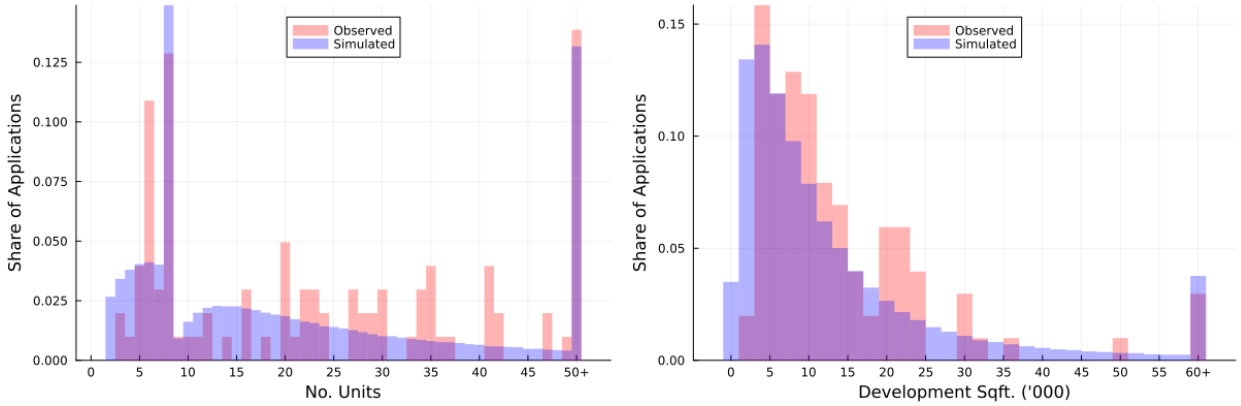


Figure 10: Model fit on modeled outcomes



(a) Number of units per development

(b) Square feet of development

Figure 11: Distribution of observed and simulated development characteristics

costs, with a mean difference of about $200k. Finally, the last two bars of Figure A7 compare the lot development rate between the observed and simulated data, which are very close, with a difference of only 0.2 percentage points.

Across the four outcome variables, these results suggest that the model predicts a large share of the variance of the observed data for the response variables.

5.2.3 Simulated Price Elasticities

Using the simulated developments, it is possible to calculate price elasticities of supply for each of the modeled outcomes. To do so, I simulate the development patterns as described in section 5.2.2, then increase the price shock, $p_{i,s}$, by 5% for each lot and re-calculate the optimal development choices. To obtain mid-point elasticities, I then calculate the percentage change in each outcome for a 5% decrease in price. Elasticities are calculated for the number of units developed, square footage developed, acquisition cost, and the lot development rate by summing across all lots in the sample for each simulation, and the model is simulated 10,000 times.

The price elasticity of supply for is 5.54 for the number of units developed, 6.12 for square footage developed, and 2.38 for the lot development rate. Both the unit count and square footage elasticities are relatively high, but within the range of estimates obtained by Epple, Gordon, and Sieg (2010) using single-family home data from Alegheny County, Pennsylvania. These estimates are roughly twice those of Baum-Snow and Han (2024), who estimate the the price elasticity of new construction on undeveloped land for floor space and units to be 3.2 and 2.8, respectively. When simulated assuming no design review costs, the price elasticity of unit count, floor area, and lot development increase to 6.31, 6.68, and 2.98, indicating that design review reduces the elasticity of the housing supply, particularly on the margin where the threshold is applied, in this case, the unit count.

6 Counterfactual Analysis

A central question in this paper is the extent to which design review inhibits the supply of multifamily housing in Seattle and, by extension, how it shapes the supply that does occur. To answer this question, I conduct a counterfactual analysis in which I simulate the model's outcomes under the baseline scenario with an 8-unit design review threshold, then re-calculate the outcomes, holding shocks constant, but setting the cost of design review to zero. The change in the outcome variables between the simulated and counterfactual scenarios is interpreted as the effect of design review on development outcomes. Figure 12 displays the estimated percent changes in the total number of units, total square feet of development, total acquisition costs, the average square footage per new unit developed, the share of in-sample lots redeveloped, and the total number of lots redeveloped. As the acquisition cost is the transfer from the developer to the existing landowner and the landowner captures all economic profits from development, the change in acquisition cost may be interpreted as the total change in surplus from removing design review.

In total, removing design review would have increased the total number of units developed by 5.5% while increasing the total square footage developed by only 1.9%, resulting in a decrease in the average square footage per unit of 4.5%. This is consistent with the model's prediction that optimal square footage per unit is decreasing in the number of units built, and with proposition 1 from section 2, that marginal developments—those that are induced by

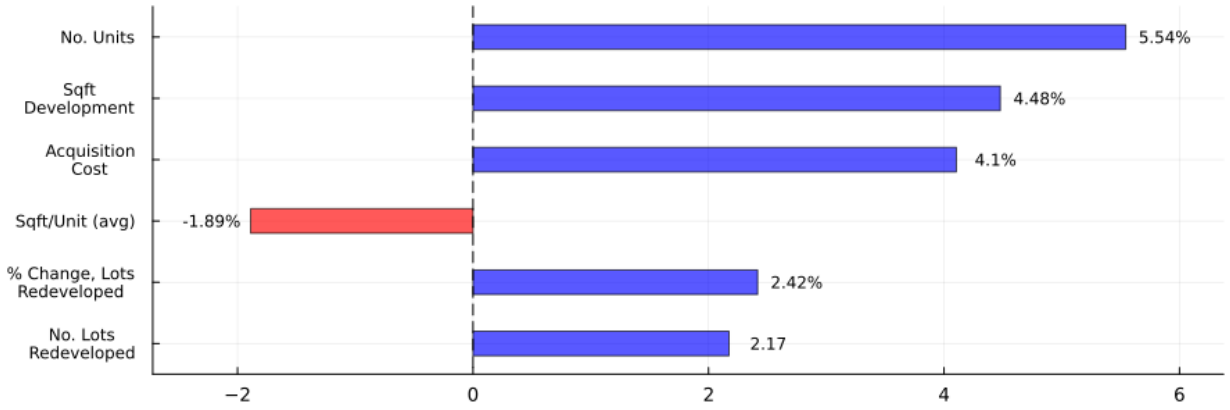


Figure 12: Change in development outcomes from removing design review

the cost of design review to build at the 8-unit threshold rather than at some unit count above 8—build larger units than they would if design review were not present. Additionally, since developers are offsetting lost profits from lower unit counts by building larger units, the model predicts that removing design review would have only increased total acquisition costs by 4.1%, proportionally less than the increase in total square footage or unit count.

The increase in unit counts is largely due to the intensive margin, i.e., to lots that were redeveloped at 8 units in the data being developed at a higher number of units. Removing design review would have increased the number of lots redeveloped by nearly 2.4%, with two additional lots being redeveloped in most simulations. Figure 13 displays a histogram of the number of units per development in the data and in the counterfactual simulations. The bunching at 8 units disappears, with the mass being spread primarily to developments with 9 to 15 units and a small share of developments with 16 or more units. Due to the newly-developed lots having unit counts above 8 units, the relative mass of developments with 2 to 7 units decreases slightly.

Figure 14 displays the spatial distribution of the changes in development outcomes from removing design review. The largest increases in the housing supply (i.e., the number of units and total square footage developed) are in the Central Area, Ranier Valley, Ballard, and Delridge neighborhoods. Each of these neighborhoods are lower-income and more racially diverse than the city as a whole, except for Ballard, which is has pockets of both both high- and low-income residents and is fairly representative of city-wide demographics. The changes in acquisition cost are generally inverted from the changes in total housing supply: areas with the lowest supply increases see the largest increases in acquisition costs. Although transfers to land owners increase when an 8-unit development becomes a more profitable 15-unit development, land owners also receive higher transfers when 30-unit development no longer faces design review costs, and the savings are instead capitalized into higher acquisition costs. Thus, neighborhoods with the most developments above eight units see the largest increases in acquisition costs. The neighborhoods with the largest increases in acquisition costs (and thus land values) are Northwest, Cascade and the University District, which all had relatively high numbers of developments above 8 units.

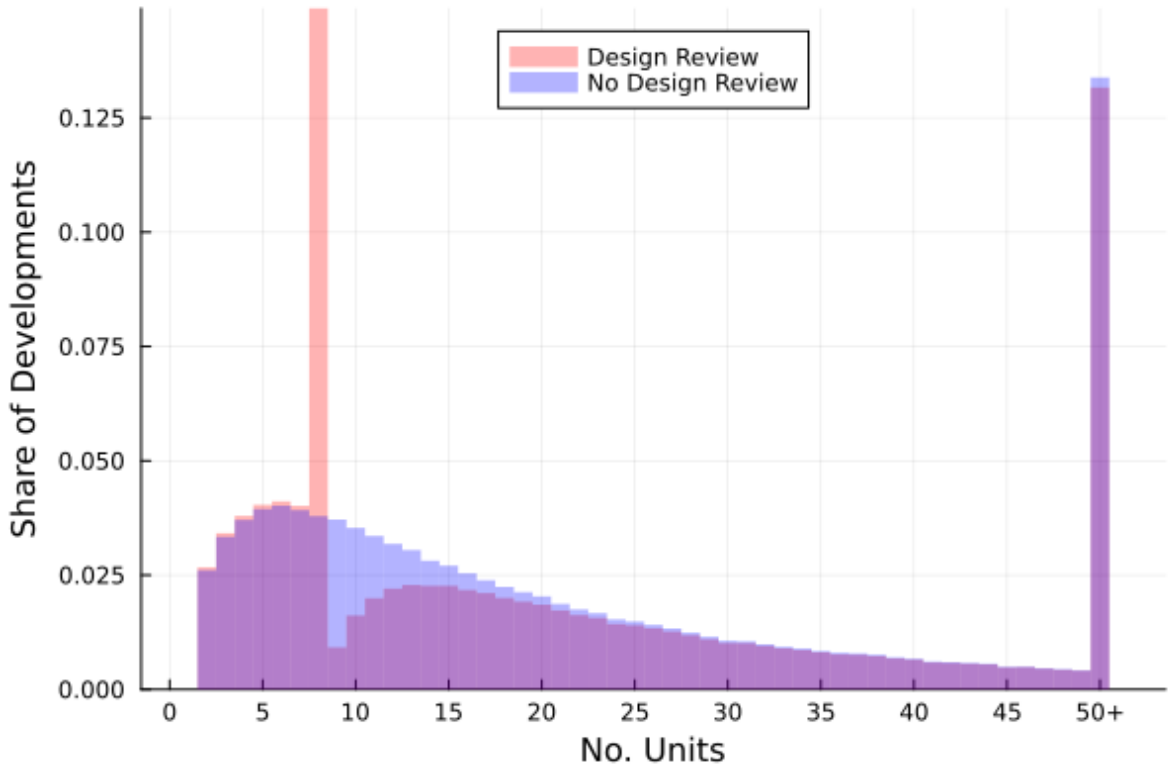


Figure 13: Simulated number of units per development with and without design review

7 Conclusion

As real home prices and rental rates continue to rise in cities across the United States and many other developed countries, policy-makers increasingly seek to reform land use regulations to increase the supply of housing. One area that has received attention both among policy-makers and among researchers, particularly in the political science literature, is the costly permitting process for multifamily developments. In the city of Seattle, Washington, from 2008 to 2018, an often-binding unit count threshold for discretionary review was in place for multifamily developments. In this paper, it is shown that undergoing design review increased permit approval time by three and a half to four months, and that developers responded by reducing the number of units in new apartment developments while increasing the size of those units. Such evidence of distortions at the threshold for discretionary review is not present in the period when a more more lenient square footage threshold was introduced in 2018.

A model of the production of housing services for multifamily developments is proposed and estimated using a sample of new developments in Seattle, Washington from 2011 to 2018, when the unit count threshold for design review was in place but the housing crisis had mostly subsided. The results displayed in section 5 imply that the median cost of design review is around $14,000, but that the top 15% of costs exceed the median marginal cost of adding a unit, at $45,000. Counterfactual simulations of every low rise-designated lot in the city of Seattle that was

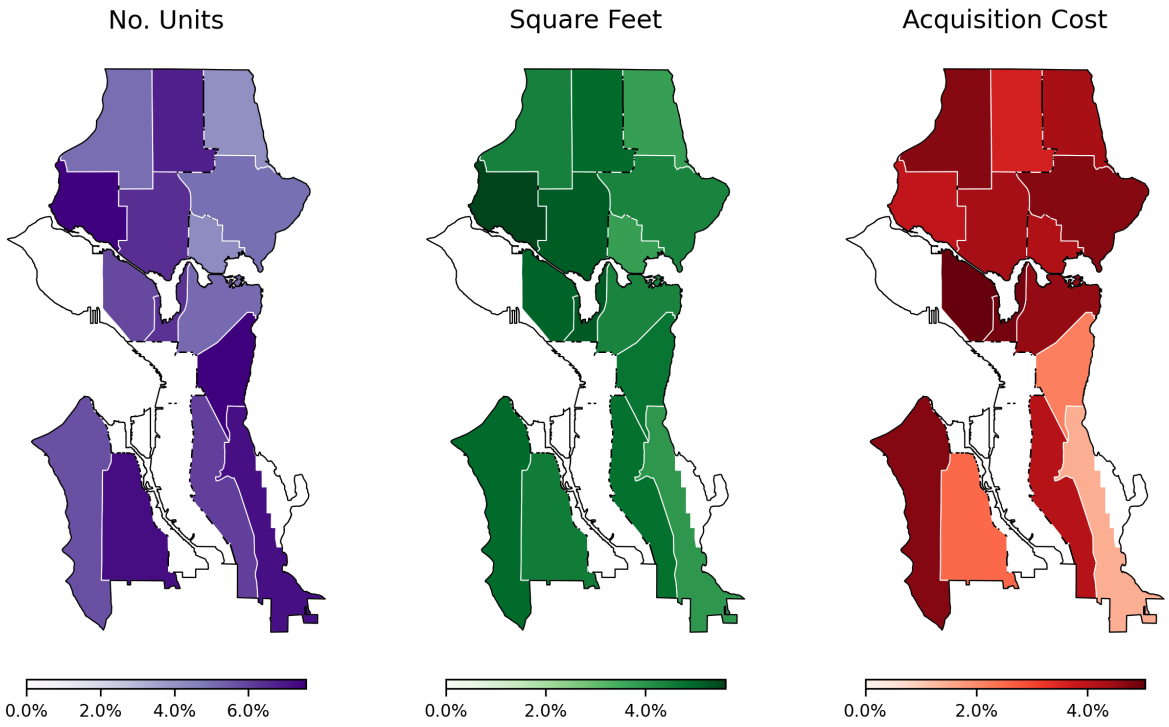


Figure 14: Counterfactual changes in model outcomes by neighborhood

within the consideration set for redevelopment during the sample period indicate that removing design review would have increased the number of new units developed by 137 (5.5%) while reducing the average size of those units by nearly 2% due to developers trading off unit count and unit size. These increases come both increases in the intensive margin, i.e., developments that would have been built regardless of design review getting larger, and in the extensive margin, i.e., additional developments being built on lots that did not get redeveloped into apartments during the sample period. The intensive margin changes are driven by developments that were observed at 8 units being built with 9 to 20 units instead. In the absence of design review, two additional lots would have been redeveloped into apartments. While many municipalities are debating upzoning as a tool to increase housing supply, the findings presented here suggest that reforming the permitting process itself—by reducing delays—can unlock a significant amount of housing supply, particularly on the intensive margin where projects are already economically viable. Additionally, if rezoning occurs on lots that are only marginally profitable, reducing permitting delays and uncertainty may be complementary to upzoning in increasing housing supply.

The distribution of increased housing supply from removing design review is concentrated in medium-density, lower-cost, and more racially diverse neighborhoods. Neighborhoods that experienced the most developments above the design review threshold during the sample period saw the largest increases in land prices, as the reduced costs of development were passed on to landowners via higher land acquisition prices.

Although further study is warranted in the margins on which developers accommodate the cost of design review, these results also suggest that permitting delays and uncertainty play a role in reducing the supply of new, multifamily housing in cities. Additionally, discrete thresholds that trigger increased development costs can distort developer behavior. Future studies may explore the uncertainty effect further by incorporating a dynamic model of development decisions in an environment where the permitting authority issues rejections more frequently than in Seattle.

Finally, the model presented here can be applied and extended in a number of settings. Most cities have easily-accessible data on the unit counts and size of new developments, and assessment values and property transfers are released publicly by county assessors throughout the country. With those data alone, this model can be estimated via maximum likelihood or simulated method of moments. As housing markets and policy gain increasing attention from economists and policy-makers alike, this framework may be used to study a range of policies and other market phenomena, such as the effects of inclusionary zoning, parking requirements, or concentration of ownership or management.

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A Appendix

A.1 Seattle's Design Review Board

There are as many design review boards in the City of Seattle as there are districts, with each district's board composed of 5 local (to the the city, though not necessarily to the district) members who serve 2-year terms that may be repeated.[28] The five members consist of one representing "development-related interests", on representing the "deisgn professions" (usually professional architects), two representing the interests of local residents, and one representing "general business interests or landscape professions". Members are appointed by either the mayor or by the City Council, with half of the members in each interest group (e.g., development interests) appointed by the mayor and the other half appointed by the City Council, with the exception of local residents, for whom half are appointed jointly by the mayor and council, with the other half split between solely the mayor and solely the council.

Prior to May 2018, there were 7 design review districts in Seattle, displayed in Figure A1. The map amended by ordinance 125562, which added an additional district in East Seattle, mostly composed of areas that were previously part of the seventh district. This map, displayed in Figure A2, became effective in May of 2018.

28. This information, as well as all information in this section, is taken from the Seattle municipal code section 23.41.

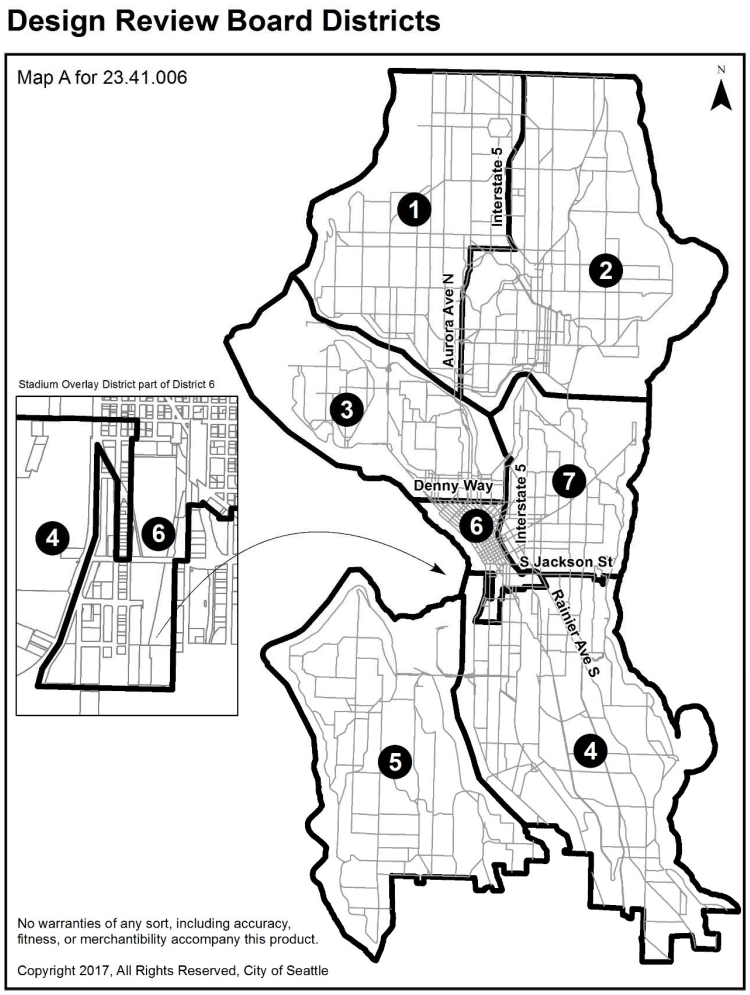


Figure A1: Design review district boundaries, pre-2018

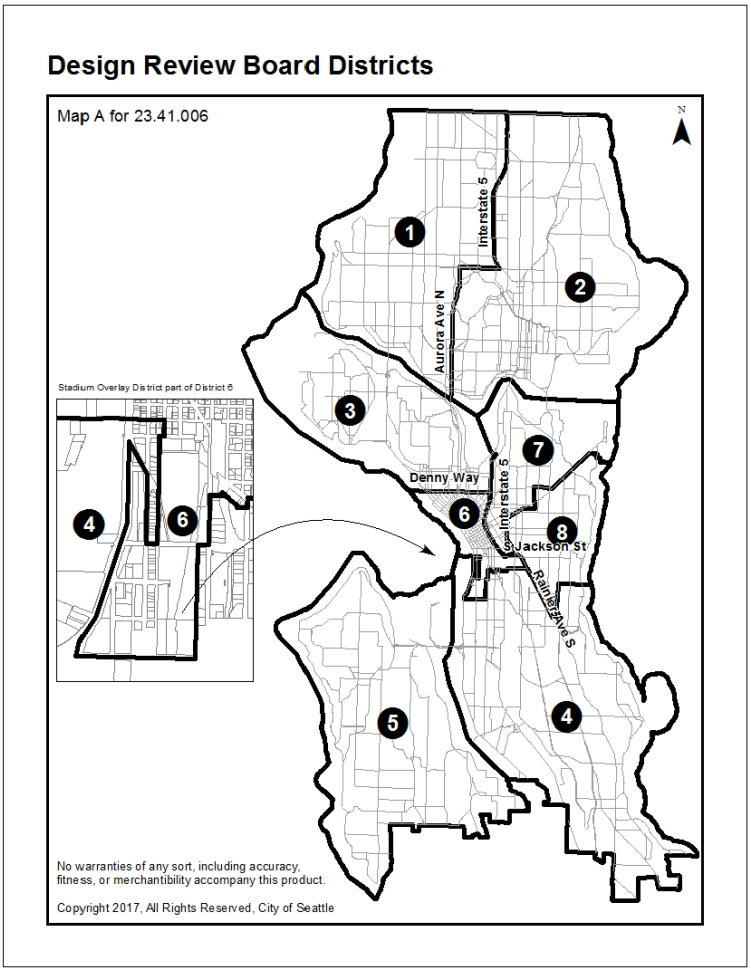


Figure A2: Design review district boundaries since 2018, as of 2024

A.2 Additional Tables, Figures, and Descriptive Analyses

A.3 Additional Tables

Zoning Designation	# of Parcels	2011–2018 Redevelopments	2018–2025 Redevelopments
Low-Rise (LR)	24,368	112	62
Mid-Rise (MR)	800	36	23
High-Rise (HR)	11	7	6

Table A1: Number of parcels and redevelopments by zoning designation and policy period

Variable	Coef.	S.E.	p-val
Land Value Share (%)	0.114	0.0477	0.0169
(Land Value Share)^2	-0.002	0.0008	0.0107
(Land Value Share)^3	0.00001	0.0000038	0.0065
log(Land Value)	0.379	0.1846	0.0401
1(Lot Sqft$\in$ (2k, 5k])	1.073	0.2782	0.0001
1(Lot Sqft$\in$ (5k, 7.5k])	0.956	0.2967	0.0013
1(Lot Sqft$\in$ (7.5k, 9k])	0.769	0.3314	0.0202
1(Lot Sqft$>$ 9k)	0.640	0.3508	0.0681
log(Land Value)$\times$ log(Lot Sqft)	-0.004	0.0090	0.6209
log(CBD Distance)	-0.153	0.0829	0.0655
log(UW Distance)	0.211	0.1101	0.0548
log(LRT Distance)	-0.152	0.0759	0.0448
log(Commercial Distance)	-0.020	0.0109	0.0707
Constant	-9.517	1.8273	0.0000
Log-likelihood	-746		
Pseudo R^2	0.197		
Obs.	17,369		
Neighborhood and zoning designation fixed effects included			

Table A2: Probit regression results for probability of development

	Obs Dropped	Total Remaining
All Parcels, 2011	—	213,285
Non-multifamily	164,894	48,391
Government-owned	5	48,386
New congregate housing	15	48,371
New townhome developments	1,814	47,614
Condo parcels	20,436	27,464
Merged parcels	311	27,423
Rezoned parcels	104	27,319
Disolved or govt-purchased parcels	1,792	25,527
Special design review cases	6	25,521
Non-LR lots	983	24,538
Low development probability	18,533	6,005

Table A3: Sample construction by filtering step

A.4 Unit Count Histogram for the Post-2018 Period

A.5 Unit Count Patterns by Policy Period

To investigate further the difference in development patterns before and after the 2018 policy change that removed an 8-unit threshold for design review and imposed a 35,000 square foot threshold, I compare predicted unit counts for each developed parcel in the sample across the policy periods and to observed unit counts. Since unit counts are much more heavily influenced by the policy environment in the pre-2018 period, the estimation is performed solely on the sample of post-2018 developments. The results of the estimation are displayed in Table A6. Of the included explanatory variables, only the coefficients on lot size and assessed land value are statistically significant at conventional levels,

	mean	sd	min	p25	p50	p75	max	N
Sqft Development ('000, K_i)	20.87	40.47	1.72	8.36	12.17	22.16	490.56	174
Lot Sqft ('000, L_i)	8.50	21.49	1.45	4.12	5.00	7.12	271.86	174
Units Added (u_i)	31	36	2	8	24	42	399	174
Units Demolished	2	4	0	0	1	2	28	174
Acquisition Cost ('000, q_i)	1,638	1,811	112	737	1,096	1,951	15,109	146
Assessed Value at Acquisition ('000)	1,624	4,352	236	655	879	1,371	50,644	174
1(Observed Acquisition Cost)	0.84	0.37	0.00	1.00	1.00	1.00	1.00	174
Sqft Development per Unit	806	581	149	401	579	1,002	2,827	174
Acquisition Cost per Sqft Development	110.17	90.31	7.42	53.05	83.92	130.81	573.94	146
Assessed Value per Sqft Development	99.97	118.56	7.71	43.04	72.71	101.88	1165.54	174
Sqft Development per Lot Sqft	2.88	2.25	0.38	1.70	2.33	3.11	18.64	174
Acquisition Cost per Units Added	81,216	88,687	6,288	32,243	51,421	99,272	557,837	146

Table A4: Summary statistics for developments in low-rise-designated lots

	2008-2018		Post-2018	
	(1)	(2)	(3)	(4)
log(Units)	0.705***	0.789***	0.691***	0.264
	(0.047)	(0.157)	(0.092)	(0.437)
1(Units>8)		-1.567***		-0.977
		(0.373)		(0.781)
1(Units>8)*log(Units)		0.340*		0.515
		(0.175)		(0.454)
Intercept	7.471***	7.478***	7.505***	8.182***
	(0.130)	(0.262)	(0.302)	(0.654)
R^2	0.614	0.679	0.636	0.654
N	182	182	52	52
No. Above 8	110	110	43	43

$^{***}: p < 0.01$,$^{**}: p < 0.05$,$^{*}: p < 0.1$. Heteroskedasticity-robust standard errors in parentheses.

Table A5: Regression results for discontinuity in capital-units relationship by policy period

but in each case, the sign is in the expected direction.

Figure A5 displays, in logs, the observed unit count for each development (Y-axis) against the predicted unit count from the regression (X-axis) for both pre- and post-2018 developments. The dashed lines indicate the 8 unit count threshold for design review that applied to developments in the pre-2018 period. The 45-degree line is also displayed for reference. Although only the post-2018 developments were used to fit the coefficients for the unit count prediction, the predicted values for the pre-2018 developments appear to fit the observed values about as well as the post-2018 developments. Notably, few post-2018 developments are predicted to have fewer than 8 units, which is not true of the pre-2018 developments. Of the 50 post-2018 developments with predicted unit counts above 8, only 6 (12%) were developed with fewer than 8 units, while 36 (32%) of the 111 pre-2018 developments with predicted unit counts above 8 were developed with fewer than 8 units. Furthermore, the pre-2018 developments in the lower-right quadrant (where predicted unit counts are above 8 but observed unit counts are below 8) are largely clustered at the 8-unit threshold,

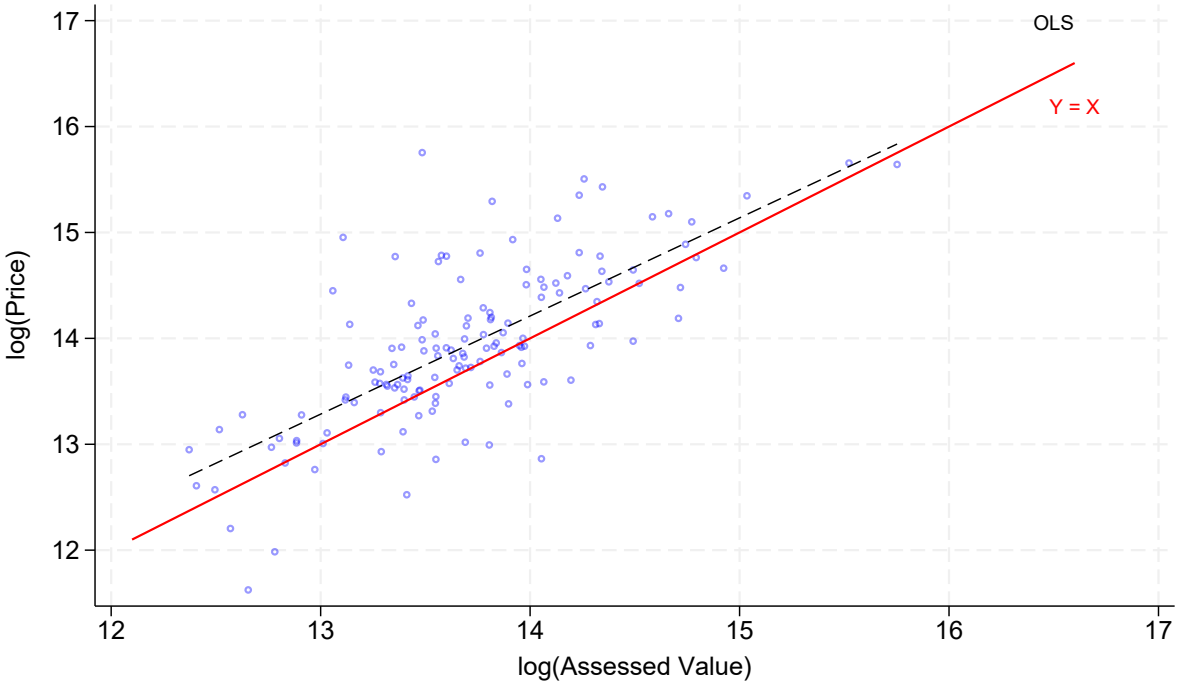


Figure A3: Relationship between acquisition price and assessed value in year of acquisition, in logs

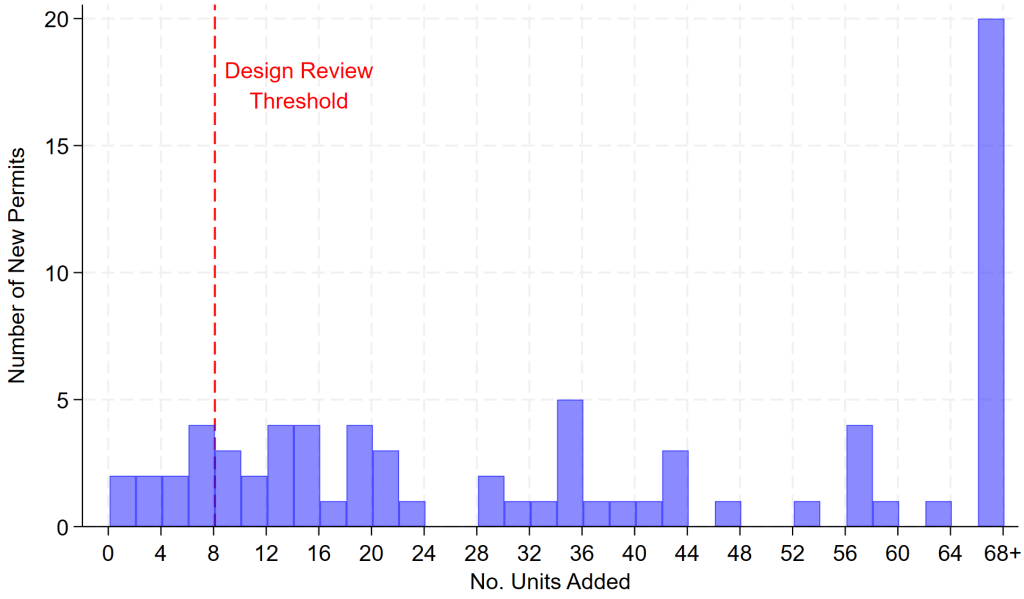


Figure A4: Histogram of units proposed after the 2018 policy change

and 8-unit developments from the pre-2018 period are overwhelmingly predicted have more than 8 units, based on a regression that fit using only post-2018 developments.

The question remains as to why lots that were developed into apartments after the 2018 policy change had char-

	(1)
Land % Assessed Value	-0.014
	(0.008)
log(Land Value)	0.448**
	(0.195)
log(Lot Sqft.)	0.488**
	(0.220)
log(Dist. CBD)	0.476
	(0.496)
log(Dist. UW)	0.302
	(0.757)
log(Dist. LRT)	-0.216
	(0.554)
log(Dist. Commercial)	0.036
	(0.830)
Linear Time Trend (years)	0.119
	(0.074)
Mean log(units)	1.88
Neighborhood FE	Yes
R^2	0.695
Obs.	56

Heteroskedasticity-robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: Regression of log unit count on exogenous parcel characteristics for post-2018 apartment developments

acteristics that were consistent with higher unit counts much more so than lots developed into apartments before the policy change. One explanation is that one alternative to re-developing a lot into an apartment building—developing it into townhomes—was made more attractive by the 2018 policy change.[29] This analysis does not account for the decision of which lots to develop. However, the regression model that predicts apartment unit counts based on lot characteristics can also be applied to lots that were developed into townhomes in each period.

Figure A6 displays histograms of the predicted unit counts for both apartment and townhome developments, by policy period. In the pre-2018 period, the predicted unit counts for lots on which townhomes were developed are tightly centered around 6 units, with very few predicted to exceed 22 units, other than outliers above 50 units, which is present in both periods. The thickest part of the distribution of predicted unit counts for apartment developments during this period is between 9 and 22 units. In the post-2018 period, the distribution of predicted unit counts for townhome developments is much wider, with a mode around 6 units but with an upper tail that does not thin out

29. Among the reforms during this period that affected townhome development was the removal of density restrictions that were twice as stringent for townhomes as for apartments.

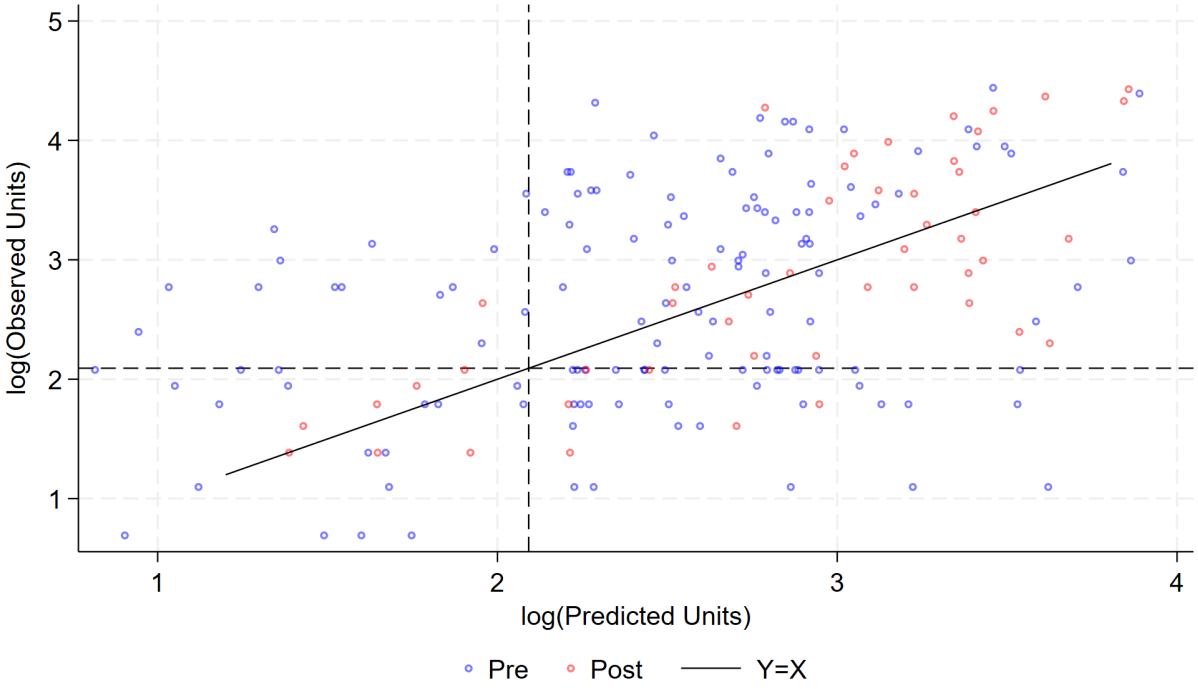


Figure A5: Box plots of unit counts, by policy period and development type

until around 40 units. The distribution of predicted unit counts for apartment developments in the post-2018 period is shifted to the right relative to the pre-2018 period and nearly uniform from 3 to 50 units, with a greater density on the upper tail.

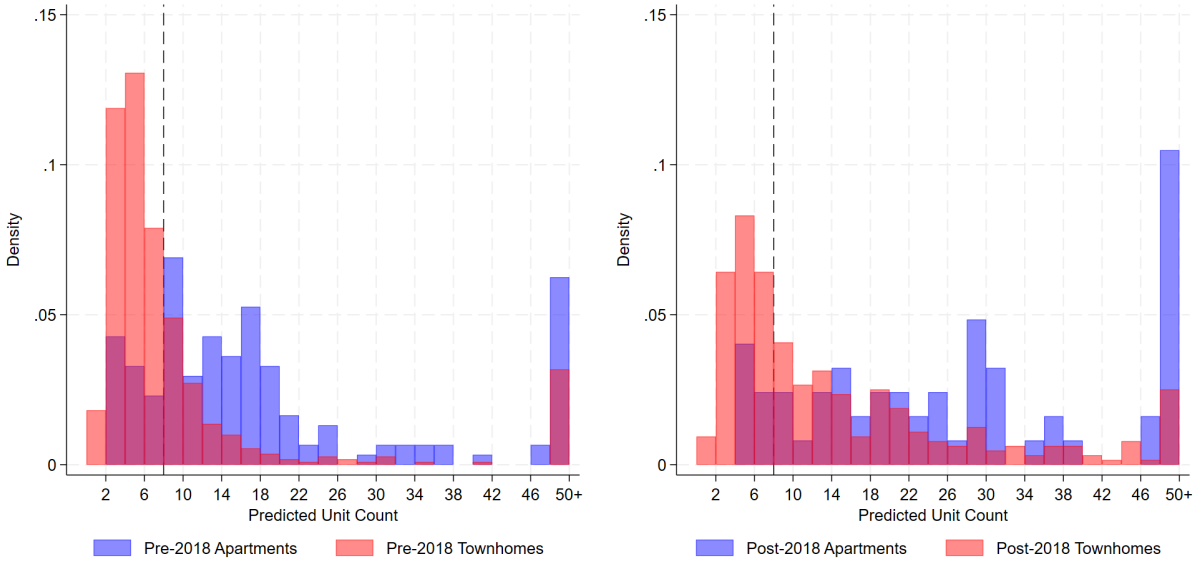


Figure A6: Histograms of predicted unit counts, by policy period and development type

The results presented here suggest that, in the two policy periods, developers chose to develop lots with observably different characteristics into apartments vs. townhomes, possibly in response to the changing policy environment. In the pre-2018 period, a much larger share of lots that were developed into apartments had characteristics that were consistent with smaller apartment buildings than those that were developed into apartments in the post-2018 period.

A.6 Scatterplots of Building Size and Units

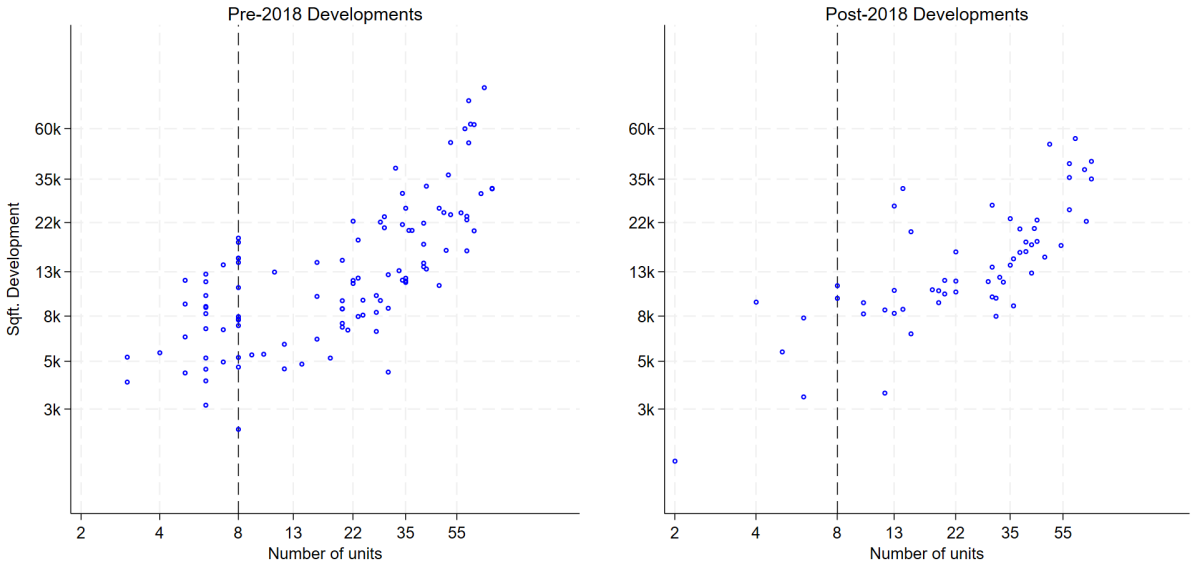


Figure A7: Scatter plot of the relationship between building square footage and number of units, by policy period

A.7 Additional Model Fit Statistics

	No. Units		Sqft ('000)		Acquisition Cost (Mil. $)	
	Data	Simulation	Data	Simulation	Data	Simulation
mean	25.2	22.4	15.06	12.76	0.98	1.18
sd	19.2	25.7	13.34	12.87	0.82	0.86
min	3.0	2.0	2.42	1.33	0.02	0.18
p5	5.0	3.0	4.46	2.36	0.33	0.32
p25	8.0	7.0	7.21	5.00	0.52	0.63
p50	22.0	14.0	11.72	8.89	0.73	0.98
p75	35.0	28.0	18.67	15.73	1.10	1.48
p95	61.0	66.0	32.51	35.71	2.59	2.66
max	75.0	147.0	93.18	73.73	10.49	4.94
% Lots Redeveloped			1.83	1.64		

Table A7: Model fit summary statistics for simulated outcomes

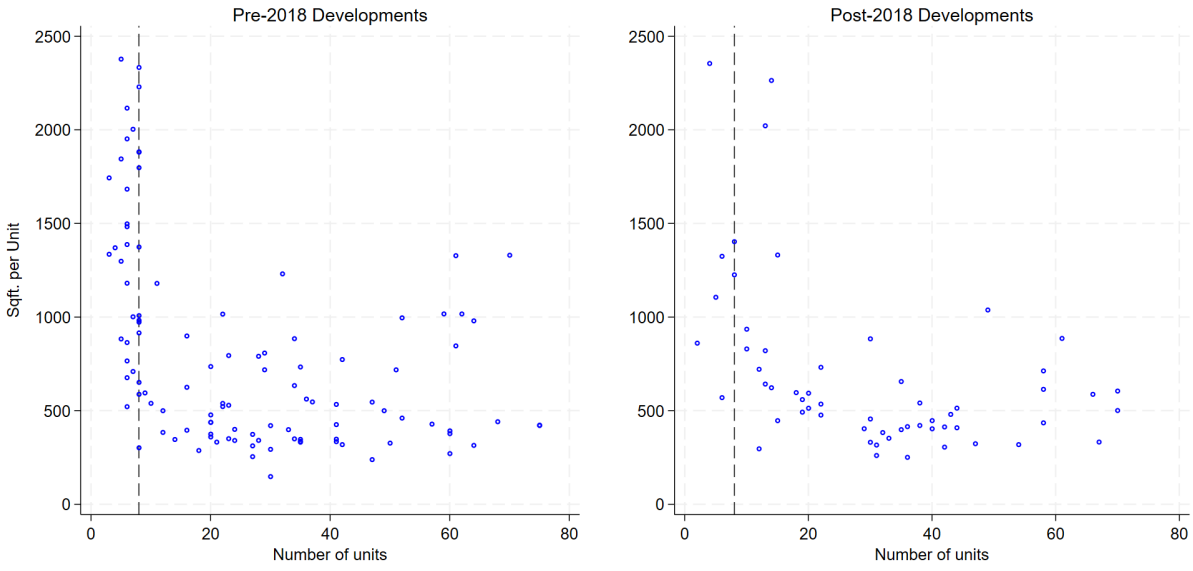


Figure A8: Scatter plot of the relationship between building square footage per unit and number of units, by policy period

A.8 Implications of Different Modeling Interpretations

The housing production function presented above can be interpreted as either a two-factor Cobb-Douglas function with decreasing returns to scale in capital and land, where land is divided evenly across all units in the development, or as a three-factor Cobb-Douglas function with constant returns to scale in capital, land, and housing units. Prior literature on housing services production, generally estimated on a sample of detached, single-family homes, either assumes a two-factor Cobb-Douglas function with constant returns to scale (Brueckner, 1981; Baum-Snow and Han, 2024) or make weak functional form assumptions and find that the production function is well-estimated by a Cobb-Douglas function with constant returns to scale (Ahlfeldt and McMillen, 2014; Combes, Duranton, and Gobillon, 2021).

Despite evidence from research on single-family home production that generally favors constant returns to scale, a decreasing returns to scale assumption for housing production in multifamily development is defensible using both the evidence from Combes, Duranton, and Gobillon (2021) and economic logic. First, Combes, Duranton, and Gobillon (2021) find that the production function exhibits slightly decreasing returns to scale, particularly for the largest lots in their sample. This suggests that, although most single-family home production exhibits constant returns, past a certain size threshold, increasing both land and non-land inputs by a factor of $\lambda > 0$ yields an increase in housing production by a factor strictly below λ. Given that the lot size and total square footage of any apartment building with unit counts above 4 tend to exceed those of all but a small fraction of single family homes, multifamily developments are highly likely to exceed the threshold at which housing production begins to exhibit decreasing returns to scale.

Additionally, in the multifamily context, if we assume a two-factor model, constant returns to scale would imply

that developers would not choose to divide a development into two or more units at any positive marginal unit cost.[30] The degree of decreasing turns determines the marginal product of adding an additional unit to the building without changing the lot size or total square footage—in other words, stronger decreasing returns to scale implies that developers would favor a building with many small housing units over one with fewer large units. This is consistent with evidence from interviews with multifamily housing developers who stated that, all else held equal, they would prefer to build more studio apartments (also known as efficiencies) than include multi-bedroom units, as renters tend to prefer lower rents to extra space.

If a three-factor model is assumed with unit count, square footage, and lot size as inputs, then the model as proposed assumes constant returns to scale. By this assumption, if average unit size is held constant, then an apartment and its lot could double in size, and the housing services delivered per housing unit would remain constant. This assumption would be violated if apartment dwellers exhibit a preference for apartment size, preferring either smaller or larger buildings.

A.9 Proof of Proposition

Let $V_p(K,u)$ be the value of a building with K square feet of capital and u units on a lot with price p, not including the cost of design review, ω, and let (K_p^*, u_p^*) be the optimal input choice in a world with no design review such that:

$$V_p(K_p^*, u_p^*) \geq V_p(K,u) \quad \forall (K,u) \tag{A1}$$

Assume that the optimal input choice for square footage is strictly increasing in price:

$$p' > p \Rightarrow K_{p'}^* > K_p^* \tag{A2}$$

Finally, let $\overline{u}$ be the design review threshold such that ω is incurred iff $u > \overline{u}$.

Proposition: $\forall p$ such that $u_p^* > \overline{u}$, $\exists \epsilon, \omega > 0$ such that $V_p(K_p^* - \epsilon, \overline{u}) \geq V_p(K_p^*, u_p^*) - \omega$

Proof. Choose p such that $u_p^* > \overline{u}$. Then, $\exists p' \neq p$ such that $u_{p'}^* = \overline{u}$ and $K_p^* > K_{p'}^*$. Thus, choose $\epsilon > 0$ such that $V_p(K_p^* - \epsilon, \overline{u}) \geq V_p(K, \overline{u})\ \forall K$. Then,

$$V_p(K_p^* - \epsilon, \overline{u}) - V_p(K_p^*, \overline{u}) \geq 0$$

$$V_p(K_p^*, u_p^*) - V_p(K_p^*, \overline{u}) \geq 0 \quad \text{(by eq. A1)}$$

30. To see this, assume $\alpha_K + \alpha_\ell = 1$. Then, $u_i^{1-\alpha_K-\alpha_\ell} = 1$, and housing services, H_i, ceases to be a function of unit count, u_i.

Now, choose $\omega \geq V_p(K_p^*, u_p^*) - V_p(K_p^*, \overline{u})$. Then,

$$V_p(K_p^* - \epsilon, \overline{u}) - V_p(K_p^*, \overline{u}) \geq V_p(K_p^*, u_p^*) - V_p(K_p^*, \overline{u}) - \omega$$
$$\therefore V_p(K_p^* - \epsilon, \overline{u}) \geq V_p(K_p^*, u_p^*) - \omega \blacksquare$$

Corollary: $\forall p, \omega$ such that $V_p(K_p^* - \epsilon, \overline{u}) \geq V_p(K_p^*, u_p^*) - \omega$ for some $\epsilon > 0$, $K_p^* - \epsilon \geq K_{p'}$ for all $p' \leq p$ such that $u_{p'}^* = \overline{u}$.

A.10 Microfoundation for the Fixed Cost Shock

Let f_i be the fixed cost of developing parcel i into an apartment building and q_i^* represent the value of parcel i at his highest and best use. Then, let $\epsilon_i = q_i^* - q_i^0$ represent the assessor's error in valuing parcel i. The zero profit condition implies that

$$q_i = \max_{u_i, K_i} \pi_i(K_i, u_i) - f_i$$

and an optimizing land owner will sell to a developer if and only if $q_i \geq q_i^0 + \epsilon_i$. Thus,

$$q_i = \max_{u_i, K_i} \pi_i(K_i, u_i) - f_i - (q_i^0 + \epsilon_i) = \max_{u_i, K_i} \pi_i(K_i, u_i) - q_i^0 - \phi_i \tag{34}$$

Where $\phi_i = f_i + \epsilon_i$ is the is the sum of the fixed cost shock and developer error for parcel i.