Under the (neighbor)Hood: Understanding Interactions Among Zoning Regulations*

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Abstract

This paper studies how various zoning regulations combine to affect housing supply, rents, and prices, and which regulations policy makers should relax if they want to reduce housing prices. Exploiting cross-sectional variation across space in novel parcel-level zoning data from Greater Boston and a boundary discontinuity design at regulation boundaries, we causally estimate the effect of various zoning regulations on housing supply, prices, and rents of single- and multifamily homes. We find that relaxing density restrictions (such as minimum lot size), alone or combined with relaxing other regulations, is most effective at increasing housing supply, particularly of multifamily properties, and reducing per-housing-unit rents and prices. Our theoretical framework and results also suggest that zoning regulations affect per-housing-unit prices by changing housing characteristics and, in effect, increasing the size of the smallest housing unit available. Our counterfactual simulations imply that the recent Massachusetts policy to increase building density near transit stations can reduce rents and sale prices, particularly in suburban municipalities.

Keywords: multifamily zoning, height restrictions, minimum lot size, density, accessory dwelling units, house prices, rents

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1. Introduction

Housing is becoming increasingly expensive in many North American cities. In 98% of census tracts in Greater Boston in 2018, for example, the median household spent more than 30% of its income on rent or mortgage costs—the threshold for being rent burdened. The scarcity of vacant parcels implies that solutions to the affordability problem must include plans to add housing by building more densely in populated areas. However, local barriers to new construction in the form of zoning regulations often prohibit this, which makes housing more expensive and adversely affects growth, aggregate output, wealth accumulation by younger households, geographic mobility, and homelessness (Hsieh and Moretti, 2019; Duranton and Puga, 2023; Dustmann et al., 2022; Ganong and Shoag, 2017; Colburn and Aldern, 2022).

Over the past century, local governments worldwide have adopted myriad zoning regulations limiting new construction. At least 54 municipal, state, and national governments worldwide have recently relaxed one or more zoning regulations in an attempt to reduce housing prices.[1] Yet it is unclear how effective these reforms will be as the literature has studied specific regulations in isolation (Ahlfeldt et al., 2017; Brueckner and Singh, 2020; Anagol et al., 2021), leaving under-addressed the question of the interactions and cumulative effects of zoning regulations on the housing market.

Our first contribution is examining how zoning regulations combine to affect the supply, prices, and rents of single-family and multifamily homes and identifying which regulations policy makers can relax to reduce housing prices. Using data for Greater Boston, we focus on the three major types of zoning regulations affecting the residential landscape of most cities worldwide: multifamily zoning (that is, whether the construction of multi-unit properties such as apartments is allowed on a parcel of land); maximum-height restrictions; and density restrictions, which determine how many housing units are allowed on a parcel. We define *relaxing regulations* or *upzoning* as increasing maximum height, allowing more density, or allowing multifamily homes.

Our first finding is that relaxing density restrictions alone or in combination with

[1] See Appendix Table C.1 for details on upzoning across 54 jurisdictions worldwide.

other regulations increases the number of housing units between 9% and 109%. This is because density restrictions such as minimum-lot-size requirements are the binding constraint on supply. In comparison, relaxing height restrictions alone or while also allowing multifamily zoning does not affect the supply of housing. We conclude that height restrictions are not a binding constraint on housing in Greater Boston. While density restrictions play the crucial role in restricting supply in Greater Boston, other zoning regulations may be binding constraints elsewhere. Nevertheless, our broader takeaways and methodology can be applied anywhere.

Our second contribution is a theoretical and empirical framework for economists and policy makers interested in understanding the effects of upzoning. Using novel parcel-level zoning data on 86 municipalities in Greater Boston, we exploit spatial variation in the three types of zoning regulations using a regression discontinuity (RD) approach. We study the discontinuity in regulations at regulatory boundaries within neighborhoods, instead of the more commonly used municipal boundaries (see Turner et al. (2014); Song (2021); Monarrez and Schönholzer (2022)). This creates two benefits and a challenge. The first benefit of this approach is that by dividing zoning boundaries into regulatory scenarios where one or more regulations change at the boundary, we can examine how regulations interact, and counterfactually simulate the policy effects of upzoning. The second benefit is that our results are not confounded by the effects of unobserved differences in municipality characteristics, which, like zoning regulations, change discretely at the border between municipalities.

The challenge of our approach arises because zoning-regulation boundaries were not drawn randomly. They were drawn to overlap with municipal boundaries, school-attendance-area boundaries, and natural features such that the underlying neighborhood quality is not continuous across these boundaries. To address this, we restrict our analysis to zoning boundaries that do not overlap with the abovementioned features. It is also likely that zoning boundaries were delineated to include or exclude certain areas for sociopolitical reasons, creating anomalous curves in the boundaries. If these curves correlate with unobserved land quality, this violates RD assumptions. We address this by following the approach of Turner et al. (2014): restricting our analysis to straight line segments of regulatory boundaries. We find no discontinuities in the vast majority of observed and unobserved location-quality covariates in our final sample of boundaries.

Using our theoretical framework, we examine three mechanisms behind differences in per-housing-unit prices and rents across regulatory boundaries: the composition effect, the sorting effect, and the option value. No arbitrage implies that the same house will have the same price across regulatory boundaries, except for a difference in the option value of land, as studied in the context of vacant land in Turner et al. (2014). However, zoning regulations can also change per-housing-unit prices at the boundary by changing housing characteristics (composition effect) and causing household sorting based on heterogeneous preferences for different house characteristics (sorting effect).

We find that per-housing-unit monthly multifamily rents fall by 4.2% and 6.9% ($54 and $101), on average, at boundaries where density regulations are relaxed alone or along with height restrictions, respectively. For single-family homes, relaxing density regulations alone or along with allowing for multifamily homes leads to an average 4.4% ($28,488) or 2.2% ($13,394) drop in the per-housing-unit sales price in areas across the boundaries. Again, we find no statistical differences in prices or rents across boundaries where multifamily and height restrictions are relaxed separately or together.

Using our empirical framework, we find that these per-housing-unit price and rent differences across boundaries are likely driven by the composition effect and household sorting based on house characteristics (sorting effect). We find little evidence of the option value effect. Thus, zoning regulations can affect per-housing-unit prices, which include differences in quality or size, by changing housing characteristics and increasing the size of the smallest housing unit available in strictly regulated zoning areas (in effect, creating a two-part tariff (Banzhaf and Mangum, 2019)). Given that 58% of the land area in Greater Boston is limited to only single-family-home construction, 70% of land is limited to no more than 35 feet tall buildings, and 25% of land is limited to only one housing unit per acre of land, zoning regulations can result in households overconsuming housing and can increase overall prices. Zoning regulations can also affect per-housing-unit prices by restricting supply at the broader neighborhood or metro level. However, our within-neighborhood RD design is not well suited to study this broad supply effect.

Our third contribution is to use our causal estimates to simulate the long-run effects of Massachusetts's 2021 Chapter 40A zoning-reform law – which allowed multifamily housing and relaxed density restrictions in neighborhoods near public transit stops – on housing supply, prices, and rents. Our counterfactual framework and estimated local average treatment effects can be used to simulate the long-run effects of upzoning if the changes are local and small. Thus, our setup is particularly well suited to studying Massachusetts's reform or similar small-scale reforms adopted across at least 13 jurisdictions worldwide in the past five years. In addition, unlike much of the literature, which studies the effects of regulations on vacant land, we provide estimates for the built-up environment which include the effects of redevelopment. Thus, in addition to the option-value effect of upzoning studied in the literature, we can simulate how the composition and sorting effects operate in built-up areas with new housing stock.

We estimate that the median long-run increase in housing supply from the Chapter 40A reform is about 0.18 housing units per parcel near a transit stop, a 23% increase. The supply effects are particularly prominent close to central Boston. Our estimates also suggest that long-run multifamily rents fall by up to 6% near transit stops in some suburban municipalities. The effects on single-family house prices are nonlinear. In the long run, sales prices fall by up to 11% near transit stations where regulatory stringency is considerably greater than the Chapter 40A mandate. However, the option value stemming from the reform moderately increases long-run single-family sale prices for homes located near transit stations close to Boston, where regulations are more relaxed.

Our paper expands the literature on land-use regulations[2] by providing a novel method to study how zoning regulations interact and which regulations should be relaxed to measurably affect housing supply and prices. Past research has studied the effects of land-use regulations in one of two ways. First, many studies analyze the effects of zoning regulations separately (Ding, 2013; Zabel and Dalton, 2011; Kulka, 2020; Davidoff et al., 2022), making it difficult to understand how different regulations interact. Second, studies such as Turner et al. (2014), Herkenhoff et al. (2018), and Cheshire

[2]Glaeser and Gyourko (2018); Jackson (2016); Chiumenti (2019); Gyourko et al. (2021); Molloy (2020); Chiumenti and Sood (2022) study supply and price effects of zoning regulations across the U.S.

and Hilber (2008) rely on surveys, such as the Wharton index (Gyourko et al., 2021), or misallocation wedges to document the effects of zoning regulations but do not provide a road map for reducing prices associated with the regulations. This paper also ties in to the literature studying the broader effects of zoning regulations. If households cannot afford to live near productive cities, they may relocate to regions with worse opportunities and health outcomes (Chetty and Hendren, 2018; Chyn and Katz, 2021). Bertaud and Brueckner (2005) and Brueckner and Singh (2020) show that height restrictions limit housing near commercial city centers and cause urban sprawl, creating damaging environmental effects (IPCC, 2022).

This paper relates to the literature studying the adoption of zoning regulation in the 20th century and its long-term consequences (Boustan, 2013; Shertzer et al., 2016, 2018). Methodologically, the paper adds to the literature using RD methods to study various spatial outcomes (Dell, 2010; Severen and Plantinga, 2018; Bayer et al., 2007; Anagol et al., 2021; Harari and Wong, 2021) and contributes to the larger literature on housing affordability (Sinai and Waldfogel, 2005; Baum-Snow and Marion, 2009; Diamond et al., 2019; Asquith et al., 2021; Pennington, 2021). Unlike most of the literature, we study the effects of zoning regulations on all building types.[3]

The rest of the paper proceeds as follows. Section 2 describes the background to the regulatory framework, and Section 3 provides the theoretical framework. Section 4 describes the data and empirical strategy. Section 5 discusses the results, and Section 6 presents the policy effects of relaxing regulations.

2. Types of Zoning-Regulations

Municipalities employ multiple types of zoning regulations to manage their local housing stock because each regulation likely serves a specific need among residents, or because residents prefer having multiple regulations in place to better control changes in neighborhood structure. In the early-to-mid 20th century in the United States, zoning regulations proliferated in part as a response to rapid urbanization before World War II and growth in housing demand experienced post-war.

[3]For instance, Zabel and Dalton (2011) and Glaeser and Ward (2009) study single-family houses and Severen and Plantinga (2018) study only multifamily buildings.

We study three types of zoning regulations common in the United States and much of the rest of the world that affect construction of residential housing. Multifamily zoning regulations either allow multifamily buildings or limit construction to single-family homes. Maximum-height regulations restrict how tall a residential building can be. The third type of zoning regulation are density restrictions, calculated as the number of dwelling units per acre (DUPAC).[4] Municipalities limit housing density either by limiting the number of housing units allowed on a parcel of land or by requiring a minimum lot size to construct new buildings.[5] The DUPAC measure allows for comparison of zoning areas that use different methods to regulate housing density.[6]

These three types of zoning regulations have straightforward definitions, but their interactions can be complex. Different regulations act as binding constraints on housing supply in different areas. For example, if a municipality allows five units to be built on an acre of land, limits building height to 20 feet, and does not allow multifamily housing, then at most five single-family homes can be built, each two floors tall and on a one-fifth-acre lot. If this municipality then allows multifamily housing, without changing DUPAC and height regulations, some apartment buildings can now be constructed but there still cannot be more than five housing units. In this example, DUPAC is the binding constraint. We conjecture that relaxing binding zoning regulations will increase housing supply, while relaxing just nonbinding zoning regulations will not.

3. Theoretical Framework

The theoretical framework we apply to understand how zoning regulations affect housing supply and prices considers two zoning areas in a city. Suppose zoning areas $k = L, R$ have different regulatory regimes. They share a border located at $x = 0$. Within a given distance from the boundary (between $\underline{x}$ and $\overline{x}$), any parcel of land may have either a single-family home (1 unit) or a multifamily building (>1 unit), provided zon-

[4]Municipalities in Greater Boston adopted broad use-type zoning categories (residential, industrial, or commercial) and height restrictions after 1917. After World War II, municipalities found that these regulations "did not sufficiently limit the housing potential of a given parcel, and recommended changes to the zoning to cap the total amount of habitable floor area in a structure relative to the area of the parcel on which it sat." They thus began adopting density regulations (MacArthur, 2019; Bobrowski, 2002).

[5]Appendix Figures C.1, C.2, C.3 show multifamily, height and DUPAC restrictions in Greater Boston.

[6]DUPAC is calculated by taking the square footage of one acre and dividing it by the specified minimum lot size in a zoning area, then multiplying this by the maximum number of units allowed per lot.

ing regulations allow it. The vector z^k denotes the three types of zoning regulations in zoning area k, where a larger z^k indicates less restrictive regulations. We assume zoning area L is more regulated than R such that $z^L \leq z^R$. The price of housing, either the sales price for a single-family home or the monthly rent for a multifamily unit, is given by $p(x, h(z^k), z^k)$. Price $p(.)$ is also a function of the bundle of housing-unit characteristics $h(z^k)$, which itself is a function of the zoning regulations. We assume that the regulatory constraints are binding.

Consumers have type τ. They are heterogeneous in their preferences (γ^τ) and the location of their outside option. The outside-option location has reservation utility of ν^τ. Consumers choosing to live in location x earn wage w, derive housing utility $V(x, h(z^k), z^k, \gamma^\tau)$, and pay price $p(x, h(z^k), z^k)$ for housing in their chosen location. Thus, the utility of a consumer is $U(x, h(z^k), z^k, \gamma^\tau) = u(w - p(x, h(z^k), z^k))V(x, h(z^k), z^k, \gamma^\tau)$. In equilibrium, residents are indifferent between all locations x and their outside option, and the housing market clears, given the following assumptions:

Assumption 1: *Housing markets are not locally segmented at the regulatory boundary* $x = 0$*; that is, they face the same demand and supply shocks.*

Assumption 2: *The city population increases at exogenous rate* $\kappa > 0$ *such that there is an increase in population and housing demand over time.*

3.1 Mechanisms behind Price Differences across Boundaries

Following Turner et al. (2014), we divide a consumer's housing utility $V(.)$ into direct housing utility $V^{direct}(x, h(z^k), z^k, \gamma^\tau)$, which is a function of location x, housing-unit characteristics $h(z^k)$, and zoning-regulation vector z^k, and zoning area housing utility $V^{neighbor}(z^k)$, which is a function of the regulatory vector.[7] Zoning area housing utility represents how zoning laws affect area density and neighbor characteristics, such as the characteristics of homes near location x. Under utility of form $u(.) = \exp^{(w - p(x, h(z^k), z^k))}$, the price per unit is given by

$$p(x, h(z^k), z^k, \gamma^\tau) = w - \nu^\tau + \ln(V^{direct}(x, h(z^k), z^k, \gamma^\tau)) + \ln(V^{neighbor}(z^k)). \tag{1}$$

[7] Turner et al. (2014) refer to direct utility as own-lot effect and neighbor utility as external-lot effect.

From Equation 1, it follows that

$$p(x, h(z^L), z^L, \gamma^\tau) - p(x, h(z^R), z^R, \gamma^\tau) = \ln(V^{direct}(x, h(z^L), z^L, \gamma^{\tau_L})) - \ln(V^{direct}(x, h(z^R), z^R, \gamma^{\tau_R})) + \ln(V^{neighbor}(z^L)) - \ln(V^{neighbor}(z^R)).$$

Assumption 3: *As* $|x_L - x_R| \to \epsilon$ *for a small* ϵ, $\ln(V^{neighbor}(z^L)) - \ln(V^{neighbor}(z^R)) \to 0$. Thus, close to the boundary, consumers in zoning areas L and R are exposed to the same immediate neighbors and density. Then, close to the boundary, the housing-unit price and rent differences expressed in Equation 2 only arise from direct location utility $V^{direct}(x, h(z^k), z^k, \gamma^\tau)$.

$$p(x, h(z^L), z^L, \gamma^\tau) - p(x, h(z^R), z^R, \gamma^\tau) = \ln(V^{direct}(x, h(z^L), z^L, \gamma^{\tau_L})) - \ln(V^{direct}(x, h(z^R), z^R, \gamma^{\tau_R})). \tag{2}$$

In our theoretical setup, the long-run equilibrium price-per-housing-unit differences across boundaries in Equation 2 are not zero; that is, $p(x, h(z^L), z^L, \gamma^\tau) - p(x, h(z^R), z^R, \gamma^\tau) \neq 0$. Under a no arbitrage condition, net of option value, the exact same house will have the same price on different sides of a zoning border. However, in our framework, differences in per-housing-unit prices and rents across zoning area boundaries arise due to the following three mechanisms. First, for owners, the option value of land jumps discretely at the boundary. Second, the regulations induce differences in housing characteristics across boundaries by increasing the smallest available housing unit. This leads to a jump in per-housing-unit price or rent of available units. We call this the composition effect. Third, consumer heterogeneity in preferences for house characteristics (γ^τ) leads to different demand elasticities across the boundary and results in a jump in prices and rents at the boundary, which we call the sorting effect.

Option value

Relaxing zoning regulations increases the option value of parcels of land, as they can now be used for denser housing (taller buildings or buildings on smaller lots) or for both types of housing. The option value results in a positive jump in price per square foot on the less restrictive side (R) of the boundary. It is only present for owners and for the purposes of this paper only affects single-family-home sale prices.

Composition effect

The price differences in Equation 2 are partly driven by differences in housing characteristics $h(z^k)$. Zoning regulations result in discrete differences in housing type and characteristics across the regulatory boundary such that $h(z^L) \neq h(z^R)$. For example, higher DUPAC in zoning area R might induce smaller minimum lot sizes and different housing characteristics. Thus, the price per housing unit jumps discretely at the boundary $(p(h(z^L)) \neq p(h(z^R)))$, falling as one moves from the restricted zoning area L with larger housing units to the less restrictive zoning area R. The mechanism of the composition effect driving price differences is novel in our understanding of the effects of regulation on prices and rents. By altering the characteristics of housing even within a building type—single- or multifamily—zoning regulations increase the price of the smallest housing unit available in the more regulated zoning areas.

Sorting effect

Household heterogeneity in outside options (ν^τ) implies that demand in zoning areas L and R is not perfectly elastic.[8] Households' heterogeneous preferences for housing characteristics γ^τ lead them to sort along the regulatory boundary $(x = 0)$, resulting in different demand elasticities across the boundary. Since there is no market segmentation (Assumption. 1), the shift in the supply curve in zoning areas L and R will result in a discrete jump in price per housing unit at the boundary.[9] If demand is more inelastic (elastic) on the more regulated side, then the price per housing unit is lower (higher) on the more relaxed side. The difference in equilibrium prices due to the sorting effect is reflected in Equation 2, in which γ^τ differs across boundaries.

4. Data and Methodology

4.1 Data and Regulatory Scenarios

Parcel-level zoning-regulation data come from the Metropolitan Area Planning Council's *Zoning Atlas*. The *Zoning Atlas* covers 101 municipalities in Greater Boston and

[8]This is unlike the models that use a boundary RD design to elicit willingness to pay for characteristics that differ discontinuously at boundaries, such as school quality (Black, 1999). Such models assume that demand for housing is perfectly elastic on both sides of the boundary. With perfectly elastic demand, housing supply shifts due to regulatory changes cannot affect prices across boundaries.

[9]Without heterogeneity in preferences, demand elasticities across boundaries are the same, and there are no differences in equilibrium prices across boundaries due to the sorting or supply effect.

displays zoning regulations as observed in 2010. Most of the regulations were first enacted in the early to mid-20th century.[10] A survey of Massachusetts municipalities by Zabel and Dalton (2011) finds minimal (10) changes to zoning ordinances in the 1980s and 1990s. All of the 10 the changes were to minimum lot size numbers rather than the regulatory boundaries.[11] Thus, we believe that our sample's zoning boundaries have stayed relatively constant, and that the 2010 data largely map onto the ordinances that shaped development over the past century.

We examine six scenarios in which one or two regulations differ across a zoning regulation boundary. The first three columns in Table 1, Panel A show scenarios 1–3, in which only one type of regulation differs at the boundary. The next three columns show scenarios 4–6, in which two regulatory types vary at a given boundary. Panel A also shows the average difference in DUPAC, height, and share of allowable multifamily housing at the boundaries for each scenario. Across the boundaries for the six scenarios, average maximum-height restrictions varies little while average DUPAC ranges from 7.9 housing units per acre to 35.6 and the share of areas allowing multifamily housing ranges from 0.5 to 0.82. Figure 1 shows the boundaries of these six scenarios.

Housing data come from property tax–assessment records compiled by the Warren Group for 2010–18. These records reflect the near universe of residential and mixed-use buildings in Greater Boston and contain information on the properties' type (single family or multifamily), size (lot size, square footage), characteristics (number of units, number of bedrooms, year of construction), and price (tax-assessed value, sale price).[12] For single-family homes, we use the most recent sale price so long as the home was sold within the study period (from 2010 to 2018); otherwise we exclude the property from our analysis of housing prices (but not housing supply). For multifamily buildings, estimat-

[10]Boston and Cambridge first adopted zoning regulations in 1918 and 1920 (Knauss, 1933; MacArthur, 2019), respectively. Their neighboring municipalities followed soon after that. Appendix Table C.2 illustrates the year of the adoption of the first zoning regulation across the 42 municipalities in our sample.

[11]Kulka (2020) also finds that rezoning requests concern minimal amounts of land and that, annually, only around five instances of rezoning occur on average in Wake County, North Carolina.

[12]Appendix Figure C.4 shows that estimates of the housing stock derived from the Warren Group data are similar to those derived using the American Community Survey. We exclude condominiums, constituting about 10% of all residential property records from 2010 to 2018, because of inconsistencies in how their tax records are reported across municipalities, which makes it difficult to reliably determine the size, sale price, or assessed value of condominium buildings.

ing housing prices is more complex because complete and consistent property-level rental data are virtually nonexistent. For example, McMillen and Singh (2020) rely on survey data to estimate rents. For relatively large apartment buildings, we match contemporary market-rate rent data from CoStar to properties in the Warren Group data. CoStar data only cover buildings with five or more units, so, for properties for which no CoStar rent data are available, we impute rent using their tax-assessed value. Market-rate rent data are used for 18,536 multifamily properties, with the remaining 112,992 multifamily properties in our data set requiring rent imputation.[13] In Section 5.4, we show that there is little statistical difference in the key rent results between our baseline sample of multifamily buildings and a subsample excluding imputed-rent properties. Table 1, Panel B reports the variation in mean number of housing units, multifamily rents, and sales prices of single-family homes for properties within 0.2 miles of the boundary between zoning areas for each scenario.

Last, we collect data to measure neighborhood quality. For school quality, we use 2016 elementary school attendance-area boundaries from the National Center for Education Statistics, excluding 15 municipalities in our sample that do not have data available (see Appendix Figure C.5 for the final 86 municipalities included in our analysis). To control for neighborhood demographic characteristics we use the 2010 US Census's census-block-level data.

4.2 Empirical Strategy

We employ a nonparametric and a semiparametric approach to estimate $V^{direct}(x, h(z^k), z^k, \gamma^\tau)$ from Equation 2.

Nonparametric model

As we have a sufficient number of observations within 0.2 miles of all six regulation scenario zoning boundaries, we estimate the nonparametric differences in housing supply, prices, and rents across regulatory boundaries following Imbens and Lemieux (2008). Like Bayer et al. (2007), we regress our outcomes of interest on a set of boundary fixed effects, which capture differences in unobserved amenities at the boundary, and a set

[13] Appendix A provides details of the imputation process and lists other data on neighborhood quality.

of fine-grained bins of distance to the boundary. Distance to the boundary is the running variable for this RD design. The width of each bin is 0.02 miles, corresponding to the average optimal bandwidth calculated using Calonico et al. (2020) across the six regulatory scenarios. We estimate the following specification:

$$Y_{xt} = \sum_{x=\underline{x}}^{\overline{x}} \mathbb{1}\delta_x^{dist} + \lambda_x^{seg} + \phi_t + \epsilon_{xt} \tag{3}$$

Here, Y_{xt} is the number of units, log sale price for single-family homes, or log monthly rent for multifamily buildings at location x in year t. δ_x^{dist} is a dummy for the distance bin that x lies in, and λ_x^{seg} is the boundary fixed effect for segment seg. ϕ_t is the sale (when the outcome variable is sale price) or rent year (when rent is the outcome) fixed effect.

For the effects of the six regulatory scenarios on the number of units per lot, we report the results for the 2018 snapshot of buildings. In addition, we restrict the sample to buildings built after the adoption of the first zoning restrictions (in 1918) so as to not confound the supply estimates with estimates of the pre-adoption residential structures. When studying the effects of the six regulatory scenarios on single-family sale prices and monthly multifamily rents, we focus on sale prices and rents from 2010 to 2018 for all buildings in our sample, no matter the build year.

Semiparametric model

We also estimate a semiparametric RD model to identify the causal effect of the regulatory treatment on the outcome variables within 0.2 miles or less of the regulatory boundary. The semiparametric approach augments the nonparametric analysis in three ways. First, it provides estimates of the marginal one-unit change in DUPAC, height, or multifamily regulations on housing supply and prices instead of the total difference across the boundaries. We use these estimates for evaluating Massachusetts's Chapter 40A upzoning policy in Section 6. Second, the semiparametric approach helps us study the marginal effect of individual regulations for regulatory scenarios 4, 5, and 6, in which two zoning regulations differ at the border. This allows us to study how various zoning regulations interact and affect equilibrium housing supply and prices. Third, we use Equations 4 and 5 for a linear probability model in which Y_{xt} is a type of building—an indicator for either two- or three-unit buildings or four- or more unit buildings relative to single-family buildings. This model allows us to study the impact of regulations on the probability that a property is of a particular type. The parsimonious semiparametric regression model is given by the following equations:

$$Y_{xt} = \rho_0 + \rho_1 \text{reg}_x + f_x(\text{dist}) + \lambda_x^{seg} + \phi_t + \epsilon_{xt} \quad \underline{x} \leq x \leq \overline{x} \tag{4}$$

$$Y_{xt} = \rho_0 + \rho_1 \text{reg}_{1x} + \rho_2 \text{reg}_{2x} + \rho_3 \text{reg}_{1x} \text{reg}_{2x} + f_x(\text{dist}) + \lambda_x^{seg} + \phi_t + \epsilon_{xt} \quad \underline{x} \leq x \leq \overline{x} \tag{5}$$

Again, Y_{xt} is the number of units, log sale price, or log monthly rent. reg_x is either a continuous regulation of DUPAC or maximum height (in 10-foot units) or an indicator of whether multifamily houses are allowed. We use Equation 4 for regulatory scenarios 1, 2, and 3, in which only one regulation differs at the boundary. We use Equation 5 for regulatory scenarios 4, 5, and 6. ρ_1 and ρ_2 in Equation 5 estimate the effects of each regulation individually, and ρ_3 estimates the interaction effect. $f_x(\text{dist})$ is an *n*th-degree polynomial in the distance to the boundary, varying from linear to a fifth-degree polynomial and specified separately on both sides of the boundary.

Exploring mechanisms behind price differences

Since housing characteristics are endogenous to zoning regulation, we do not control for them in the baseline nonparametric and semiparametric models, which compare per-housing-unit prices across boundaries and estimate the total price effect of the regulations. Additional nonparametric models help us understand the role of the three mechanisms—composition effect, sorting effect, and option value—in driving the total effect. To isolate the composition and sorting effects, we control for unit characteristics—that is, lot size, number of housing units per building, and number of bedrooms and bathrooms—and compare sale-price and rent differences across boundaries. Note that we cannot isolate the composition effect from the sorting on house characteristics (sorting effect), which would require exogenous variation in the sorting of households. In principle, if we could completely control for housing unit characteristics, any residual per-housing-unit sale-price differences or single-family houses would arise only from the option-value effect (no option value effect in rents).

In practice, we control for observable housing unit characteristics. If we do not fully account for unobserved housing unit characteristics and sorting on those characteristics, this might also drive per-housing-unit price differences. This can create biased estimates because γ^{τ} can affect both house characteristics (people choose houses based on their preferences) and the price (larger homes cost more because people with a higher willingness to pay purchase them). The bias in the estimation is likely negative because the willingness to pay for a large house is higher for households who live on the relaxed-regulation side compared to households on the strict-regulation side. If a negative bias exists, the estimated results are likely underestimated, and our results represent a lower bound on the house price and rent differences across regulatory boundaries.

4.3 RD Boundary Selection and Assignment

Zoning-regulation boundaries are likely not randomly drawn across areas. In many cases, these boundaries overlap roads, municipal and school boundaries, and natural features such that the underlying quality of neighborhoods is not continuous across boundaries. Discontinuity in land or neighborhood quality violates the RD assumption that all relevant covariates besides the zoning-regulation treatment must vary smoothly at the regulatory boundary.

To account for this nonrandomness, we take several steps to arrive at a set of plausibly exogenous regulatory boundaries. Figure 2 shows the elimination of the boundaries across Greater Boston after each step. Based on *Zoning Atlas* data, there are 26,306 zoning-regulation boundaries along which at least one type of zoning regulation differs. We remove zoning boundaries that overlap with municipal borders, important geographic features (lakes, rivers, and streams), and built infrastructure (interstates, state highways, arteries, and connector roads). Properties on either side of boundaries that overlap with these features cannot be considered similar because taxes and local public goods differ or because boundaries represent physical barriers (for example, highways and rivers). A total of 21,328 zoning boundaries remain after boundaries that overlap with these features are removed (Figure 2b). Next, we remove zoning boundaries that overlap with elementary school attendance-area boundaries. We also remove zoning boundaries across which the zone-use type (residential or mixed use) differs since amenities associated with different zone-use-type areas likely vary discretely at the boundary. After these boundaries are eliminated, 9,674, or 36.8%, of the baseline zoning boundaries remain. As a result, residential buildings are assigned to their closest zoning boundary within the same municipality, school attendance area, and zone-use type. We exclude any building more than 0.2 miles from its assigned boundary.

Furthermore, municipalities may have had political and racial motives when drawing the original zoning boundaries between 1918 and 1956, when most of these boundaries were delineated. For instance, Shertzer et al. (2016) find that Chicago's 1923 zoning maps placed industrial-use zones in racial minority areas. These motives may have resulted in curves or bends in the zoning boundary, including or excluding specific buildings or neighborhoods. If these curves correlate with unobserved differences in land quality that have persisted (Sood and Ehrman-Solberg, 2022) and were not eliminated in the previous steps, this violates the RD continuity assumption. To account for this, we restrict our sample to properties assigned along straight-line boundary segments, following a procedure similar to Turner et al. (2014).[14] This results in our final exogenous sample of 2,835 zoning boundaries, which constitutes 10.8% of the original sample (Figure 2d). The average length of zoning boundaries in the final sample is 0.35 miles, longer than the original average boundary length of 0.2 miles. Our boundary selection strategy removed shorter boundary segments, which are more likely endogenously determined.

Assignment of regulatory scenarios to boundaries

If the assignment of regulatory scenarios to boundaries is not random, we might not be able to compare results across different regulatory scenarios since the local average treatment effects may be driven by unobserved factors that are also driving the regulatory assignment. Using a t-test, we study whether the mean neighborhood characteristics for boundaries across the six regulatory scenarios are significantly different. Note that these t-tests do not preclude household sorting across individual zoning boundaries. We find little difference in mean distance of boundaries to the center of their municipality across the six scenarios (Table 1 Panel C). There is also little difference in the mean share of the population under the age of 18 or over 65. While the mean

[14]For each building, we first find a straight line connecting a property to its assigned boundary. A second line with a midpoint where this straight line meets the zoning boundary is drawn, measuring 100 meters long, with 50-meter segments between the midpoint and each endpoint. If both endpoints are within 15 meters of the zoning boundary, we determine the building to be located along a straight segment of this boundary. We exclude properties if either endpoint is more than 15 meters away.

share of Black residents varies from 4.9% to 12.4% across regulatory scenarios, this variation amounts to only one-half of one standard deviation of the census-block-level estimate. Thus, the treatment heterogeneity across the assignment of regulatory scenarios to boundaries is minimal and the type of regulatory change is not systematically assigned to particular areas, allowing us to compare estimates across different scenarios.

4.4 Testing Spatial RD Assumptions

In this section, we test whether all relevant covariates (except the treatment and outcomes of the treatment) are continuous across the boundaries. We estimate Equation 3, where the dependent variables are measures of parcel quality, distance to various amenities, and predicted sale price or rent. We plot the coefficients on the distance bins in Figures 3 and 4. Negative-value distance bins indicate the more regulated side of a zoning boundary.[15] Coefficients are normalized to zero at bins closest to the boundary on the less regulated side (from 0 to 0.02 miles).

Continuity of observable and unobservable location quality

Figure 3 shows that distances to the nearest major body of water, green space, assigned elementary school, and municipal center as well as commute distance to downtown Boston are continuous and not statistically distinguishable from zero for all buildings within 0.2 miles of either side of the boundary in almost all regulatory scenarios.[16] In addition, there are no measurable differences in depth to bedrock, which affects construction costs, for parcels within 0.2 miles of either side of the boundary. Appendix Figure C.7 displays continuity of parcel quality and distance to neighborhood amenities across additional regulatory boundaries.

However, for two measures of location quality, continuity is not straightforward. First, while the jump at the boundary is not statistically significant, buildings on the

[15] In cases in which regulations change but are not consistently relaxed on the same side of the boundary (for example, height increases while DUPAC decreases), we consider the strictly regulated side to be either the one that does not allow multifamily housing (scenarios 4 and 5) or the one in which the height and DUPAC measures decrease the most (scenario 6).

[16] We use Euclidean distance to calculate the nearest distances in miles since we find that Euclidean distance and the walking distance between a property and its nearest neighbor across the boundary in our sample are highly correlated (Appendix Figure C.6). Additionally, we calculate the commute distance to downtown Boston as the Manhattan distance from a building to its nearest transit station plus the distance from the station to a common point in Boston along a public transit route.

restrictive side are measurably farther from the nearest major road or highway in a few regulatory scenarios. In Section 5.4, we test whether the key results are driven by distance to the road or highway, and we find that they are not. Second, we find that while the parcel-level average slope of the land is continuous at the boundary itself, the slope varies above 0.1 miles away on the less restrictive side for the boundaries across which DUPAC and height regulations change. We do not find such differences for other regulatory types (Appendix Figure C.8). Again, we find that the key results are not driven by parcel-level slope variation (see Section 5.4).

Next, we investigate the continuity in unobserved location quality across the boundaries. To do so, we regress single-family-home sales prices and multifamily rents on the previously discussed location-amenity and parcel-quality measures and boundary fixed effects (Equation 3). Figure 4 plots the predicted sales prices and rents. If unobserved location-quality differences exist, this will result in discrete jumps in predicted prices or rents at the zoning boundary.[17] We find no discontinuities in predicted sales prices in any of our six regulatory scenarios and no discontinuities in predicted rents at boundaries across which DUPAC and height regulations change. There are statistically significant differences in multifamily rents across the boundaries across which only DUPAC regulations change. However, the magnitude of the differences is minuscule (0.004) compared to the differences in rent we find across such boundaries in Section 5.3. This finding suggests, however, that unobservable location quality might affect our rent-difference estimates at boundaries across which only DUPAC changes.

Continuity of neighborhood quality

Despite households' sorting across boundaries based on their preferences for house characteristics (γ^τ), Assumption 3 requires that neighborhood quality be continuous across the zoning boundaries. Three additional pieces of evidence support this assumption. First, the optimal bandwidth at which we measure the regulation's causal effects is relatively small (0.02–0.03 miles). At a 0.04-mile (211 foot) bandwidth, corresponding to the first two bins around the boundary, four to five houses are compared, on average.

[17] We observe a slight trend in the predicted sale prices and rents across all boundaries. This is expected given that distances to location amenities are factored into equilibrium sale prices and rents.

Thus, it is not hard to imagine that neighborhood quality is similar close to the boundary on both sides. Second, a concern might be that neighbors on either side of a zoning boundary do not interact with each other if even minor physical divisions exist—for example, small residential roads. In Section 5.4, we remove boundaries that overlap with any type of roadway (major roadways were already removed). We find that the effect on prices and rents is qualitatively similar to the baseline effect. Last, for further robustness, we also control for neighbor demographics at the census-block level and income at the block-group level and find qualitatively similar effects as the baseline results.[18]

Ultimately, with the one exception of rent estimates at boundaries across which only DUPAC changes, we find continuity in wide-ranging indicators across zoning boundaries. Thus, we are confident that the final sample of straight-line boundaries is plausibly exogenous and that our spatial RD assumptions hold.

5. Results

As in Section 4.4, we present the supply, sale-price, and rent effects from Equation 3 binned into 0.02-mile bins around a zoning boundary. The 95% confidence intervals are reported using standard errors clustered at the boundary level to account for spatial correlation (Abadie et al., 2022). Robust standard errors for the –0.02- to 0-mile bin are reported in brackets for comparison. Since we examine the impact of zoning regulations instituted in the early to mid-20th century on housing supply and prices in the early 21st century, our results are best interpreted as long-run effects.

5.1 Effects of Regulations on Housing Supply

The largest effects on housing supply occur at zoning boundaries across which DUPAC regulations are relaxed alone or in combination with one or both of the other two regulatory types. Figure 5 plots the nonparametric differences in the number of housing units per lot on either side of a zoning boundary. For boundaries across which only DUPAC regulations change, there is an average 0.11-unit discrete jump in housing units per parcel, or an 8.7% increase over the 1.3-unit average on the strict side of the boundary. Even larger increases occur across boundaries across which DUPAC

[18] The set of controls is the shares of population that are (a) ≤ 18, (b) ≥ 65, (c) Black residents, (d) Asian residents, (e) Hispanic residents, (f) non-Hispanic white residents, and (g) ≥ 4 household members.

is relaxed along with other zoning regulations. For boundaries across which DUPAC and multifamily-housing regulations are relaxed, the average number of units jumps by 53.7%. For boundaries across which both DUPAC and height regulations are relaxed, the average number of units increases by 109%. Relaxing density and height restrictions simultaneously is similar to São Paulo's relaxation of regulations on floor-area ratio as studied by Anagol et al. (2021), who also find a near doubling of the number of housing permit applications. Last, relaxing multifamily-housing regulations alone leads to an increase of 0.598 units per lot, or 51.2%.

In regulatory scenarios in which height regulations change either alone or along with reforms allowing multifamily housing, we cannot statistically distinguish from zero the long-run differences in housing units. These null effects imply that height regulations are not a binding constraint for housing developers at the regulations' current levels. Instead, housing supply is more likely constrained by limits on housing density and the inability of developers to construct anything except single-family homes. While height restrictions do not constrain housing supply in Greater Boston, they may be a binding constraint in other metropolitan areas in the US and worldwide (Brueckner and Singh, 2020; Nakajima and Takano, 2021).

5.2 Effects of Regulations on the Type of Housing

We use our semiparametric linear probability model (from Equations 4 and 5) to study regulation's effects on the type of housing.[19] Two types of multifamily housing are examined—gentle-density multifamily housing (two or three units) and high-density multifamily housing (four or more units). We interpret a given regulation's effect as a change in the probability that a gentle- or high-density multifamily property is constructed compared to single-family housing.

Whereas relaxing DUPAC restrictions increases housing supply overall, allowing multifamily housing changes the types of buildings that are built. Together, relaxing these two regulatory types leads to more housing that is densely constructed. Allowing multifamily housing alone or in combination with relaxing DUPAC regulations in-

[19]The bandwidth is $\underline{x}, \overline{x} = 0.2$ miles, and the distance to the boundary trend is linear. We get similar results with a cubic polynomial trend (Appendix Table C.3).

creases gentle-density properties in a neighborhood. As Table 2 shows, allowing multifamily housing alone doubles the probability of a gentle-density building being constructed to 0.48 (compared to 0.23 on the stricter side of the boundary). The effect of relaxing multifamily housing increases the probability of a high-density building by 123%. However, this effect is less precisely estimated compared to the estimates for gentle-density housing, likely because of the smaller number of high-density buildings. These results may also point to other barriers to the construction of larger apartment buildings, such as higher costs and greater community opposition.

As with the nonparametric results, we find positive effects on all housing types when DUPAC and height regulations are relaxed together but null effects when either height regulations change alone or they change along with reforms allowing multifamily housing. Again, the null effects imply that among the multiple existing regulations, not all are binding at their current levels, and therefore relaxing the nonbinding ones in isolation will have no impact on prices.

5.3 Effects of Regulations on Sale Prices and Rents

Differences in per-housing-unit prices and rents across boundaries come primarily from regulations that restrict new housing development. This mainly occurs across zoning boundaries on one side of which density regulations are relaxed. We first use our baseline nonparametric model to estimate causal differences in sales prices and rents, excluding housing-characteristic controls that are endogenous to zoning regulations (Figure 6). We then discuss the relative roles the composition effect, sorting mechanism, and option value play in shaping the effect of zoning regulations on housing prices and rents.

Single-family-home sale prices

When only DUPAC regulations are relaxed, per-housing-unit single-family-home sales prices on the more relaxed side of the boundary decline 4.4%, or $28,488, relative to the mean sales price for single-family homes on the stricter side of the boundary.[20] At boundaries where on one side both DUPAC and multifamily-housing regulations are

[20] Using a similar approach, Kulka (2020) finds a comparable 8.8% increase in sales price at boundaries where the minimum lot size changes in North Carolina.

relaxed, sales prices fall across the boundary by 2.2%, or $13,394, relative to the mean. Next, we investigate the mechanisms behind these per-housing-unit price effects.

After controlling for house characteristics in Figure 7, we no longer find statistically significant differences in per-housing-unit prices across boundaries where DUPAC changes alone or in combination with reforms allowing multifamily housing. Thus, the composition effect and sorting on house characteristics likely drive the baseline per-housing-unit sale-price differences across the boundaries for these two regulatory scenarios within broader neighborhoods. With our methodology, we cannot fully distinguish the role of sorting on unobservable characteristics from the option-value effect for single-family-home sale prices. However, since controlling for census-block-level demographic characteristics in addition to house characteristics has no further impact on sale-price differences (Appendix Figure C.11), both the option-value and sorting on unobservable characteristics are likely relatively small.

Another way to assess the role of the composition effect is to see whether housing-unit characteristics discretely change at the boundary. As shown in Figure 8, lot sizes, building square footage, and the number of bedrooms and bathrooms all drop discretely across boundaries where DUPAC regulations change alone or in combination with multifamily-housing regulation. We find no statistically significant differences in sales price at boundaries across which DUPAC and height regulations change or only multifamily regulation changes, even though we find supply effects at these boundaries. That there is no evidence of a composition effect across these boundaries is unsurprising given that housing characteristics do not change across these boundaries.[21]

Thus, it seems that the difference in per-housing-unit sale prices across zoning boundaries is driven by the fact that regulations target housing characteristics. Quality-adjusted single-family-housing prices change little across the zoning boundaries within neighborhoods. Instead, per-unit single-family-housing prices decline from relaxing regulations, particularly density regulations, which allows smaller, more affordable homes to be built.

[21] Since we concluded that height regulations on their own or with allowing multifamily homes have no impact on supply, theory indicates that the only source for long-run sale-price differences across such boundaries is the jump in option value. But, Appendix Figure C.10 shows little evidence of this.

Multifamily rents

When only DUPAC regulations are relaxed, per-housing-unit monthly multifamily rents decline 6.9%, or $101, relative to the mean rent on the more restrictive side (Figure 6). After controlling for housing characteristics, rent differences are no longer statistically distinguishable from zero (Figure 7). As with sale prices, the composition effect and sorting on house characteristics seems to drive the changes in rents across boundaries where only DUPAC regulations change. Since there is no option value for renters, if the composition effect explains the rent changes, then the sorting on unobservable house characteristics is likely minimal. That controlling for demographic characteristics makes little difference confirms this (Appendix Figure C.11).[22]

Across boundaries where DUPAC and height regulations change together, multifamily per-housing-unit rents fall by an average of 4.2%, or $54, relative to the mean rent on the restrictive side. This effect is not statistically significant for most distance bins. However, differences in rents are precisely estimated when we control for housing characteristics but not when we also control for demographics. Since housing characteristics are not statistically different across boundaries where DUPAC and height regulations change together, the composition effect is unlikely to explain the difference in baseline rents. Thus, in contrast to sale-price differences, the rent differences at this boundary type are likely driven by sorting on unobserved housing characteristics.[23]

Discussion

An important caveat of our analysis is that our causal estimates presented here are local average treatment effects estimated from housing units within 0.2 miles of a regulation boundary. Like all RD designs, these results may not extend beyond this sample. However, the RD design sheds light on how different regulations interact. We show that even though multiple regulations exist, relaxing only those regulations that are binding (which may vary from city to city) will affect the supply and price of housing. In addition, using the RD design, we find that regulations target housing characteristics and

[22]The predicted rent for boundaries where only DUPAC regulations change jumps slightly at the boundary (see Figure 4). Thus, some caution is required when interpreting the effects as causal.

[23]For boundaries where multifamily-housing regulation changes, either by itself or along with density regulations, we cannot study differences in rents because multifamily buildings are not allowed on one side of the boundary; hence, we observe no multifamily buildings on the more strictly regulated side.

effectively lower per-unit prices by shifting the composition of the housing stock toward smaller, cheaper units. Thus, even within broader neighborhoods in a metro area, zoning regulations increase the entry cost into highly regulated areas. As highlighted above, zoning regulations can also affect per-housing-unit prices by restricting supply at the broader neighborhood or metro level, which cannot be captured with an RD design.

5.4 Robustness of Analysis

Our baseline housing-supply results, which removed buildings constructed before 1918, hold when a more conservative cutoff of 1956 is applied, and so they are not driven by buildings constructed in the intervening years (Appendix Figure C.9 and Table C.4). Our baseline housing-price results may be influenced by how we impute monthly rents for some multifamily properties. Our combination of CoStar market-rate and imputed multifamily rents generally track rents at the census-block-group level from the American Community Survey (Appendix Figure A.1). However, we slightly overestimate the proportion of buildings with monthly rents from \$500 to \$1,400. This could result in upward-biased estimates for rents if we systematically impute low rents on the relaxed side of the zoning boundary. To check for biases in our rent results, we drop properties in the \$500–\$1,400 rent range and reestimate nonparametric differences across regulatory boundaries. We find similar and precisely estimated rent differences across boundaries where only DUPAC regulations change (Figure 9a). However, rent effects across boundaries where DUPAC and height regulations change are noisier (Figure 9b), likely because fewer observations remain after the additional rent restrictions. Regardless, we do not find a qualitative change in rent effects when moving from the more strictly regulated to the less strictly regulated side of the boundary, suggesting that rent imputations are not driving our rent results for this regulatory scenario.

While there are no discontinuities at boundaries for any of the relevant covariates we examine (Figure 3), we do find that properties on the more strictly regulated side of zoning boundaries are, on average, farther away from highways in almost all regulatory scenarios. This may confound our price results if relatively affluent neighborhoods were able to prevent highway construction in their area, as distance to highways would then capture systematic differences in unobserved neighborhood quality. To assuage these concerns, we control for distance to the highways in our nonparametric model. Figures 9c–9e show no differences in sale prices or rents after adding the control.

For boundaries where DUPAC and height regulations change, land parcels on the more relaxed side have lower mean slope and depth to bedrock. This may indicate that land on this side of the boundary is better suited for construction of denser forms of housing such as apartment buildings, which in turn would affect our supply and price results. Again, after controlling for distance to highways, mean parcel-level slope, and depth to bedrock in the nonparametric model for DUPAC- and height-regulation boundaries, we find that the results closely match our baseline results (Figure 9f).

Another concern might be that neighbors on either side of a boundary do not interact with each other, even across small residential roads. For robustness, we remove from our baseline sample boundaries that overlap with any type of road, leaving us with roughly half of the baseline boundaries. As a result, we observe larger differences in single-family-home sale prices across all binding regulatory scenarios. Across boundaries where only DUPAC regulations change, single-family-home sales prices decline by 8.7% in the sample when omitting all road-boundary overlaps (Figures 9g) compared to a 4.4% decline in our baseline sample of boundaries. Multifamily rents decline 8.2% in the no-roads sample (Figures 9h) compared to 6.9% in the baseline. Across boundaries where DUPAC and multifamily regulations change, the equivalent effects are a 4.1% decline in the no-roads sample (Figures 9i) compared to a 2.2% decline in the baseline analysis. We take these results as further evidence that differences in unobserved neighborhood quality do not drive our baseline results.

6. Policy Effects of Relaxing Regulations

We use our model and causal estimates to simulate the long-run supply and price effects of small-scale upzoning reforms, which are an increasingly popular response to housing unaffordability. These reforms relax zoning regulations in specific zoning areas, such as those near transit stations or within commercial districts. Our counterfactual exercise focuses on Massachusetts's Chapter 40A upzoning reform of 2021, which requires municipalities to zone for multifamily housing and allow housing density of 15 units per acre within a 0.5-mile radius around train stations. While not enough time has passed since the 2021 reforms to study realized supply and price effects, we simulate the long-run impact of this policy. Since our causal estimates from Section 5 span 60 years, during which Greater Boston's population increased 59%, our counterfactual supply and price effects should be interpreted as long-run effects of the 2021 reforms, assuming a similar population growth rate in the long run.[24]

A few considerations should be borne in mind. First, our RD research design is well suited to studying small-scale upzoning reforms like Chapter 40A or similar reforms adopted in at least 13 jurisdictions worldwide (Appendix Table C.1). However, our framework is not well suited to studying the general equilibrium effects of zoning reforms that affect whole metro areas or states.[25] Second, while previous studies focused on the effects of zoning on vacant land (Turner et al., 2014; Brueckner and Singh, 2020), our counterfactual approach studies the potential effects of reforms in densely populated areas because our estimates represent equilibrium differences in a highly developed urban environment.

To examine the effects of Chapter 40A, we increase DUPAC to the maximum allowable 15 units and allow multifamily housing around the existing regulatory boundaries that are within 0.2 miles of a train station.[26] The new vector of regulations is denoted as $z_{40A}(x)$, while the pre-2021 vector is given by $z_0(x)$. The average change in sales prices and rents ($p(x)$) and the number of housing units is given by Δp.

$$\Delta p = \frac{1}{\overline{x} - \underline{x}} \int_{\underline{x}}^{\overline{x}} \big(\max\{0, (z_{40A}(x) - z_0(x))\} \times \theta_i \times p(x)\big) d(x) \tag{6}$$

$$\theta_i = \begin{cases} \hat{\rho}_1 & i = \text{regulatory scenario 1, 2, 3} \\ \hat{\rho}_1 + \hat{\rho}_3 \text{reg}_2 + \hat{\rho}_2 + \hat{\rho}_3 \text{reg}_1 & i = \text{regulatory scenario 4, 5, 6} \end{cases}$$

θ_i is the average joint treatment effect of the marginal one-unit change in regulations.

[24] In the short run, if there were no change in housing supply, the only change from the 2021 reforms would be the increased option value for landowners; that is, there are no price effects via the composition or sorting effect in the absence of supply changes in the short run.

[25] We also assume the small-scale upzoning reform does not create a political backlash leading to more restrictive zoning in other areas of Greater Boston.

[26] There is no change in height regulations under Chapter 40A.

Estimates $\hat{\rho}_1, \hat{\rho}_2, and \hat{\rho}_3$ come from Equations 4 and 5.[27]

Figure 10 plots the average long-run estimated change in housing supply and prices stemming from Chapter 40A based on Equation 6. We find that 34% of train stations, particularly close to downtown Boston, already allowed multifamily housing or housing density above 15 units per acre, and so we do not expect to see any effect from the reforms in these areas. Around the remaining train stations, the median long-run increase in housing supply is about 0.18 units per parcel, a 23% increase (Figure 10a). This is particularly prominent in the inner ring of suburbs, where the effects are driven by relaxing density regulations in particular. Brueckner and Singh (2020) also find that stringency of floor-area-ratio regulations is high close to central business districts. In addition, we find that long-run multifamily-housing rents decrease around train stations in many municipalities not bordering Boston (Figure 10b). Monthly multifamily per-housing-unit rents fall by a median of $88 per month, or 4.9%. This effect implies that zoning regulations are especially binding for renters in suburban municipalities.

For sales prices of single-family homes, the effects of Chapter 40A are more mixed, with long-run prices increasing in some areas while decreasing in others (Figure10c). This is primarily driven by the positive interaction term ($\hat{\rho}_3$) across boundaries where DUPAC and multifamily-housing regulations change together (see Appendix Table C.5). Where pre-2021 housing density is low, allowing multifamily buildings lowers long-run single-family-home sales prices, indicating that the negative composition and sorting effects outweigh the positive option-value effect. As a result, we find a substantial decline in median single-family per-housing-unit sales prices by $131,617, or 8.5%. In contrast, where pre-2021 housing density is high, the marginal price effect of allowing multifamily housing is positive, indicating that the option-value effect outweighs the composition and sorting effects. However, the increase in the median single-family-

[27] See Appendix B for more details. We estimate semiparametric Equations 4 and 5 for three different municipality types defined by the Metropolitan Area Planning Council: inner-core municipalities, which are Boston and municipalities near Boston; mature suburbs, which are municipalities near the inner core; and developing suburbs, which are municipalities farther from the inner core (Figure C.12 provides a map of municipality types). Appendix Tables C.5 and C.6 show the semiparametric results across the three municipality types. Within a municipality type, there is little heterogeneity in the assignment of boundaries to regulatory scenarios, allowing us to compare Chapter 40A's effects across regulatory scenarios within a municipality type.

per-housing-unit sales price of $5,735, or 1.2%, is smaller.

In summary, policy makers interested in reducing housing costs through small-scale upzoning should account for the entirety of the local zoning-regulation landscape and relax regulations that act as a binding constraint on supply. It is also important to consider spatial heterogeneity in supply and price effects. For example, in response to upzoning in Greater Boston, prices and rents are more likely to fall in suburban municipalities with strict levels of zoning before 2021, compared to downtown Boston, where zoning regulations have until now affected prices and rents by lowering the rents and prices of the smallest housing unit available. Last, upzoning might not affect the supply and prices of all housing types equally. For example, in Greater Boston, confirming the theoretical literature (Anenberg and Kung, 2020; Molloy et al., 2022), we find that the price declines from upzoning are more significant for single-family prices than rents, both in magnitude and number of areas affected.

7. Conclusion

Using novel data and methods, this paper studies which zoning reforms are most effective at increasing the supply of new housing and reducing prices and rents. We find that relaxing density regulations, alone or together with reforms relaxing height and multifamily-housing restrictions, reduces single-family-home sale prices and multifamily-housing rents in Greater Boston. Relaxing only height or multifamily-housing regulations does not have price effects that can be statistically distinguished from zero. This is because density restrictions, such as minimum-lot-size requirements, are the binding constraint in Greater Boston. In other cities, the binding constraint may be maximum-height restrictions or minimum-parking requirements. Thus, recent policy efforts abolishing single-family-home zoning in Minneapolis (Minnesota), California, and Oregon are likely to only affect affordability if multifamily-housing zoning is the binding constraint in these locales. We also find that zoning regulations affect prices primarily through changing housing characteristics and forcing households to overconsume housing, increasing housing costs overall. Our results also suggest that small-scale upzoning policies, such as Massachusetts's Chapter 40A law, could reduce rents and sales prices, particularly in suburban towns with stringent zoning regulations.

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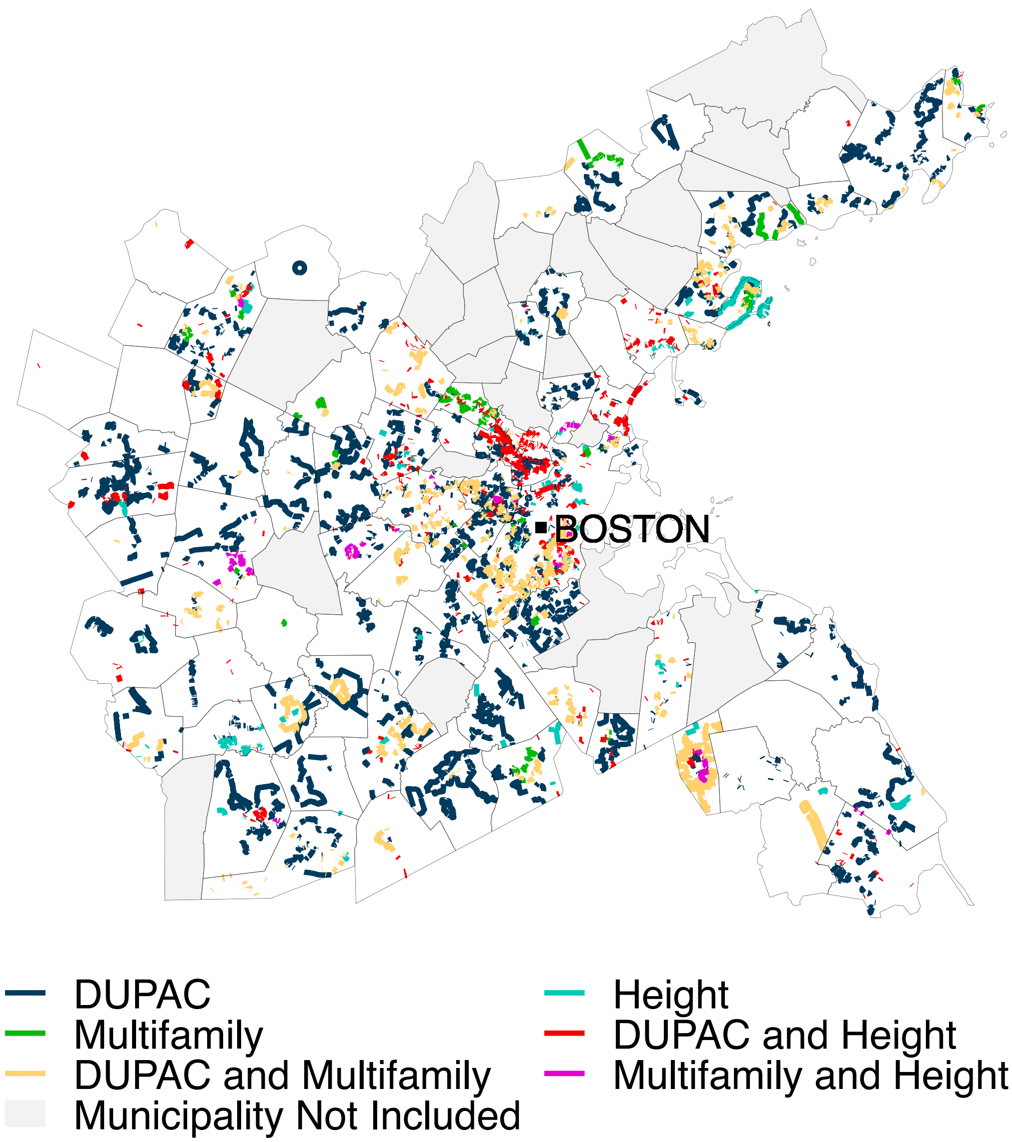
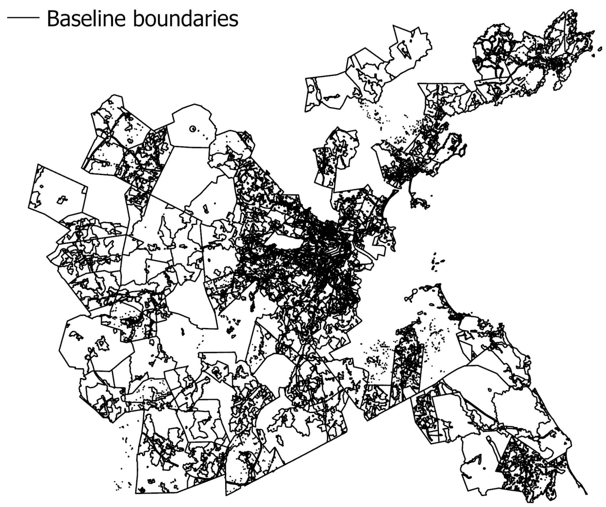
Figure 1: RD boundaries where zoning regulations change

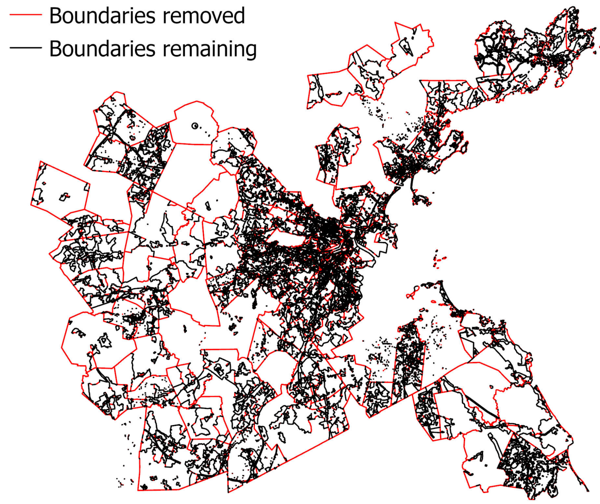


Note: This map shows the boundaries where multifamily-housing regulations, maximum-height restrictions, and DUPAC (dwelling units per acre) regulations change either alone or in combination. "Changes" refers to cross-sectional differences in the regulations on either side of a boundary. The figure plots the final sample of boundaries, which excludes regulatory boundaries that overlap with water bodies, large roads, municipality boundaries, and elementary school attendance-area boundaries. Only boundaries within areas that are either residential or mixed-use zoning are considered. The base maps for these boundaries can be found in Appendix Figures C.1, C.2, and C.3. * denotes the city of Boston.

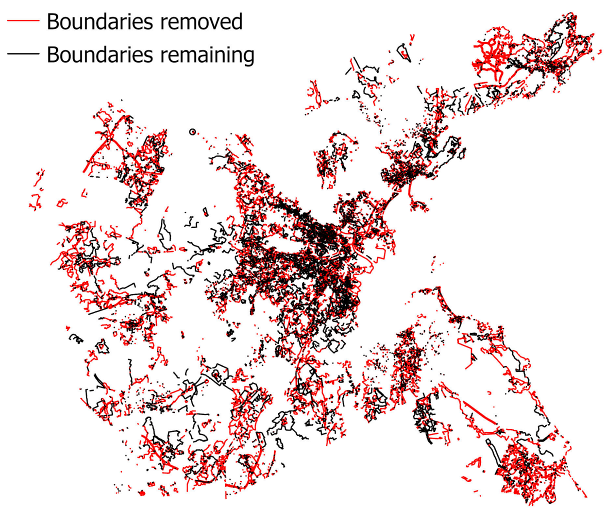
Figure 2: Step-by-step RD regulatory-boundary selection



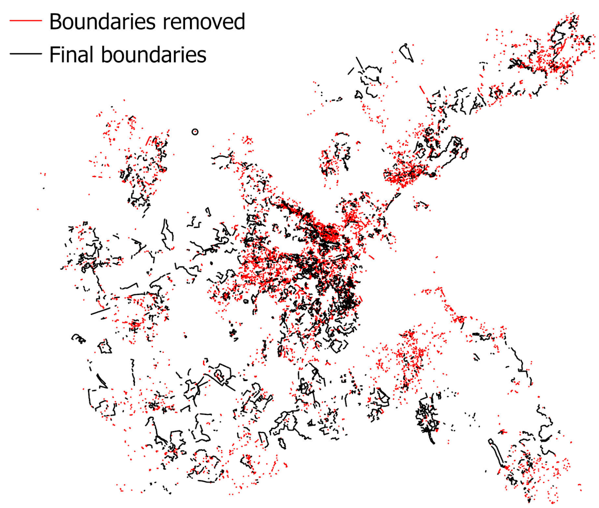
(a) Baseline: no. of boundaries =26,306; mean boundary length= 0.2 miles



(b) Removing roads, municipal, & natural boundaries: no. of remaining boundaries =21,328; mean boundary length= 0.18 miles



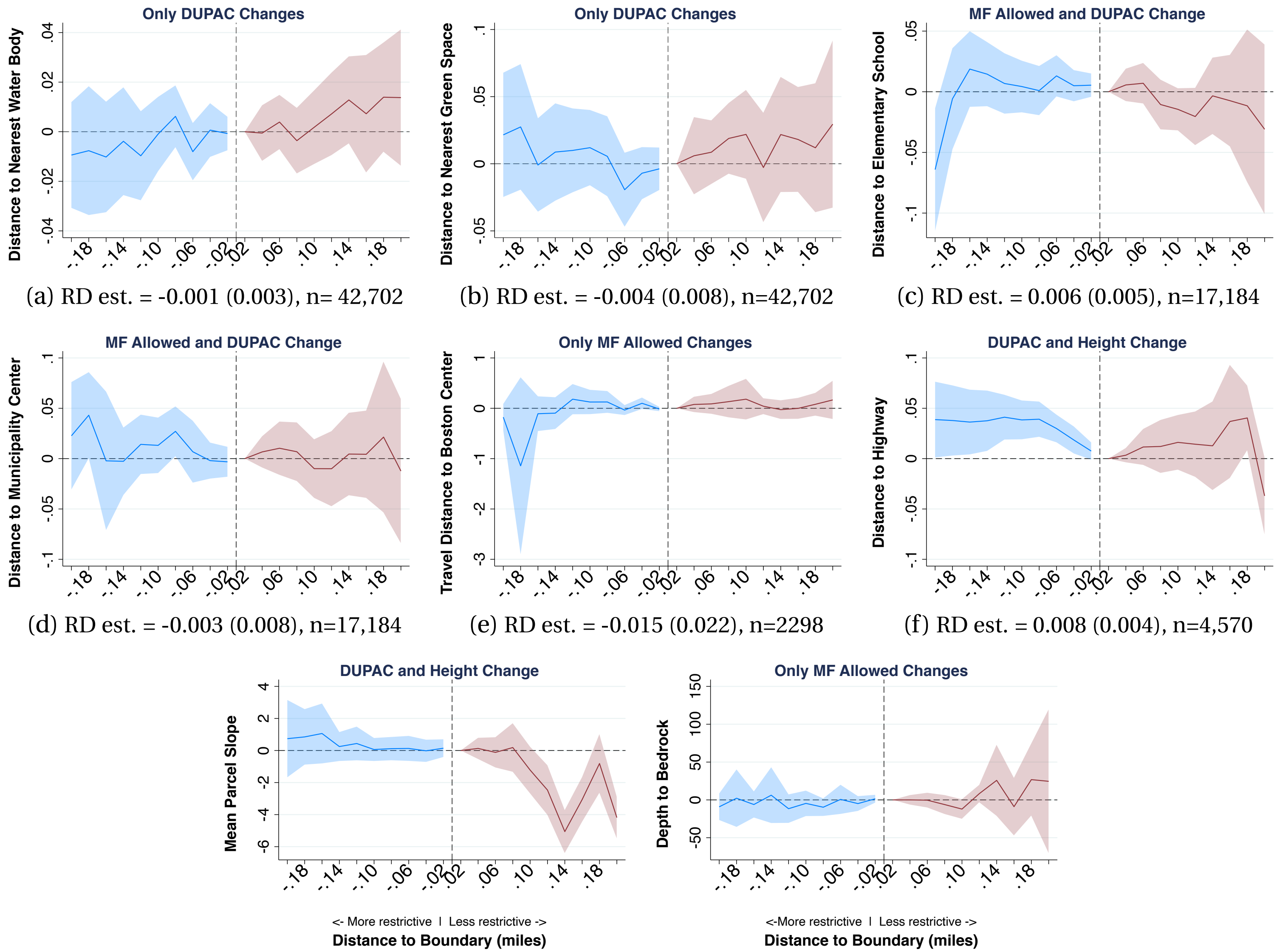
(c) Removing school and broad-use-type zoning boundaries: no. of remaining boundaries =9,674; mean boundary length= 0.11 miles



(d) Keeping boundaries with straight line segments: no. of remaining boundaries =2,835; mean boundary length= 0.35 miles

Note: This figure displays the step-by-step removal of boundaries to arrive at the final set of boundaries in Figure 1. Figure 2a plots the baseline map of all zoning-regulation boundaries. Figure 2b plots in red the zoning boundaries removed because they overlap with major roads, municipal boundaries, or water bodies such as lakes and rivers. Figure 2c plots in red the boundaries removed because they overlap with school-district boundaries, elementary school attendance-zone boundaries, or broad-use-type zoning (residential or mixed-use) boundaries. Figure 2d plots in red the boundaries removed because they do not have a straight line segment.

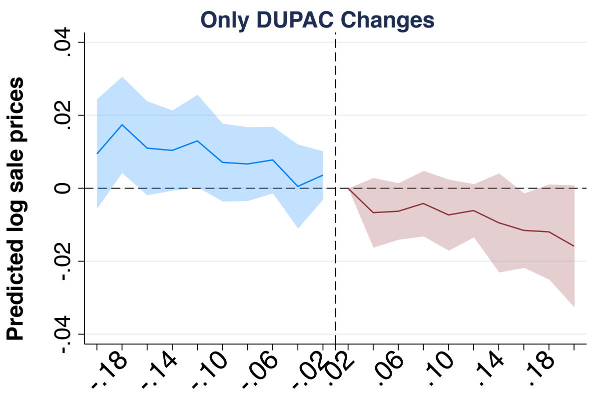
Figure 3: Neighborhood amenities and parcel attributes at regulatory boundaries



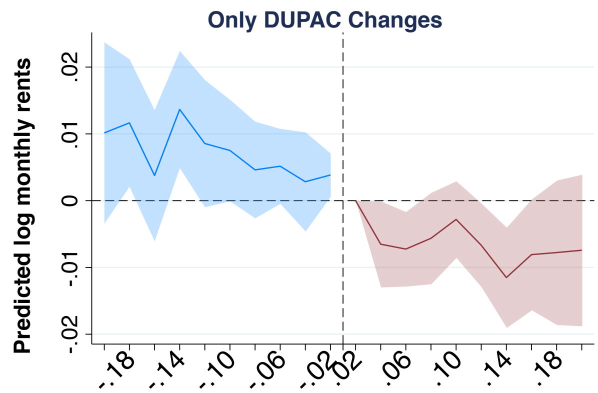
(a) RD est. = -0.001 (0.003), n= 42,702
(b) RD est. = -0.004 (0.008), n=42,702
(c) RD est. = 0.006 (0.005), n=17,184
(d) RD est. = -0.003 (0.008), n=17,184
(e) RD est. = -0.015 (0.022), n=2298
(f) RD est. = 0.008 (0.004), n=4,570
(g) RD est. = 0.144 (0.280), n=3941
(h) RD est. = 1.475 (2.601), n=1941

Note: Figures are created by plotting coefficients from regressing distance to nearest amenities or parcel attributes on boundary fixed effects and distance to boundary (bins of 0.02 miles). Negative distances indicate the more strictly regulated side. The bin closest to the boundary on the less strictly regulated side (0–0.02 miles) is normalized to 0. 95% confidence intervals are shown. Standard errors are clustered at the boundary-segment level. The coefficient and standard error on the -0.02–0 bin on the more restricted side are reported. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

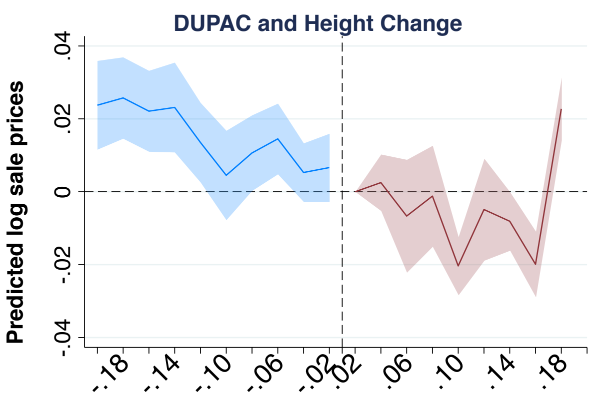
Figure 4: Unobserved location quality across regulatory boundaries



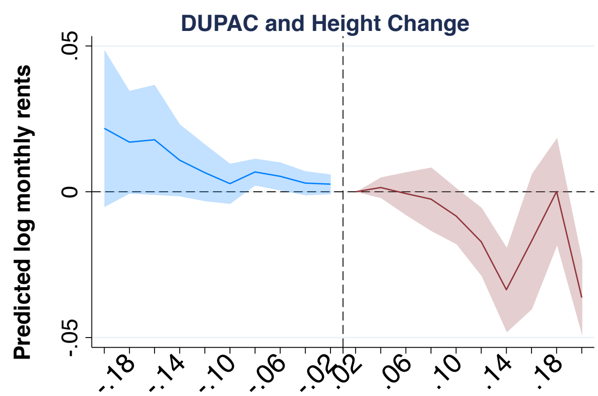
(a) RD est. = 0.004 (0.003), n=44,053



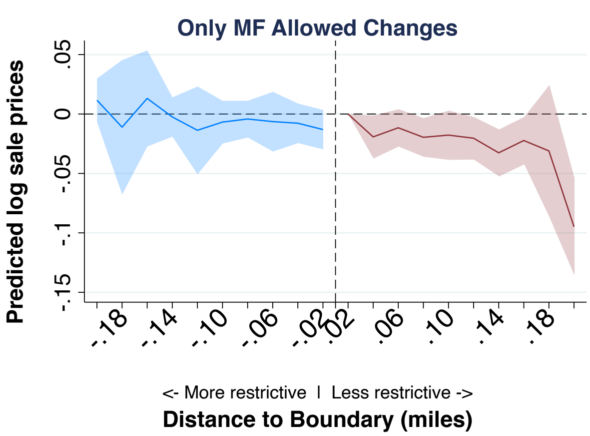
(b) RD est. = 0.004 (0.002)*, n=305,229



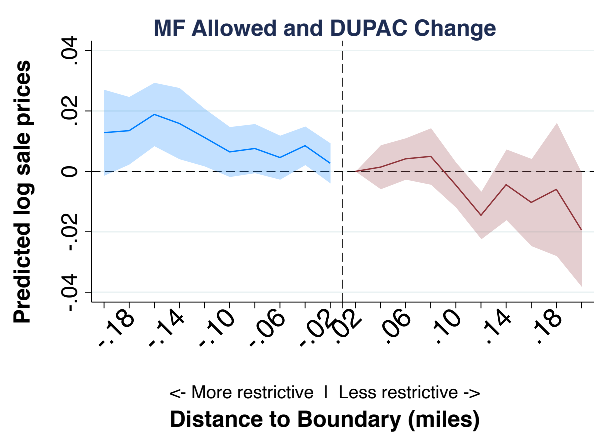
(c) RD est. = 0.007 (0.005), n=2,669



(d) RD est. = 0.003 (0.002), n=35,157



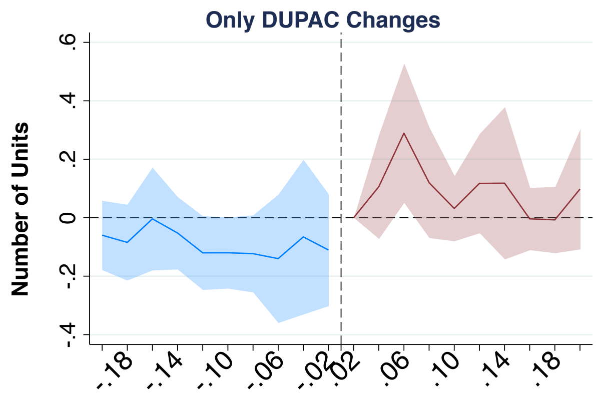
(e) RD est. = -0.013 (0.008), n=1,824



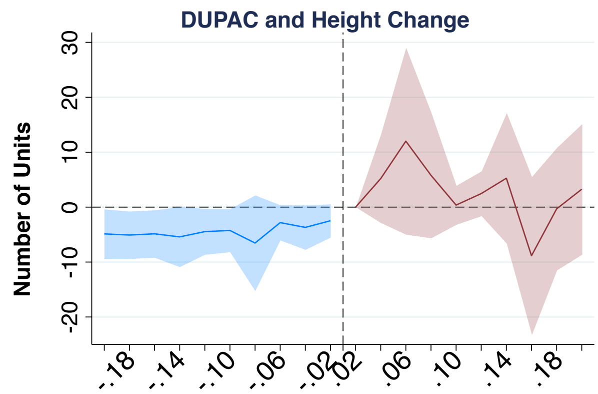
(f) School RD est. = 0.001 (0.004), n=15,031

Note: Figures are created by plotting coefficients of predicted log sale prices and rents in 0.02-mile distance-to-boundary bins. The model regresses log prices and rents on observed amenities, parcel attributes, and boundary fixed effects. Negative distances indicate the more strictly regulated side. The bin closest to the boundary on the less strictly regulated side (0–0.02 miles) is normalized to 0. 95% confidence intervals are shown. Standard errors are clustered at the boundary-segment level. The coefficient and standard error on the -0.02–0 bin on the more restricted side are reported. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

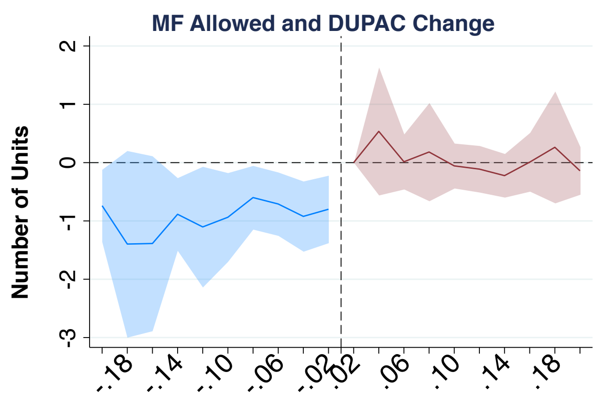
Figure 5: Effect of regulations on number of units



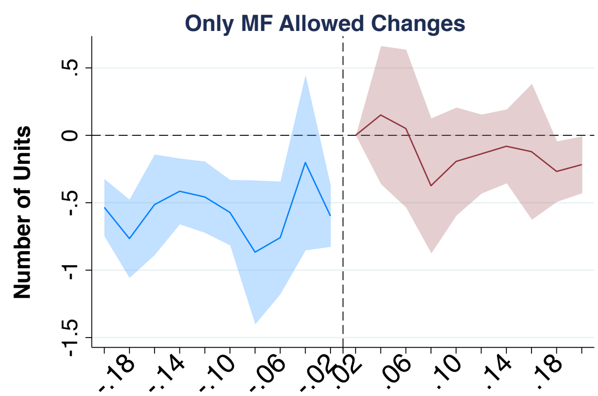
(a) RD est = -0.110 (0.097) [0.075], n = 33,940



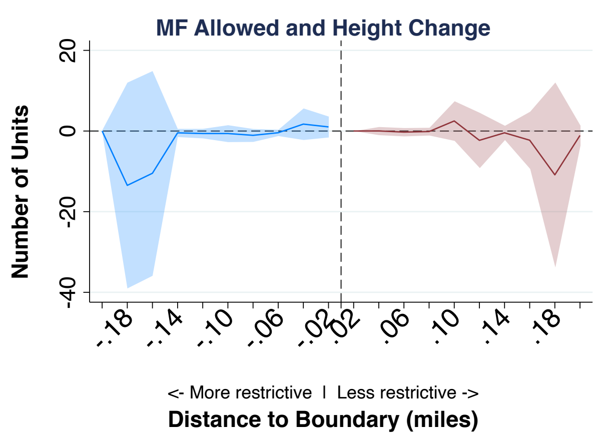
(b) RD est = -2.474 (1.532) [1.075]*, n = 1,806



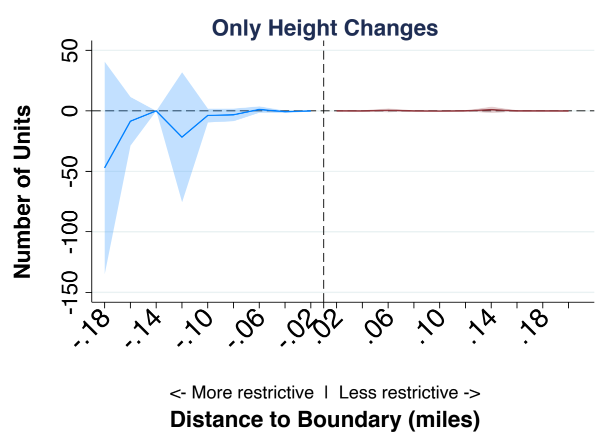
(c) RD est = -0.799 (0.294)* [0.253]**, n = 11,541



(d) RD est = -0.598 (0.114)*** [0.08]***, n = 1,535



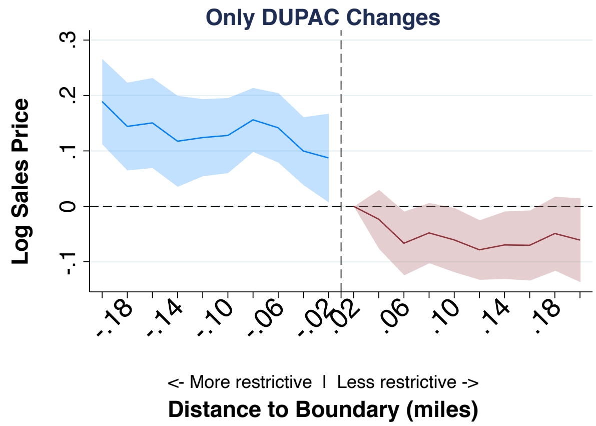
(e) RD est = 1.022 (1.268) [1.109], n = 504



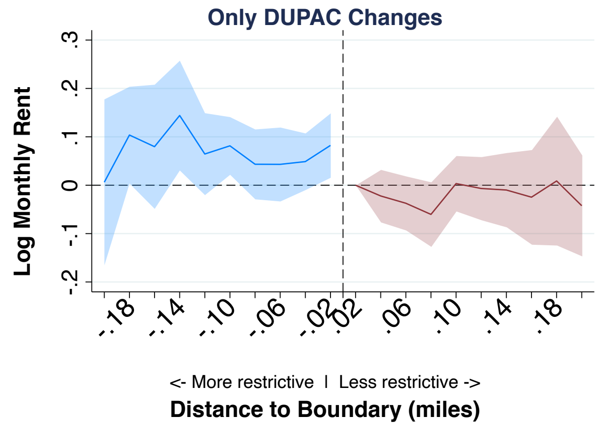
(f) RD est = -0.063 (0.293) [0.208], n = 1,854

Note: Plots are created by regressing number of units in 2018 on boundary fixed effects and distance to boundary (bins of 0.02 miles). All buildings are built after 1918. Negative distances indicate the more strictly regulated side. The bin closest to the boundary on the less strictly regulated side (0–0.02 miles) is normalized to 0. 95% confidence intervals are shown with clustered standard errors at the boundary-segment level. The coefficient, with clustered standard error in parentheses and robust standard error in square brackets, is reported for the -0.02- to 0-mile bin on the restricted side. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

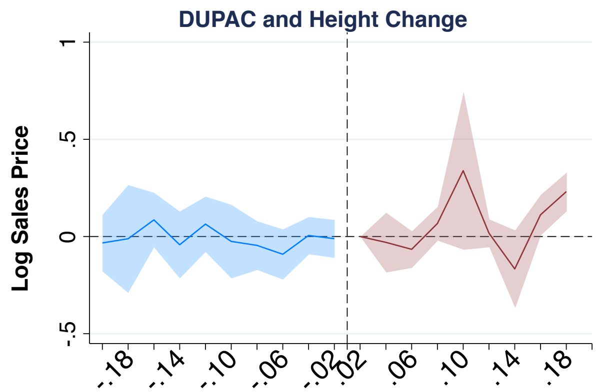
Figure 6: Effects of regulations on multifamily-housing rents and single-family-home sale prices



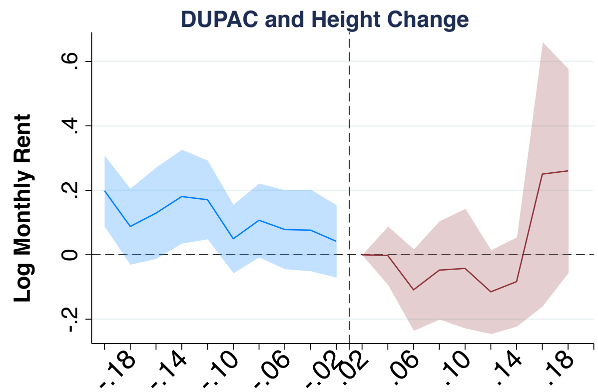
(a) RD est. = 0.044 (0.02)* [0.01]***, n = 56,561



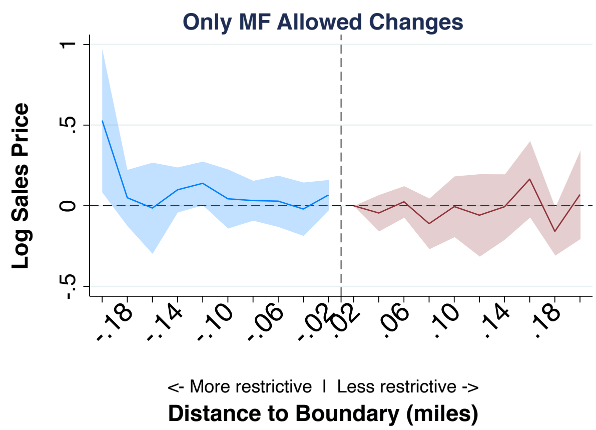
(b) RD est. = 0.069 (0.03)** [0.01]***, n = 50,374



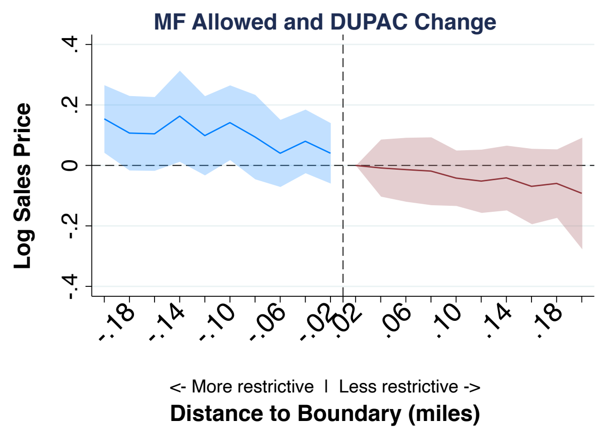
(c) RD est. = -0.011 (0.049) [0.02], n = 3,117



(d) RD est. = 0.042 (0.057) [0.01]***, n = 21,907



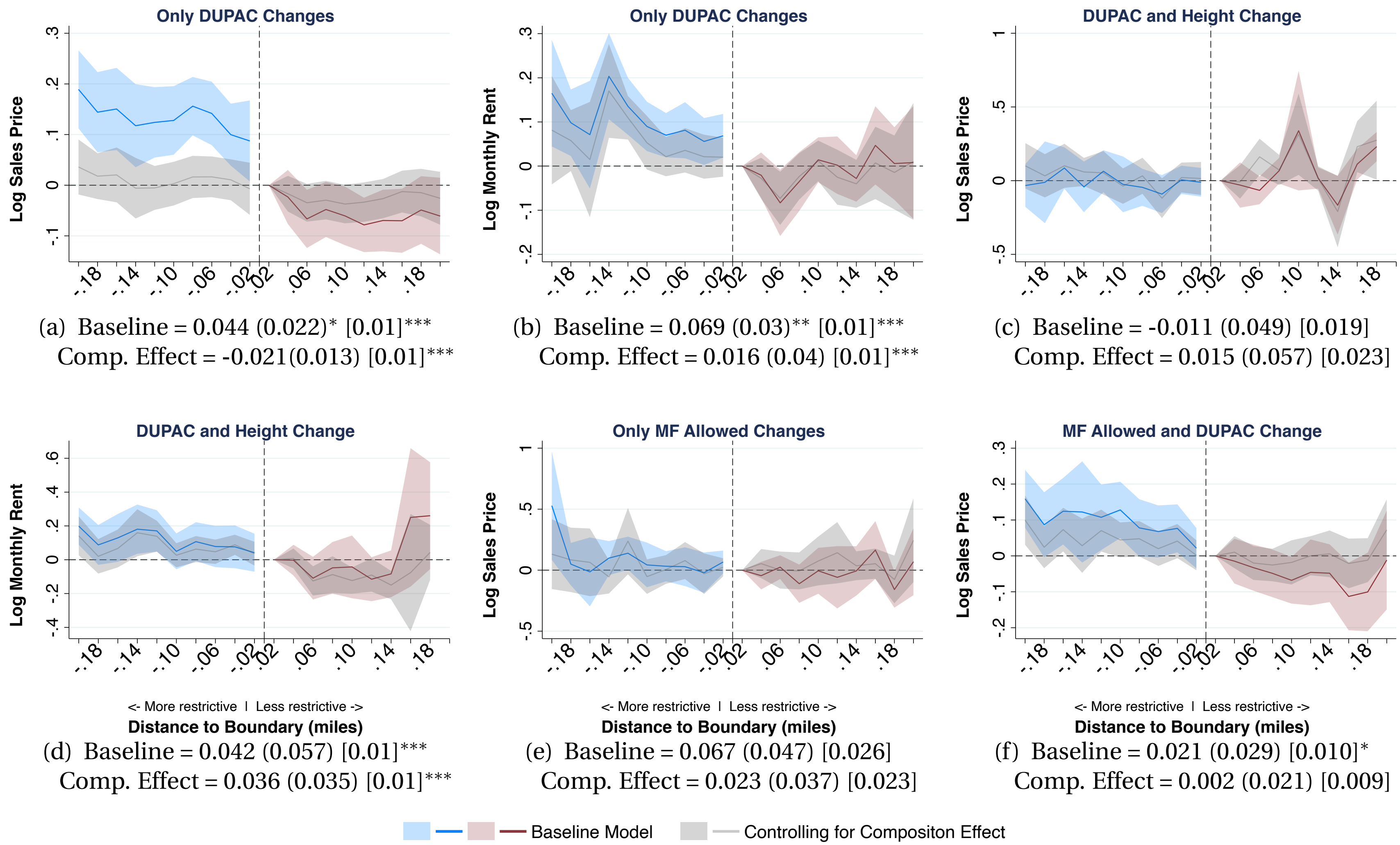
(e) RD est.= 0.067 (0.047) [0.03]*, n = 2,174



(f) RD est. = 0.022 (0.0286) [0.01]*, n = 18,815

Note: Plots are created by regressing log single-family-home sale prices or log multifamily-housing monthly rents on boundary fixed effects, sale-year or rent-year fixed effects (2010-18), and 0.02-mile bins of distance to boundary. Coefficients on distance bins are plotted. Negative distances indicate the more strictly regulated side. The bin closest to the boundary on the less strictly regulated side (0–0.02 miles) is normalized to 0. 95% confidence intervals are shown with clustered standard errors at the boundary-segment level. The coefficient, with clustered standard error in parentheses and robust standard error in square brackets, is reported on the -0.02- to 0-mile bin on the more restricted side. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$.

Figure 7: Mechanisms behind equilibrium price effects



(a) Baseline = 0.044 (0.022)* [0.01]***
Comp. Effect = -0.021(0.013) [0.01]***

(b) Baseline = 0.069 (0.03)** [0.01]***
Comp. Effect = 0.016 (0.04) [0.01]***

(c) Baseline = -0.011 (0.049) [0.019]
Comp. Effect = 0.015 (0.057) [0.023]

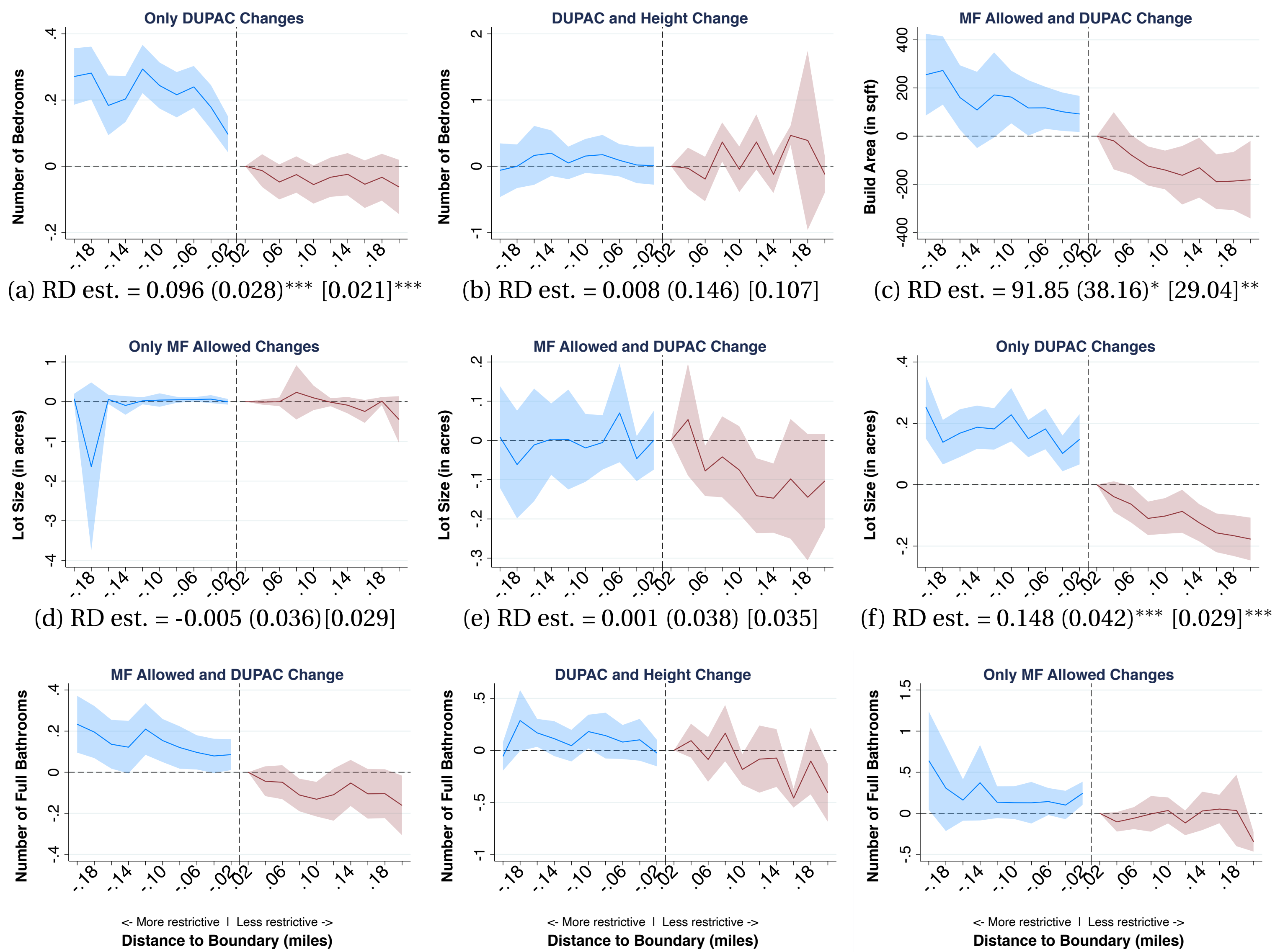
(d) Baseline = 0.042 (0.057) [0.01]***
Comp. Effect = 0.036 (0.035) [0.01]***

(e) Baseline = 0.067 (0.047) [0.026]
Comp. Effect = 0.023 (0.037) [0.023]

(f) Baseline = 0.021 (0.029) [0.010]*
Comp. Effect = 0.002 (0.021) [0.009]

Note: Plots are created by regressing log single-family-home sale prices or log multifamily-housing monthly rents on boundary fixed effects, sale-year or rent-year fixed effects (2010–18), and 0.02-mile bins of distance to boundary. Compared to the baseline model, the composition-effect (Comp. Effect) model controls for housing units' characteristics. The 0- to 0.2-mile bin is normalized to 0. 95% confidence intervals are shown with clustered standard errors at the boundary-segment level. The coefficient, with clustered standard error in parentheses and robust standard error in square brackets, is reported on the -0.02- to 0-mile bin on the more restricted side. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 8: Housing characteristics at regulatory boundaries



(a) RD est. = 0.096 (0.028)*** [0.021]***

(b) RD est. = 0.008 (0.146) [0.107]

(c) RD est. = 91.85 (38.16)* [29.04]**

(d) RD est. = -0.005 (0.036) [0.029]

(e) RD est. = 0.001 (0.038) [0.035]

(f) RD est. = 0.148 (0.042)*** [0.029]***

(g) RD est. =0.086 (0.038)* [0.029]**

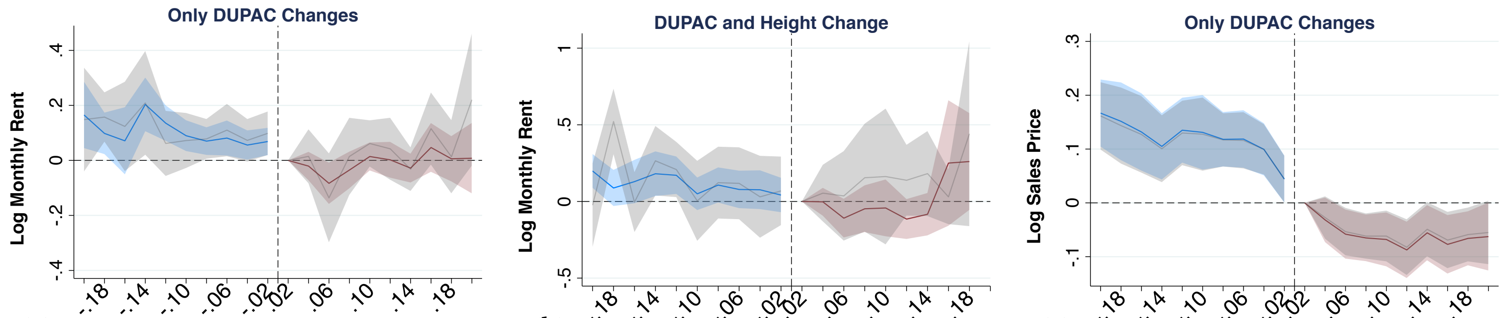
(h) RD est. = -0.025 (0.064) [0.070]

(i) RD est. = 0.243 (0.071)*** [0.057]

Note: This figure plots building characteristics across regulatory boundaries in 2018. Plots are created by regressing unit characteristics on boundary fixed effects and distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. Negative distances indicate the more strictly regulated side. The bin closest to the boundary on the less strictly regulated side (0–0.02 miles) is normalized to 0. 95% confidence intervals are shown. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. Standard errors are clustered at the boundary-segment level.

Figure 9: Robustness tests on rent and sale-price effects

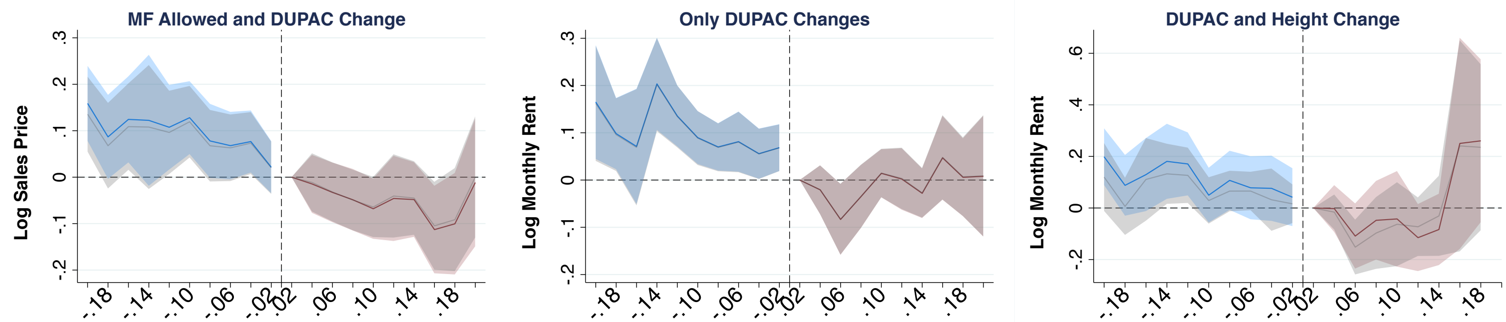
Panel A: Baseline and robustness models



(a) Baseline = 0.068 (0.025)** [0.006]*** Robustness = 0.098 (0.040)* [0.0105]***

(b) Baseline = 0.042 (0.057) [0.0104]*** Robustness = 0.069(0.113) [0.023]**

(c) Baseline = 0.044 (0.022)* [0.007]*** Robustness = 0.044 (0.022)* [0.007]***



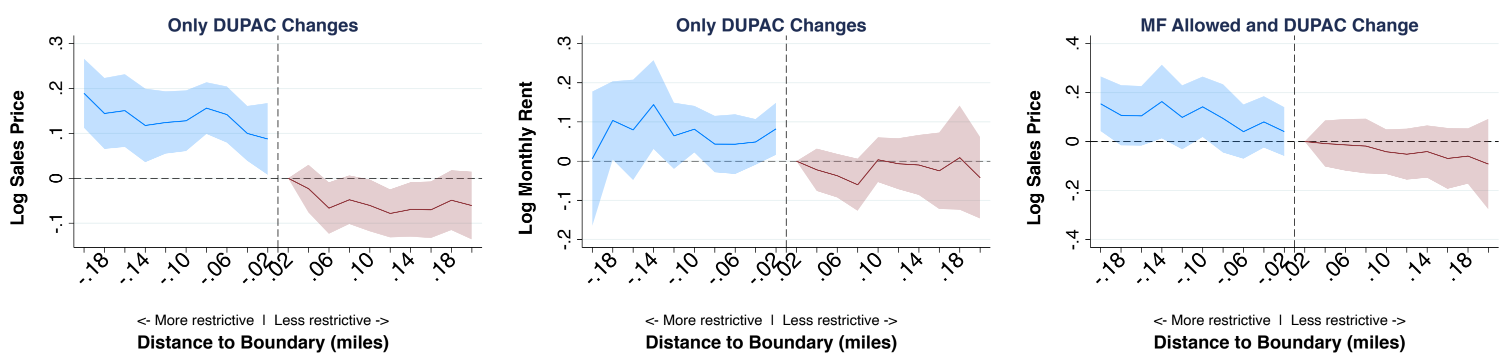
(d) Baseline = 0.022 (0.029)* [0.010]* Robustness = 0.020 (0.029)* [0.010]*

(e) Baseline = 0.069 (0.025) [0.006]*** Robustness = 0.068 (0.025)** [0.006]***

(f) Baseline = 0.042 (0.057) [0.010] *** Robustness = 0.016(0.038) [0.009]

Baseline Model Robustness Model

Panel B: Keeping boundaries with no roads



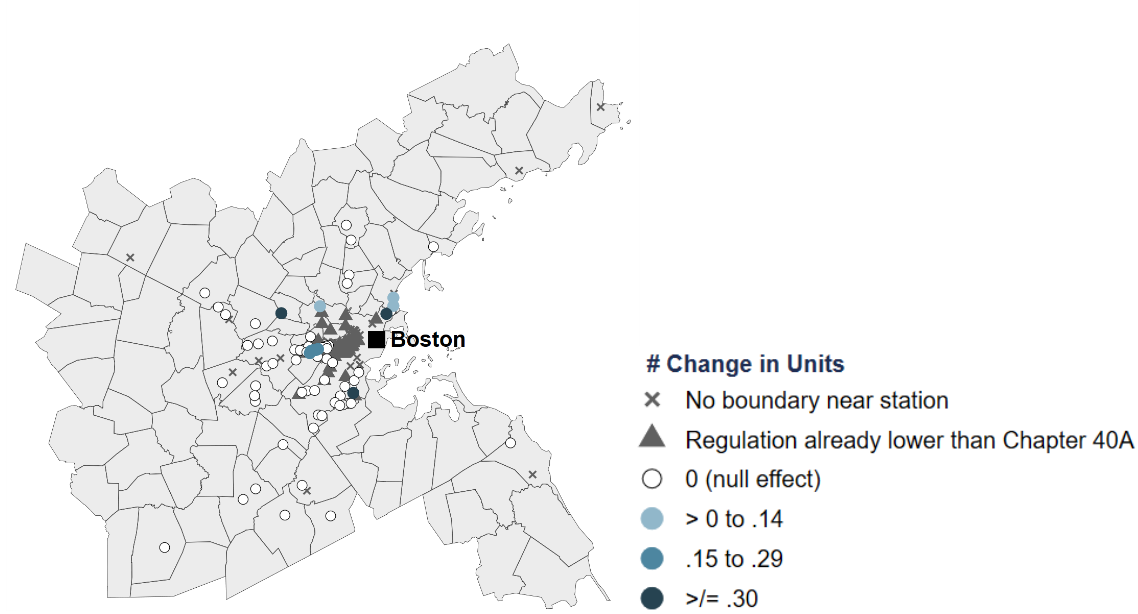
(g) Baseline = 0.087 (0.041)* [0.012]***

(h) Baseline = 0.082 (0.034)* [0.011]***

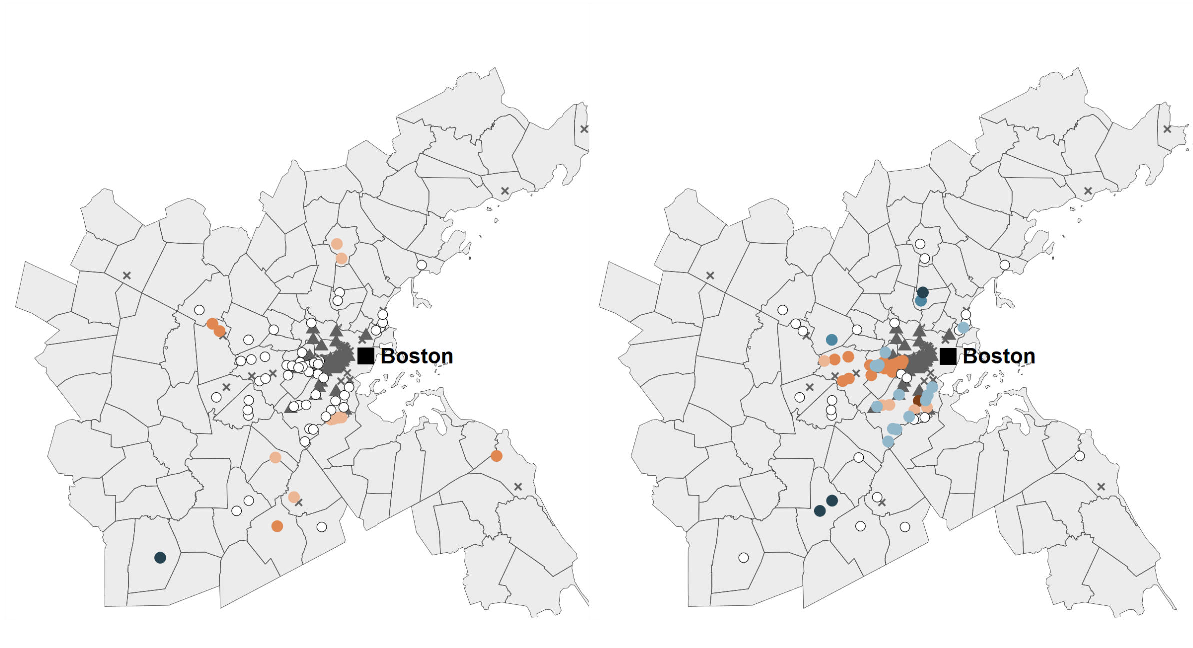
(i) Baseline = 0.041 (0.051) [0.019]*

Note: Figures 9a and 9b show effects excluding rents of \$500–\$1,400. Figures 9c, 9d, 9e, and 9f show effects after controlling for distance to highway, mean parcel slope, and parcel depth to bedrock. Figures 9g, 9h, and 9i show effects for boundaries not overlapping with any roads. The coefficient, with clustered standard error in parentheses and robust standard error in square brackets, is reported on the -0.02- to 0-mile bin. DUPAC is dwelling units per acre, and MF is multifamily-housing zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 10: Policy effects of Chapter 40A: Relaxing regulations near transit stations

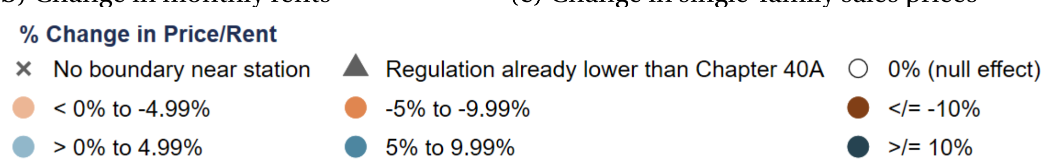


(a) Change in number of units



(b) Change in monthly rents

(c) Change in single-family sales prices



Note: This figure plots the average change in number of housing units per lot, percent monthly multifamily-housing rents, and percent single-family-home sale prices from relaxing regulations under Chapter 40A near transit stations. Chapter 40A allows multifamily housing in places where it is not currently allowed and increases allowed dwelling units per acre (DUPAC) to 15 units. For the counterfactual calculations, we focus on boundaries that lie within 0.5 miles of a given commuter-rail or metro station. Stations that do not have boundaries within a 0.5-mile radius are marked with an X on the map. Stations marked with a gray triangle are excluded from analysis because Chapter 40A has no effect on them (density is already higher than 15 dwelling units per acre and multi-family buildings are already allowed).

Table 1: Zoning-regulation scenarios

	(1)	(2)	(3)	(4)	(5)	(6)
Regulatory Scenarios (Sc.)	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5	Sc. 6
Panel A: Boundary-level summary statistics across regulatory scenarios						
Multifamily Changes	X			X	X	
Height Changes		X		X		X
DUPAC Changes			X		X	X
Mean DUPAC	9.34	7.92	13.87	11.89	11.20	38.58
Mean Height (10 feet)	3.51	4.13	3.39	3.50	3.45	4.33
Mean Multifamily	0.50	0.50	0.63	0.51	0.51	0.82
No. of Boundaries	161	124	1557	61	775	426
Panel B: Property-level summary statistics across regulatory scenarios						
Mean Housing Units	1.44	1.66	1.26	1.77	1.48	3.58
(Obs.)	(1,535)	(1,854)	(33,940)	(504)	(11,541)	(1,806)
Mean Multifamily	1,203	1,032	1,370	1,116	1,507	1,220
Rent (Obs.)	(7,297)	(3,610)	(50,435)	(1,369)	(42,705)	(21,950)
Mean Single-family	589,852	708,097	596,585	656,608	546,947	515,845
Sale Prices (Obs.)	(2,178)	(3,140)	(56,561)	(990)	(18,815)	(3,177)
Panel C: T-test mean difference from regulatory scenario 3						
Dist. to Municipality Center	1.401	1.495	1.643	1.374	1.949	1.289
(miles) (Difference) [t-stat]	(-0.242)	(-0.149)	-	(-0.269)	(0.305)	(-0.354)
	[-2.056]	[-1.202]	-	[-1.527]	[4.431]	[-5.116]
Mean Share $\leq$ 18	0.210	0.205	0.220	0.235	0.223	0.185
(Difference) [t-stat]	(-0.119)	(-0.015)	-	(0.015)	(0.003)	(-0.036)
	[-1.196]	[-1.524]	-	[1.056]	[0.574]	[-6.011]
Mean Share $\geq$ 65	0.142	0.132	0.139	0.140	0.144	0.115
(Difference) [t-stat]	(0.003)	(-0.007)	-	(0.001)	(0.005)	(-0.024)
	[0.389]	[-0.755]	-	[0.087]	[0.574]	[-4.440]
Mean Share Black	0.060	0.063	0.049	0.088	0.124	0.089
(Difference) [t-stat]	(0.11)	(0.014)	-	(0.039)	(0.075)	(0.040)
	[0.784]	[0.995]	-	[1.920]	[7.747]	[4.564]
No. of Boundaries	91	77	906	37	445	277

Note: This table represents all regulatory scenarios in which one or two of the three main types of regulation (DUPAC, height, allowing multifamily housing) change at RD boundaries. DUPAC is maximum dwelling units per acre. Panel A shows means calculated at the boundary level for different scenarios. In Panel B, means are calculated for properties lying within 0.2 miles of the boundary for different scenarios. The mean number of units is reported for 2018 housing units built after 1918, while 2010–18 multifamily-housing rents and single-family-house sale prices are reported for all housing units. Panel C reports the mean regulatory-scenario characteristics with t-test difference from scenario 3 in parenthesis and t-statistic in square brackets.

Table 2: Supply: Types of buildings across regulatory boundaries (built after 1918)

	Dep. Var.: $\mathbb{1}$[Building type = 2–3 units]						Dep. Var.: $\mathbb{1}$[Building type = 4+ units]					
Reg. Scenario:	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MF allowed	0.478			-0.214	0.005		0.016			-0.138	0.006	
	(0.098)***			(0.757)	(0.025)		(0.012)			(0.252)	(0.015)	
	[0.027]***			[410]	[0.013]		[0.009]			[0.225]	[0.009]	
Height (H)		0.025		-0.087		-0.029		-0.021		-0.060		-0.047
		(0.025)		(0.197)		(0.025)		(0.022)		(0.085)		(0.029)
		[0.022]		[0.112]		[0.023]		[0.020]		[0.076]		[0.022]*
DUPAC (DU)			0.001		-0.004	-0.102			0.001		0.001	-0.009
			(0.001)		(0.004)	(0.051)*			(0.001)		(0.001)	(0.004)*
			[0.0005]*		[0.001]**	[0.003]**			[0.0003]**		[0.001]	[0.003]**
MFXDU					0.016						0.002	
					(0.003)***						(0.002)	
					[0.001]***						[0.001]	
HXDU						0.001						0.001
						(0.0004)*						(0.0003)**
						[0.0003]***						[0.0004]***
MFXH				0.119						0.049		
				(0.209)						(0.077)		
				[0.118]						[0.069]		
N	1,495	1,760	33,071	485	11,264	1,587	1,165	1,172	31,835	437	9,477	1,163
R^2	0.539	0.381	0.435	0.284	0.389	0.454	0.598	0.493	0.565	0.070	0.309	0.564
$\mathbb{E}(y)$	0.231	0.041	0.045	0.116	0.171	0.350	0.013	0.021	0.008	0.007	0.015	0.113

Note: This table presents the results from a linear probability model (Equations 4 and 5) in which a dependent-variable value of 0 is a single-family house and a value of 1 is either a 2- to 3-unit building or 4- or more unit building 0–0.2 miles on either side of the boundary in 2018. All buildings are built after 1918. Linear polynomial in distance to boundary is used. Each column shows the coefficients associated with a regression for boundaries in a particular regulatory scenario. "Only MF" are boundaries where only multifamily-housing (MF) regulation changes, "Only H" are boundaries where only height (H) regulation changes, and "Only DU" are boundaries where only DUPAC (dwelling units per acre) regulation changes. "MF & H," "MF & DU," and "H & DU" are boundaries where MF and H, MF and DUPAC, and H and DUPAC, respectively, change. The unit on height is in terms of 10 feet, and DUPAC is in terms of one housing unit. Standard errors are clustered at the boundary level (in parentheses), and robust standard errors are in square brackets. * $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$.

Under the (neighbor)Hood: Understanding Interactions Among Zoning Regulations

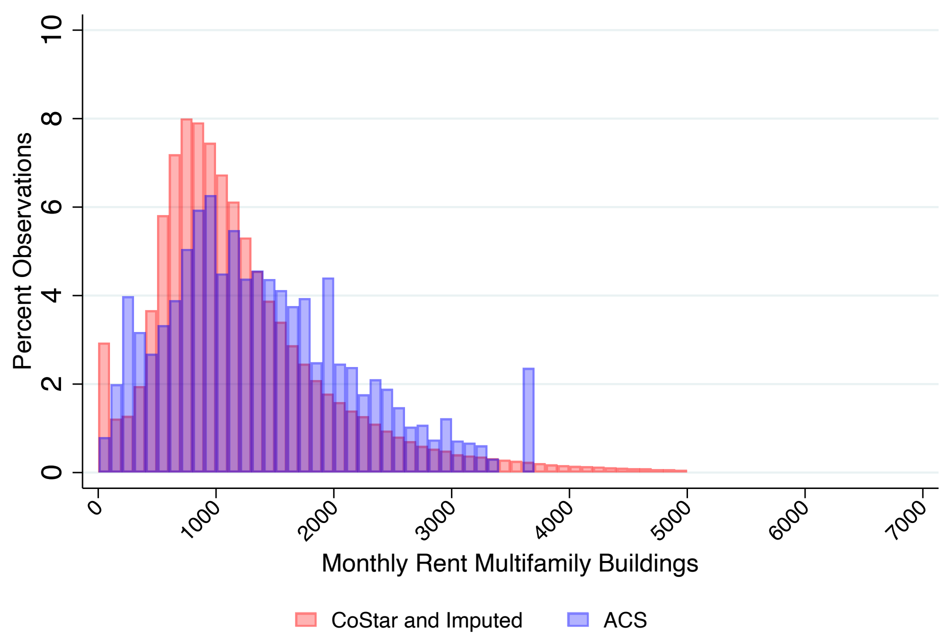
by Amrita Kulka, Aradhya Sood, and Nicholas Chiumenti

ONLINE APPENDIX

A. Data appendix and rent imputation

For the buildings that have CoStar market rent available [18,536 buildings from 2010-2018], we use market rent per unit directly. CoStar uses websites like Apartment.com and field visits and surveys to get market rental data. For the remaining 112,992 buildings, we impute rent by calculating the owner cost of housing following Bureau of Economic Analysis (BEA) methodology by Katz et al. (2017), taking the assessed value of the property and multiplying it by 0.629% to get the annual owner cost of housing. We then divide this number by 12 to get a monthly rent estimate. The distribution of CoStar market rent and imputed rent values combined is shown in red in Figure A.1 and plotted against the 2018 American Community Survey block-group level rent (blue). The baseline results use CoStar market rent data and BEA imputation for the remainder of properties.

Figure A.1: Rent imputation for multifamily buildings



Note: This figure plots the rental data from CoStar and imputed rental values (red) against the American Community Survey block group (2018) rental distribution (blue).

For data on proximity to green spaces, roads, and transit stops, we use location data from

MassGIS. For parcel-level data on land quality (slope, soil quality, and depth to bedrock), we use data from the Massachusetts Natural Resources Conservation Service.

References

Katz, Arnold J et al., "Imputing Rents to Owner-Occupied Housing by Directly Modelling Their Distribution," *WP2017-7, BEA Working Paper*, 2017.

B. Details on policy counterfactual

This section describes how we simulate Massachusetts' Chapter 40A upzoning policy counterfactual using our semiparametric estimates. In particular, we explain how we calculate θ_i in Equation 6. The Chapter 40A upzoning policy will allow for DUPAC= 15 units and multifamily housing within a half-mile radius of transit stops. Our estimates are local average treatment effects at the boundary and, therefore, cannot be applied to large changes in regulation or changes further away from the boundary.

We first identify all boundaries in our final boundary sample that lie within half a mile radius of all metro and commuter rail stations in Greater Boston. We then exclude boundaries for which only one side of the boundary lies within 0.5 miles, but the other does not. Stations for which we do not find a regulatory boundary with both sides within a 0.5-mile radius are marked with an X in Figure 10. We have at least one regulatory boundary (possibly multiple boundaries) within half a mile for the remainder of the transit stations. Note that by design at a given boundary, $z_0(x)\ \forall x < 0 \neq z_0(x)\ \forall x \geq 0$. We calculate the effects θ_{ik} of Chapter 40A separately on either side $k \in L, R$ of the boundary and take the unweighted average to arrive at θ_i for boundary scenario i.

We now describe how we calculate the average sale price, monthly rent, and housing unit effects for the relaxed and strict side of the four regulatory scenarios with non-null semiparametric estimates (Tables C.5 and C.6).[1] We calculate regulation effects θ_i relative to the average of the dependent variable $\bar{Y}$ at a given boundary (note Y is either the number of units, log sale price for single-family homes, or log monthly rent for multifamily houses). The average of dependent variables is calculated at the municipality level to avoid noise from small sample sizes near a given station.[2]

Scenario 1: Allowing multifamily housing

[1]We show price and rent results in percentage terms. Since sales prices and rents are estimated as log-level specifications, we multiply all expressions by 100 to show percentages.

[2]At a given station, there may be very few sales from 2010 to 2018.

For this regulatory scenario, the counterfactual effect occurs only on the strict side of the boundary, which does not allow multifamily houses before the Chapter 40A policy. θ_1 is given below where $\hat{\rho}$ is from Equation 4.

$$\theta_1 = \frac{1 * \hat{\rho}_{MF}}{\bar{Y}}.$$

Scenario 3: Only density changes

For this regulatory scenario, the counterfactual effect occurs on strict L and relaxed R sides of the boundary, that is, DUPAC (DU_{40A}) increases to 15 housing units if the existing DUPAC (DU_0) is lower than 15. The effect θ_{3k} for $k \in L, R$ is given by

$$\theta_{3k} = \frac{(\max[0, DU_{40A} - DU_{0k}] * \hat{\rho}_{DU})}{\bar{Y}}.$$

Scenario 5: Relaxing density and multifamily housing

For this regulatory scenario, on the strict side of the boundary, Chapter 40A manifests through allowing multifamily houses and increasing DUPAC (DU_{40A}) to 15 if not already the case, that is, if $DU_0 < 15$. On the other hand, on the relaxed side of the boundary, the effect of Chapter 40A comes only through allowing the density to 15 DUPAC if $DU_0 < 15$.

Strict side L

$$\theta_{5L} = \frac{(\max[0, DU_{40A} - DU_{0L}] * \hat{\rho}_{DU} + 1 * \max[0, DU_{40A} - DU_{0L}] * \hat{\rho}_{MFXDU})}{\bar{Y}} + \frac{1 * \hat{\rho}_{MF} + \hat{\rho}_{MFXDU} * DU_{0L}}{\bar{Y}}.$$

Relaxed side R

$$\theta_{5R} = \frac{(\max[0, DU_{40A} - DU_{0R}] * \hat{\rho}_{DU} + 1 * \max[0, DU_{40A} - DU_{0R}] * \hat{\rho}_{MFXDU})}{\bar{Y}}.$$

Scenario 6: Relaxing density and height Since the Chapter 40A upzoning policy does not change height (H) regulations, the only change at these boundaries occurs through a change in DUPAC. Again, the counterfactual effect occurs on both sides $k \in L, R$ of the boundary by increasing DUPAC (DU_{40A}) to 15 housing units if the existing DUPAC (DU_0) is lower than 15.

$$\theta_{6k} = \frac{\max[0, DU_{40A} - DU_{0k}] * (\hat{\rho}_{DU} + \hat{\rho}_{DUXH} * H_{0k})}{\bar{Y}.}$$

Calculation of counterfactual effects

For the baseline effects, $\hat{\rho}_1, \hat{\rho}_2, \hat{\rho}_3$ are estimated from semiparametric models with a linear polynomial in the distance to boundary variable (Table C.5). However, as can be seen from Table C.6, the estimates are not significantly different if a cubic polynomial is used in the distance to the boundary variable. For the regulatory scenario with the most observations (only DUPAC changes, scenario 3), we select a bandwidth of 0.02 miles. For all other regulatory scenarios, a bandwidth of 0.2 miles is chosen. After calculating θ_i for $i = 1, 3, 5, 6$, we plot the counterfactual effects in Figure 10 using Equation 6. Stations marked with a gray X are not considered in our analysis because there are no regulatory boundaries within 0.5 miles of the station. The Chapter 40A law will have no effect near stations marked with gray triangles because density is already at or above the suggested maximum value of DUPAC = 15 or multifamily zoning already exists. Among the remaining stations with multiple regulatory scenarios, we plot scenarios that result in price decreases over scenarios that result in price increases. In addition, if multiple boundaries are present at a station, we select the largest effects, that is, the largest increase in the number of units and the largest decrease in prices or rents. Null effects are plotted as white dots.

C. Additional tables and figures

Table C.1: Recent zoning reform across the world

No	Country	State	Municipality	Year	MF	Height	Density	Geographic Level	Statutory coverage
1	Brazil	–	Sao Paolo	2016	X	X	X	city	jurisdiction-wide
2	Canada	Ontario	–	2022	X	X	X	state	jurisdiction-wide
3	Ireland	–	–	2022			X	country	small-scale
4	Japan	–	Kyoto	2022		X		city	small-scale
5	New Zealand	–	–	2021			X	country	jurisdiction-wide
6	Switzerland	–	Zurich	2018			X	city	jurisdiction-wide
7	USA	Alaska	Anchorage	2022-3	X	X	X	city	jurisdiction-wide
8	USA	Arkansas	Fayetteville	2018	X		X	city	jurisdiction-wide
9	USA	Arizona	Tucson	2021	X		X	city	jurisdiction-wide
10	USA	California	Berkeley	2021-2-3	X	X	X	city	jurisdiction-wide
11	USA	California	Oakland	2023	X		X	city	small-scale
12	USA	California	San Diego	2020-2-3	X		X	city	small-scale
13	USA	California	San Francisco	2018-22	X		X	city	jurisdiction-wide
14	USA	California	San José	2019	X		X	city	jurisdiction-wide
15	USA	Colorado	Denver	2019	X		X	city	jurisdiction-wide
16	USA	Connecticut	New Haven	2021	X		X	city	jurisdiction-wide
17	USA	Florida	Jacksonville	2022	X		X	city	jurisdiction-wide
18	USA	Florida	Gainesville	2022	X		X	city	jurisdiction-wide
19	USA	Georgia	Atlanta	2018-9	X		X	city	jurisdiction-wide
20	USA	Georgia	Decatur	2023	X		X	city	jurisdiction-wide

continues...

Table C.1: Recent zoning reform across the world (continued)

No	Country	State	Municipality	Year	MF	Height	Density	Geographic Level	Statutory Level
21	USA	Illinois	Chicago	2020-2	X		X	city	small-scale
22	USA	Iowa	Iowa City	2021	X		X	city	small-scale
23	USA	Kentucky	Louisville	2021			X	city	jurisdiction-wide
24	USA	Kentucky	Lexington	2021	X		X	city	jurisdiction-wide
25	USA	Maine	Auburn	2022	X		X	city	small-scale
26	USA	Maine	Portland	2022	X		X	city	small-scale
27	USA	Massachusetts	–	2021	X		X	state	small-scale
28	USA	Michigan	Grand Rapids	2019	X		X	city	jurisdiction-wide
29	USA	Michigan	Ann Arbor	2021	X		X	city	jurisdiction-wide
30	USA	Minnesota	Saint Paul	2022	X		X	city	jurisdiction-wide
31	USA	Minnesota	Minneapolis	2019-21	X		X	city	jurisdiction-wide
32	USA	Minnesota	Rochester	2022	X		X	city	jurisdiction-wide
33	USA	Missouri	Kansas City	2022	X		X	city	jurisdiction-wide
34	USA	Montana	Missoula	2020	X		X	city	jurisdiction-wide
35	USA	New Jersey	Jersey City	2022	X		X	city	small-scale
36	USA	New Jersey	Maplewood	2020	X		X	city	jurisdiction-wide
37	USA	New Jersey	Princeton	2020	X		X	city	jurisdiction-wide
38	USA	North Carolina	Charlotte	2021-2	X		X	city	jurisdiction-wide
39	USA	North Carolina	Durham	2019	X		X	city	jurisdiction-wide
40	USA	North Carolina	Raleigh	2020-1-2	X		X	city	jurisdiction-wide
41	USA	Oregon	–	2019	X		X	multi-city	jurisdiction-wide

continues...

Table C.1: Recent zoning reform across the world (continued)

No	Country	State	Municipality	Year	MF	Height	Density	Geographic Level	Statutory Level
42	USA	Pennsylvania	Philadelphia	2019	X		X	city	jurisdiction-wide
43	USA	South Dakota	Rapid City	2019	X		X	city	jurisdiction-wide
44	USA	Texas	Austin	2019	X	X	X	city	small-scale
45	USA	Utah	Salt Lake City	2023	X		X	city	jurisdiction-wide
46	USA	Vermont	Burlington	2020			X	city	jurisdiction-wide
47	USA	Virginia	Alexandria	2021	X		X	city	jurisdiction-wide
48	USA	Virginia	Arlington	2023	X		X	city	jurisdiction-wide
49	USA	Washington	Seattle	2019	X		X	city	jurisdiction-wide
50	USA	Washington	Tacoma	2019	X		X	city	jurisdiction-wide
51	USA	Washington	Everett	2020			X	city	small-scale
52	USA	Washington	Spokane	2022	X		X	city	jurisdiction-wide
53	USA	Wisconsin	Madison	2023		X	X	city	small-scale
54	USA	Wyoming	Laramie	2022	X		X	city	jurisdiction-wide

Note: This table provides a list of recent upzoning across the world where a jurisdiction relaxed at least one of the following zoning regulation–allowing for multi-family zoning (MF), relaxing height restrictions, or increasing allowed density. Geographic level represents the jurisdiction where zoning reform applies and statutory Level indicates whether the reform applies to the entire jurisdiction or only parts within it (small-scale).

Table C.2: Adoption of first zoning laws across municipalities

Town	Year	Town	Year
ARLINGTON	1924-8-30	MEDFORD	1925
BEDFORD	1928	MELROSE	1924-5-6-7-8
BELMONT	1925-6-7	MILTON	1922-6
BOSTON	1918-23-4-9-30-1-2	NATICK	1931
BROOKLINE	1922-4-8	NEEDHAM	1925-6-31
CAMBRIDGE	1924-5-6-7-8-9-30	NEWTON	1922-5-6-9
CHELSEA	1924	REVERE	1925-9
CONCORD	1928	SALEM	1925-7-8-9
DEDHAM	1924	SOMERVILLE	1925-9
EVERETT	1926-8	STONEHAM	1925-6-7-8-9-30-31-32
FRANKLIN	1930	SUDBURY	1931
GLOUCESTER	1926-7	SWAMPSCOTT	1924
HUDSON	1927	WAKEFIELD	1925-7-9
HULL	1931-2	WALPOLE	1925-8
LEXINGTON	1924-9	WALTHAM	1925-8-9
LINCOLN	1929	WATERTOWN	1026-7-9-30-1
LYNN	1924-5-6-9	WELLESLEY	1925
MALDEN	1923-6-32	WESTON	1928
MARBLEHEAD	1927-8-30	WESTWOOD	1929
MARLBOROUGH	1927	WINTHROP	1922-8-9
MARSHFIELD	1926	WOBURN	1925

Note: This table provides the date of first height or land-use zoning adoption across municipalities in Greater Boston Area. Data is from Knauss (1933).

Table C.3: Supply: types of housing across regulatory boundaries (built after 1918, cubic polynomial in distance)

	Dep. Var.: Building type 2-3 units (Gentle-Density)						Dep. Var.: Building type 4+ units (High-Density)					
Reg. Scenario:	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MF	0.455			-0.357	0.001		0.014			-0.140	-0.003	
	(0.102)***			(0.752)	(0.029)		(0.011)			(0.251)	(0.016)	
	[0.038]***			[0.429]	[0.016]		[0.009]			[0.225]	[0.010]	
H		0.028		-0.093		-0.063		-0.018		-0.060		-0.080
		(0.026)		(0.200)		(0.029)*		(0.016)		(0.084)		(0.034)*
		[0.024]		[0.118]		[0.026]*		[0.016]		[0.075]		[0.025]**
DU			0.001		-0.004	-0.012			0.001		0.001	-0.010
			(0.001)		(0.004)	(0.005)**			(0.001)		(0.001)	(0.004)**
			[0.0005]		[0.001]*	[0.003]***			[0.0003]**		[0.001]	[0.003]***
MFXDU					0.016						0.002	
					(0.002)***						(0.002)	
					[0.001]***						[0.001]	
HXDU						0.001						0.001
						(0.0004)**						(0.0004)**
						[0.0003]***						[0.0003]***
MFXH				0.136						0.047		
				(0.211)						(0.076)		
				[0.123]						[0.068]		
N 1,495	1,760	3,3071	485	1,1264	1,587	2,538	1,165	1,722	3,1835	431	9,477	1,163
R^2	0.542	0.382	0.435	0.316	0.389	0.457	0.598	0.494	0.565	0.071	0.310	0.570
$\mathbb{E}(y)$	0.231	0.041	0.045	0.116	0.171	0.350	0.013	0.021	0.008	0.007	0.015	0.113

Note: This table presents the results from a linear probability model (Equations 4 and 5) where dependant variable value of 0 is a single-family house and value of 1 is either a 2-3 unit building or 4 or more unit building 0-0.2 miles on either side of the boundary in 2018. All buildings are built after 1918. Cubic polynomial in distance to boundary is used. Only MF are boundaries where only multifamily (MF) regulation changes, Only H are boundaries where only height (H) changes, and only DU are boundaries where only dwelling units per acre (DUPAC) regulation changes. MF & H, MF & DU, and H & DU are boundaries where MF and height, MF and DUPAC, and height and DUPAC both change, respectively. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. Clustered standard errors are in parenthesis and robust standard errors in square brackets. * $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$.

Table C.4: Supply: types of housing across regulatory boundaries (built after 1956)

	Dep. Var.: $\mathbb{1}$[Building type = 2-3 units]						Dep. Var.: $\mathbb{1}$[Building type = 4+ units]					
Reg. Scenario:	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU	Only MF	Only H	Only DU	MF & H	MF & DU	H & DU
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MF allowed	0.264			-1.575	0.0246		0.030			0.193	-0.010	
	(0.084)**			(0.757)	(0.025)		(0.026)			(0.075)*	(0.024)	
	[0.058]***			[0.540]**	[0.017]		[0.019]			[0.264]	[0.014]	
Height (H)		0.036		-0.668		0.096		-0.036		0.043		-0.013
		(0.015)*		(0.357)		(0.056)		(0.037)		(0.029)		(0.054)
		[0.030]		[0.216]**		[0.048]*		[0.024]		[0.070]		[0.040]
DUPAC (DU)			0.001		0.010	-0.007			0.001		0.001	-0.005
			(0.001)		(0.003)**	(0.004)			(0.001)		(0.003)	(0.005)
			[0.001]		[0.002]***	[0.004]			[0.0004]*		[0.002]	[0.005]
MFXDU					0.007						0.006	
					(0.003)*						(0.003)	
					[0.002]***						[0.002]*	
HXDU						0.000						0.0005
						(0.0005)						(0.001)
						[0.0005]						[0.0004]
MFXH				0.587						-0.049		
				(0.319)						(0.026)		
				[0.182]**						[0.074]		
N	482	1,029	21,108	193	5,075	621	454	1,026	20,789	177	4,765	511
R^2	0.535	0.365	0.291	0.405	0.400	0.524	0.821	0.632	0.477	0.068	0.432	0.741
$\mathbb{E}(y)$	0.078	0.028	0.019	0.090	0.075	0.264	0.020	0.026	0.004	0.011	0.015	0.105

Note: This table presents the results from a linear probability model (Equations 4 and 5) where dependant variable value of 0 is a single-family house and value of 1 is either a 2-3 unit building or 4 or more unit building 0-0.2 miles on either side of the boundary in 2018. All buildings are built after 1956. Linear polynomial in distance to boundary is used. Only MF are boundaries where only multifamily (MF) regulation changes, Only H are boundaries where only height (H) changes, and only DU are boundaries where only dwelling units per acre (DUPAC) regulation changes. MF & H, MF & DU, and H & DU are boundaries where MF and height, MF and DUPAC, and height and DUPAC both change, respectively. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. Clustered standard errors are in parenthesis and robust standard errors in square brackets. * $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$.

Table C.5: Semi-parametric effects of regulation on supply and prices

	Dep. Var.: Number of units				**Dep. Var.: Single-family sales price**				**Dep. Var.: Multifamily rent**	
Reg. Scenario:	Only MF	Only DU	MF & DU	DU & H	Only MF	Only DU	MF & DU	DU & H	Only DU	DU & H
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Inner Core Municipalities										
MF allowed	0.620***		-7.958		0.069		-0.300*			
	(0.133)		(7.046)		(0.060)		(0.124)			
Height (H)				0.058				0.041		0.016
				(0.481)				(0.029)		(0.027)
DUPAC (DU)		0.062*	0.060	0.119		0.009***	-0.011*	0.001	0.002	-0.002
		(0.028)	(0.076)	(0.063)		(0.002)	(0.005)	(0.002)	(0.002)	(0.002)
MFXDU			0.570				0.015*			
			(0.447)				(0.007)			
HXDU				-0.010				0.000		0.000
				(0.006)				(0.000)		(0.000)
N	7,281	1,584	5,113	1,128	10,193	1,762	5,862	1,139	36,229	17,341
Panel B: Mature Suburb Municipalities										
MF allowed	-0.157		0.050		-0.038		-0.020			
	(0.412)		(0.457)		(0.099)		(0.062)			
Height (H)				-8.968				-55.560***		7.640 ***
				(8.934)				(11.900)		(1.593)
DUPAC (DU)		0.009	-0.799*	2.067		-0.001	0.017	-13.033***	-0.005***	-0.312***
		(0.005)	(0.354)	(4.836)		(0.002)	(0.033)	(2.650)	(0.001)	(0.055)
MFXDU			0.566*				-0.011			
			(0.239)				(0.021)			
HXDU				-0.535				$0.000^{\dagger}$		$0.000^{\dagger}$
				(1.165)				(0.000)		(0.000)
N	518	15,394	3,951	330	656	25,352	5,994	492	6,773	177

Continues...

Table C.5: Continued

	Dep. Var.: Number of units				Dep. Var.: Single-family sales price				Dep. Var.: Multifamily rent	
Reg. Scenario:	Only MF	Only DU	MF & DU	DU & H	Only MF	Only DU	MF & DU	DU & H	Only DU	DU & H
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Panel C: Developing Suburb Municipalities									
MF allowed	-0.267**		-0.821		-0.517***		-1.448***			
	(0.083)		(0.724)		(0.139)		(0.390)			
Height (H)				-0.947*				-0.490		0.552**
				(0.382)				(0.530)		(0.187)
DUPAC (DU)		0.039	-0.427	-1.176*		-0.012	-0.501***	-0.634	0.107***	0.504***
		(0.075)	(0.381)	(0.536)		(0.044)	(0.139)	(0.734)	(0.021)	(0.055)
MFXDU			0.430				0.602***			
			(0.378)				(0.163)			
HXDU				0.300*				0.154		-0.127***
				(0.134)				(0.182)		(0.014)
N	180	6,346	3,319	177	339	9,721	4,063	269	2,243	461

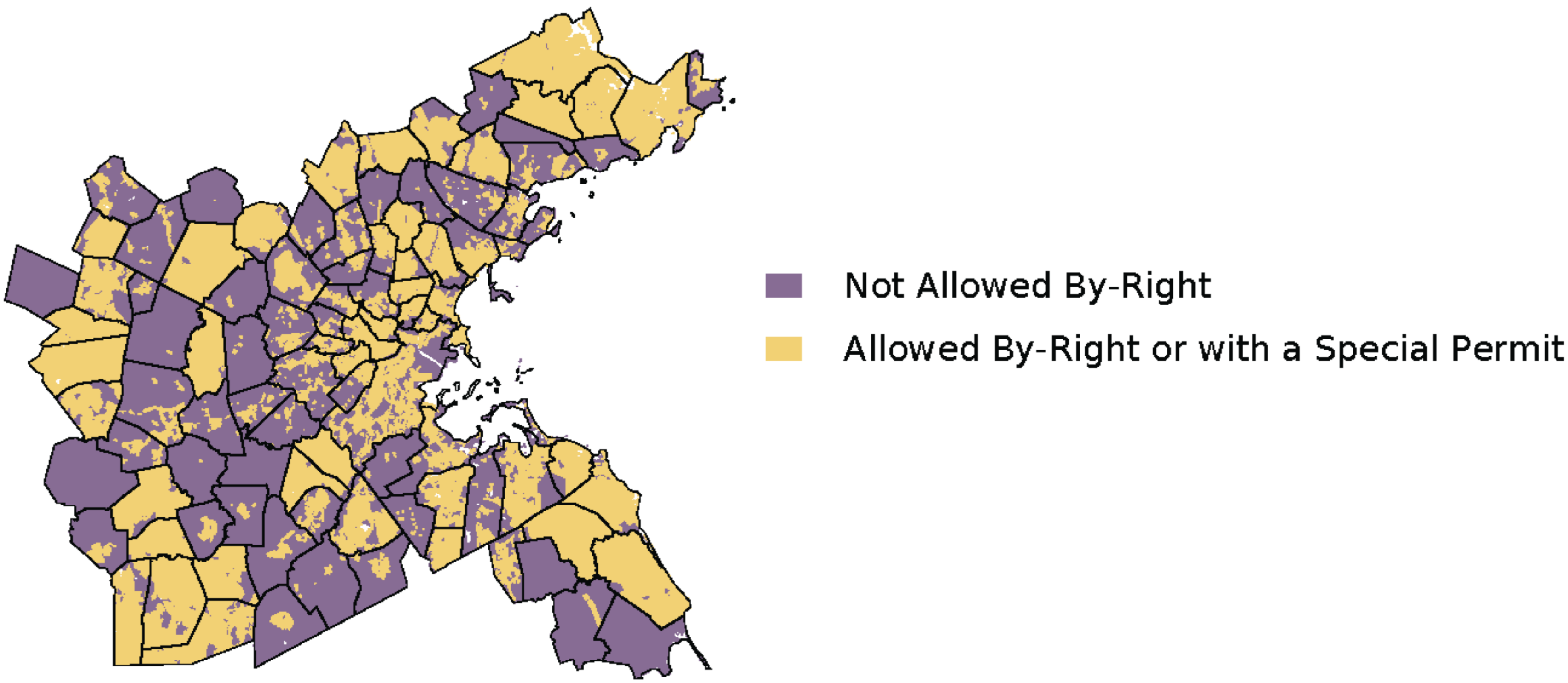
Note: This table presents the results from Equation 4 where the dependent variable is either log of monthly owner cost of housing or monthly rent 0-0.2 miles around the boundary. Boundary fixed effects and year fixed effects are included [2010-2018]. Only MF are boundaries where only multifamily (MF) regulation changes and only DU are boundaries where only dwelling units per acre (DUPAC) regulation changes. MF & DU and H & DU are boundaries where MF and DUPAC both change and height and DUPAC both change, respectively. Since there are no renters on one side of a boundary where allowing multifamily homes changes, we do not show results on rents for that type of boundary. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. * $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$. † implies coefficient cannot be calculated due to multicollinearity.

Table C.6: Semi-parametric effects of regulation on supply and prices (cubic polynomial in distance)

	Dep. Var.: Number of units				**Dep. Var.: Single-family sales price**				**Dep. Var.: Multifamily rent**	
Reg. Scenario:	Only MF	Only DU	MF & DU	DU & H	Only MF	Only DU	MF & DU	DU & H	Only DU	DU & H
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Inner Core										
MF allowed	0.522**		-8.482		0.062		-0.247*			
	(0.191)		(7.007)		(0.053)		(0.110)			
Height (H)				-1.790				0.034		0.018
				(1.108)				(0.032)		(0.032)
DUPAC (DU)		0.053	0.059	-0.014		0.003	-0.012*	0.001	0.001	-0.002
		(0.027)	(0.075)	(0.100)		(0.002)	(0.005)	(0.002)	(0.001)	(0.003)
MFXDU			0.575				0.015*			
			(0.449)				(0.007)			
HXDU				0.007				0.000		0.000
				(0.010)				(0.000)		(0.000)
N	1,128	7,281	5,113	1,584	1,139	10,193	5,862	1,762	36,229	17,341
Panel B: Mature Suburbs										
MF allowed	0.193		0.154		0.015		0.007			
	(0.238)		(0.503)		(0.158)		(0.066)			
Height (H)				-11.819				-53.382***		13.173***
				(8.696)				(10.670)		(0.522)
DUPAC (DU)		0.002	-0.791*	1.589		0.002	0.013	-12.569***	-0.001	-0.767***
		(0.004)	(0.358)	(9.189)		(0.001)	(0.032)	(2.373)	(0.002)	(0.042)
MFXDU			0.561*				-0.009			
			(0.238)				(0.021)			
HXDU				-0.344				0.000†		0.000†
				(2.087)				(0.000)		0.000
N	518	15,394	3,951	330	656	25,352	5,994	492	6,773	177

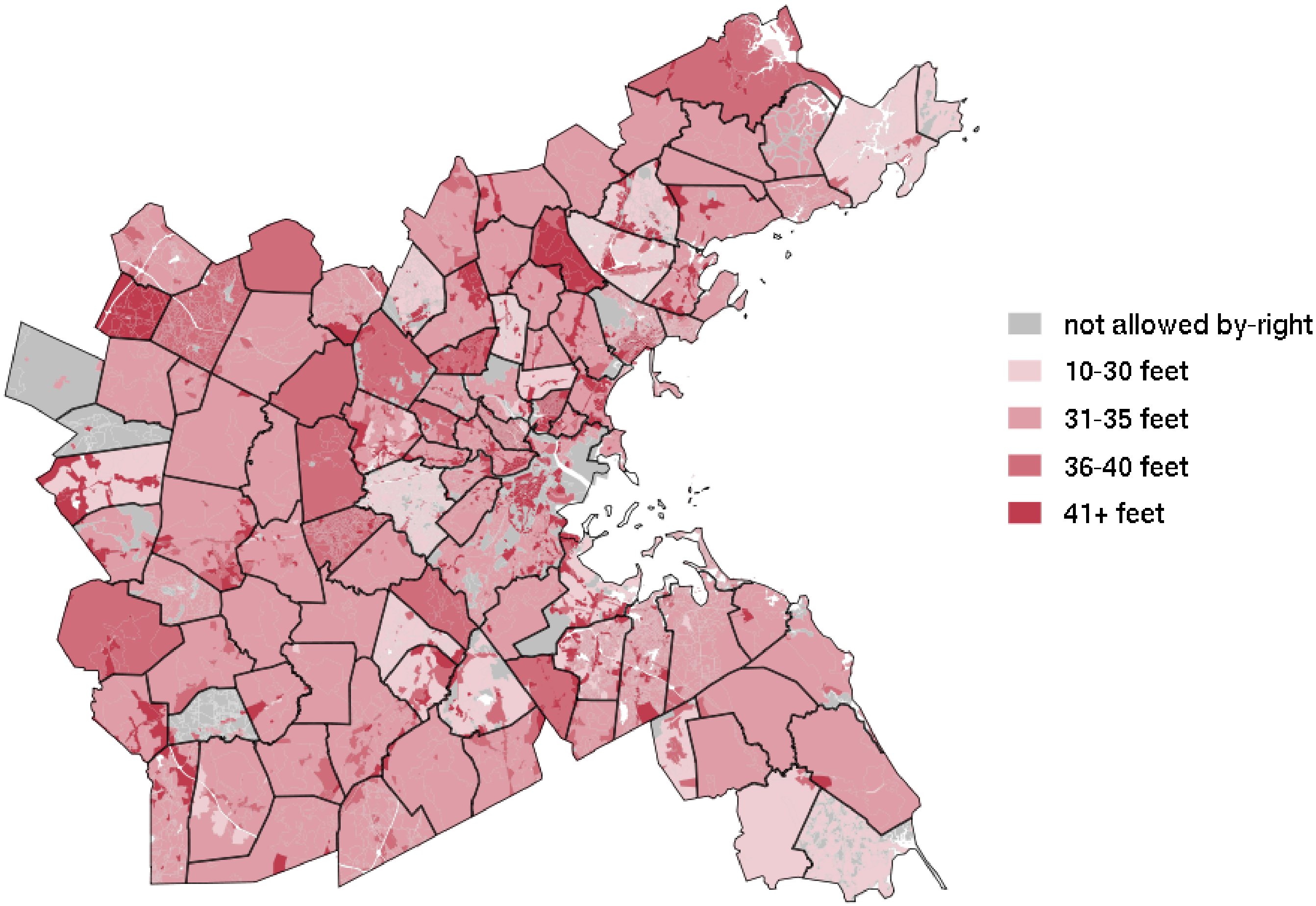
Note: This table presents the results from Equation 4 where the dependent variable is either log of monthly owner cost of housing or monthly rent 0-0.2 miles around the boundary. Boundary fixed effects and year fixed effects are included [2010-2018]. Only MF are boundaries where only multifamily (MF) regulation changes and only DU are boundaries where only dwelling units per acre (DUPAC) regulation changes. MF & DU and H & DU are boundaries where MF and DUPAC both change and height and DUPAC both change, respectively. Since there are no renters on one side of a boundary where allowing multifamily homes changes, we do not show results on rents for that type of boundary. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. † implies coefficient cannot be calculated due to multicollinearity.

Figure C.1: Multifamily zoning in greater Boston area



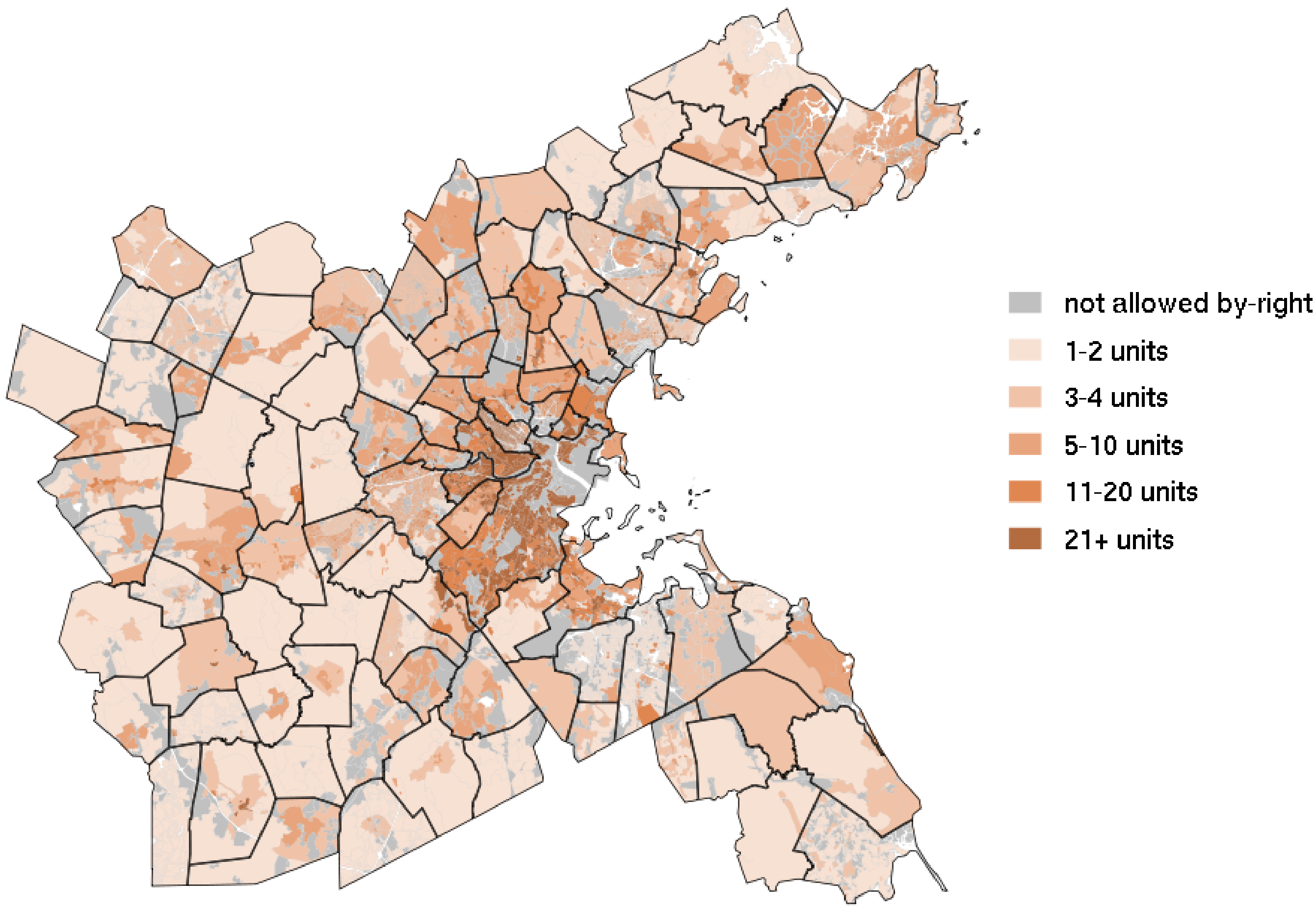
Note: This figure plots the multifamily zoning in greater Boston area. Allowed includes areas where multifamily construction is allowed by right and by special permit.

Figure C.2: Maximum height restrictions in greater Boston area



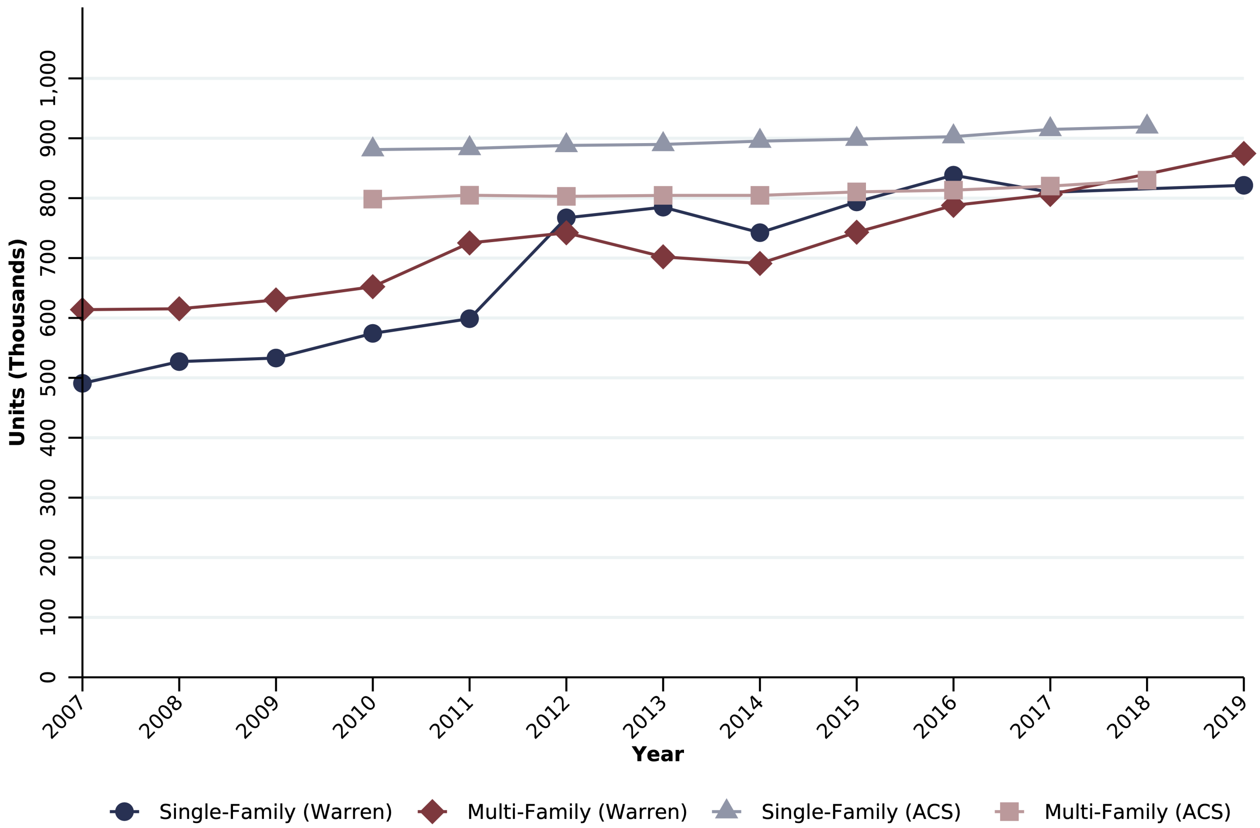
Note: This figure plots the maximum-height restrictions in greater Boston area in feet.

Figure C.3: Maximum density (DUPAC) restrictions in greater Boston area



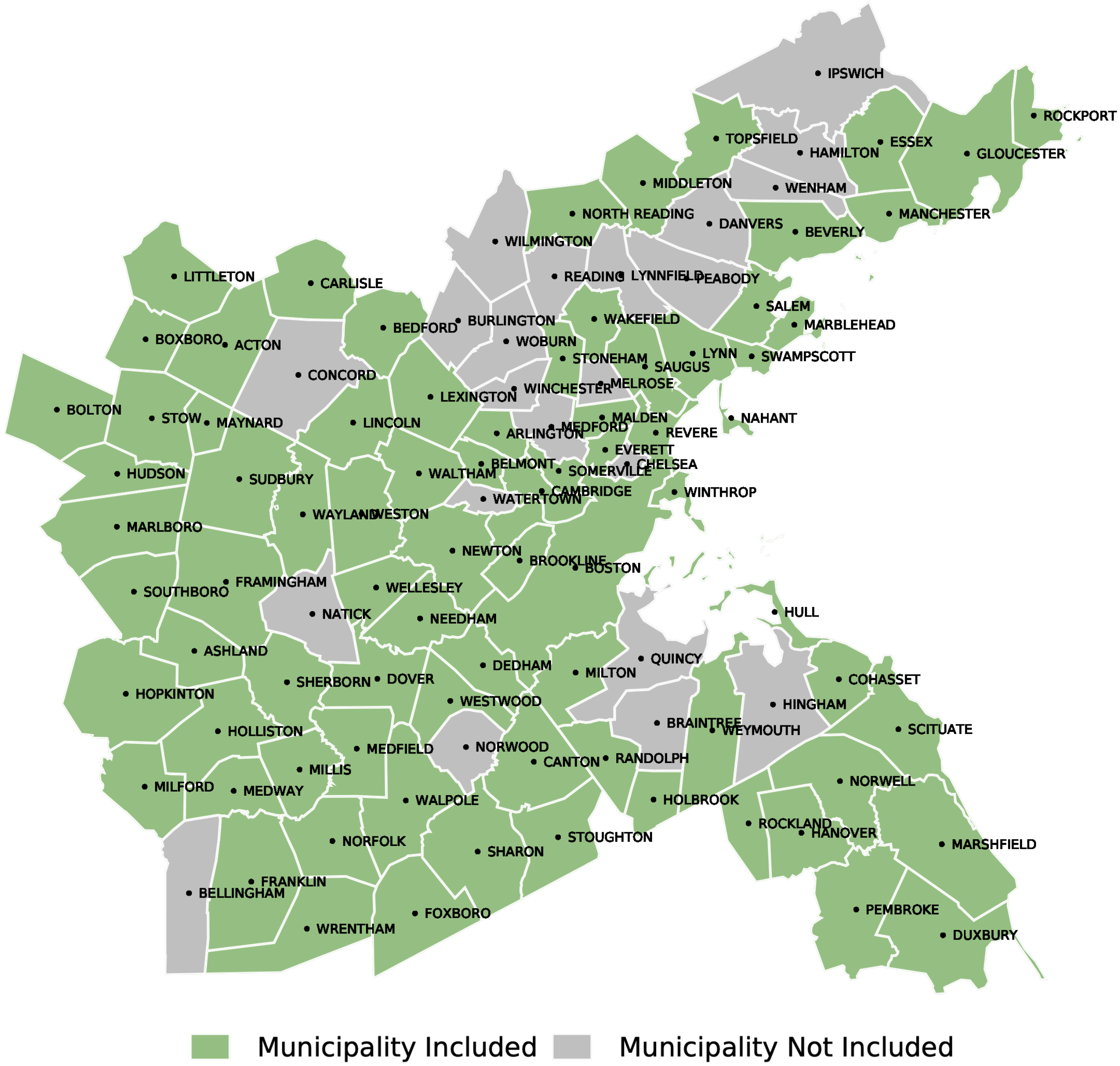
Note: This figure plots the maximum DUPAC (dweelng units per acre) restrictions in greater Boston area.

Figure C.4: Total units by housing type: Warren and American Community Survey data



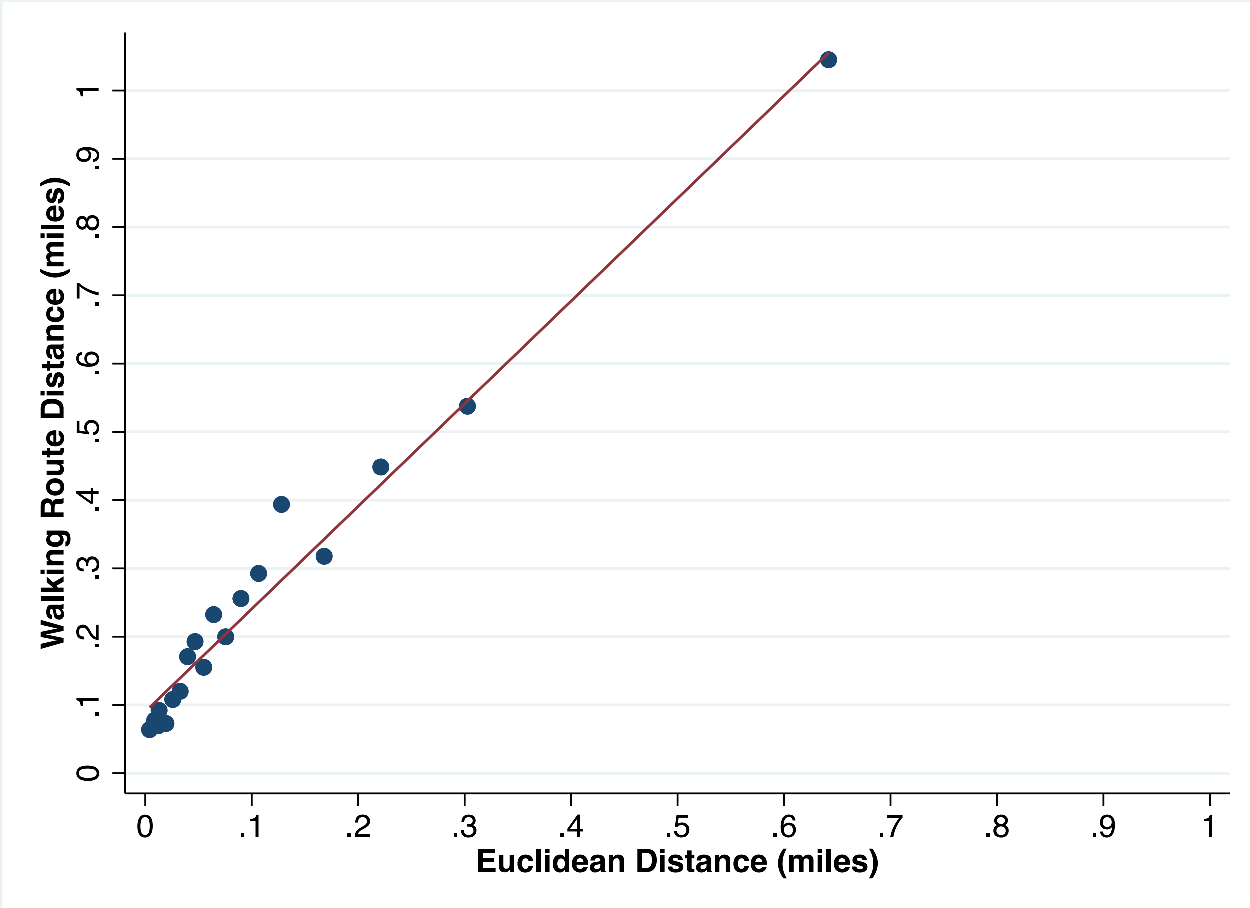
Notes: Single-family units from American Community Survey include all 1 unit housing units (attached and detached). Single-family units in Warren include property addresses with 1 unit listed. All other types counted as multifamily. Counts only Massachusetts counties for the Boston-Cambridge-Newton MSA (2007-2019).

Figure C.5: Towns included in sample



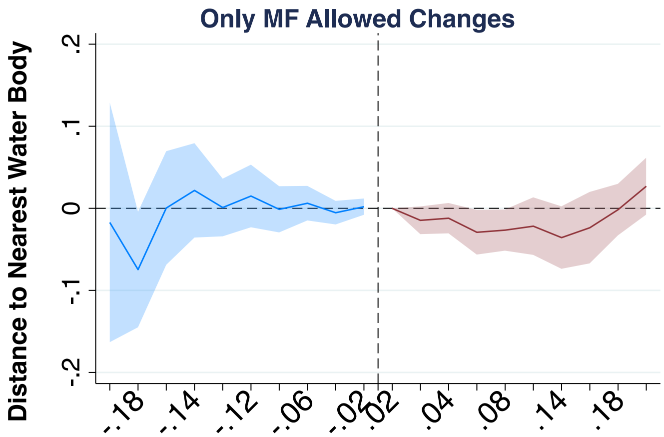
Note: Municipalities are included if they either had open enrollment school attendance policies or had elementary school attendance boundary data included in the 2016 School Attendance Boundary Survey. Municipalities were excluded if they lacked school attendance boundary data and did not have open enrollment.

Figure C.6: Correlation between straight line and walking distance

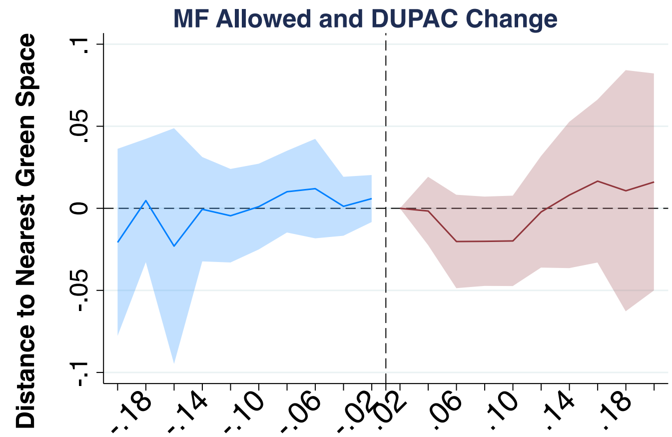


Note: This figure plots the Euclidean distance against the walking distance between the closest property on the less restrictive side of a regulatory boundary and the closest property on more restrictive side. The Euclidean distance is the direct path between two properties (in miles), while the walking route distance is the shortest path using the local road and sidewalk network. Distances were calculated using the geographic coordinates for each of the closest properties. The walking route distance was calculated using Project OSRM's Open Source Routing Machine, which finds the shortest path between two points based on the road and sidewalk network of local area.

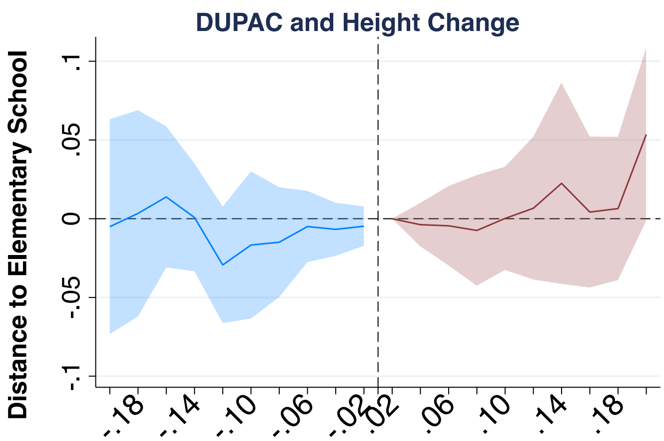
Figure C.7: Neighborhood amenities and parcel attributes at regulatory boundaries (continued)



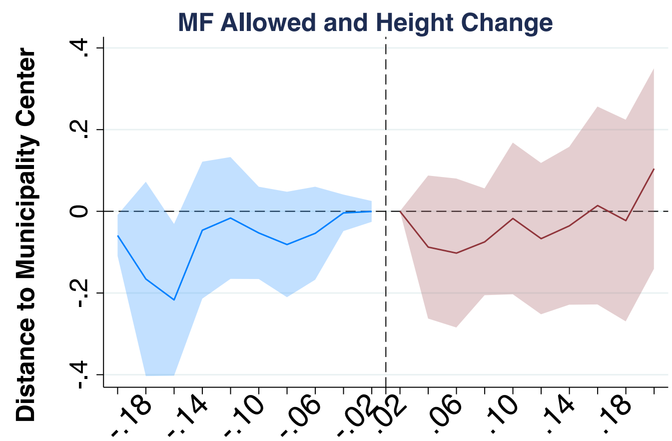
(a) RD est. = 0.002 (0.005), n = 2,298



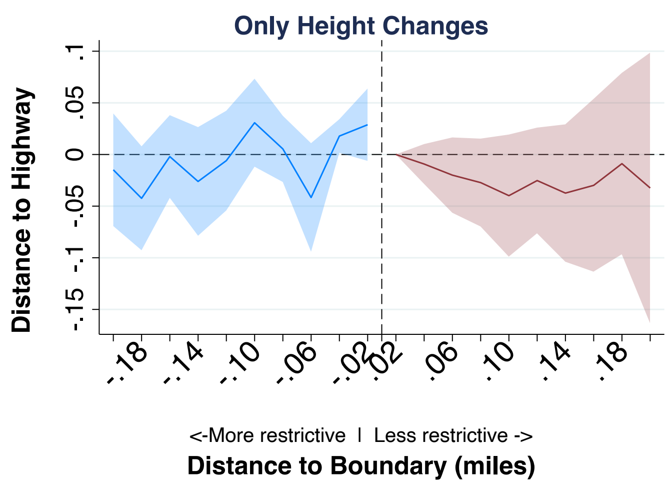
(b) RD est. = 0.006 (0.007), n = 17,184



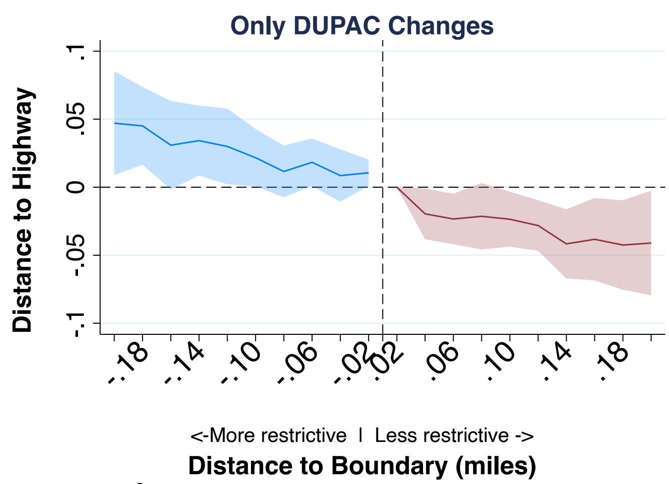
(c) RD est. = -0.005 (0.006), n = 4,570



(d) RD estimate = -0.0003 (0.013), n=753



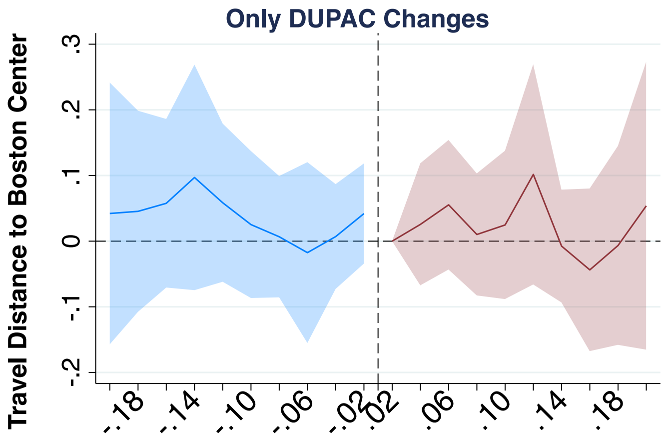
(e) RD est. = 0.029 (0.018), n = 2,593



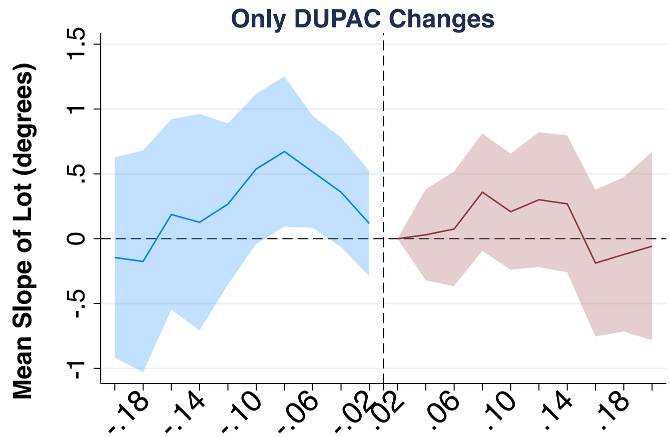
(f) RD est. = 0.011 (0.005)*, n = 42,702

Note: Figures are created by plotting coefficient from regressing distance to nearest amenities or parcel attributes on boundary fixed effects and distance to boundary (bins of 0.02 miles). Negative distances indicate more regulated side. Bin closest to boundary on less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown. Standard errors are clustered at boundary segment level. The coefficient and standard error on -0.02-0 bin on the restricted side is reported. DUPAC is Dwelling units per acre and MF is multifamily zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

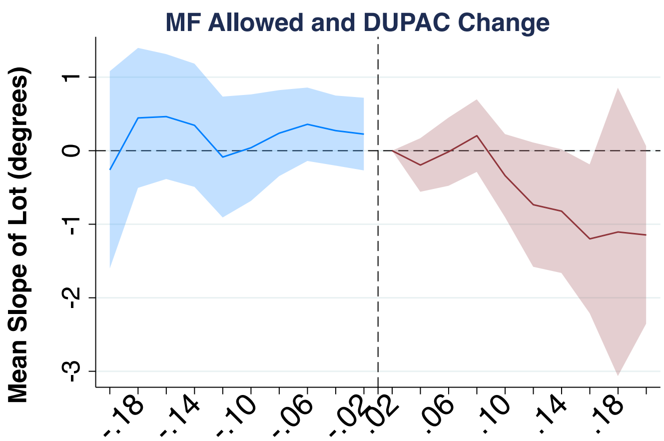
Figure C.8: Neighborhood amenities and parcel attributes at regulatory boundaries (continued)



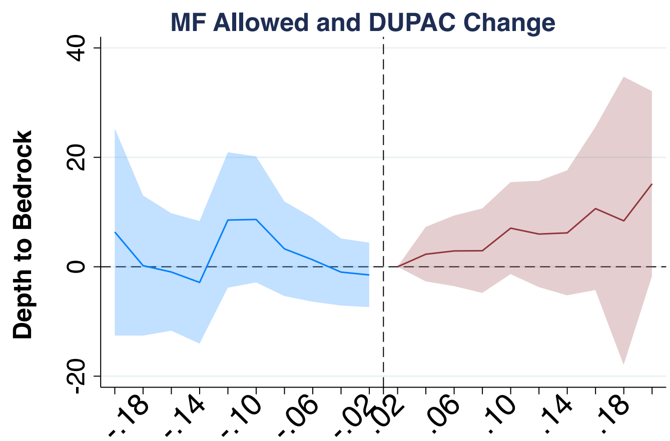
(a) RD est. = 0.042 (0.039), n = 42,438



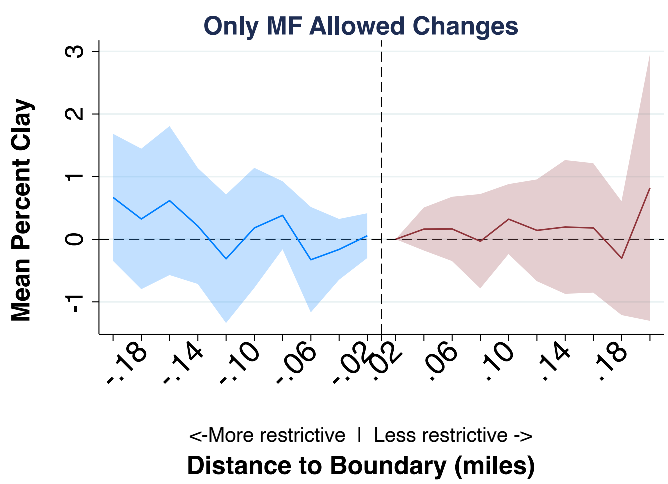
(b) RD est. = 0.117 (0.207), n = 34,172



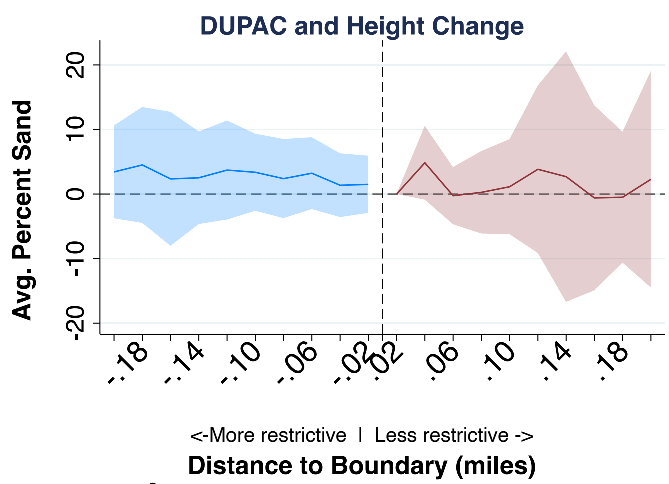
(c) RD est. = 0.226 (0.251), n = 14,484



(d) RD estimate = -1.493 (3.001), n=14,484



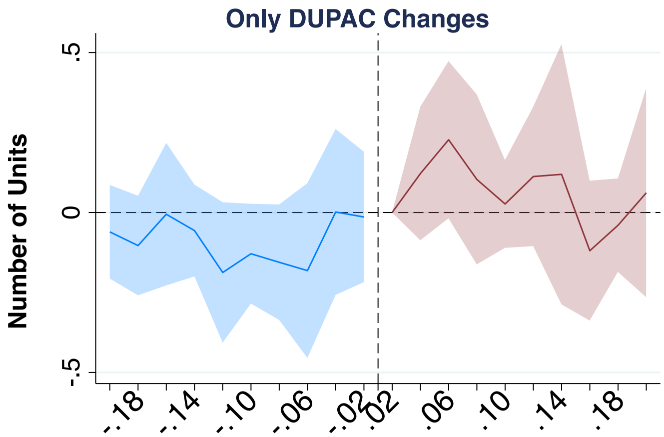
(e) RD est. = 0.057 (0.180), n = 1,941



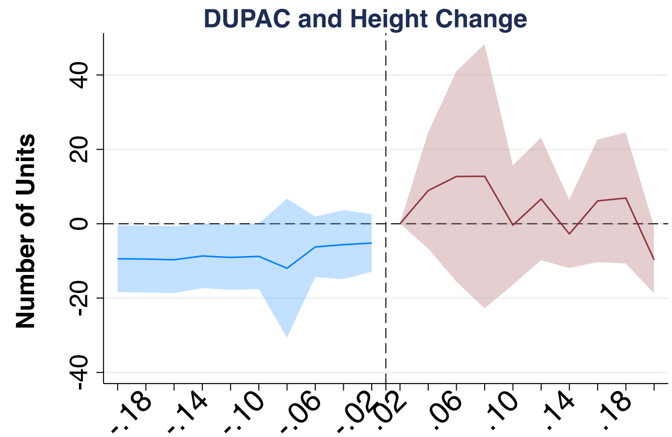
(f) RD est. = 1.499 (2.250), n = 3,941

Note: Figures are created by plotting coefficient from regressing distance to nearest amenities or parcel attributes on boundary fixed effects and distance to boundary (bins of 0.02 miles). Negative distances indicate more regulated side. Bin closest to boundary on less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown. Standard errors are clustered at boundary segment level. The coefficient and standard error on -0.02-0 bin on the restricted side is reported. DUPAC is Dwelling units per acre and MF is multifamily zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

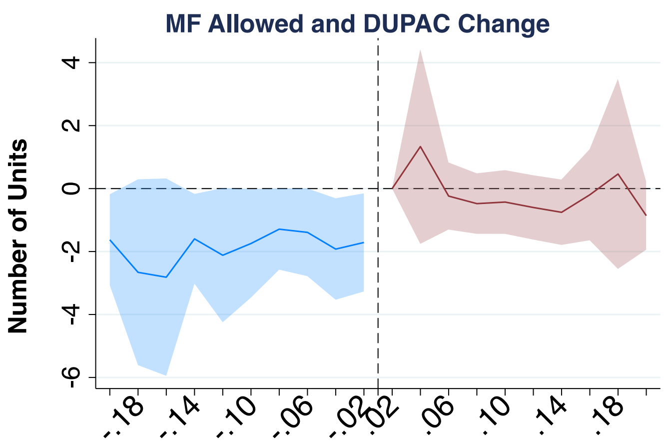
Figure C.9: Effect of regulations on number of units (buildings built after 1956)



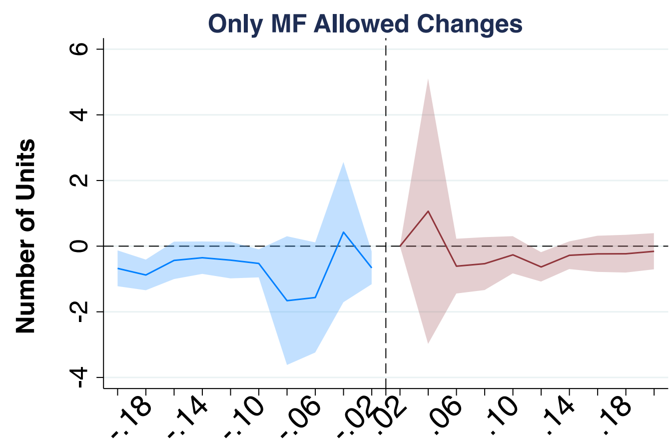
(a) RD est. = -0.014 (0.104) [0.095], n = 21,601



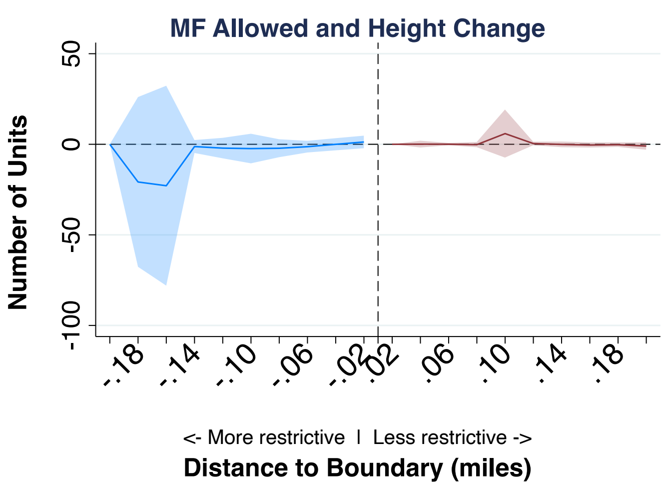
(b) RD est. = -5.194 (3.918) [2.913], n = 718



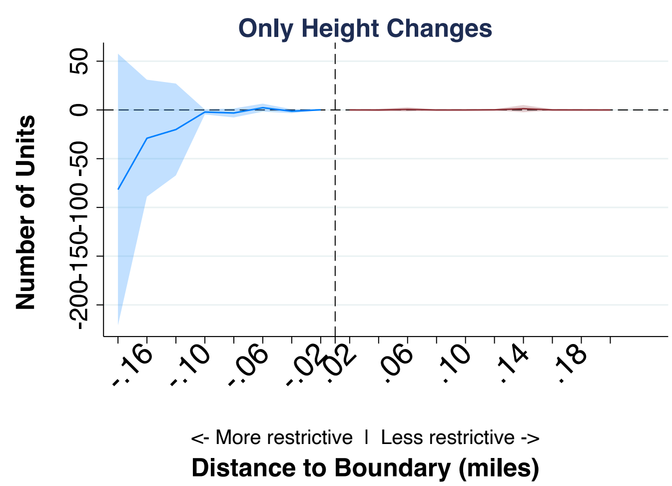
(c) RD est. = -1.712 (0.792)* [0.671]*, n = 5,223



(d) RD est. = -0.663 (0.249)* [0.321]*, n = 501



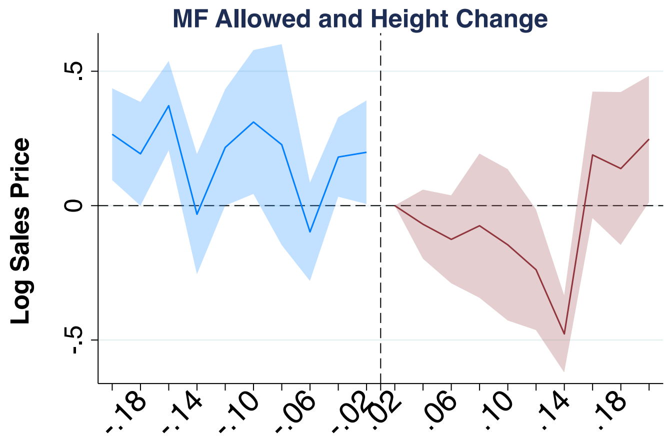
(e) RD est. = 1.271 (1.673) [1.645], n = 207



(f) RD est. = 0.128 (0.253) [0.234], n = 1,854

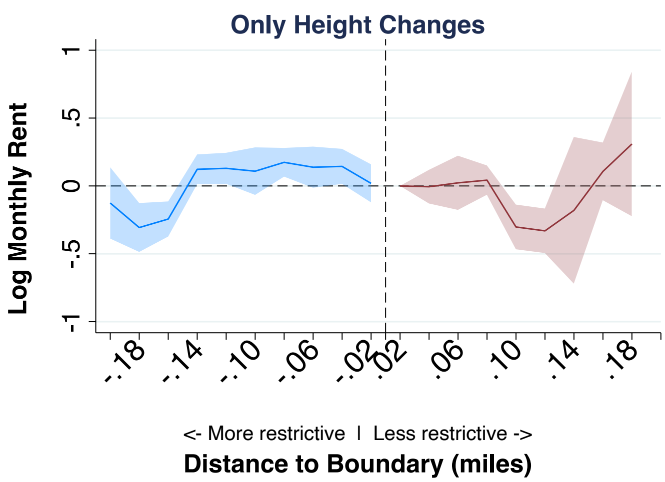
Note: Plots are created by regressing number of units in 2018 on boundary fixed effects and distance to boundary (bins of 0.02 miles). All buildings are built after 1956. Negative distances indicate the more regulated side. The bin closest to boundary on the less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown with clustered standard errors at boundary segment level. The coefficient, clustered standard error in parenthesis, and robust standard error in square brackets is reported on -0.02-0 bin on the restricted side. DUPAC is Dwelling units per acre and MF is multifamily zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure C.10: Effects of height and multifamily regulation on housing costs

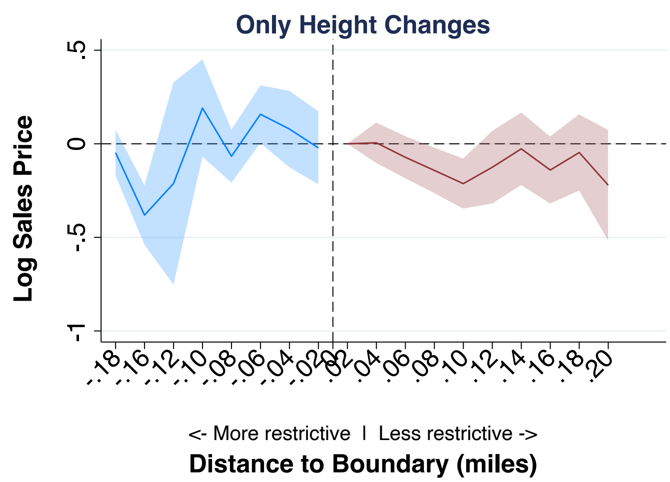


(a) RD est. = 0.198 (0.093)* [0.035]***, n = 990

Change in Only Multifamily or Multifamily and Height Regulation



(b) RD est. = 0.019 (0.070) [0.026], n = 3,609

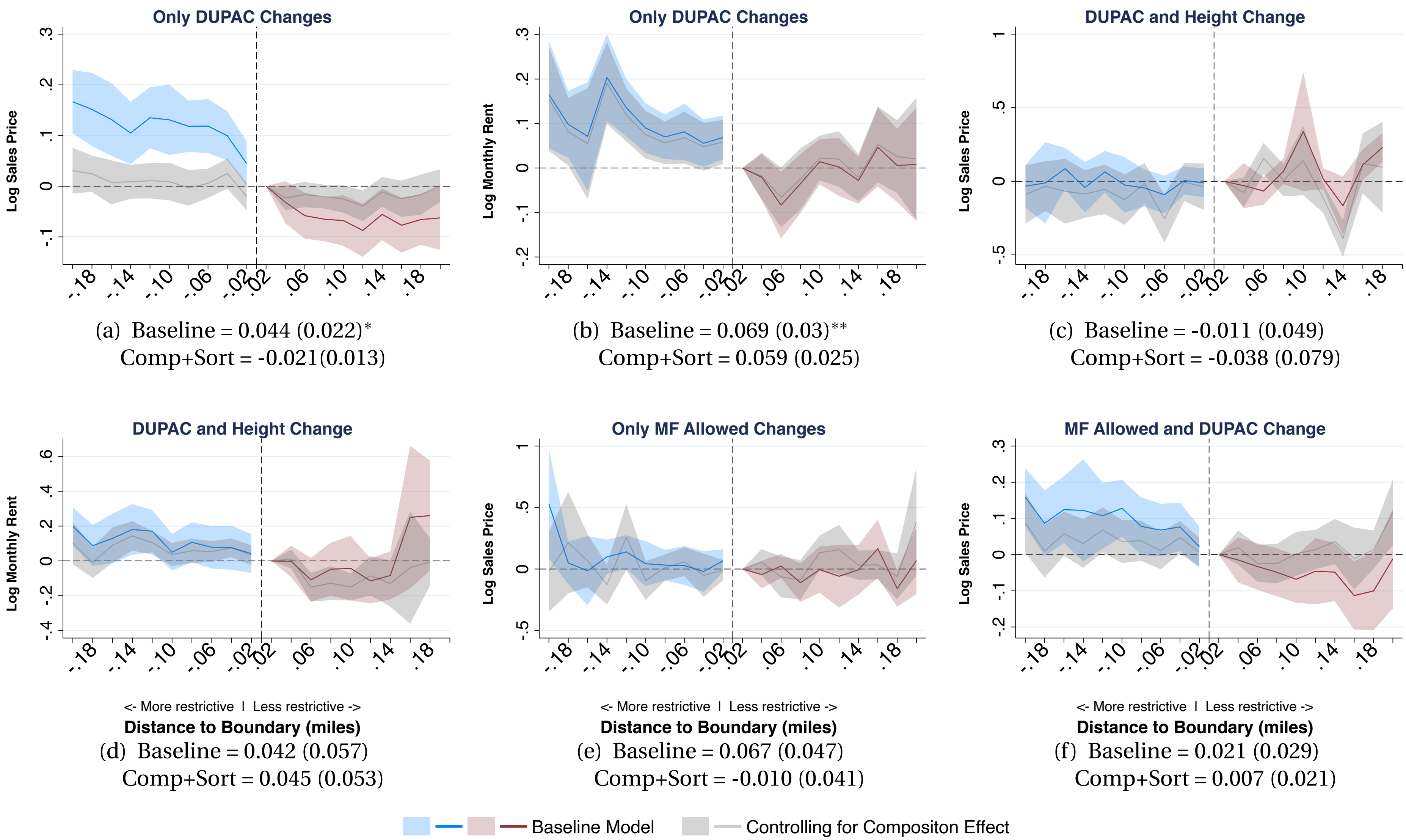


(c) RD est. = -0.022 (.097) [0.029], n = 3,140

Change in Only Height Regulation Boundaries

Note: Plots are created by regressing log prices on boundary fixed effects, year fixed effects [2010-2018], and 0.02 miles bins of distance to boundary. Coefficients on distance bins are plotted. Negative distances indicate the more regulated side of a boundary. The bin closest to boundary on less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown. The effects are on monthly rents for multifamily (MF) buildings or monthly owner cost of housing for single-family houses. Standard errors are clustered at the boundary level. Since there are no MF builings on one side of a boundary where allowing MF and Height changes, we do not show results on rents.

Figure C.11: Mechanisms behind equilibrium price effects (including sorting effect)



(a) Baseline = 0.044 (0.022)*
Comp+Sort = -0.021(0.013)

(b) Baseline = 0.069 (0.03)**
Comp+Sort = 0.059 (0.025)

(c) Baseline = -0.011 (0.049)
Comp+Sort = -0.038 (0.079)

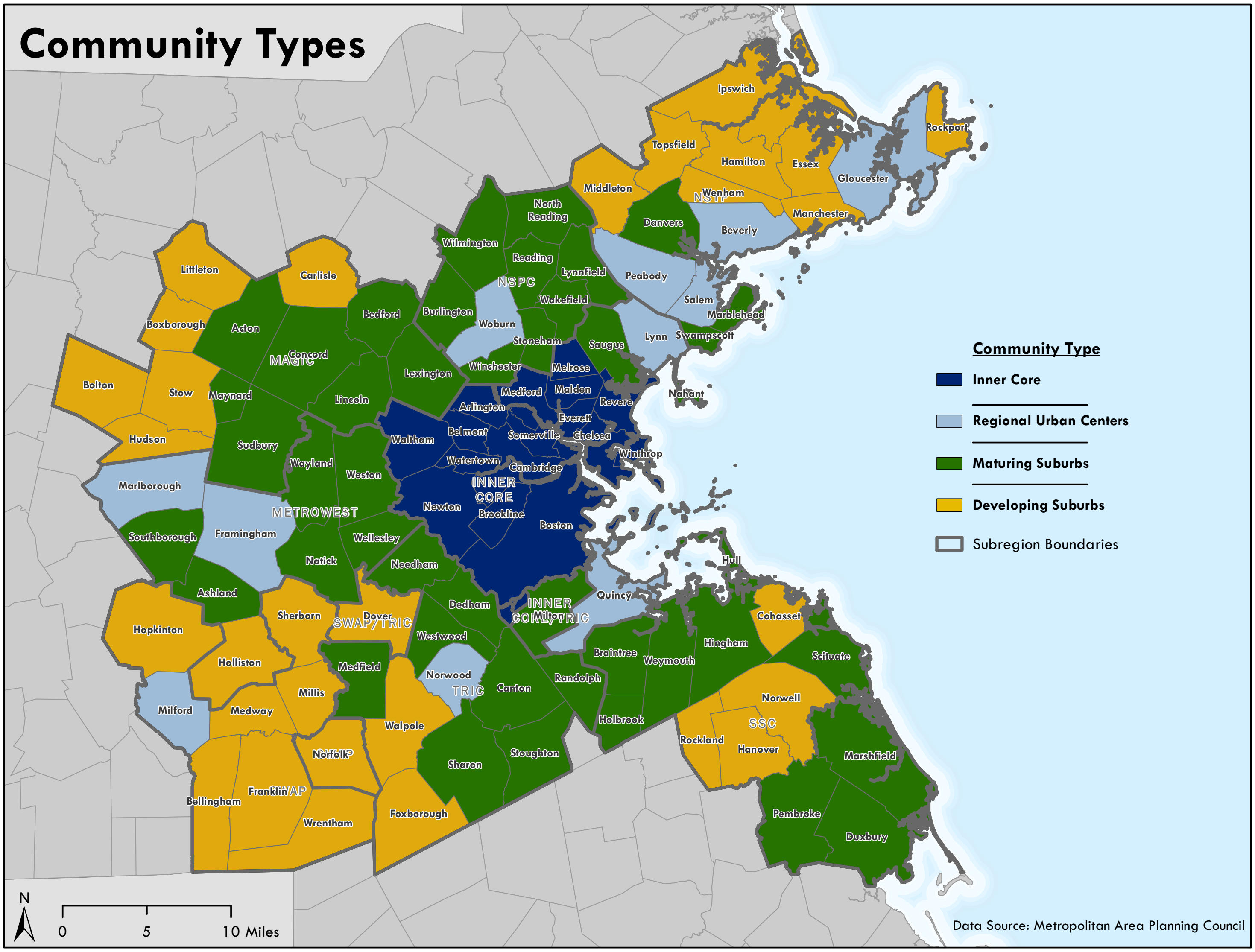
(d) Baseline = 0.042 (0.057)
Comp+Sort = 0.045 (0.053)

(e) Baseline = 0.067 (0.047)
Comp+Sort = -0.010 (0.041)

(f) Baseline = 0.021 (0.029)
Comp+Sort = 0.007 (0.021)

Note: Plots are created by regressing log single-family sale prices or log multifamily monthly rents on boundary fixed effects, sale year/rent year fixed effects [2010-2018], and 0.02 miles bins of distance to boundary. Compared to the baseline model, composition effect and sorting effect (Comp.+Sort) model controls for housing units characteristics and 2010 Census block controls. The 0-0.2 mile bin is normalized to 0. 95% confidence intervals are shown with clustered standard errors at boundary segment level. The coefficient, clustered standard error in parenthesis, and robust standard error in square brackets is reported on -0.02-0 bin on the restricted side. DUPAC is Dwelling units per acre and MF is multifamily zoning. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure C.12: Greater Boston area municipality types



Note: This figure highlights how the Metropolitan Area Planning Council (MAPC) divides towns in the Greater Boston Area into four distinct municipality types. Source: Metropolitan Area Planning Council community types. Towns classified as "Inner core" are high density inner cities and historic, high-density suburbs near the urban core. Towns classified as "Maturing Suburbs" are moderate density towns that are nearly built out or lower-density towns approaching buildout. Towns in the "Developing Suburbs" category are mixed density with well-defined town centers and room to grow or very low density with a country character and room to grow. Finally "Regional Urban Centers" are large, high-density urban centers not proximate to Boston or small and mid-sized urban downtowns with diverse neighborhoods. Since regional urban centers do not fit well into a monocentric city model, we exclude them for the purposes of our spatial heterogeneity analysis in Section 6.