How to Increase Housing Affordability? Understanding Local Deterrents to Building Multifamily Housing*

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Abstract

This paper studies how various land-use regulations interact to affect housing supply and affordability. We use cross-sectional variation across space from a novel parcel-level zoning data and a boundary discontinuity design at regulation boundaries to obtain causal estimates for the effect of various zoning regulations on the supply of different types of housing, single-family house prices, multifamily rents, and households' willingness-to-pay for higher density. We find that relaxing density restrictions (minimum lot size and maximum dwelling units), either alone or jointly with relaxing other regulations, is most effective at increasing supply, particularly of multifamily properties, and reducing rents and house prices. Conversely, enabling multifamily zoning or relaxing height regulations alone has little impact. Our results suggest that the small-scale reforms in zoning regulations proposed around the country can increase housing affordability. However, a fall in multifamily rents is often accompanied by a reduction in single-family house prices, complicating the political economy of land-use reform.

Keywords: multifamily zoning, height restrictions, density, house prices, rents

JEL: R21, R31, R58, H77, H11, K25

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1. Introduction

Housing is becoming increasingly unaffordable in many North American cities. For example, in 2018, the median share of rent to income was above 30% (the threshold for being considered rent-burdened) in 722 of 735 census tracts in Greater Boston, and the median share of owner costs to income was above 30% for 719 tracts. Local barriers to new construction, often in the form of land use regulations, can make housing more expensive and have adverse effects on growth, wealth accumulation by younger households, and geographic mobility (Hsieh and Moretti, 2019; Herkenhoff et al., 2018; Dustmann et al., 2022; Ganong and Shoag, 2017; Deryugina and Molitor, 2021).

Over the past century, local governments have accumulated and adopted multiple forms of zoning regulations that limit new construction. Yet, it is unclear to policymakers which of these regulations matter, how much they matter, and how they interact. For example, California, Oregon, and Minneapolis recently allowed for near-universal multifamily zoning without relaxing density and height regulations (Miller, 2019; Wamsley, 2019; Economist, 2021). Massachusetts recently relaxed restrictions on multifamily homes and density near transit stops by amending the state's Chapter 40A law.

Our first contribution is to compare the interaction of various zoning regulations and study their effects on the supply of different housing types and housing costs.[1] We focus on three principal regulations. These are multifamily zoning i.e. whether or not the construction of multi-unit properties (such as apartments) is at all allowed on a lot, height restrictions, and density restrictions that determine the number of housing units allowed on one acre of land (minimum lot size and maximum allowable units per lot). Increasing height, allowing more density, and allowing multifamily homes constitutes a relaxation of these regulations. We find that relaxing density restrictions, either individually or combined with other regulations, results in the largest increases in the number of units and the most significant fall in multifamily rents.

Our second contribution is to provide a framework to use boundary discontinuity

[1]The literature has analyzed the effects of these regulations separately. For example, for impact of density regulations, see (Anagol et al., 2021; Gray and Millsap, 2020), building heights (Brueckner and Singh, 2020; Ding, 2013), and minimum lot sizes (Zabel and Dalton, 2011; Kulka, 2020).

designs with discontinuities in land-use regulations (jumps in size and type of housing) to study the causal effects of regulations on housing costs stemming from both direct effects of the regulation and indirect externality effects. This is unlike the literature that uses administrative boundaries to causally identify the impact of regulations on housing costs (Turner et al., 2014; Shanks, 2021). In contrast, we examine buildings around regulation boundaries *within* towns and elementary school attendance areas to eliminate the sorting of households into states, municipalities, and schools (Holmes, 1998; Black, 1999; Schönholzer and Zhang, 2017).

Our setting is the Greater Boston Area. We use a novel parcel-level land-use regulation data (Zoning Atlas) for 86 towns and exploit spatial variation in zoning regulations using a regression discontinuity approach. We demonstrate the exogeneity of the regulation boundaries in our sample. Further, we show that neighborhood amenities are continuous at these boundaries and that current land-use regulations are, for the most part, not predictive of older housing built before the introduction of land-use zoning in the early-mid 20th century.

After examining the effects of (interactions of) regulations on housing supply, we find that housing units increase between 27% and 92% at boundaries at which density regulations are relaxed alone or combined with relaxing height regulations or allowing multifamily housing. In addition, we find a corresponding decrease in the number of bedrooms and bathrooms and living area square footage for these combinations of regulation changes, indicating that the effect is driven by a change in the composition of properties in areas with relaxed regulation. However, allowing multifamily zoning independently or only relaxing height regulations does not substantially increase the number of units. Moreover, the supply effects are more substantial for smaller multifamily buildings (two and three units) than larger apartments (four or more units).

Our third contribution is to study how the interaction of land-use regulations affects housing costs for both single-family homeowners and renters of units in multifamily homes. It is essential to consider the competing interests between current homeowners, new home buyers, and renters. In her review of the land-use regulations literature, Molloy (2020) notes that research on market-rate multifamily housing is mainly absent.

On the one hand, land-use regulations can be rent-seeking on behalf of existing homeowners (Glaeser and Gyourko, 2018). On the other hand, relaxing regulations can create negative externalities for current residents, especially if residents prefer lower neighborhood density (Autor et al., 2014; Diamond and McQuade, 2019; Mast, 2020).

Land-use regulations can affect prices in two ways. First, they directly affect prices by changing the option value (owners only), unit characteristics, and the number of units constructed in a given area. We call this the direct price effect. Second, regulations vary the neighborhood housing density and neighbor demographics, potentially creating negative externalities for current residents. Following Turner et al. (2014), we call this the indirect price effect. To study the direct and indirect price effects, we use the spatial regression discontinuity (RDD) design to estimate the causal effects of zoning regulations on prices close to the boundary and further away from it.

To estimate the direct price effects, we focus on a narrow band around a given boundary where amenities (including neighborhood density and neighbor demographics) are continuous, and discontinuities at the boundary arise due to regulation differences. Monthly multifamily rents fall between 2.6% and 12.6% (or $27 to $144 on average) for each unit added due to relaxing density regulations alone or in combination with allowing for more building height. For single-family homes, the effects are even larger. Relaxing density regulations alone lead to monthly owner costs of housing falling by 16.7% (or $425 on average) per unit of housing added. House prices drop by 9.17% ($204) per unit at boundaries where density regulations are relaxed and multifamily homes are allowed, the two most commonly combined regulations in the suburban communities of Greater Boston. Examining the cross-boundary differences of the (interaction of) various regulations, we find that a fall in multifamily rents is usually accompanied by a fall in house prices, complicating the political economy of zoning reform.

To estimate the indirect price effects of land-use regulations, we compare buildings further away from the boundary, subject to the same regulation scenario and thereby the same direct effects, but experiencing varying indirect effects as density and neighbors change away from the boundary. Results from the hedonic "donut" RDD suggest that distaste for density is substantial among single-family homeowners. Our results suggest that a 1% increase in density of two- and three-unit buildings leads to a fall in owner cost of housing of 0.17 to 0.21%. For renters, we find no distaste for higher density. This result lends credence to the literature that finds that stricter zoning laws limit negative externalities for current residents, and relaxing zoning laws would reduce single-family house prices by lowering perceived neighborhood quality.

We find that zoning regulation constraints do not bind in developing suburbs far from the central business district (CBD). Therefore, we see more significant increases in supply near the CBD, where land is most in-demand per the theoretical predictions of a monocentric city model. However, we find the largest decreases in prices in mature suburbs that provide an easy commute to Boston, face lower demand, and where strict regulations lead to higher prices. These results have implications for recent amendment to Massachusetts's Chapter 40A law that would increase density near important transit stops. Our counterfactual calculations suggest that a small local relaxation of density and height near transit stops in the suburban towns decreases rents up to $600 per month (average $123). In addition, relaxing density alone or with allowing for multifamily housing decreases monthly owner cost of housing up to $760 (average $247), both in CBD and suburbs.

In addition to the multitude of land-use regulations, the political economy is complicated because new construction decisions in the U.S. are made locally. As a result, different forms of local governance crucially affect how effective relaxing various land-use regulations are.[2] Consistent with the literature, we find that the mayoral and open town meeting forms of local governance, as opposed to the representative town meeting system, are most conducive to increasing the supply of multifamily units and reducing rents (Hankinson and Magazinnik, 2020). Finally, we study how land-use regulations interact with Massachusetts' Inclusionary Zoning (IZ) policy designed to override aspects of municipal zoning bylaws to build more affordable units.[3] We study whether IZ can substitute for relaxed land-use regulations and find that primarily it does not.

[2]A key issue in building multifamily housing are the numerous delays and uncertainty faced by developers to get projects approved by local town councils (Einstein et al., 2019; Schuetz, 2020b).

[3]Inclusionary zoning policies have gained popularity in many cities like New York (Soltas, 2021) and provide a substitute for relaxing land-use, which is politically challenging (Glaeser, 2021).

This paper ties into many strands of the literature relating to the wide effects of land-use regulations. The effect of individual land-use regulations on building permits and house prices has been studied across North America (Glaeser and Gyourko, 2018; Glaeser et al., 2005; Jackson, 2016) and in Boston area (Dain, 2019; Glaeser and Ward, 2009; Chiumenti, 2019; Rollins et al., 2006). Research on housing affordability of multifamily homes is largely limited to project-based low-income buildings (Diamond et al., 2019; Baum-Snow and Marion, 2009; Sinai and Waldfogel, 2005).[4] This paper is also related to the literature on neighborhood choice (Bayer et al., 2007; Albouy, 2016).

In addition to the adverse effects of regulations on growth and wealth accumulation, if households cannot afford to live near productive cities, they may re-locate to regions with worse opportunities and health outcomes (Chetty and Hendren, 2018; Chyn and Katz, 2021). Additionally, the racial segregation consequences of land-use regulations have been documented in many settings (Resseger, 2013; Shertzer et al., 2016; Trounstine, 2018; Rothstein, 2017). Lastly, Bertaud and Brueckner (2005) and Brueckner and Singh (2020) show that building height restrictions limit housing near CBD and cause urban sprawl, creating damaging environmental effects (IPCC, 2022). The paper proceeds as follows. Section 2 lays out the regulatory framework. Section 3 introduces the data. Section 4 provides the theoretical and empirical framework. We discuss the results in Section 5. In Section 6, we perform a policy counterfactual. Section 7 discusses interactions of land-use regulations with other local barriers.

2. Regulatory Framework for Multifamily Housing

2.1 Zoning Regulations

We focus on three land-use zoning regulations that affect the building of multifamily and single-family units in different ways. These are whether multifamily housing is allowed, maximum height restrictions, and maximum dwelling units per acre (DUPAC) restrictions. Figure 1 shows how the three regulations vary across the municipalities in our sample in Greater Boston. While all three land-use regulations have relatively

[4] See Ellen (2015) and Schuetz (2020a) for a broader discussion of housing affordability.

straightforward definitions, their implementation and interaction can be complex.[5]

Multifamily Zoning: Multifamily housing construction (such as apartment buildings) can be allowed by right, by special permit, or not allowed at all on a particular lot.[6] This zoning law regulates the *type* of housing and is the most common way multifamily housing is regulated in North America. Figure B.1 shows that there is considerable variation in this zoning regulation's use both within and across towns in Greater Boston, with some municipalities disallowing multifamily construction entirely while others allow it only in certain areas. Only 16% of the land area in Greater Boston allows multifamily housing by right, with another 26% allowing it by special permit.

Building Heights Restrictions: Building height restrictions indicate the maximum allowable building height in feet. Even if multifamily zoning is allowed, municipalities often limit the *size and shape* of buildings by using heights restrictions. Figure B.2 shows the variation in building height restrictions across Greater Boston. Regulations for 70% of the land area limit building heights to 35 feet (or 3.5 floors) or less.

Dwelling Units per Acre (DUPAC): DUPAC regulations limit *residential density and the total number of units* that can be built. DUPAC is calculated by counting the number of lots that can be constructed on an acre after taking into account *minimum lot size requirements* and multiplying this number by the maximum allowable dwelling units for each of those lots. Thus, this measure captures not only the land-use restrictions from *minimum lot size* requirements but also *maximum dwelling units* restrictions, allowing comparisons of municipalities who may regulate density in different ways. Figure B.3 shows how the DUPAC restrictions vary across Greater Boston. Roughly 24% of the land area in Greater Boston allows only one unit to be built per acre.

2.2 History and Interaction of Zoning Regulations

While the individual effects of some of these regulations on supply and prices of single-family homes have been documented, it is not well understood how they interact and differently affect the supply for both single and multifamily housing and prices for own-

[5] We do not incorporate parking requirements due to lack of granular data. In addition, this paper does not study the effects of rising construction costs on housing costs (Schmitz et al., 2020).

[6] We combine multifamily allowed by-right areas with those allowing multifamily construction with a special permit and compare the effects against areas where multifamily housing is not allowed at all.

ers and renters.[7] For example, given multifamily zoning, how do maximum building heights restrictions interact with density restrictions to affect whether multifamily housing is below or above nine units?

We study three types of interaction scenarios. First, only one of the three zoning laws differs at the boundary segment. Second, two zoning laws differ, but the other remains the same. Third, all three regulations differ. Table 1 shows all seven possible zoning regulation scenarios. Note that, as can be seen from Figure 1, regulation scenarios 6 and 7 (DUPAC and height differing and all three regulations differing) are more prevalent near downtown, while regulation scenarios 3 and 5 (only DUPAC changes and DUPAC and multifamily zoning change) are prevalent everywhere.

It is worth considering why we see the multiple regulation instruments deployed simultaneously. It could be because each regulation provides a particular benefit to property holders, and homeowners seeking to preserve their housing values may prefer having layers of regulations, making it harder to overcome challenges to zoning reform. Historical events may also have led to redundancy in zoning regulations. The cities of Boston and Cambridge, Massachusetts, first widely adopted use (residential, industrial, or commercial) and maximum height restrictions in 1918 and 1920 (Knauss, 1933; MacArthur, 2019), respectively, following New York's introduction of zoning laws in 1916. Neighboring suburban towns of Brockton, Brookline, and Newton soon followed and adopted use and maximum height restrictions in the early 1920s (Hillard, 2020; Neilson, 1934).[8] However, by the 1950s, these cities found that use and height regulations "did not sufficiently limit the housing potential of a given lot, and recommended changes to the zoning to cap [density] the total amount of habitable floor area in a structure relative to the area of the lot on which it sat." (MacArthur, 2019). After 1956, cities passed the Enabling Act and adopted comprehensive zoning laws, including density regulations (Bobrowski, 2002). While most of our analysis focuses on properties built after 1918 – the year of initial introduction of zoning regulations – we show that

[7]In the data, we observe single and multifamily housing units but not the share of renters in each of these categories. We categorize results by single-family "owners" and multifamily "renters" for simplicity, given that most single-family residents are owners and most multifamily residents are renters.

[8]Table B.1 illustrates the year of first zoning adoption (mostly height restrictions) across 42 towns.

our results are robust to focusing on properties built after 1956 when the comprehensive zoning code was adopted.

2.3 Inclusionary Zoning and Chapter 40B

Many states and cities in the U.S. have inclusionary zoning policies that provide incentives to developers to build affordable housing units, usually in mixed-income properties (e.g., New York City's 421-A property tax exemption (Soltas, 2021)). In Massachusetts's Chapter 40B law which enables local Zoning Boards of Appeals to approve new housing construction under relaxed zoning laws if at least 20-25% of the units have long-term affordability restrictions. Chapter 40B is used chiefly as a tool to build housing in areas with more lax zoning, such as taller building heights or more units per acre. This paper studies whether Chapter 40B acts as a compliment or a substitute for relaxed zoning.

3. Data

3.1 Land-Use Data

Data on parcel-level land-use zoning regulations comes from digitized zoning maps compiled by the Metropolitan Area Planning Council (MAPC) for their Zoning Atlas project. The 101 towns included in the Zoning Atlas dictate our overall sample of municipalities in Greater Boston. The Zoning Atlas was constructed between 2010-2020 and provides a snapshot of zoning regulations. However, most zoning regulations were set during the early to mid-20th century with few zoning changes afterward and almost always in the direction of more restrictive zoning.[9]

To the best of our knowledge, the 2020 MAPC Zoning Atlas and 2021 Desegregate Connecticut Zoning Atlas (Bronin, 2021) are the only comprehensive zoning datasets in North America, providing complete zoning codes and bylaws data. 26 of the towns in our sample are included in the Wharton Land Use Survey (WRLURI). To give a sense of comparability, we correlate regulations in these 26 towns with WRLURI. A one standard deviation increase in average density at the town level in our sample corresponds

[9] Zabel and Dalton (2011) find that there are 27 changes to minimum lot size regulations in the Greater Boston area between 1988-1997 (also see Glaeser and Ward (2009)). The towns adopting zoning changes had higher house prices and larger lot sizes. Kulka (2020) finds that in Wake County, rezoning requests concern minimal amounts of land. Annually, there are around five rezonings that take place.

to a fall of 0.007 standard deviations in WRLURI. A one standard deviation increase in average town-level height corresponds to a decrease of 0.06 in WRLURI.[10]

3.2 Housing Market and Price Data

Housing Characteristics: The data on housing units and characteristics comes from town-level tax assessment records compiled by the Warren Group for 2010 to 2018. These records reflect the near universe of all residential and mixed-use buildings in Greater Boston. Figure B.4 plots the total number of single-family and multifamily units from the Warren Group data against the units from the American Community Survey (ACS). The dataset contains information on the type of building (whether it is single-family or multifamily), the number of units in a property, lot size and building area, the year a property was built, the tax assessed value, sales value and date, building characteristics like number of rooms, bathrooms, etc.[11]

Single-Family House Prices: We primarily use tax assessor data for single-family houses. We focus on tax assessor data for two reasons. First, given that we look within 0.3 miles of our regulations boundaries which are, on average, 0.1 miles long, we want universe of house price data for 2010-2018 for our analysis. Nevertheless, results are qualitatively robust when we focus only on sales price data (see Appendix Figure B.14). Second, in our sample, the assessed value to sales price ratio is similar on both sides of the boundary. Appendix Figure B.5 plots the assessed-sales ratio for the single-family houses sold (2010-2018) against the sales value. The pattern observed in the figure where the assessed-sales ratio is higher for lower sales price homes compared with higher-priced ones is a nationwide phenomenon documented in Berry (2021). However, since this pattern is the same on both sides of the boundary, we do not think that using assessed values instead of sales values changes the qualitative nature of the results. To compare house prices to rents, we follow the procedure laid out by the Bureau of Economic Analysis (BEA) (Katz et al., 2017) and use 6.29% of house assessed value to

[10] Standardized averages across towns in allowing multifamily zoning by right or by special permit in our sample positively correlates with 0.04 standard deviations of WRLURI. Correlating with multifamily by right only gives the more intuitive correlation of -0.07 with WRLURI, suggesting that special permits are correlated with strict zoning.

[11] Condominiums are excluded from this analysis because they can have one or more units, and it is not easy to classify them into either single-family or multifamily categories.

get the annual owner cost of housing.

Multifamily Rents: Unit or building-level rental data are challenging to find, especially historical rental data. McMillen and Singh (2020), for instance, use survey data on rent. Data from CoStar provides historical rental information for buildings with five or more units and detailed information on multifamily building characteristics such as number of units, floors, year built, lot size, etc. For the buildings for which we have CoStar market rent, available [18,536 buildings 2010-2018], we use it directly. For the remaining 112,992 buildings, we impute rent using building characteristics from CoStar, Warren Group, and ACS block group characteristics.[12] Appendix A describes the procedure in detail. We discuss the results using only non-imputed CoStar rents in Section 5.2.

3.3 School Attendance Boundaries and Inclusionary Zoning Data

School quality is an essential factor for household location (Black, 1999). We are careful to rule out that this channel drives our estimates. We use the 2016 elementary school attendance area boundaries from the National Center for Education Statistics School Attendance Boundary Survey (SABS). In the final sample, we exclude 15 towns for which we cannot find school attendance boundary information. Figure B.6 displays the final sample of 86 towns. Data on Massachusetts' Inclusionary Zoning law Chapter 40B comes from the Massachusetts Department of Housing and Community Development.[13]

4. Model and Empirical Framework

To study the causal effects of land-use regulations on the supply of different types of housing, multifamily rents, and single-family house prices, we first build a theoretical framework (Sections 4.1 and 4.2). Next, we address the endogeneity concerns (Sections 4.3 and 4.4). The price of housing and rents are correlated with the underlying quality of that location, including the unobserved location quality. Thus, we need a source of variation that is orthogonal to unobserved location amenities. Land-use zoning regulation

[12]While it may seem unusual to impute rental data for buildings, it is similar to using assessed property values where the imputation process is outsourced to towns or counties.

[13]Of the 522 comprehensive permits Chapter 40B buildings in the 86 towns, we geolocate 85.8% and match them with corresponding tax assessment records. We do a better job geocoding the multifamily 40B buildings (89.9%) than single-family 40B buildings (75.7%), for which house numbers are missing to preserve anonymity. 79.2% percent of units in Chapter 40B properties are in rented multifamily buildings.

boundaries offer this variation under certain conditions.

4.1 Theoretical Framework

To understand how various land-use regulations interact and affect the supply of housing and housing costs, we extend the framework from Turner et al. (2014) to our setting in two ways. First, we incorporate the effect of regulations on building characteristics and thereby housing costs instead of considering the impact on vacant parcels of land only. Second, we add into the framework how household sorting at regulation boundaries is reflected in price discontinuities across those boundaries.

In a closed monocentric city model, location $x(d)$ is characterized by distance d to the central business district (CBD). Consider two neighborhoods L and R on either side of a zoning regulation boundary at location $x(d) = 0$.[14] At each location $x(d)$ within bandwidth $-\underline{x}$ and $\underline{x}$, there is a parcel of residential land that can be developed for either single-family or (if allowed) multifamily use. The two neighborhoods L and R share a boundary at 0. Let $p(x, z(x), d)$ be the monthly mortgage for owners or rent for renters for a housing unit at location x at distance d from the CBD.[15] Price is also a function of zoning regulation vector $z(x) \in \{z^L, z^R\}$ at location $x(d)$. Vector $z(x)$ denotes whether multifamily zoning is allowed, maximum building height, and maximum dwelling units per acre in neighborhoods L and R. A higher $z(x)$ indicates lower zoning regulations. Without loss of generality, assume that the left neighborhood is always more regulated than the right such that $z^L \leq z^R$. Assume that zoning regulation constraints are binding. Also, assume that city population increases at an exogenous rate $\kappa > 0$ such that there is increase in population over time, despite the closed-city assumption.

Consumers earn wage w, choose location $x(d)$, derive location utility $V(x)$, and pay $p(x, z, d)$ for their chosen location. They belong to a type τ and are heterogeneous in preferences (γ^τ) and their outside option location. The utility of a resident is $U(x) =$

[14] Because we are characterizing spatial equilibrium within a metro area and focus on small regulatory changes as are currently discussed by policymakers, we specify a closed monocentric model of the city which allows for changes in equilibrium prices when supply changes due to regulation change. This contrasts with Rosen-Roback model, where changes in supply result in cross-city migration, and prices and amenities adjust in response to demand by new residents (Almagro and Domınguez-Iino (2019)).

[15] We consider the distinction between owners and renters when discussing the option value of land use regulations. Renters rent from absentee landlords.

$u(w - p(x,z,d))V(x,\gamma^{\tau})$. For ease of discussion, we assume $u(x) = \exp^{w-p(x,z,d)}$. Conditional on distance to CBD d, consumers choose between living in L, R or the outside option location with reservation utility ν^{τ}. We assume that there are no moving costs across locations and that housing markets are perfectly competitive. In addition, we assume that housing markets are not locally segmented at the regulation boundary i.e., that buildings are exchanged in the same market on both sides of the boundary. In equilibrium, residents are indifferent between all locations and the outside option, and the housing market clears.

4.2 Mechanisms Behind Price Effects Across Regulation Boundaries

By design, differences in binding land-use regulations across boundaries can result in differences in housing unit type and characteristics. We now discuss in detail four fundamental mechanisms that can result in cost differences in land values and housing unit costs across regulation boundaries when land-use regulations change.

Equilibrium price effect: In our framework, demand curves are downward sloping (on both sides of the boundary). This follows from the assumption that households have heterogeneous outside options ν^{τ}. Changes in the supply of housing change the marginal individual that locates at a given boundary $x(d) = 0$. This is unlike the models that use boundary discontinuity designs to elicit willingness to pay for characteristics that differ discontinuously at boundaries, such as school quality (Black, 1999), which assume that demand for housing is perfectly elastic.[16] In addition, assuming that households have heterogeneous preferences for unit characteristics γ^{τ} at the same boundary $x(d) = 0$, households will sort along the regulation boundary based on these preferences. In particular, this may lead to households with a preference for larger units, conditional on other neighborhood characteristics, to sort into neighborhood L. This will result in different demand elasticities on either side of the boundary. Figure 2(a) illustrates the scenario where demand is more inelastic on the regulated side of the boundary (L); however the opposite could also be true. Finally, following the assumption that markets are not locally segmented around regulation boundaries, shifts in the supply in the local market due to regulation differences would result in a discontinuous jump in price per

[16] Under this assumption, housing supply shifts from regulation cannot affect prices across boundaries.

housing unit at the boundary. If demand is more inelastic (elastic) on the regulated side L (as illustrated in Figure 2(a)), then there would be lower (higher) prices on the relaxed side of the boundary. We call this the equilibrium effect, represented by **A** in Figure 2(b). On a given side of the boundary, this effect is the same whether the housing unit is closer to or further away from the boundary. To the best of our knowledge, the importance of heterogeneous preferences for characteristics for understanding regulation boundary discontinuities is a novel mechanism studied in this paper. Without this assumption, demand elasticities across boundaries are equalized and there is no equilibrium price effect **A** as in Turner et al. (2014).

Option value: Relaxed land-use regulations represent increased options because land can be used for both single-family and multifamily use (or different heights, lot sizes etc), thereby increasing the future sales value of land. This effect is only present for owned units and is absent for renters. The option value results in a positive jump in land value per square foot on the relaxed side (R) of the boundary. Importantly, the option value affects land prices independently of what type of structure is put on the land. Figure 2(b) represents the resulting jump from option value in *price per unit* of housing as **B**. On a given side of the boundary, this effect is the same whether the housing unit is at or further away from the boundary.

Housing characteristics: Let $h(x)$ be the vector of housing unit characteristics, some of which are observable to the econometrician (such as lot size, number of bedrooms, number of bathrooms, etc.) and others are unobservable (i.e. quality of the unit's inner fixtures, size of the garden, etc). Across the regulation boundary, since the housing type and characteristics can differ, the price per housing unit will also differ. This is because the type of housing, in particular, the smallest housing unit available, changes at the boundary on the relaxed side of the boundary.[17] We call this effect **C** in Figure 2(b), where the jump in price per housing unit at the boundary is negative on the relaxed side (R) of the boundary. On a given side of the boundary, this effect is the same whether the housing unit is closer to or further away from the boundary. The housing character-

[17] In the case of DUPAC, the change can come from the smaller minimum lot size for R neighborhood. If maximum height changes across the boundary, the shift would be in number of floors.

istics effect **C** is crucial in our setting where we study all types of housing, and zoning regulations alter the characteristics and type of housing (single-family or multifamily), making different housing types mutually exclusive. This is unlike the literature which compares similar types of housing on either side of a given boundary.[18]

Indirect effect: Land use regulations can also affect the housing costs per unit at $x(d)$ because they alter the neighborhood density and neighbor demographics near $x(d)$. We call this externality the indirect price effect. If households dislike higher density (Strange, 1992), the indirect effect of relaxed land-use regulation on price per housing unit is negative, i.e., higher density would reduce prices. In Figure 2(b), we call this effect **D**. The indirect effect is continuous at the boundary $x = 0$ as housing units close to the boundary on either side are equally exposed to the neighborhood amenity of the other side. The effect of regulation spillovers of the neighboring side decays at rate π as one moves away from the boundary (Irwin and Bockstael, 2002; McConnell and Walls, 2005; Pennington, 2021). Note that the indirect effect only captures aforementioned neighborhood density (dis)amenities because differences in roads, municipal amenities, and schools have been removed (see section 4.4.1 for details).

Direct and Indirect Price Effects

Define *direct price effects* of land-use regulations on cost per housing unit as $V^{direct}(x) = A + B - C$ where,

$$V^{direct}(x, z^L, z^R, d, \gamma^\tau) = \begin{cases} V^{direct}(z^L) = \pi D & \text{if } x \leq 0 \\ V^{direct}(z^R) = A + B - C + \pi D & \text{if } x > 0 \end{cases}$$

Define $V^{indirect}(x, z, d, \gamma^\tau)$ as the *indirect price effect* on housing costs per unit at location x. With a general formulation of the utility over income after housing expenditure (U), we define the utility of living in location x, $u(x)$ as a function of both direct and indirect effects of regulation as follows:

$$u(x) = U(w - p(x, z, d))V^{direct}(x, z, d, \gamma^\tau)V^{indirect}(x, z, d, \gamma^\tau) \tag{1}$$

[18]For instance, Turner et al. (2014) compare single-family homes and Severen and Plantinga (2018) compare apartments on either side of the boundary.

Under the functional form of $U(x) = \exp^{(w-p(x))}$, the price per unit is given by:

$$p(x, z, d) = w - \nu^{\tau} + \ln(V^{direct}(x, z, d, \gamma^{\tau})) + \ln(V^{indirect}(x, z, d, \gamma^{\tau})) \tag{2}$$

4.3 Empirical Specification

We use a spatial RD design around regulation boundaries to estimate causal effects of regulation on (i) housing supply and unit characteristics, (ii) direct effects of regulation on housing costs, and (iii) indirect effects on costs to assess residents' valuations of surrounding residential density. From Equation 2 it follows:

$$\begin{aligned} p(x, z^L, d) - p(x, z^R, d) = \ln(V^{direct}(x, z^L, d, \gamma)) - \ln(V^{direct}(x, z^R, d, \gamma)) + \\ \ln(V^{indirect}(x, z^L, d, \gamma)) - \ln(V^{indirect}(x, z^R, d, \gamma)) \end{aligned} \tag{3}$$

Close to the boundary, where there is a density spillover from the more relaxed side to the more restricted side, the direct effect on price per unit can be estimated, holding fixed the indirect spillover effect. $-S \leq x \leq S$ correspond to sections B2 and B3 in Figure 2(b) and represent the cutoff distances at which direct effects are estimated (V^{direct}). As $|x_R - x_L| \to 0$, then:

1. At the boundary, regulations result in a jump in the number of units leading to sorting (equilibrium effect (A)), option value (B), and housing unit characteristics (C) and $\ln(V^{direct}(x, z^L, d), \gamma^{\tau}) - \ln(V^{direct}(x, z^R, d), \gamma^{\tau}) \to \rho_1$.
2. Neighbor and density composition varies continuously at the boundary and $\ln(V^{indirect}(x, z^L, d, \gamma^{\tau})) - \ln(V^{indirect}(x, z^R, d, \gamma^{\tau})) \to 0$.

When we take Equation 3 to the data where ($-S \leq x \leq S$), the RD model in Equation 4 estimates ρ_1–the combined effects of A, B and C. If an econometrician is able to condition on *all* observed and unobserved unit characteristics, the direct effect would only consist of the option value and equilibrium effect (B+A) for owners. To isolate option value B, one can compare land price per square foot for vacant parcels along the lines of Turner et al. (2014). In general, this framework cannot disentangle the equilibrium effect A from effects B and C as long as there is sorting at the boundary.

We estimate the direct price effects of regulations in levels rather than differences. The parsimonious regression specification is given by

$$Y_{xt} = \rho_0 + \rho_1 1\{\text{Regulation}_x\} + f_x(\text{dist}) + \lambda_x^{seg} + \phi_t + \epsilon_{xt} \quad \text{if} - S \leq x \leq S \tag{4}$$

where Y_{xt} is log monthly owner cost of housing for single-family homes or monthly rent for multifamily houses at location x in year t. Regulation$_x$ is either DUPAC, maximum height, multifamily allowed (0/1 dummy), or a combination of these three regulations at location x. $f_x(\text{dist})$ is a linear function in distance to the boundary estimated separately on either side of the boundary. λ_x^{seg} is the boundary fixed effect for boundary segment seg which captures differences in unobserved amenities at the boundary level, and ϕ_t are year fixed effects. Since house characteristics such as lot size are endogenous to the regulation, we do not control for them in this regression (Equation 4).[19]

We use a linear probability version of Equation 4 to study the effects of land use regulations on housing supply where Y_x is an indicator for either two- or three-unit buildings or four-plus-unit buildings relative to single-family homes. We focus on buildings that pre-date land-use regulations for our linear probability model specification i.e., buildings built after 1918 (or 1956 in appendix)–two critical dates in the history of land use regulation in Greater Boston (see Section 2.2). We also use these years to analyze the endogeneity of the regulations in section 4.4.2.

As one moves away from the boundary ($x < -S, x > S$), the regulation effect on housing cost per unit comes from both the direct and indirect effects. Define ρ_2, ρ_3 as the willingness-to-pay for density. For $|x_R - x_L| \to \epsilon > 0$,

1. $\ln(V^{direct}(x, z^L, d), \gamma^\tau) - \ln(V^{direct}(x, z^R, d), \gamma^\tau) \to \rho_1$.
2. Neighbors and neighborhood density differs as one moves away from the boundary so that, $\ln(V^{indirect}(x, z^L, d, \gamma^\tau)) - \ln(V^{indirect}(x, z^R, d, \gamma^\tau)) \to \rho_2, \rho_3$.

To estimate the indirect effects of land use regulations on house prices and rents, we focus on areas away from the boundary ($x > |S|$), i.e. segments B1, B4 in Figure 2(b). To disentangle the direct and indirect price effects, we estimate the following *hedonic* regression from Equation 3:

$$Y_{xt} = \rho_0 + \rho_1 1\{\text{Regulation}_x\} + \rho_2\theta_x^{HD} + \rho_3\theta_x^{GD} + \rho_4 h(x) + f_x(\text{dist}) + \lambda_x^{seg} + \phi_t + \epsilon_{xt} \tag{5}$$

[19]The appendix shows results where we control for the year a property was built, recognizing that structures built at different times can vary in quality and style, unrelated to zoning regulations.

Like in Equation 4, ρ_1 estimates the direct effect of the regulation. To study the effect of regulation spillovers we consider two measures of neighborhood density that households may have different valuations for –gentle-density and high-density.[20] Gentle-density, θ_{GD}, is given by the fraction of two- and three-unit buildings in a 0.1-mile radius of a given property x. High-density, θ_{HD}, is given by the fraction of four-plus-unit buildings in a 0.1 miles radius of property x. ρ_2 and ρ_3 are the coefficients of interest for estimating indirect effects. In contrast to the direct effects estimation in Equation 4, to estimate indirect effects we control for a rich set of unit-level attributes ($h(x)$) that affect prices such as year built, lot size, building area, number of bedrooms, etc.

Since neighborhood quality spills over across the boundary and there is no change in density or neighbors immediately at the boundary, we estimate this specification as a "donut RD" starting at $x = 0.1$ miles from the boundary on both sides. We show robustness with respect to bandwidth choice in Section 5.2.3. To disentangle the direct effects of A, B, and C from indirect effects D, we compare housing costs on the same side of the boundary with different distances to the boundary i.e. comparing segment B3 and B4 Figure in 2(b). We mention one caveat at this point. In this paper, we do not distinguish between the effect of higher density itself from changes in neighbor characteristics and neighborhood quality that follow from changes in residential density.

Differential Effects of Regulations on Supply

Not all (combinations of) regulations affect the supply of housing and, therefore, prices in the same manner. Allowing multifamily housing and maximum height regulations affect the *size* and *type* of housing, conditional on density. Consequently, we expect density and its interactions with other regulations to be the only regulations that increase units directly. Regulations that do not impact supply (in terms of number of units) are not expected to lower prices through the channel of increasing supply. For owners, relaxing any regulation increases the option value of the property i.e., it increases the future sales value of the land. Finally, the impact of residential spillovers is specific to the definition of spillovers used in this paper, i.e., the share of two- and three-unit or four-plus-unit homes within a 0.1 miles radius of a building. Therefore, regulations that

[20]We follow Baca et al. (2019) in their concept and definition of gentle-density.

affect the *type* of housing or the *number of units* should affect this share. The only regulation that affects neither the type of housing nor density is maximum height.

4.4 Exogeneity of Land-Use Regulation Boundaries

This section discusses the exogeneity of land-use regulation boundaries. To identify the causal effects of regulation, we need to assume that a) on both sides of the regulation boundary, the type of housing and density differ due to the regulation, b) close to the boundary, unobserved quality of the location does not change, and c) the location of zoning boundaries is as good as random. We address each of these assumptions in turn. To see that the regulation boundaries affect both the number of units built and the type of buildings built across the regulation boundaries see Section 5.1, Figure 4 and Table 3.

4.4.1 Amenities along Land-Use Regulation Boundaries

To ensure that across the regulation boundaries, major amenities associated with municipalities like taxes, government spending, and town-specific zoning laws on wetlands do not change, we compare houses across regulation boundary within towns. In addition, school quality is a primary location amenity for many households. To control for school quality variation, we compare buildings within the same elementary school attendance area. Additionally, many regulation boundaries may coincide with significant roads/highways or geographic features. To account for this and keep the latent quality of the location continuous at the boundary, we remove all regulation boundaries that intersect with highways, major roads, and geographic features like rivers, streams, and lakes. Lastly, we compare buildings within the same broader land-use type area, either residential or mixed-use. Figure 1 plots all remaining boundaries where either multifamily regulation, maximum height restrictions, or density units per acre changes either by themselves or together.

We check continuity of amenities across boundaries, by comparing buildings within 0.2 miles (or smaller) on either side Figures 3 and B.8 plot the coefficients on the distance bins from regressing distance to various neighborhood amenities on boundary fixed effects and 0.02 mile bins of distance to the boundary.[21] Negative distances (i.e. to

[21]of the permissible boundaries.[22] Throughout the paper we use straight line distances. One might be worried that these distances do not reflect actual travel distances. To assuage these concerns, Figure B.7

the left of 0) indicate the more regulated side of a boundary. As can be seen from the figures, distance to rivers, lakes, town center, major roads, closest elementary school, and open space is continuous at the regulation boundaries. We therefore confirm that amenities are continuous at the boundary.

4.4.2 Endogeneity of Land-Use Regulation Boundaries

There is a concern that zoning regulation boundaries themselves are endogenous to location or neighborhood quality (Davidoff, 2015). For example, Shertzer et al. (2016) find evidence in Chicago that historic industrial use zoning was disproportionately allocated to neighborhoods with racial minorities. Glaeser and Ward (2009) find that town population density in 1940 can explain 68% of the across-town variation in the 2004 average minimum lot size. Our analysis compares buildings within towns, school attendance zones, and land-use type (residential or mixed-use) to control for such a scenario. While we control for observed and unobserved amenities of a location such that they do not vary across the land-use regulation boundaries, another potential concern is that these boundaries would have been shaped around the historic building structures of the Greater Boston area. To address this concern, we study whether the type of buildings built before 1918 or 1956 (years of zoning adoption) differ by present-day observed regulation boundaries.

The linear probability model (LPM) laid out in Equation 4 tests whether present-day regulations predict the type of buildings built (either two- and three-unit apartments or four-plus-unit apartments versus single-family buildings) before 1918 or 1956. Table 2 shows the results from LPM model for buildings built before 1918 (see Appendix Table B.2 for buildings built before 1956). The type of building built (single-family versus multifamily) do not vary in statistically significant ways across boundaries where only density (DUPAC) and multifamily change. It seems that density and multifamily regulation boundaries were somewhat designed around both historic gentle-density (two- and three-unit) and high-density (four-plus-unit) buildings. This is also true, to some extent, for density and height boundaries, particularly regarding historic high-density

shows the correlation between straight line and walking distances across the boundaries in our sample. Since these two measures are highly correlated, we proceed with straight line distances.

buildings. Therefore, based on these results, we are more confident in the exogeneity of only multifamily, only DUPAC, and DUPAC and height regulation boundaries than the boundaries where multifamily and DUPAC restrictions change.

5. Results

5.1 Regulations and Supply

As highlighted in the previous section, different land-use regulations should differ in their effect on the supply of housing. In particular, multifamily zoning or relaxing height restrictions do not necessarily result in more units built unless these regulations are accompanied by relaxing density (dwelling units per acre). Following the methodology in Bayer et al. (2007), we regress number of units on boundary fixed effects and 0.02 mile bins of distance to the boundary. Positive distances indicate the more relaxed side of a boundary, negative distances the stricter side. We plot the distance coefficients and normalize the first bin on the relaxed side to 0. Standard errors are clustered at the boundary segment level. Figure 4 displays the results.[23] The optimal bandwidth calculated using Calonico et al. (2020) lies between 0.01 and 0.03 miles for all boundary types and dependent variables. For our figures, the closest distance bins to the boundary (0.02 miles) correspond to the optimal bandwidth and deliver estimates in line with the best practices in the literature.

As can be seen from sub-figures (a), (b), and (c) of Figure 4, relaxing density alone or in combination with allowing multifamily or relaxing height restrictions has the largest effect on increasing supply, as measured by the number of units built. Relaxing density restrictions alone results in an average 0.43 unit increase 0.02 miles from the regulation boundary. Relaxing both density and allowing for multifamily housing results in an average 0.45 unit increase, and relaxing both density and height restrictions results in an average 2.4 unit increase at 0.02 miles from the boundary. For these three regulation scenarios, the effect is persistent further away from the boundary and precisely estimated up to 0.2 miles from the boundary. While these effect sizes may seem small, there is an average of 1.6 units among buildings on both sides at boundaries where only

[23] See Section 5.2.3 for robustness in bandwidth choice.

density regulations change and both density and multifamily regulations change. There are 2.6 units, on average, at boundaries where both density and height change. This implies that the changes in these three regulation scenarios result in a 27-92% difference in the supply of units at the boundary.

As predicted, we see no effects at boundaries where either only height regulations change or where height changes along with allowing for multifamily homes. The number of units increases by 0.63 on the less restrictive side when only multifamily regulation changes. However, examining confidence intervals, this effect is not persistent away from the boundary. This result is consistent with recent examples of zoning reforms enacted in the U.S. city of Minneapolis, which allowed building two- and three-unit houses on land previously zoned for single-family use in 2018. Recent reporting has found that "only 23 building permits have been issued for new duplexes and triplexes in places they would not have previously allowed" (Webster and Corey, 2021).

To study housing supply differences, it is also important to look at the type of housing because the avenue of land-use regulation reform might be more effective at increasing the supply of particular multifamily housing types. To investigate this question, we run a linear probability model (equation 4) where the outcomes are indicators for the type of housing. The indicators take on the value one for gentle-density (two- and three-unit) or high-density (four or more units) properties respectively and are zero for single-family housing. We focus on a 2018 snapshot of buildings built after the adoption of the first height restrictions in 1918 i.e., buildings that were not grandfathered in. We interpret the effects of a given regulation as increasing the probability of a given multifamily house type *compared to* single-family housing.

Table 3 shows the results (see Table B.3 where we restrict to buildings built after 1956).[24] We find that allowing multifamily homes and relaxing density restrictions increases the probability of a given property being a gentle-density property compared to a single-family home. In particular, column 1 shows that the probability of gentle-density buildings more than doubles relative to single-family homes when multifamily homes are allowed. Effects for high-density buildings are similarly large but less pre-

[24] Also see Appendix Figure A.2 for an area-level housing supply measure.

cisely estimated (column 5) perhaps due to the smaller number of such buildings. Alternatively, this could point to the fact that facilitating the supply of larger apartment buildings is complicated by other factors such as higher construction costs and community opposition. Relaxing density restrictions by 4.4 units, the average difference across such boundaries, increases the likelihood of gentle-density construction by 14.4% (Table 3 column 2). Similarly, relaxing density by 6.3 units, the average difference across boundaries where both density and multifamily zoning regulations change, increases the likelihood of gentle-density construction by 15.8% (column 3). For this regulation scenario, allowing multifamily homes increases the probability of gentle density by 75.2%.

For the supply of high-density buildings, we continue to find a substantial effect of relaxing dwelling units per acre, either alone or by allowing multifamily housing. Relaxing density regulations by 4.1 units, the average difference across such boundaries, increases the likelihood of high-density construction by 34.1% (column 6). Similarly, increasing density by 5.9 units, the average difference across boundaries where both density and multifamily zoning changes, increase the likelihood of high-density construction by 78.7% (column 7). We find strong effects for boundaries where density and height regulations are relaxed, but only for high-density buildings. This sheds light on the large unit increase we find in Figure 4 (c) being driven by high-density properties. This is not surprising as such boundaries are often found in areas with high population density (see Figure 1 and Appendix Figure B.9) that are driving the effect.

5.1.1 Regulations and Housing Unit Characteristics

In addition to the number of units and type of buildings, the unit characteristics should also differ across regulation boundaries if regulations are binding.[25] Figure 5 highlights these results. Relative to the mean at boundaries where only density changes, we find a 3.9% decrease in number of bedrooms and a 9.5% decrease in number of bathrooms on the relaxed side of the boundary. Among boundaries where both multifamily and density change, we find a 6.5% decrease in living area square footage on the relaxed side. The lot size is defined at the building level for both apartments and single-family

[25] We find that about 40% of properties are binding in terms of maximum dwelling units ($\approx$ 8% violating) and less than 1% are binding in term of height ($\approx$ 15% violating).

houses, which explains why there is no effect in Figure 5d as larger apartment buildings require a larger footprint. Appendix Figures B.10 and B.11 further highlight these results.[26] Interestingly, we find almost no differences in unit characteristics at boundaries where height and density regulations change. Consequently, these boundaries seem to represent the cleanest shift in just the supply of observably homogeneous units.

5.1.2 Spatial Heterogeneity in Supply Effects

So far, we have concentrated on the average treatment effect of regulations, but these can be heterogeneous across space and vary depending on the distance to the central business district (CBD). For our spatial heterogeneity analysis, we follow the MAPC in their classification of towns into one of four categories (Appendix Figure B.12). The CBD represents the inner core. Suburban municipalities close to the CBD are mature suburbs, and municipalities further from the CBD are developing suburbs. Regional centers form self-contained local labor markets. We estimate supply effects separately for these four types of towns. In particular, we estimate the number of units, similar to Figure 4, across four town categories. Figure 6 plots the supply effects for various boundaries. The bandwidth for these analyses is the optimal bandwidth of 0.02 miles on either side of the boundary. We plot statistically significant coefficients at the 5% level (imprecisely estimated results are grey).

We find increases in the number of units across the inner core, the mature suburbs, and regional centers when regulations are relaxed. There are no statistically significant differences in the number of units across the regulation boundaries in the developing suburbs. A likely explanation is that zoning regulations do not bind in the more sparsely populated areas with more undeveloped land. At boundaries where only density changes, the inner core sees an increase of 1.5 units on the more relaxed side of the boundary while allowing multifamily homes and changing density leads to between 0.5 and 0.7 additional units in the regional centers and mature suburbs, respectively. As we highlighted before, the most significant increase in the number of units occurs at boundaries where height and density change together, with 2.6 units added on the re-

[26] Relative to the mean at boundaries where only DUPAC changes, we find a 10.4% drop in living area and a 25.9% decrease in lot size on the relaxed side. At boundaries where both multifamily and density change, we see a fall of 5.2% in the number of bedrooms and 5.7% fall in the number of bathrooms.

laxed side of the boundary in the inner core and 2 units in the mature suburbs.[27] Overall, the results indicate more substantial supply effects in areas with more binding regulation constraints, either due to high demand in the inner core or strict regulations in the mature suburbs.

5.2 Direct Price Effects: Housing Prices and Rents

5.2.1 Direct Price Effects of Regulations

We now discuss how land-use regulations affect the prices of single-family and rents for multifamily homes. Since we find that relaxing density alone and in combination with other regulations reliably increases the supply of all types of units while height regulations, either alone or with multifamily zoning, have no such effect, in this section we focus on regulations that interact with density (DUPAC) regulations from this point onwards. Concretely, we focus on density and combinations of density with maximum height and multifamily regulation, which amount to 77% of multifamily and 84% of single-family properties in our sample (Table 1). See Appendix Figure B.13 for the impact of non-density regulations on prices and rents.

Figure 7 plots the effects of regulations on the log of house prices (monthly owner cost of housing) for single-family (SF) homeowners and monthly rents for multifamily (MF) renters.[28] Following the same strategy we use in section 5.1, we regress log housing costs on boundary fixed effects, year fixed effect (2010-2018), and 0.02 mile bins of distance to the boundary. As noted in Equation 4, we do not control for housing unit characteristics which are endogenous. Standard errors are clustered at the boundary segment level. When only density regulations are relaxed, monthly rents in multifamily properties 0.02 miles away from the boundary are 5.4% lower on the less restrictive side than those on the more stringent side. This represents a 12.6% or \$144 lower rent per unit added in Figure 4 due to relaxed regulation. Meanwhile, the monthly housing costs for single-family property owners falls by an average of 7.2% (or 16.7% $\approx$ \$425 per

[27] The effects at boundaries where both height and density change are not statistically significant at the 5% level (t-statistics are 1.63-1.92). Nevertheless, we plot them because price effects at these boundaries are precisely estimated.

[28] The boundaries for multifamily and single-family homes are comparable. Less than 1% of properties in the sample lie at boundaries with no multifamily homes. Less than 2% of properties lie at boundaries with no single-family homes on either side.

unit added). Given that there is also an option value for single-family homes, which increases the price when regulations are relaxed, we conclude that the difference in unit characteristics (Effect C) outweigh the equilibrium effect (Effect A) and the option value (Effect B). This is in line with the recent literature (Pennington, 2021; Asquith et al., 2021). Viewed through the lens of our theoretical framework, the fact that house prices fall more than rents despite the opposing option value for single-family homes suggests that the effects from the change in house characteristics is larger for single-family homes than apartments when DUPAC is relaxed. Finally, the affordability impact of relaxing density is more significant for house prices than multifamily rents, making it more difficult to achieve politically.[29]

When DUPAC is relaxed and multifamily is allowed we can only consider the effect on single-family homes since multifamily homes are directly banned on the strict side of the boundary (Figure 7(c)). Monthly owner costs of single-family housing fall by 4.1% right at the boundary on the more relaxed side, with an increasing gradient as we move further away, indicating that negative externalities of density take over away from the boundary. These are substantial effects amounting to a 9.2% drop in monthly owner cost for each unit added (a decrease in $204 per month). As before, the house characteristics effect (C) seems to outweigh the option value (B) of relaxed regulation.

When density and height regulations change together (Figure 7(d,e)), monthly rents fall by an average of 6.2% at the boundary while there is no detectable effect on the prices of single-family homes. As the average number of units added on the relaxed side of this boundary type was over 2, the per-unit fall in rents is smaller at 2.6% or $27 per month. Monthly owner costs drop by 0.7% or $16 per month, though this effect is not statistically significant even near the boundary. These findings are further borne out in Table B.4 where we find negative effects on rents driven by the impact of relaxing density (we do not expect height alone to have a negative effect on prices). Returning to the model, the difference between the effects for rents and house prices could be explained through either the option value (Effect B) or differences in house characteristics (Effect C). In Figure B.11 we show that most house characteristics do not differ at this

[29] Anenberg and Kung (2020) also find limited effects of relaxing zoning on neighborhood rents.

type of boundary. In addition, Table B.4 (columns 5) shows that the marginal impact of height on prices is positive. Therefore, we think it is likely that the option value of additional height substantially counteracts the characteristics effects for single-family homes when density and height change together. Returning to Figure 1, we can see that boundaries where density and height regulations are relaxed together tend to be concentrated in the inner core with fewer single-family homes (Figure B.9) who may have different preferences than single-family homeowners away from the CBD.

For robustness, we show that the direct effects of regulations on single-family prices are similar if we use sales prices rather than assessed prices (Appendix Figure B.14). If we use only CoStar rents rather than both CoStar and imputed rents, we do not find any statistically significant differences in rents across regulations boundaries where density changes alone. The null results could be due to missing rental data for many buildings and the concentration of CoStar rental properties near the inner core of the metro area. When density changes along with relaxing height, we find rental effects similar to the baseline results (Figure B.14d).[30]

Another potential confounder for the results is that supply can vary from year to year in terms of its quality and type. For example, more recently built multifamily properties can have higher quality. This type of variation may not be related to regulations and can bias the direct price effects. Appendix Table B.5 shows results of equation 4 where we control for year built of the building. Compared to results from Table B.4, we find that when we control for the year built, there are no quantitative differences in the effects on rents. For single-family prices, we find that effect sizes are similar except for the effect of allowing multifamily homes, which shrinks considerably, suggesting that housing characteristics change systematically over time along these boundaries.

5.2.2 Spatial Heterogeneity in Direct Price Effects

In a monocentric city model, prices and rents offset the cost of commuting to the CBD where all jobs are located. Thus, the model would predict that relaxing binding land use regulations would have the highest potential of lowering prices further away from

[30] Figure B.14d shows that CoStar rents decreases if we exclude mixed-use properties from our sample. These properties represent only a small fraction in our full sample (3%) but represent 12% in the non-imputed CoStar sample.

the CBD. We estimate the direct price effect per unit supplied by estimating the effect of regulation combinations on prices (similar to Figure 7) and divide it by the first stage supply effect (Figure 6). Results are plotted in Figure 8 by MAPC community type.

Both monthly rents and house prices fall by 4.6% in the inner core at boundaries where only density changes (top panel). At boundaries where multifamily regulations and density change together, we find monthly house prices fall by 9.9% per unit in mature suburbs and 9.5% in regional centers, indicating that this combination of regulations might be a promising path to relaxing prices in established suburbs from which many households commute to the inner core. As before, it is not possible to calculate effects on rents in this scenario. The bottom left panel shows that boundaries where height and density change together affect rents in the inner core (decline of 3.3% per unit per month) and even more in the mature suburbs (decline of 9.7% per unit per month). Rents fall increasingly the further the distance to inner core as predicted in a monocentric city model and consistent with the results in Section 5.2. Note that the spatial pattern in the drop in prices is inverse to the increase in the number of units (Figure 6), demonstrating that, post zoning reforms, more units are added in the inner core than suburbs, but costs are less likely to fall in the inner core, perhaps due to higher demand and sorting. These figures show that the highest potential for reducing rents and home values lies in the mature suburbs rather than the inner core.

Summing up, we find that equilibrium effects and differences in house characteristics dominate the option value when relaxing density regulations. We also find that relaxing density with allowing multifamily housing strongly impacts house prices. When both density and height regulations change, we find strong decreases in rents and no change in the prices of single-family homes.

5.2.3 Bandwidth Analysis

We check the robustness of our price direct effect estimates by varying the RD bandwidth while estimating Equation 4. Figure 9 plots the direct price effect for the three main regulation scenarios for bandwidths ranging from 0.05 miles to 0.35 miles distance to the boundary in increments of 0.05 following the recent literature (Shanks, 2021; Severen and Plantinga, 2018). In addition to robustness, this analysis provides evidence of the presence of density spillovers.

Similar to the effects for single-family home prices (e.g. Figure 7b) and multifamily rents (e.g. Figure 7a), we see a steeper price gradient for single-family home prices further away from the boundary than we do for rents. Thus, for single-family homes, the spillover effects at the boundary (π) decays fast (right panels of Figure 9).[31] In almost all cases, the larger the bandwidth, the more negative the effect on single-family house prices of relaxing regulation. These plots look similar to Figure 2, where there is a direct effect at the boundary and then an indirect effect that decays over space. This provides suggestive evidence that in addition to the direct effect stemming from house characteristics, option value and equilibrium forces that jump discontinuously at the boundary, single-family households have a *distaste* for density which manifests itself more at an increased distance to the boundary.[32] Consequently, we expect to find a negative coefficient of residential density in equation 5 for single-family prices.

For renters (left panels of Figure 9), we find that the direct effect is not sensitive to the choice of bandwidth across all regulations.[33] As we have already shown using the optimal bandwidth that a direct effect of the regulation exists, we predict from these figures that we will not see strong indications of indirect effects on rents when we estimate equation 5 (Section 5.3).

5.3 Indirect Price Effects: Housing Prices and Rents

In this section, we study the indirect effects of the regulations, recognizing that zoning regulations can change the neighborhood's perceived quality by changing neighbor demographics and neighborhood density. For example, increasing housing supply through DUPAC increases density, indirectly lowering housing costs if people prefer to live in less dense areas. This difference in housing costs can be considered a willingness to pay for density. As highlighted in Section 4.2, we can disentangle the direct and indirect effects of the regulation by comparing prices directly at the boundary to those further away. Comparing places away from the boundary gives us the joint effects of

[31] Appendix Figures A.3 and A.4 address the concern that these gradients might be driven by the next-closest regulation boundaries.

[32] Density is not disliked everywhere. Anagol et al. (2021) find positive taste for density in Sao Paulo.

[33] The 0.05 miles coefficient slightly diverges, but is not statistically different from others.

option value, house characteristics, sorting and density amenity (Figure 2).

The findings from bandwidth selection robustness are supported by Table 4 which reports the results from estimating equation 5. Here buildings are considered within 0.1 to 0.3 miles around the zoning boundary (see Table B.6 for alternative bandwidths). Table 4 highlights the indirect price effects for different neighborhood density – the share of high-density (four-plus-unit buildings, θ_{HD}) and gentle-density (two- and three-unit buildings, θ_{GD}) within a 0.1-mile radius of a property. We find a wide range of coefficient sizes for multifamily renters–almost none precisely estimated, corroborating the findings in Section 5.2.3 that there is no significant preference for residential density among renters (Table 4 top panel). Therefore, the only effect of regulations on rental prices is through the direct effect.

The bottom panel of Table 4 highlights the extent to which single-family homeowners might dislike living in denser areas. These coefficients are negative and generally precisely estimated. As the bandwidth analysis suggested, we find sizable negative effects of higher neighborhood gentle-density on owner costs of housing at boundaries where density regulations change, either alone or with multifamily zoning and/or with height changes.[34] An increase in the share of the gentle-density of 1 percentage points results in 0.17 (0.21) percentage points falls in monthly owner cost of housing at boundaries where only density regulation (density and multifamily regulation) changes. This is not surprising given that these boundaries have, on average, higher density (10.3 units) than the other boundaries (5.2 units when only density varies and 6.7 units when density and multifamily regulations vary).

A possible confounding explanation for negative coefficients on density that is unrelated to neighborhood density itself is that parcels away from the boundary might be different than parcels at the boundary. Due to the spillover right at the boundary this does not seem unreasonable. In Table B.7 we compare parcel characteristics at the boundary to those away from the boundary for different definitions of boundary vs in-

[34] Counter-intuitively, the negative effect sizes are larger for neighborhood gentle-density than for high-density, implying that homeowners dislike two- and three-unit buildings in their immediate vicinity more than four-plus-unit homes. Figure B.9 shows that this is misleading and is likely to be because single-family homes rarely lie directly next to high-density properties.

terior. A comparison of means shows that the number of bedrooms and bathrooms are slightly higher away from the boundary and the living area is slightly larger. These differences are likely driven by the comparison on strict sides of the boundary (in Figures 7 there is a visible gradient on the strict but not the relaxed side of the boundary). While we control for observable building characteristics in regression 5, it seems possible that part of the effect captured by θ_{GD} and θ_{HD} might be a result of single-family home characteristics changing in ways that are not observable to us.

When considering different avenues for zoning reforms, it is crucial to consider the direct and indirect effects to avoid the pitfalls that new construction can generate from neighborhood opposition. Relaxing density restrictions alone or in combination with multifamily zoning increases supply and decreases rents and single-family house prices. In contrast, relaxing density and height restrictions in higher density areas reduce rents but not single-family house prices through direct or indirect channels. Both the bandwidth and indirect effects analysis point towards single-family home residents, unlike multifamily residents, disliking living near higher density.

Finally, Appendix Figure B.15 plots the indirect price effects for homeowners following equation 5 across the 4 MAPC community types. The effect of density on house prices in mature suburbs is unambiguously negative for both high and gentle neighborhood density and across boundary types. We find the largest negative effects in mature suburbs for gentle-density at boundaries where height and density change together. Figure B.16 shows corresponding indirect effects for renters. This finding, when paired with the previous results, implies that while mature suburbs have one of the largest potentials for increasing supply and lowering prices, this is likely to come at the cost of homeowners' perceived neighborhood quality.

6. Policy Effects of Relaxing Land-Use Regulations

We evaluate the consequences on housing costs of a small change in the land-use regulation within an 0.3 mile radius of a single train stop at a time. This policy experiment is based on the 2021 amendment to Massachusetts's Chapter 40A law (Zoning Act) amendment requiring communities to zone for multifamily development and allowing density of at least 15 units per acre near metro transit stops. [35] Our framework is well suited to study such small changes in limited areas.[36]

The thought experiment is to relax regulations on the stricter side of the boundary (L) up until location $\underline{x}$, while holding the regulations on the relaxed side fixed. Denote the vector of new land-use regulation as z_1^L and old regulations as z_0^L such that for each location x for $\underline{x} < x < 0$, $x(z_1^L) = x(z_0^L) + \Delta$. Let $\bar{P}_1(\underline{x})$ and $\bar{P}_0(\underline{x})$ denote the average final and initial housing cost. Let $\bar{P}_i(\underline{x})$ be defined as $\bar{P}_i(\underline{x}, z_i^L, z_i^R) = \frac{1}{\underline{x}} \int_0^{\underline{x}} p(x) d(x)$ for $i = 0, 1$. Then, the average change in housing costs near the transit stations is given by

$$\Delta \bar{P}(\underline{x}) = \frac{1}{\underline{x}} \int_0^{\underline{x}} \Big(\ln(V^{direct}(x, z^1)) - \ln(V^{direct}(x, z^0)) + \ln(V^{indirect}(x, z^1)) - \ln(V^{indirect}(x, z^0)) \Big) d(x) \tag{6}$$

Figure 10 plots the average change in monthly owner costs and rents from relaxing land-use regulations near 23 metro and commuter rail transit stops across Greater Boston. We picked transit stations to reflect various community types and regulation scenarios. Following equation 6, we calculate the difference in prices between new and old regulations stemming from the sum of differences in direct and indirect effects. We calculate the price effects for a 10% relaxation in DUPAC, 10 feet (1 floor) increase in height, and a switch from 0 to 1 in allowing multifamily housing. We take into account the land-use regulation scenario and regulation levels currently in place at a transit station and calculate the price effects of a regulation change within 0.3 miles of a given transit station. To estimate changes in indirect effects, we calculate the implied changes in the supply of 2-3 unit housing from equation 4 and value this change using ρ_3 in equation 5.[37]

As can be seen in Figure 10, monthly owner costs and prices fall by up to $770. The figure plots changes in housing costs for the regulation scenario with the highest impact at a given station. A small-scale relaxation of land-use restrictions almost always lowers

[35] The January 2021 amendment to M.G.L c. 40A (the Zoning Act) was part of the broader Enabling Partnerships for Growth Act passed by the Massachusetts state legislature. While the amendment was passed in 2021, it did not go into effect until January 2022.

[36] It is not well-suited to study general equilibrium effects from large-scale land-use changes.

[37] In spatial heterogeneity analysis, we do not find statistically significant effects on supply of 4-or-more unit housing. Therefore, we focus on the supply of two- and three-unit unit housing.

house prices, but rents fall intermittently (yellow points represent results with no statistical significance).[38] The fall in rents and owner costs is lower (not more than $100 per month) in the inner core. Prices decrease more in the mature suburbs (such as Needham Heights station in Needham, and Wellesley Hills and Wellesley Square stations in Wellesley). Wellesley Square station highlights that boundaries where height and density change together can lead to significant rent decreases ($530 per month) with almost no reduction of house prices ($15). Allowing multifamily housing and increasing density near Wellesley Hills stop would significantly decrease monthly owner cost ($766), while increasing allowed height in combination with density would reduce rents by $600.

The importance of relaxing height and density together for reducing rents is overlooked in current policy making. Circling back to Massachusetts Chapter 40A amendment, after a 10% relaxation in density and allowing multifamily homes, Newton Highlands Station in Newton and Swampscott Station reach densities of over 10 dwelling units per acre, thereby moving considerably closer to the policy goal. The other towns in the mature suburbs that we consider in this calculation are even further away from reaching this threshold. In many of those towns, reaching 15 dwelling units per acre would require a 5-fold or more increase in the density, which is far from the small changes that we can consider within our framework.

7. Other Local Barriers to Reducing Housing Costs

7.1 Local Town Governance and Land Regulations

Local governments in Eastern and Midwestern states of the U.S. set zoning laws and review new housing projects at the municipality (town) level. The four types of local governments in Massachusetts are the Mayoral system (40.87% of sample properties), Town Manager system (7.26%), Open Town Meeting (OTM, 18.93%), and Representative Town Meeting (RTM, 32.94%), where the latter two are more common in smaller towns (see Figure B.17). These local governance structures have different approval processes for new construction. For example, in OTM, any local voter can attend and vote

[38] Molloy et al. (2020) also find that zoning regulations increase house prices more than rents because because supply constraints increase the expected future rent.

in zoning matters, while voters select representatives to attend town meetings in RTM, Council, and Mayor system. Thus, one can expect heterogeneity in the supply and price effects of zoning regulations across different forms of local governance. While we do not observe changes in town governance structure in our sample, we run our housing supply and price analysis separately by local governance structure. These results should not be interpreted as causal effects of governance structure.[39]

For municipalities with OTM or Mayoral structure, we find positive effects of increasing dwelling units per acre on both gentle and high-density supply (Appendix Table B.8). We also find that allowing multifamily homes in combination with relaxing density increases both gentle and high-density supply. However, we see much smaller and imprecise effects for towns with RTM. This result is in line with the recent literature, finding that it is harder to build multi-unit housing in places with a more representative town structure (Hankinson and Magazinnik, 2020). The intuition behind this result is that in OTM, powerful constituencies with higher participation (along the lines of Einstein et al. (2019)) can concentrate new housing in already dense areas.

In towns with OTM or Mayors, which saw the highest increase in supply from relaxed regulation, we find that multifamily rents fall by 4.6% when DUPAC increases by average 15.3 units under the Mayoral system (Appendix Table B.9). Single-family prices fall by 8.7% and 1% when DUPAC increases by average 5.1 units under OTM and mayor structure, respectively. Along boundaries where both multifamily and DUPAC are relaxed, the fall in single-family prices at the boundary is 8.7% for OTM, 7.0% for RTM, and 4.3% for Mayor system.[40] Additionally, we find indirect price effects along boundaries where only DUPAC regulation changes and both DUPAC and multifamily regulations change. In particular, preferences for higher density are negative throughout, particularly for single-family home prices. The effect sizes are more extensive for towns with Mayors and RTM than those with OTM. We conclude that the type of town governance structure is strongly related to the effectiveness of a given land-use regulation. These effects

[39]We show results for boundaries that are most represented across all types of towns and governance structures (DUPAC, DUPAC and multifamily). Town Manager system is omitted due to low sample size.

[40]Effect is calculated by relaxing multifamily regulation (0 to 1) when average DUPAC is 4.0, 4.7, and 15.6 units, respectively.

go beyond capturing heterogeneity between towns closer to the central business district and different types of suburbs. Understanding these effects has important policy implications because relaxing regulations will have a different impact when channeled through different forms of town governance.

7.2 Inclusionary Zoning and Land Regulations

Relaxing zoning regulations is just one tool available for policymakers who are seeking to expand the supply of housing. Inclusionary zoning like Massachusetts' Chapter 40B represent an alternative.[41] To examine how Chapter 40B affects housing affordability we study the effect zoning differences have on the supply of Chapter 40B properties. We test if inclusionary zoning is a substitute or complement to relaxed land-use regulations using Equation 4.[42] Results are presented in Appendix Table B.10 for boundaries where all three key regulations change as these are the only boundaries where we find precise effects, given that Chapter 40B buildings are concentrated near the city center (Figure B.9) where this type of boundary is also found (Figure 1).

In areas where multifamily zoning is not allowed, the only single-family Chapter 40B buildings are built. Chapter 40B multifamily apartments are mostly constructed in areas where multifamily zoning is allowed (1.8 percentage points increase). Thus, Chapter 40B acts as a complement for relaxing multifamily zoning, at least for multi-unit buildings. When multifamily housing is allowed and height and DUPAC restrictions are lower, the supply of all Chapter 40B buildings increases. In particular, the supply of affordable *multifamily* buildings increases by 2.1 to 25.2 percentage points.[43] Thus, Chapter 40B has acted as a complement to more lax land-use regulation.

Given the estimates from Table B.10, the total probability for a multifamily 40B building to be built is 28.9 percentage points if we sum over all the joint effects when all three regulations change.[44]. The 28.9 percentage points estimate represents an upper bound

[41]Note that Chapter 40B can still face community opposition and many local approvals are overturned later by state courts in lengthy litigation processes (Greenberg, 2021).

[42]We use a wider bandwidth ($C = 0.5$ miles) for these regressions since there are only 522 Chapter 40B buildings in 86 towns, and even fewer around regulation boundaries.

[43]The effect of relaxing DUPAC by average 17.4 units change across boundary is 2.1 percentage points. The effect of relaxing height by average 2.1 floor change across boundary is 25.2 percentage points.

[44]Fisher (2007) finds that 44% of 369 40B applications were actually built in 1999-2005. The remaining 205 applications were either not approved, approved but appealed, or approved and not built

of approval rates, and in many areas this approval probability is likely to be close to zero given that in many municipalities we observe no Chapter 40B buildings. Given this probability, to increase the current multifamily 40B building stock by 50% to 141 buildings, there would need to be an estimated 488 building applications (3.5 times more than are currently made). Since developers are unlikely to bring forward such a large number of applications, the approval probability would need to increase significantly for inclusionary zoning policies like Chapter 40B to make a significant dent in affordability. In addition, new Chapter 40B buildings are more likely in areas with lower regulation, given the complementary of land-use regulations and inclusionary zoning.

8. Conclusion

This paper highlights which zoning regulations might be most effective at increasing the supply of multifamily housing and reducing housing costs, thereby contributing to broader housing affordability. We find that relaxing density restrictions alone and in combination with relaxing maximum height restrictions and allowing multifamily homes are the most effective ways of increasing the supply of multifamily buildings and reducing multifamily rents and single-family home prices. However, allowing multifamily housing alone without increasing density is less likely to increase the supply of apartments and lower rents. Furthermore, the fall in prices from relaxed regulations comes from two sources: directly from the change in regulation, which changes the size and types of housing built in an area, and indirectly through changes in neighborhood density. Therefore, while lowering housing costs through zoning reforms may help first-time home-buyers and lower-income renters, it comes at the expense of —and thus will likely generate substantial political opposition from—current homeowners.

In addition, our results indicate that the impact of relaxing regulations on supply and prices is filtered through spatial and local governance differences. In line with this, we find that making small changes to zoning regulations, such as relaxing density by 10% near transit stations, could reduce monthly house prices and rents by up to $770 (average decrease in monthly rent by $123 and the average decrease in monthly owner cost by $247), with larger decreases in the suburbs of Boston than the inner core. One should note that even with relaxing zoning, very low-income households may not find housing affordable to them, so relaxing land-use regulations do not substitute for rent-subsidized housing.

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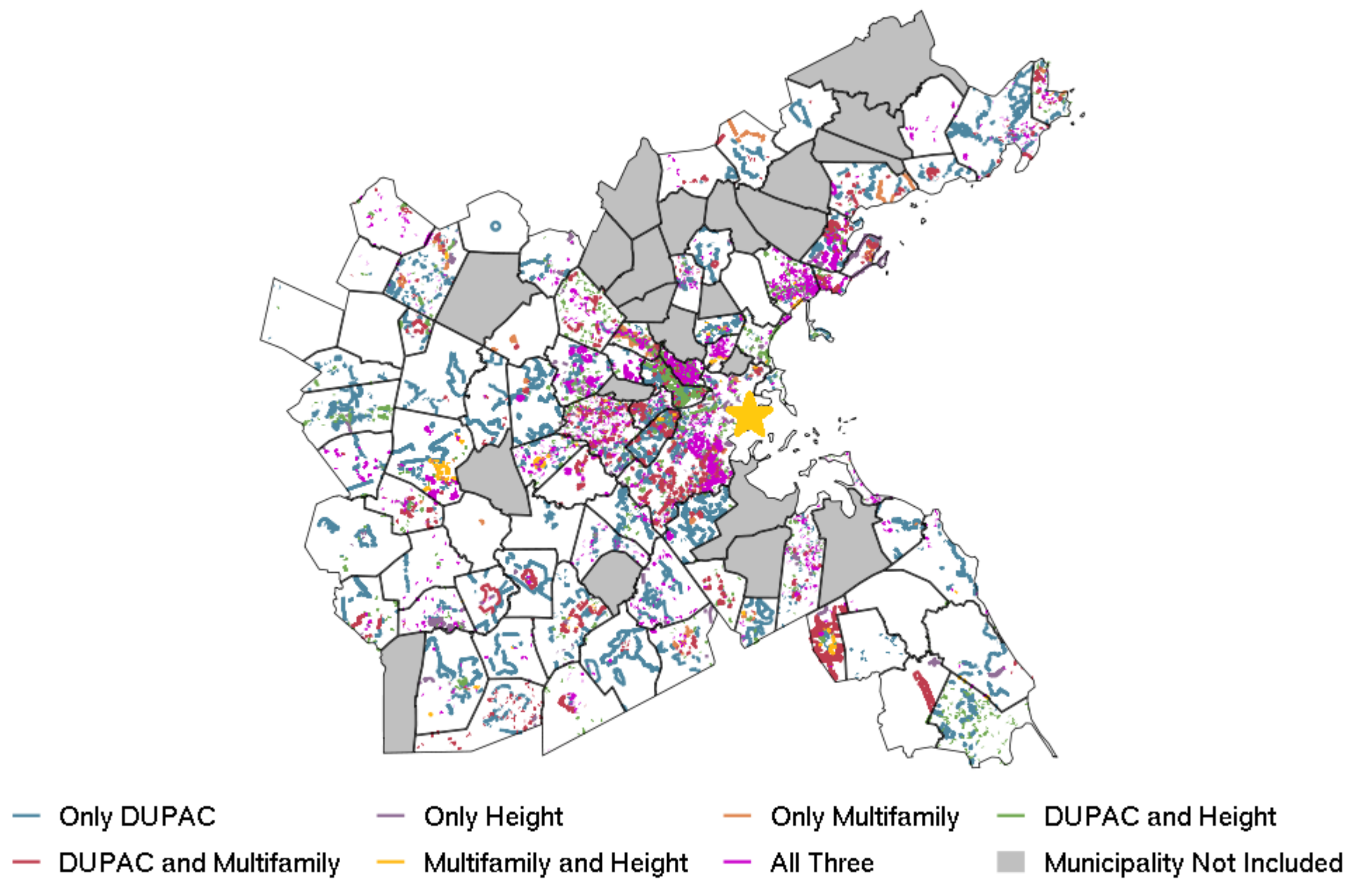
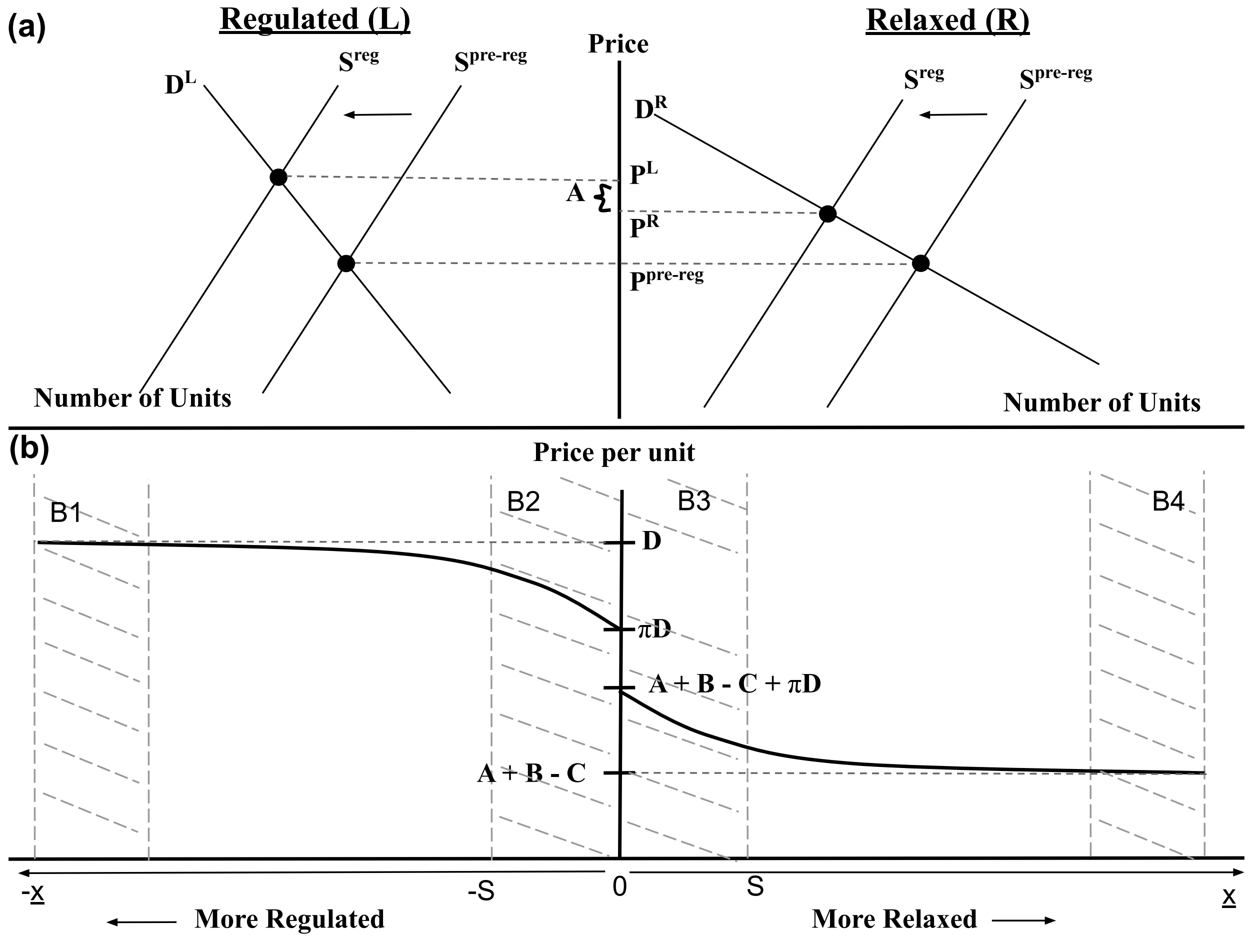
Figure 1: Boundaries with Differences in Land-Use Regulations



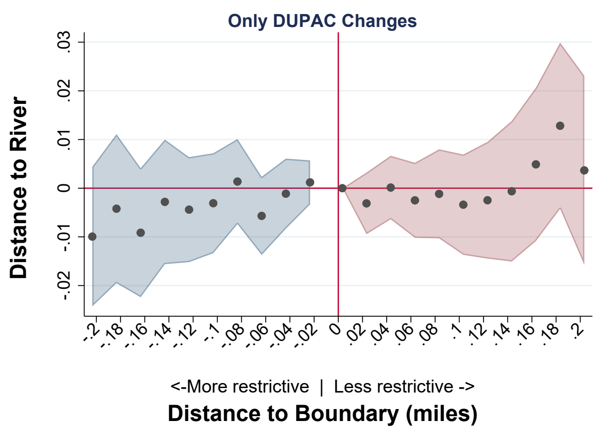
Note: This map shows the boundaries where multifamily (MF) regulation, maximum height restrictions, and dwelling units per acre (DUPAC) changes either by itself or in combination with another regulation change. "Changes"refers to cross-sectional differences in the regulations on either side of the boundary. The figure plots the final sample of boundaries which excludes regulation 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. These do not include regulations boundaries that overlap with major roads or geographic features. The base maps for these boundaries can be found in Appendix Figures B.1, B.2, and B.3. * denotes city of Boston.

Figure 2: Price Effects at Regulation Boundary

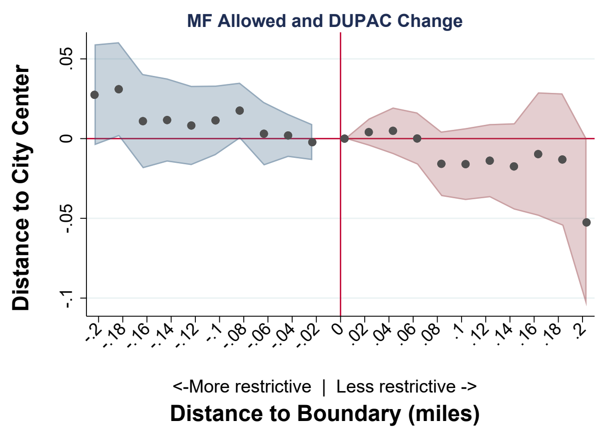


Note: Panel (a) of this theoretical figure plots the Equilibrium Price Effect **A** from Section 4.2 across the boundary $x = 0$ on the Regulated (L) and Relaxed (R) sides of the regulation boundary. Panel (b) plots the price per housing unit across both sides of regulation boundary. In addition to Equilibrium Effect **A**, it also plots the effect of Option Value **B**, Housing Characteristics **C**, and Indirect Price Effect **D**. While effects A, B, and C jump discontinuously at boundary $x = 0$, neighborhood density amenity ($D = V^{direct}$) is continuous at the boundary but decays away from it at rate π. For $-S \leq x \leq S$ or segments B2 and B3, we estimate the direct price effect ($V^{indirect}$) of regulation while neighborhood amenities remain constant. Moving away from the boundary, indirect price effects can be estimated for segments B1 and B4. See Section 4.2 for details.

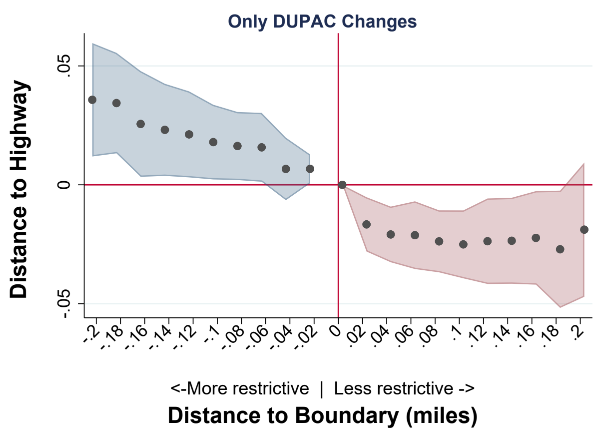
Figure 3: Amenities at Regulation Boundaries



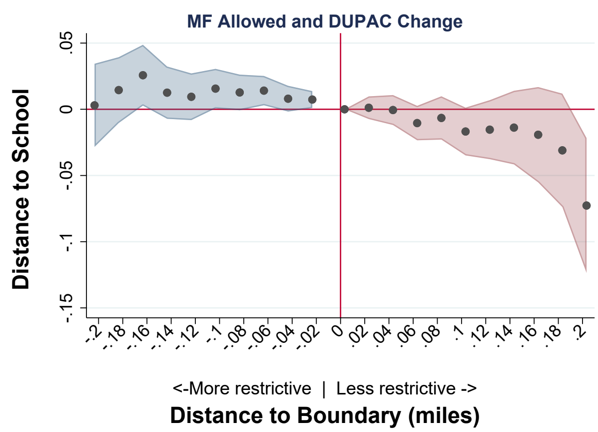
(a) River/Lake RD estimate = 0.001, (t stat = 0.52)



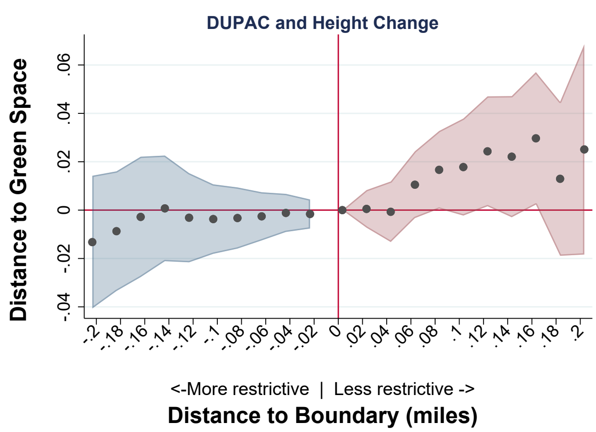
(b) Center RD estimate = -0.002, (t stat = -0.39)



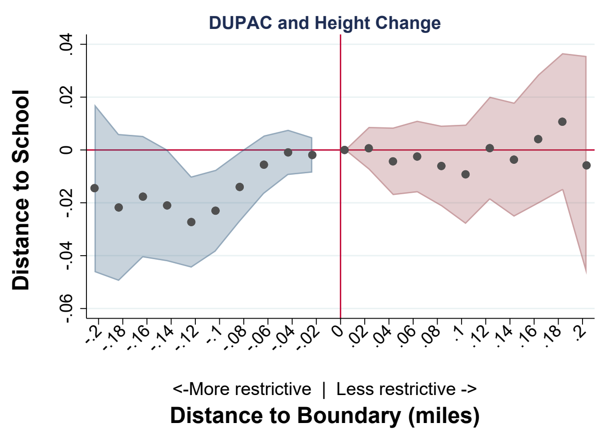
(c) Road RD estimate = 0.007, (t stat = 2.16)



(d) School RD estimate = -0.007, (t stat = 2.25)



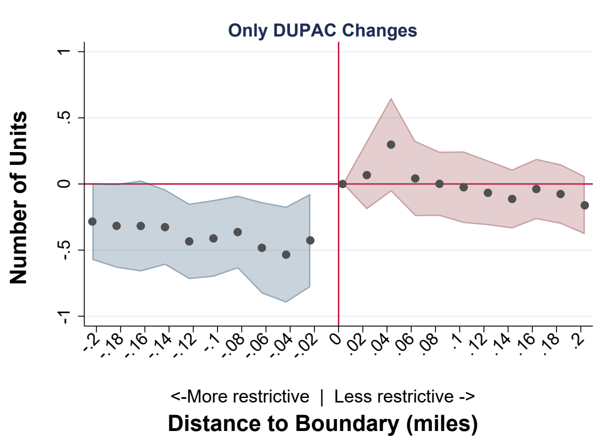
(e) Open Space RD estimate = -0.002, (t stat = -0.52)



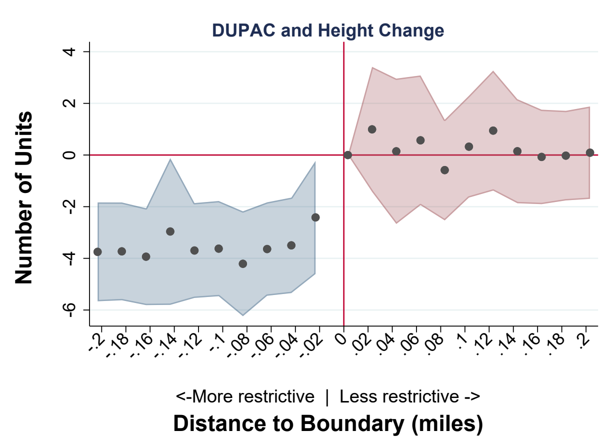
(f) School RD estimate = -0.002, (t stat = -0.56)

Note: Plots are created by regressing distance to amenities in 2018 on boundary fixed effects and distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. 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. DUPAC is Dwelling units per acre and MF is multifamily zoning. Standard errors are clustered at boundary segment level.

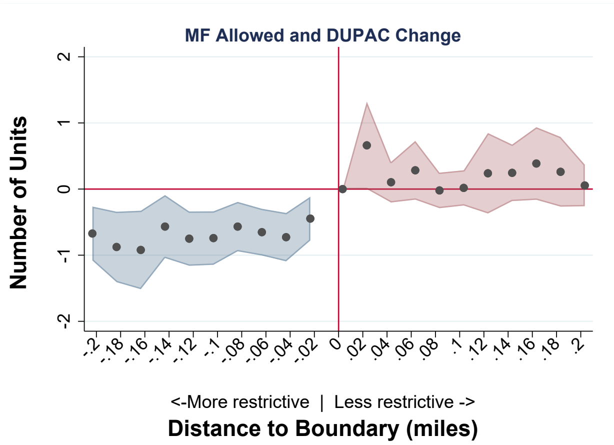
Figure 4: Effect of Regulations on Supply of Number of Units



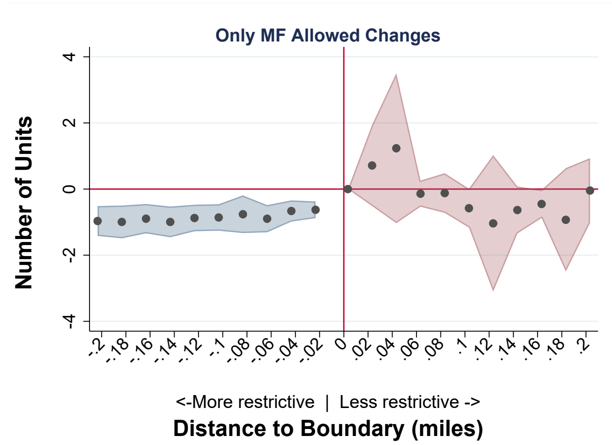
(a) RD est. = -0.43 (t-stat = -2.37), n = 85,015



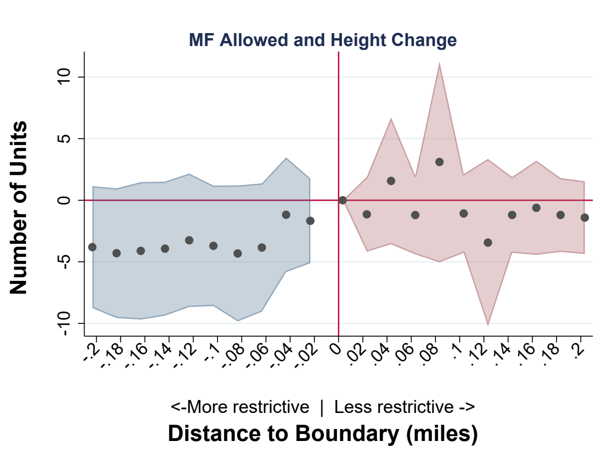
(b) RD est. = -2.42 (t-stat = -2.17), n = 15,574



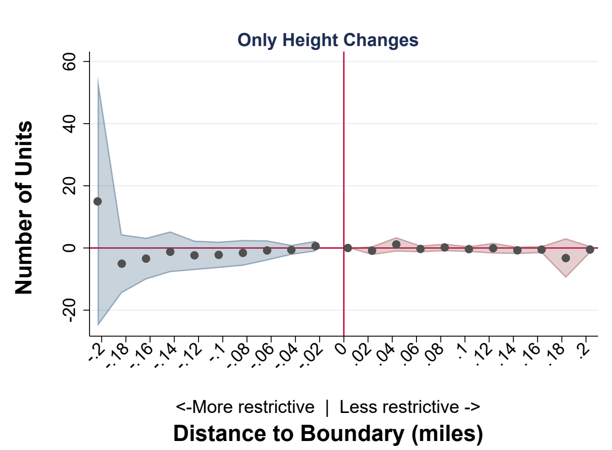
(c) RD est. = -0.45 (t-stat = -2.65), n = 37,212



(d) RD est. = -0.63 (t-stat = -4.90), n = 4348



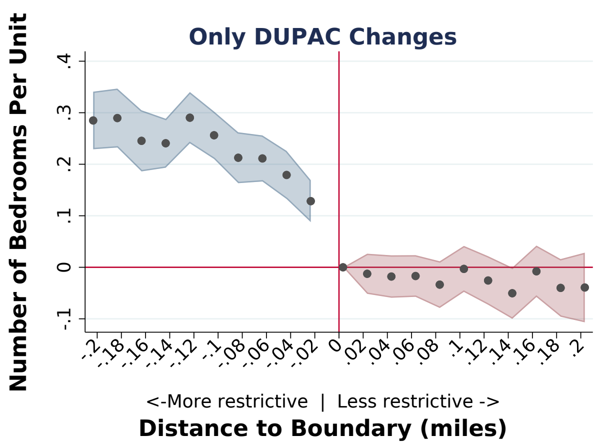
(e) RD est. = -1.67 (t-stat = -0.97), n = 2345



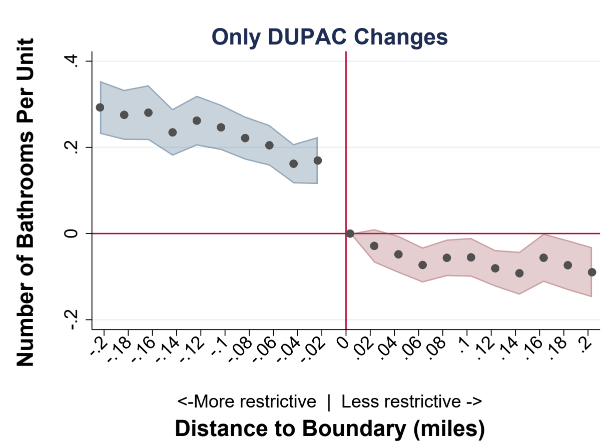
(f) RD est. = 0.60 (t-stat = 0.69), n = 6214

Note: Plots are created by regressing number of units in 2018 on boundary fixed effects and distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. All buildings are built after 1918. 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. Dwelling units per acre is DUPAC and multifamily allowed is MF. Standard errors are clustered at the boundary segment level.

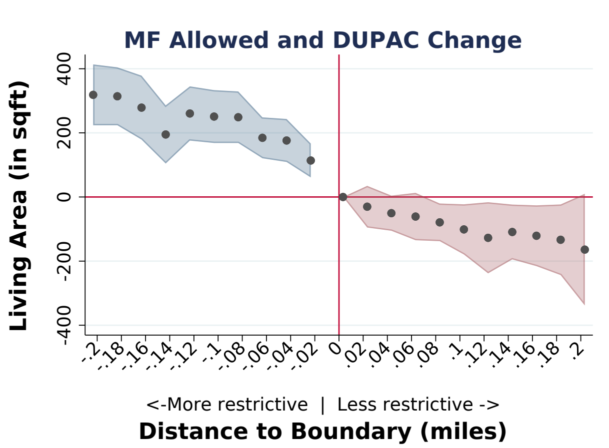
Figure 5: Housing Characteristics at Regulation Boundaries



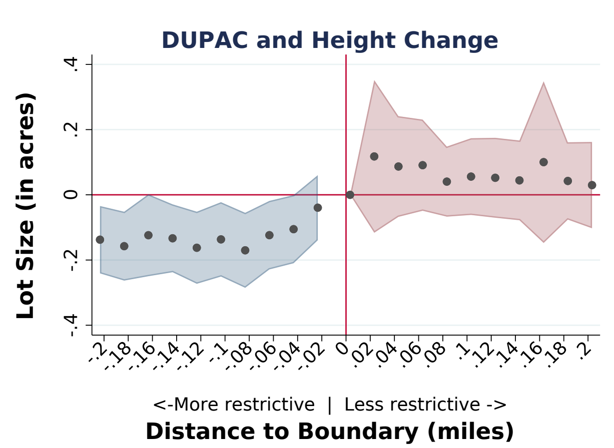
(a) RD est. = 0.13 (t stat = 6.18), n = 76,499



(b) RD est. = 0.17 (t stat = 6.08), n = 76,995



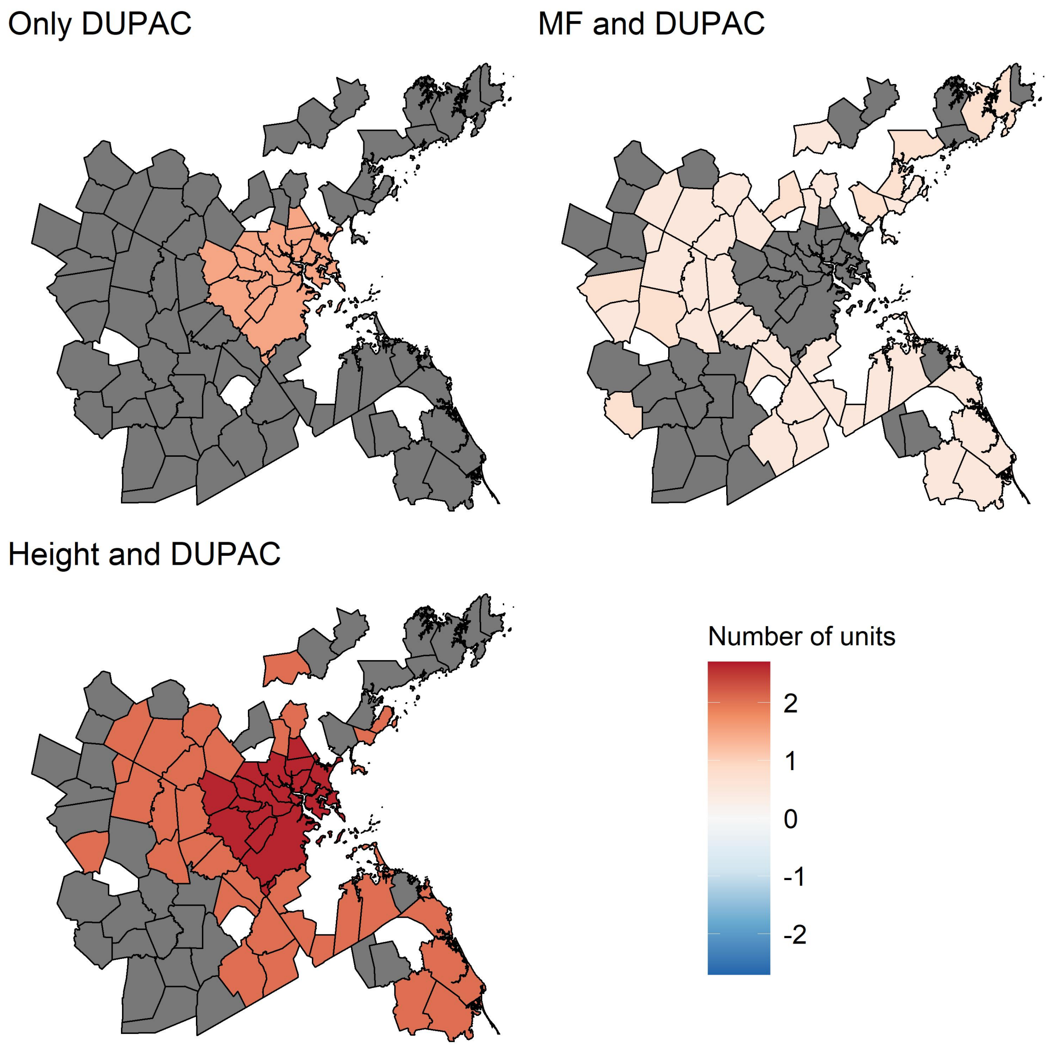
(c) RD est. = 113.8 (t stat = 4.23), n = 30,826



(d) RD est. = -0.04 (t stat = -0.78), n = 3699

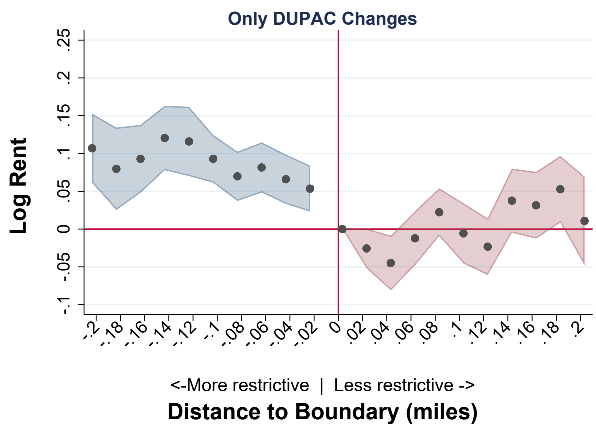
Note: This figure plots building characteristics across regulation boundaries in 2018. Plots are created by regressing unit characteristics on boundary fixed effects and distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. Negative distances indicate more regulated side. Bin closest to boundary on less 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 zoning. Standard errors are clustered at the boundary segment level.

Figure 6: Effects of Regulations on Supply across Space

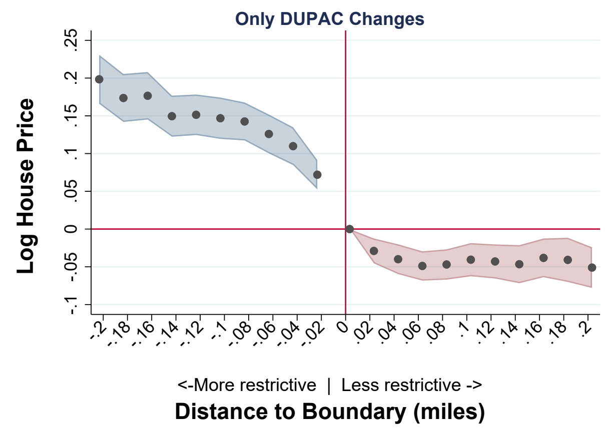


Note: These figures highlight the effects of different (combinations of) regulations on the number of units by community type in 2018. For each community type, we regress the number of units on boundary fixed effects and distance to boundary (bins of 0.02 miles) as in Figure 4. The effect we show here is the coefficient on the distance bin from 0-0.02 miles on the stricter side of the boundary relative to 0-0.02 miles on the relaxed side. Grey areas represent areas without statistically significant results for the number of units or without statistically significant price results in Figure 8. Standard errors are clustered at the boundary segment level.

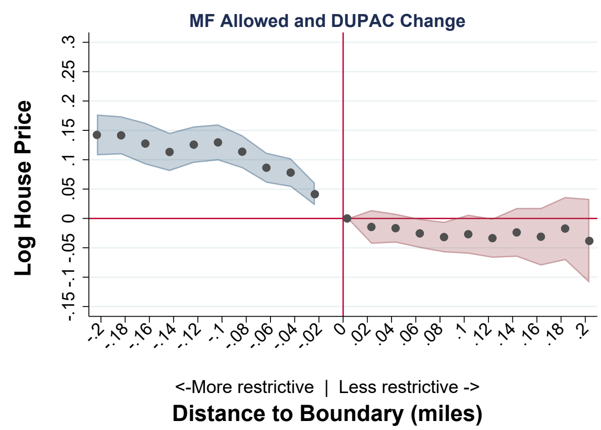
Figure 7: Effects of Regulations on Rents and Owner Costs of Housing



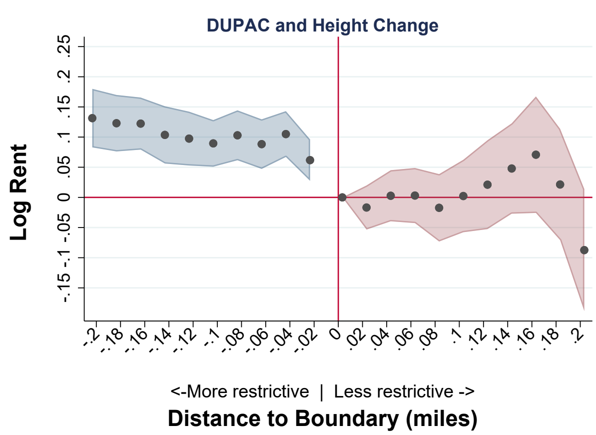
(a) RD est. = 0.054 (t-stat = 3.44), n = 175,740



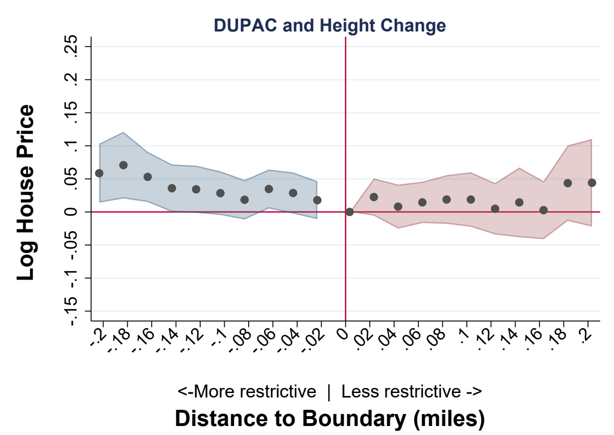
(b) RD est. = 0.072 (t-stat = 7.27), n = 783,003



(c) RD est. = 0.041 (t-stat = 4.19), n = 306,654



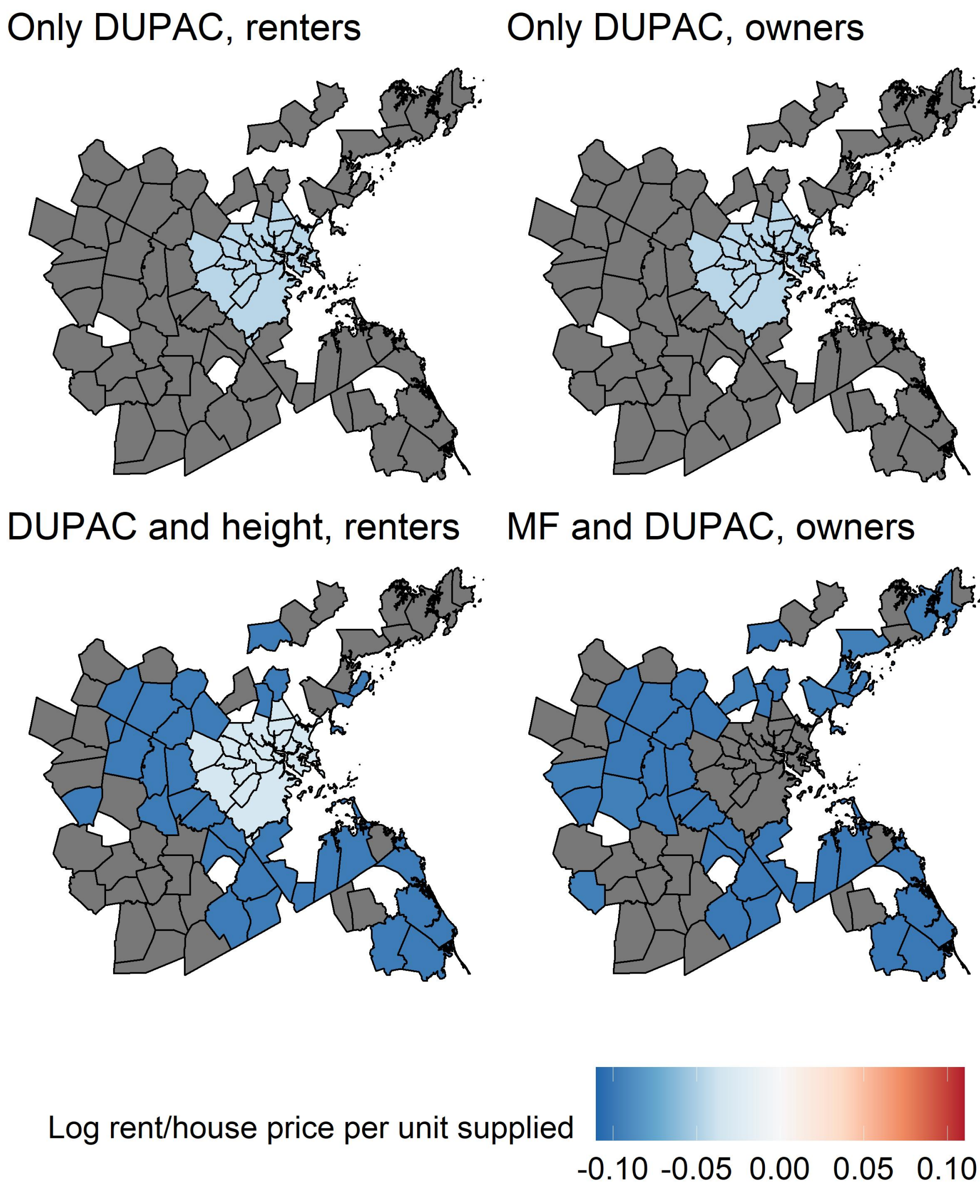
(d) RD est. = 0.062 (t-stat = 3.53), n = 135,975



(e) RD est. = 0.018 (t-stat = 1.21), n = 130,920

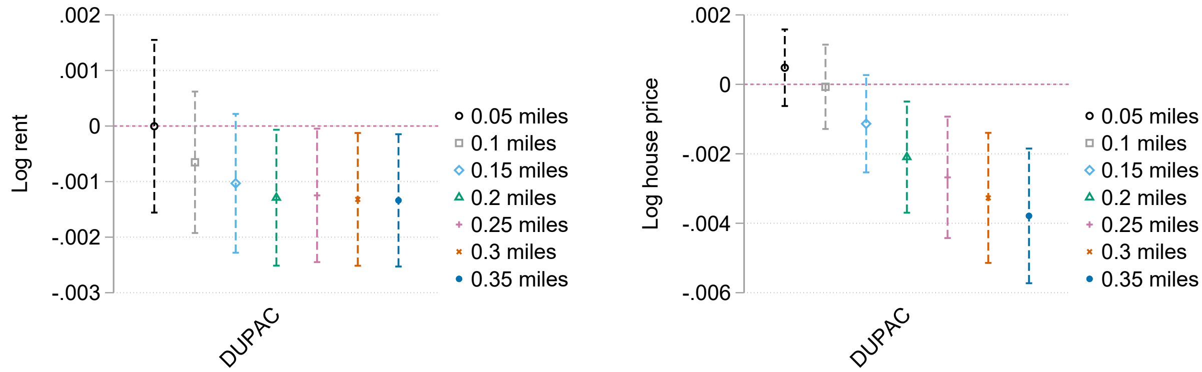
Note: Plots are created by regressing log prices on boundary fixed effects, year fixed effects [2010-2018], and 0.02 miles bins of distance to boundary. Coefficients on distance bins are plotted. Negative distances indicate the more regulated side of a boundary. The bin closest to boundary on less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown. Left panel indicates effect on monthly rents for multifamily (MF) buildings. Right panel indicates effect on monthly owner cost of housing for single-family houses. The unit on DUPAC (dwelling units per acre) is in 1 housing unit. Standard errors are clustered at the boundary level. Since there are no MF builings on one side of a boundary where allowing MF and DUPAC changes, we do not show results on rents.

Figure 8: Effects of Regulations on Prices across Space



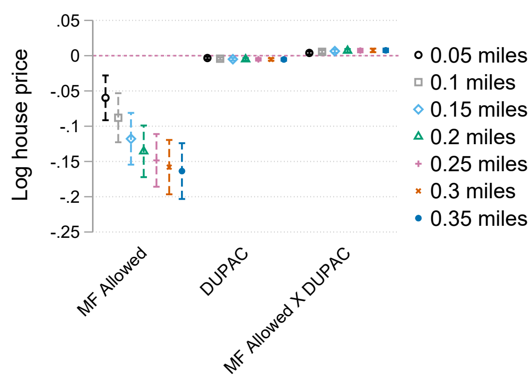
Note: These figures highlight the effects of regulations on 2010-2018 housing costs (log monthly rents for multifamily units on left and log monthly owner cost of housing for single-family houses on right) across space per unit added due to the regulation, i.e. divided by the results from Figure 6. For each community type, we regress price on boundary fixed effects and distance to boundary (bins of 0.02 miles) as in Figure 7. Year fixed effects are included. The effect we show here is the coefficient on the distance bin from 0-0.02 miles on the stricter side of the boundary relative to 0-0.02 miles on the relaxed side divided by the corresponding effect on units shown in Figure 6. DUPAC is dwelling units per acre and MF is multifamily zoning. Grey areas represent no statistically significant results. Standard errors are clustered at the boundary level.

Figure 9: Price Effects across Various Distance Bandwidths



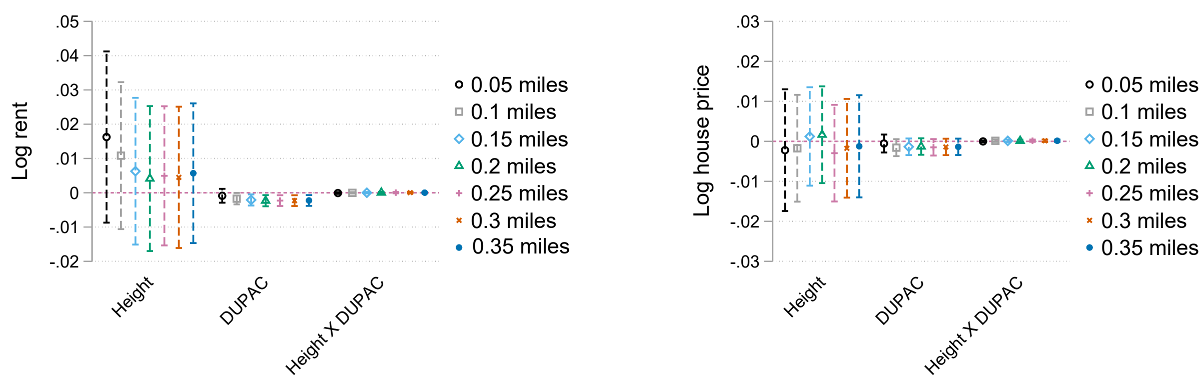
(a) (b)

Change in DUPAC Regulation Boundaries



(c)

Change in DUPAC and Multifamily Regulation Boundaries

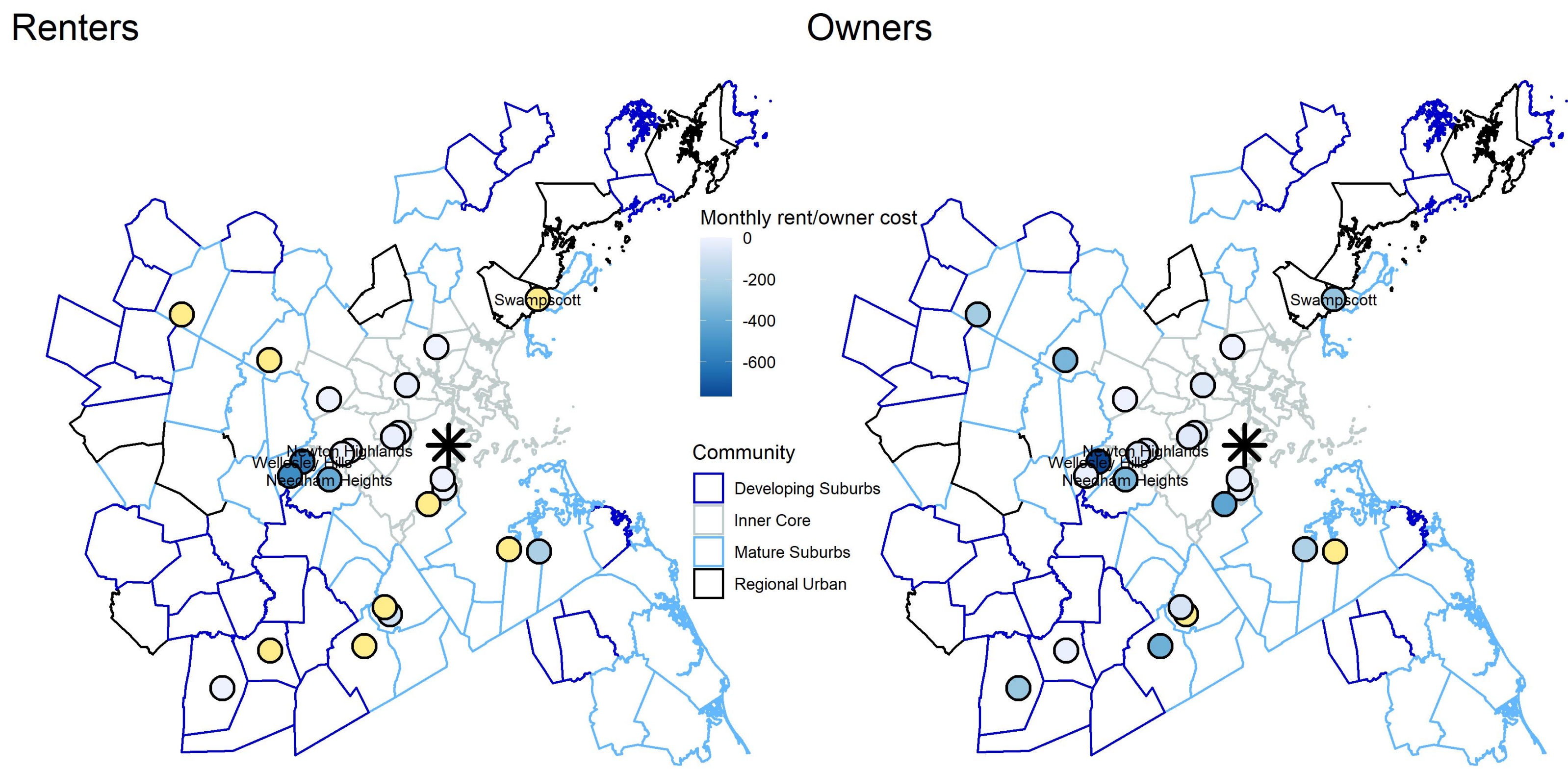


(d) (e)

Change in DUPAC and Height Regulation Boundaries

Note: This figure plots coefficient from from Equation 4 on multifamily (MF), height, and dwelling units per acre (DUPAC) when the regulation RD boundary varies from 0.05-0.35 miles. Coefficients for log monthly rents [2010-2018] are plotted left (a,c,e). Coefficients for log monthly owner cost [2010-2018] of housing are plotted right (b,d,f). The unit on height is in 10 feet and DUPAC is in 1 housing unit. Year fixed effects are included. Standard errors are clustered at the boundary level.

Figure 10: Policy Effects: Relaxing Regulations near Transit Stops



Note: This figure plots the average change in monthly owner costs for single-family houses and monthly multifamily rents from relaxing regulations near 23 metro and commuter rail transit stops. Yellow points represent statistically insignificant results. Star indicates the city of Boston. Price differentials are plotted for the regulation scenario with the highest impact. Stations where dwelling units per acre (DUPAC) is relaxed: Shawmut* (Boston), Fairbanks Street^{o} (Brookline), Porter Square^{o} (Cambridge), Malden Center^{o} (Malden), Waltham^{o} (Waltham), Canton Junction^{o} (Canton), Wellesley Square^{o} (Wellesley), Norfolk^{o} (Norfolk), Franklin/Dean College^{o} (Franklin). Stations where multifamily and DUPAC are relaxed: Beaconsfield^{o} (Brookline), Ashmont^{o} (Boston), Eliot^{o} (Newton), Newton Highlands^{o} (Newton), Needham Heights^{o} (Needham), South Acton^{o} (Acton), Capen Street^{o} (Milton), Swampscott^{o} (Swampscott), Wellesley Hills^{o} (Wellesley), Lincoln^{o} (Lincoln),Sharon^{o} (Sharon), Weymouth Landing^{o} (Weymouth). Stations where height and DUPAC are relaxed: Canton^{+} (Canton), Ashmont^{+} (Boston), Beaconsfield^{+} (Brookline), Fairbanks Street^{+} (Brookline), Porter Square^{+} (Cambridge), Malden Center^{+} (Malden), Eliot^{+} (Newton), Newton Highlands^{+} (Newton), Waltham^{+} (Waltham), Needham Heights^{+} (Needham), Wellesley Hills^{+} (Wellesley), Wellesley Square^{+} (Wellesley), East Weymouth^{+} (Weymouth), Franklin/Dean College^{+} (Franklin) .* indicates renters and owners, $^{+}$ only renters, ^{o} only owners.

Table 1: Interaction of Various Zoning Regulation Scenarios

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regulation Scenarios	**MF Changes**	**Height Changes**	**DUPAC Changes**	**MF Rent (% Obs.)**	**SF Prices (% Obs.)**	**Mean DUPAC**	**Mean Height (10 feet)**	**Mean MF Allowed**
Scenario 1	X			-	3.0	9.3	3.5	0.27
Scenario 2		X		4.9	2.6	10.3	3.5	0.56
Scenario 3			X	53.5	55.5	9.9	3.4	0.58
Scenario 4	X	X		-	1.5	6	3.7	0.29
Scenario 5	X		X	-	20.2	9.2	3.4	0.43
Scenario 6		X	X	41.7	8.4	26.6	3.9	0.77
Scenario 7	X	X	X	-	8.8	12	3.6	0.39

Note: This table represents all zoning regulation scenarios resulting from an interaction of the three main regulations (DUPAC, height, allowing multifamily (MF)). DUPAC is maximum dwelling units per acre. Columns (1), (2), and (3) highlight which regulations are involved under which scenario. Columns (4) and (5) show the percentage of multifamily rent and single-family (SF) house price observations under each of these scenarios. By design, any regulation scenario where MF allowed changes (scenarios 1, 4, 5, and 7), we cannot study the effects on multifamily rents because multifamily homes are directly banned on the strict side of the boundary. Columns (6), (7), and (8) show the average levels of the regulation on both sides of regulation boundary.

Table 2: Type of Housing Built Before 1918

	2-3 units (Gentle-Density)				4+ units (High-Density)			
	Only MF	Only DU	MF & DU	H & DU	Only MF	Only DU	MF & DU	H & DU
MF allowed	0.016		0.114***		0.007		0.043*	
	(0.092)		(0.032)		(0.048)		(0.017)	
Height (H)				0.011				0.010
				(0.013)				(0.010)
DUPAC (DU)		-0.000	0.001	0.001		-0.000	0.001	0.005***
		(0.001)	(0.002)	(0.001)		(0.001)	(0.001)	(0.001)
MFXDU			-0.005*				-0.003*	
			(0.002)				(0.001)	
HXDU				-0.000				0.000
				(0.000)				(0.000)
N	2,918	29,485	17,833	16,821	1,373	19,054	10,440	8,461
R^2	0.374	0.296	0.294	0.237	0.323	0.369	0.208	0.378
$\mathbb{E}(y)$	0.566	0.397	0.436	0.568	0.078	0.067	0.037	0.141

Note: This table presents the results from a linear probability model (equation 4) 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 0-0.3 miles on either side of the boundary in 2018. All buildings are built before 1918. 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. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3: Supply: Types of Housing across Regulation Boundaries (Built after 1918)

	2-3 units (Gentle-Density)				4+ units (High-Density)			
	Only MF	Only DU	MF & DU	H & DU	Only MF	Only DU	MF & DU	H & DU
MF allowed	0.418***		0.044*		0.033		0.002	
	(0.073)		(0.021)		(0.017)		(0.009)	
Height (H)				-0.011				-0.007
				(0.010)				(0.007)
DUPAC (DU)		0.002**	-0.008**	-0.002		0.001**	0.000	0.004*
		(0.001)	(0.003)	(0.002)		(0.000)	(0.001)	(0.002)
MFXDU			0.012***				0.002*	
			(0.002)				(0.001)	
HXDU				0.0003*				-0.000
				(0.0001)				(0.000)
N	5,838	92,046	35,194	13,101	5,006	87,697	30,129	9,878
R^2	0.457	0.397	0.371	0.509	0.405	0.490	0.271	0.522
$\mathbb{E}(y)$	0.157	0.061	0.159	0.290	0.017	0.012	0.015	0.067

Note: This table presents the results from a linear probability model (equation 4) 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 0-0.3 miles on either side of the boundary in 2018. All buildings are built after 1918. 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. 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.

Table 4: Indirect Price Effects Away from Regulation Boundaries

	Only MF	Only DUPAC	MF & DUPAC	DUPAC & Height	All
			Multifamily (rents)		
θ^{HD}	-	0.168	-	-0.100	-
		(0.119)		(0.093)	
θ^{GD}	-	-0.101*	-	0.040	-
		(0.051)		(0.047)	
N		43,993		35,347	
$\mathbb{E}(y)$		\$1,049		\$1,017	
$\mathbb{E}(\theta^{HD})$		0.054		0.079	
$\mathbb{E}(\theta^{GD})$		0.388		0.532	
			Single-Family (owner cost of housing)		
θ^{HD}	-0.495	-0.103	-0.102	-0.097	-0.051
	(0.250)	(0.092)	(0.060)	(0.056)	(0.095)
θ^{GD}	0.159	-0.166***	-0.213***	-0.056	-0.213***
	(0.102)	(0.038)	(0.048)	(0.043)	(0.062)
N	20,517	446,515	147,523	63,495	63,695
$\mathbb{E}(y)$	\$2,710	\$2,519	\$2,256	\$2,321	\$2,494
$\mathbb{E}(\theta^{HD})$	0.010	0.001	0.010	0.023	0.016
$\mathbb{E}(\theta^{GD})$	0.061	0.053	0.104	0.192	0.150

Note: This table shows the coefficients on share of high-density (4 + units) buildings (θ^{HD}) and share of gentle-density (2-3 units) buildings (θ^{GD}) within 0.1 mile radius around a house across different regulation boundaries from Equation 5 for buildings 0.1-0.3 miles on either side of the regulation boundaries. Top panel presents results where dependent variable is log monthly rents [2010-18]. Top panel controls include year built, lot and building sizes, and dummy for building type. For bottom panel it is log monthly owner cost of housing [2010-18]. Year fixed-effects are included. Bottom panel controls include year built, lot and building sizes, and number of bedrooms, bathrooms and floors. MF is multifamily. DUPAC is dwelling units per acre. All is boundary where MF, DUPAC, and Height regulations all change. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

How to Increase Housing Affordability? Understanding Local Deterrents to Building Multifamily Housing

by Amrita Kulka, Aradhya Sood, and Nicholas Chiumenti

ONLINE APPENDIX

A. Data Appendix

A.1 Rent Imputation

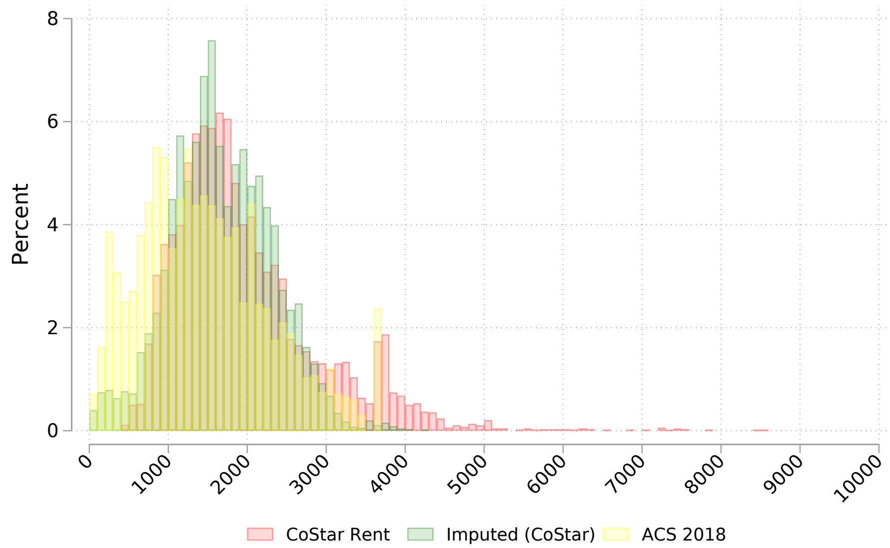
For the buildings that have CoStar market rent available [18,536 buildings from 2010-2018], we use it directly. CoStar uses websites like Apartment.com and field visits and surveys to get market rental data. For the remaining 112,992 buildings, we impute rent using CoStar characteristics, Warren Group data and ACS block group characteristics. The distribution of CoStar market rent is in red in Figure A.1 panel (a) plotted against the 2018 ACS block-group level rent (yellow). For the buildings that have detailed CoStar data, we impute rent using a linear regression model using the detailed characteristics from CoStar, Warren Group, and ACS block group characteristics and CoStar data on market rent. This distribution is plotted in green in Figure A.1. As can be seen from the Figure A.1 panel (a), CoStar's rental distribution leans towards the higher-end rental market. To capture the entire distribution of rents for the remainder buildings, particularly multifamily buildings with two-four units, we proceed in two steps.

First, we use the Bureau of Economic Analysis (BEA) imputation of 6.29% of the assessed value for *all* multifamily buildings. This distribution is plotted in pink against the 2018 ACS rent distribution (yellow) in Figure A.1 panel (b). Second, we impute rent using a linear regression model using the characteristics Warren Group and ACS block group characteristics and CoStar data on market rent.[1] The ACS imputed rent distribution is plotted in blue in Figure A.1 panel (b). Since BEA imputation matches the ACS rental distribution better than the imputed ACS rent distribution, we use BEA imputed rent for the non-CoStar buildings.[2]

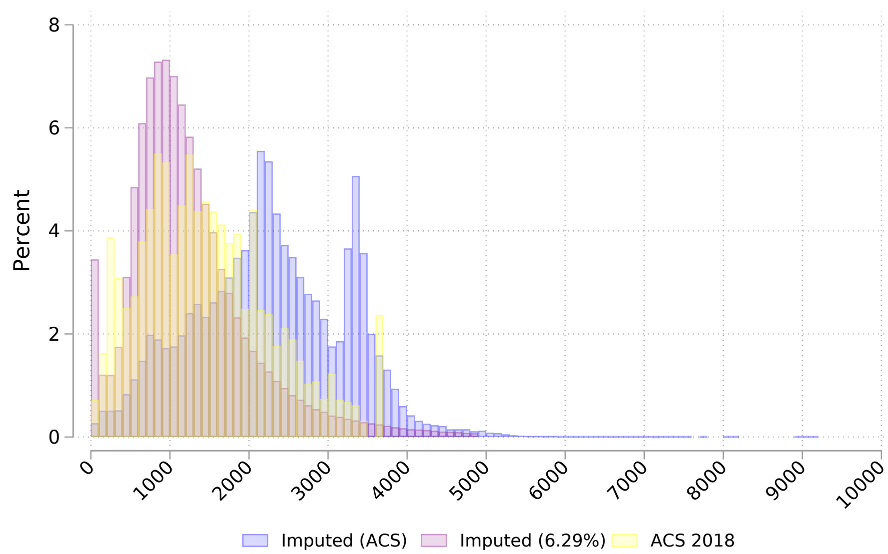
[1]These buildings do not have detailed CoStar building characteristic data.

[2]Baseline results use CoStar actual market rent data and BEA imputation for the remainder. For robustness, we also use CoStar actual and imputed rent data along with BEA imputation, but results don't change significantly compared to the baseline rental measure.

Figure A.1: Rent Imputation for multifamily Houses



(a) CoStar Imputation



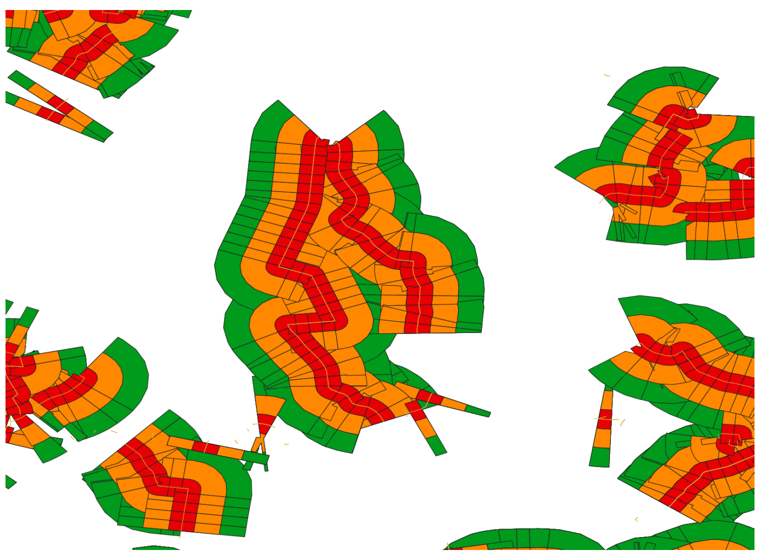
(b) BEA and ACS Imputation

Note: Panel (a) plots the rental data from CoStar against the imputed rental values using CoStar variables and against the ACS (2018) rental distribution. Panel (b) plots the ACS (2018) rental distribution data against the ACS variables, and the 6.29% Bureau of Economic Analysis (BEA) estimation.

A.2 Regulations and Supply: Neighborhood Level

In addition using a linear probability model to study the effect of land-use regulations on supply, we also run regressions at neighborhood level. A neighborhood is a 0.1X0.1 or 0.1X0.3 or 0.1X0.5 mile box on either side of the boundary (see Figure A.2). In each box, neighborhood density is measured as share of total gentle or high-density lots, unit-level density (total units /total lots), or area-level density (total building area /total lot area). The empirical model is given by Equation 4. Qualitatively, these results are similar to the results presented in Table 3 and Figure 4. Note that this is not chosen to be the primary specification because about half of our boundaries 0.1 miles or smaller. Use of this specification, thus, results in dropping off of about half of the boundaries.

Figure A.2: Example Construction of Neighborhood Density



Note: This figure plots a sample of boundaries and the construction of neighborhood density around a regulation boundaries. Red indicates 0.1X0.1 mile boxes around the boundary. Orange indicates 0.1X0.3 mile and green indicates 0.1X0.5 mile.

A.3 Distance to Nearby Boundaries

Identifying the direct effect of the zoning regulation in a boundary RD framework depends on other factors not varying discontinuously at the boundary (e.g., Figure 3). In terms of the indirect effect, a possible confounding factor is that it might be capturing changes in residential density from other nearby zoning regulation boundaries. Figures A.3 shows a histogram of the distance to the closest, 2nd closest, and 3rd nearest boundaries in our sample. The 2nd closest boundary is, on average, 0.376 miles. The third closest boundary is 0.464 miles away. This may seem concerning since we estimate indirect effects at 0.1-0.3 miles from the boundary.

Figure A.4 shows how the share of single-family, gentle-density and high-density homes in a 0.1 mile radius evolves over space away from the boundary. Since we show that boundaries lead to sharp changes in the type and number of homes, if our estimates of indirect effects were driven by proximity to the next regulation boundary, we would expect to see large gradients in the shares away from the boundary. On the contrary, we see that the share of different types of homes is quite flat up until 0.2 miles from the boundary (which includes homes up until 0.25 miles from the boundary). Therefore, we are reassured that indirect effects are driven by the density of homes induced by this zoning regulation and not the next closest one.

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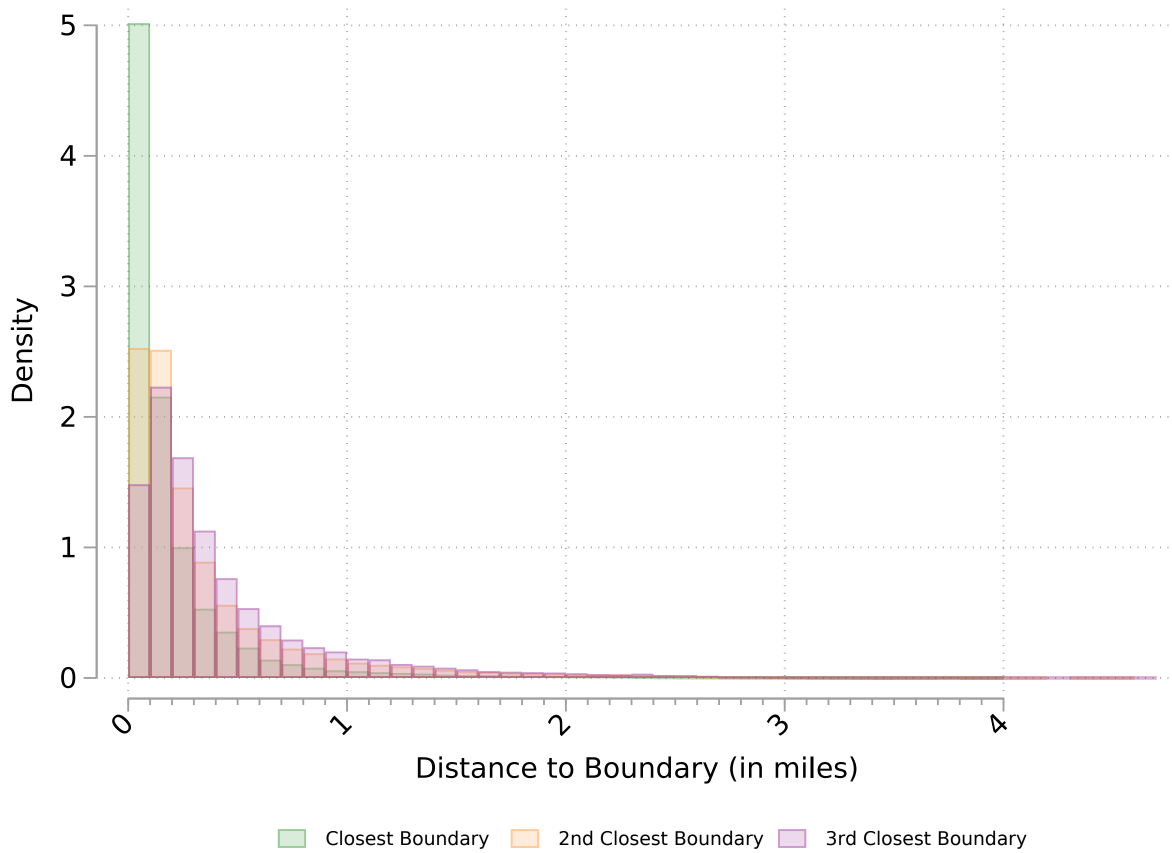
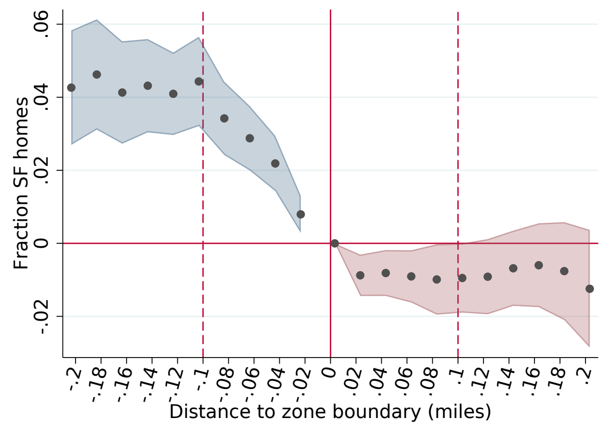
Figure A.3: Building Distance to Nearby Boundaries

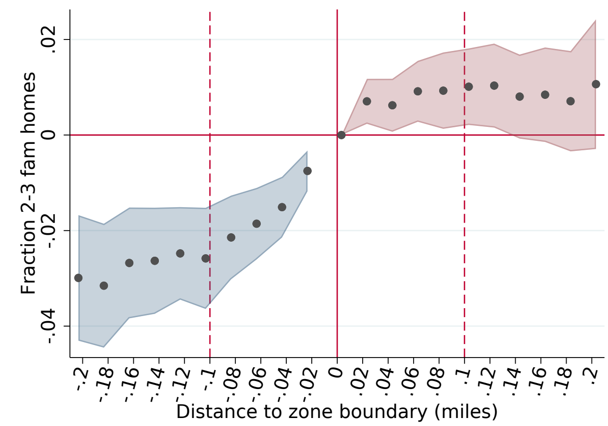


Note: This figure plots the distance to the first, second, and third nearest boundaries for all buildings in the sample (2018).

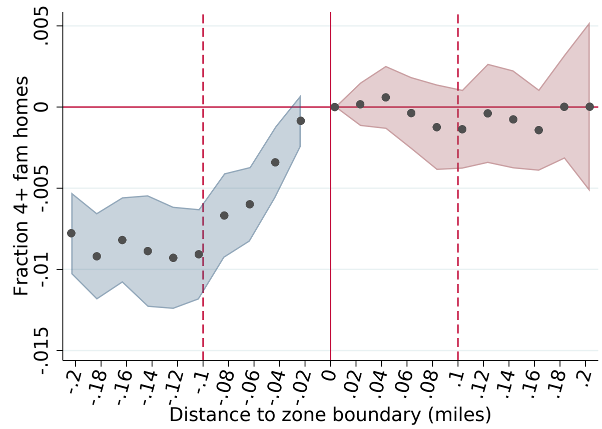
Figure A.4: Shares of Single-Family, Gentle-Density, and High-Density Homes



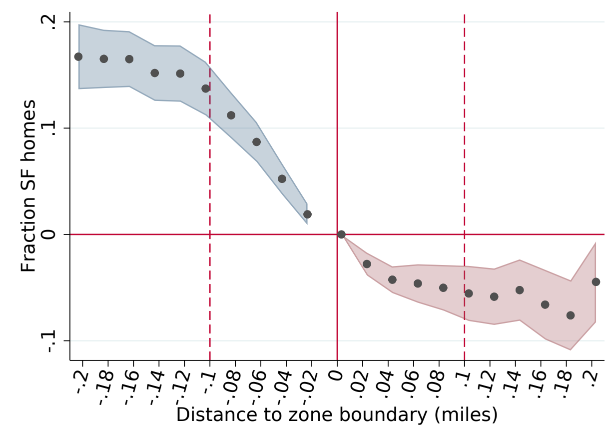
(a) SF (Dupac)



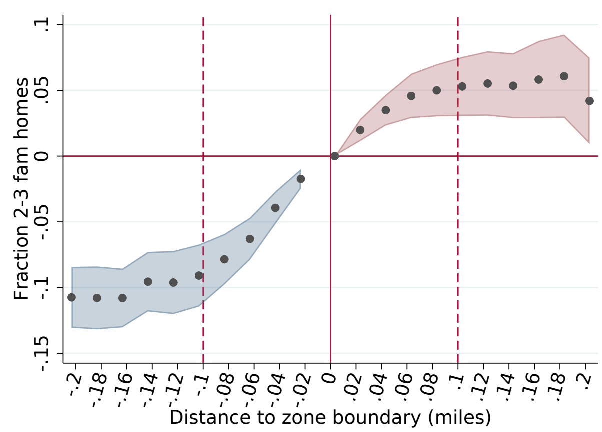
(b) Gentle-Density (Dupac)



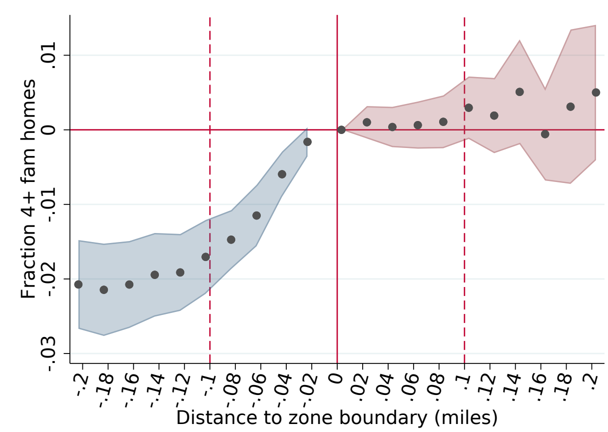
(c) High-Density (Dupac)



(d) SF (MF + Dupac)



(e) Gentle-Density (MF + Dupac)



(f) High-Density (MF + Dupac)

Note: This figure plots the share of single-family, gentle-density (2-3 unit), and high-density (4+ units) homes along the boundary in 2018. Shares are calculated as the fraction of homes of a given type within an 0.1 mile radius around every property. Plots are created by regressing shares on boundary fixed effects, and bins of distance to the boundary (bins of 0.02 miles). Coefficients on the distance bins are plotted. Negative distances indicate the more regulated side of a boundary. The bin closest to the boundary on the less regulated side (0-0.02 miles to the boundary) is normalized to 0. 95% confidence intervals are shown.

B. Additional Tables and Figures

Table B.1: Adoption of Zoning Laws across Towns

Town	Year	Town	Year
ARLINGTON	1924-8-30	MEDFORD	1925
BEDFORD	1928	MELROSE	1924-5-6-7-8
BELMONT	1925-6-7	MILTON	1022-6
BOSTON	1918-23-4-9-30-1-2-56	NATICK	1931
BROOKLINE	1922-4-8	NEEDHAM	1925-6-31
CAMBRIDGE	1924-5-6-7-8-9-30-56	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 other types of zoning adoption across towns in Greater Boston Area. Data is from Knauss (1933).

Table B.2: Type of Housing Built Before 1956

	2-3 units (Gentle-Density)				**4+ units (High-Density)**			
	Only MF	Only DU	MF & DU	H & DU	Only MF	Only DU	MF & DU	H & DU
MF	0.233*		0.117*		0.026		0.019*	
	(0.105)		(0.028)		(0.023)		(0.009)	
H				0.004				0.003
				(0.011)				(0.007)
DU		0.001	-0.004	0.001		0.000	0.001	0.004***
		(0.001)	(0.002)	(0.001)		(0.000)	(0.001)	(0.001)
MFXDU			0.002				-0.001	
			(0.002)				(0.001)	
HXDU				-0.000				-0.000
				(0.000)				(0.000)
N	6,653	67,656	38,323	25,281	4,388	53,614	26,535	14,234
R^2	0.470	0.396	0.340	0.332	0.280	0.399	0.177	0.386
$\mathbb{E}(y)$	0.361	0.236	0.323	0.498	0.031	0.036	0.022	0.108

Note: This table presents the results from a linear probability model (equation 4) 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 0-0.3 miles on either side of the boundary in 2018. All buildings are built before 1956. 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. 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.

Table B.3: Supply: Types of Housing across Regulation Boundaries (Built after 1956)

	2-3 units (Gentle-Density)				**4+ units (High-Density)**			
	Only MF	Only DU	MF & DU	H & DU	Only MF	Only DU	MF & DU	H & DU
MF	0.250***		0.042*		0.066		0.011	
	(0.066)		(0.019)		(0.035)		(0.014)	
H				-0.011				0.004
				(0.011)				(0.008)
DU		0.002**	0.003	0.001		0.002*	0.000	0.003
		(0.001)	(0.003)	(0.003)		(0.001)	(0.002)	(0.002)
MFXDU			0.004				0.003*	
			(0.002)				(0.001)	
HXDU				0.000				-0.000
				(0.000)				(0.000)
N	2,103	53,875	14,704	4,641	1,991	52,957	13,946	4,189
R^2	0.384	0.274	0.318	0.510	0.574	0.487	0.410	0.650
$\mathbb{E}(y)$	0.081	0.025	0.069	0.165	0.030	0.008	0.018	0.075

Note: This table presents the results from a linear probability model (equation 4) 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 0-0.3 miles on either side of the boundary in 2018. All buildings are built after 1956 when comprehensive zoning is adopted. 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. 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.

Table B.4: Effects of Regulation on Prices

	Multifamily (rents)		Single-Family (housing costs)			
	Only DU	DU & H	Only MF	Only DU	MF & DU	DU & H
MF allowed			-0.040		-0.136***	
			(0.022)		(0.019)	
Height (H)		0.004				0.002
		(0.011)				(0.006)
DUPAC (DU)	-0.001*	-0.002**		-0.002*	-0.005***	-0.001
	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
MFXDU					0.007***	
					(0.001)	
HXDU		0.000				0.000
		(0.000)				(0.000)
N	174,726	135,593	49,853	771,615	304,340	129,779
$\mathbb{E}(y)$	$1,142	$1,057	$2,446	$2,520	$2,228	$2,171
R^2	0.617	0.630	0.696	0.732	0.768	0.871

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.

Table B.5: Effects of Regulations on Prices (with Year Built)

	Multifamily (rents)		Single-Family (housing costs)			
	Only DU	DU & H	Only MF	Only DU	MF & DU	DU & H
MF allowed			-0.018		-0.093***	
			(0.017)		(0.014)	
Height (H)		0.006				0.001
		(0.009)				(0.006)
DUPAC (DU)	-0.001	-0.002***		-0.003***	-0.003***	-0.002
	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
MFXDU					0.004***	
					(0.001)	
HXDU		0.000				0.000
		(0.000)				(0.000)
N	171,945	133,766	49,701	769,028	303,811	129,547
$\mathbb{E}(y)$	\$1,145	\$1,062	\$2444	\$2,515	\$2,227	\$2,168
R^2	0.659	0.713	0.782	0.807	0.825	0.894

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. In addition to boundary fixed effects and year fixed effects [2010-2018], we also control for year-built fixed effects. Standard errors are clustered at the boundary level. 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. Standard errors are clustered at the boundary level.* p<0.05, ** p<0.01, *** p<0.001.

Table B.6: Price Effects Away from Regulation Boundaries: Robustness

	Only MF	Only DUPAC	MF & DUPAC	DUPAC & Height	All
		Multifamily (rents): bandwidth 0.1-0.2 miles			
θ^{HD}	-	0.225	-	-0.104	-
		(0.151)		(0.112)	
θ^{GD}	-	-0.081	-	0.029	-
		(0.048)	)	(0.052)	
N		33,486		27,652	
		Multifamily (rents): bandwidth 0.1-0.35 miles			
θ^{HD}	-	0.079	-	-0.067	-
		(0.108)		(0.105)	
θ^{GD}	-	-0.102*	-	0.025	-
		(0.051)		(0.039)	
N		46,268		36,870	
		Single-Family (owner cost of housing): bandwidth 0.1-0.2 miles			
θ^{HD}	-0.274	-0.070	-0.120	0.081	-0.099
	(0.155)	(0.094)	(0.069)	(0.068)	(0.068)
θ^{GD}	0.022	-0.151***	-0.197***	-0.068	-0.197***
	(0.132)	(0.039)	(0.044)	(0.04)	(0.056)
N	15,275	289,725	98,090	44,646	42,467
		Single-Family (owner cost of housing): bandwidth 0.1-0.35 miles			
θ^{HD}	-0.364	-0.130	-0.119*	-0.111	-0.047
	(0.283)	(0.092)	(0.06)	(0.058)	(0.087)
θ^{GD}	0.131	-0.169***	-0.211***	-0.069	-0.224***
	(0.082)	(0.041)	(0.044)	(0.04)	(0.058)
N	22,386	496,837	162,598	68,595	70,288

Note: This table plots coefficient on share of high-density (4 + units) buildings (θ^{HD}) and share of gentle-density (2-3 units) buildings (θ^{GD}) within 0.1 mile radius around a house across different regulation boundaries from Equation 5 for buildings within either 0.1-0.2 or 0.1-0.35 miles on either side of the boundary. The preferred specification with bandwidth of 0.1-0.3 miles is in the main paper. Top panel presents results where dependent variable is log monthly rents [2010-2018]. Top panel controls include year built, lot and building sizes, and dummy for building type. For bottom panel it is log monthly owner cost of housing [2010-2018]. Bottom panel controls include year built, lot and building sizes, and number of bedrooms, bathrooms and floors. Standard errors are clustered at the boundary level. Boundary fixed effects and year fixed effects are included. Only MF are boundaries where only multifamily (MF) regulation changes. Only DUPAC are boundaries where only dwelling units per acre regulation changes. * p<0.05, ** p<0.01, *** p<0.001.

Table B.7: Difference in House Characteristics at the Boundary and Away From It

	Mean	(SD)	Mean	(SD)	Interior − Boundary
	Boundary (0-0.02)		Interior (0.02-0.3)		t-Test
Lot size (acres)	0.41	(1.38)	0.46	(1.29)	0.05***
Living area (sqft)	1715.87	(1235.11)	1862.44	(1026.17)	146.57***
Number of Bedrooms	2.88	(1.09)	3.09	(1.01)	0.21***
Number of Bathrooms	1.56	(1.00)	1.69	(0.86)	0.13***
Number of Units	2.53	(10.02)	1.86	(10.23)	-0.67***
Number of Floors	1.90	(0.74)	1.79	(0.64)	-0.11***
	Boundary (0-0.1)		Interior (0.1-0.3)		t-Test
Lot size (acres)	0.41	(1.28)	0.51	(1.33)	0.10***
Living area (sqft)	1751.07	(1076.85)	1955.39	(1023.96)	204.31***
Number of Bedrooms	2.96	(1.07)	3.18	(0.93)	0.22***
Number of Bathrooms	1.60	(0.89)	1.75	(0.87)	0.15***
Number of Units	2.14	(9.11)	1.73	(11.41)	-0.41***
Number of Floors	1.85	(0.70)	1.75	(0.59)	-0.10***
	Boundary (0-0.2)		Interior (0.2-0.3)		t-Test
Lot size (acres)	0.43	(1.32)	0.56	(1.21)	0.13***
Living area (sqft)	1810.91	(1053.20)	2019.20	(1070.31)	208.29***
Number of Bedrooms	3.03	(1.03)	3.24	(0.91)	0.21***
Number of Bathrooms	1.65	(0.88)	1.80	(0.87)	0.15***
Number of Units	2.07	(10.89)	1.32	(4.63)	-0.75***
Number of Floors	1.82	(0.67)	1.72	(0.54)	-0.11***
N	166,985		29,403		196,388

Note: This table illustrates the mean and standard deviation (SD) for housing building characteristics for buildings at the boundary (0-0.02 miles) and further away from it (0.02-0.03 miles) across 3 different boundary types: boundaries where only DUPAC (dwelling units per acre), multifamily and DUPAC, and DUPAC and height regulations change. We also provide t-Test statistic for differences in means for buildings at the boundary and interior buildings. * p-value< 0.05, ** p-value< 0.01, *** p-value< 0.001.

Table B.8: Town Governance Heterogeneity: Supply

		OTM		RTM		Mayor	
		2-3	4+	2-3	4+	2-3	4+
Only DU	DU	0.016***	0.008*	0.001***	0.000	0.002	0.006***
		(0.004)	(0.004)	(0.000)	(0.000)	(0.003)	(0.002)
	N	22,937	22,681	11,223	11,116	11,981	11,618
	MF	-0.069**	-0.028***	0.048	-0.017	0.207**	0.119*
		(0.028)	(0.011)	(0.056)	(0.018)	(0.086)	(0.056)
MF X DU	DU	-0.034***	-0.008*	0.020	-0.020	0.005	0.006*
		(0.012)	(.004)	(0.029)	(0.014)	(0.004)	(0.003)
	MF X DU	0.036***	0.009***	-0.004	0.019	-0.004	-0.001
		(0.009)	(0.004)	(0.026)	(0.012)	(0.004)	(0.003)
	N	4,849	4,686	3,734	3,623	4,351	3,904

Note: This table presents the results from a linear probability model (equation 4) 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 0-0.3 miles on either side of the boundary in 2018 for different forms of local town governments: open town meetings (OTM), representative town meetings (RTM), or mayoral system (Mayor). We control for boundary fixed effects. Standard errors are clustered at the boundary level. MF is multifamily regulation. DU is dwelling units per acre (DUPAC). The unit on DUPAC is in 1 housing unit. * p<0.05, ** p<0.01, *** p<0.001.

Table B.9: Town Governance Heterogeneity: Price Effects

		OTM		RTM		Mayor	
		MF	SF	MF	SF	MF	SF
	DU	-0.008	-0.017***	0.004***	-0.001	-0.003***	-0.002*
		(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Only DU	N	19,537	324,427	15,969	211,798	119,211	275,067
	θ^{GD}	-0.246	-0.033	0.011	-0.344***	-0.073	-0.133***
		(0.113)	(0.047)	(0.107)	(0.103)	(0.063)	(0.051)
	θ^{HD}	-0.237	-0.082	-0.126	-0.337	0.199	-0.310**
		(0.211)	(0.100)	(0.288)	(0.211)	(0.120)	(0.116)
	N	7,251	156,638	4,121	100,858	23,848	102,691
	MF		-0.199***		-0.131***		-0.183***
			(0.054)		(0.032)		(0.032)
MF X DU	DU		-0.025		-0.012		-0.007***
			(0.017)		(0.017)		(0.001)
	MF X DU		0.028		0.013		0.009***
			(0.014)		(0.014)		(0.002)
	N		85,280		77,119		161,811
	θ^{GD}		-0.107*		-0.201***		-0.197***
			(0.047)		(0.065)		(0.079)
	θ^{HD}		-0.142*		-0.136		-0.133
			(0.068)		(0.146)		(0.108)
	N		37,176		32,550		52,254

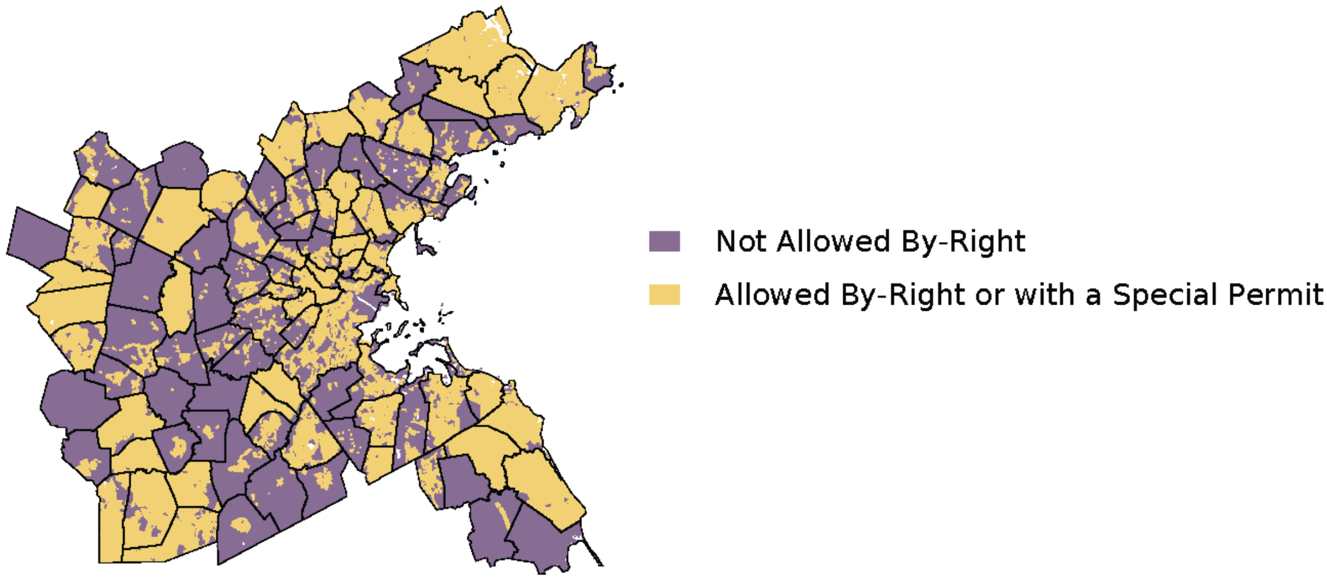
Note: This table presents results from Equation 4 & 5 for different forms of local government: open town meetings (OTM), representative town meetings (RTM), or mayoral system (Mayor). Dependent variable is log of either monthly owner cost of housing (single-family) or monthly rent (multifamily (MF)). Share of high-density (4 + units) buildings is θ^{HD} and share of gentle-density (2-3 units) buildings is θ^{GD} within 0.1 mile radius around a house. We control for boundary fixed effects. We also use year fixed effects. Standard errors are clustered at the boundary level. MF is multifamily regulation. DU is dwelling units per acre (DUPAC). The unit on DUPAC is in 1 housing unit. * p< 0.05, ** p< 0.01, *** p< 0.001.

Table B.10: Land Regulation and Inclusionary Zoning (Chapter 40B)

	MF	H	DU	MF X H	MF X DU	H X DU	MF X H X DU	R^2	E(y), N
All	-0.336*	0.005	0.000	0.080*	0.008*	-0.0005*	-0.001*		0.004
	(0.158)	(0.004)	(0.000)	(0.036)	(0.004)	(0.00002)	(0.001)	0.418	6,392
MF	-0.827***	0.017	0.002	0.209***	0.019***	-0.001***	-0.004***		0.006
	(0.168)	(0.010)	(0.001)	(0.043)	(0.005)	(0.000)	(0.001)	0.819	3,770

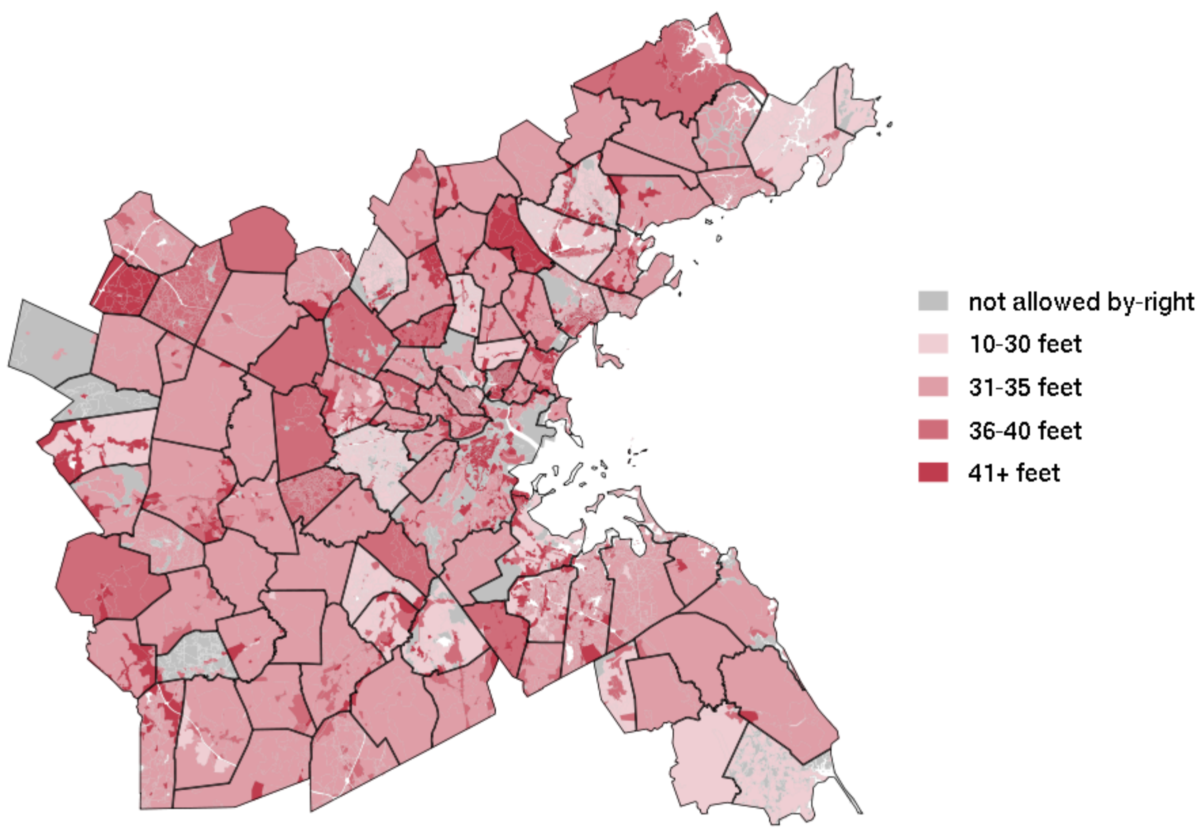
Note: This table presents the results from Equation 4 for buildings 0-0.5 miles around the boundary. The dependent variable is an indicator whether a property was built using Massachusetts' Chapter 40B inclusionary zoning policy to override local zoning rules in 2018. We control for boundary fixed effects. Standard errors are clustered at the boundary level. Results presented here are for boundaries where all regulations change at the same time. "All" indicates any building built using Chapter 40B's comprehensive permitting procedure while "MF" indicates multifamily buildings built using this procedure. Each column shows the effect of a different zoning policy on the supply of properties built using Chapter 40B. MF indicates multifamily regulation. DU is dwelling units per acre and H is height. The unit on height is in 10 feet and DUPAC is in 1 housing unit. Standard errors are clustered at the boundary level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure B.1: Multifamily Zoning in Greater Boston Area



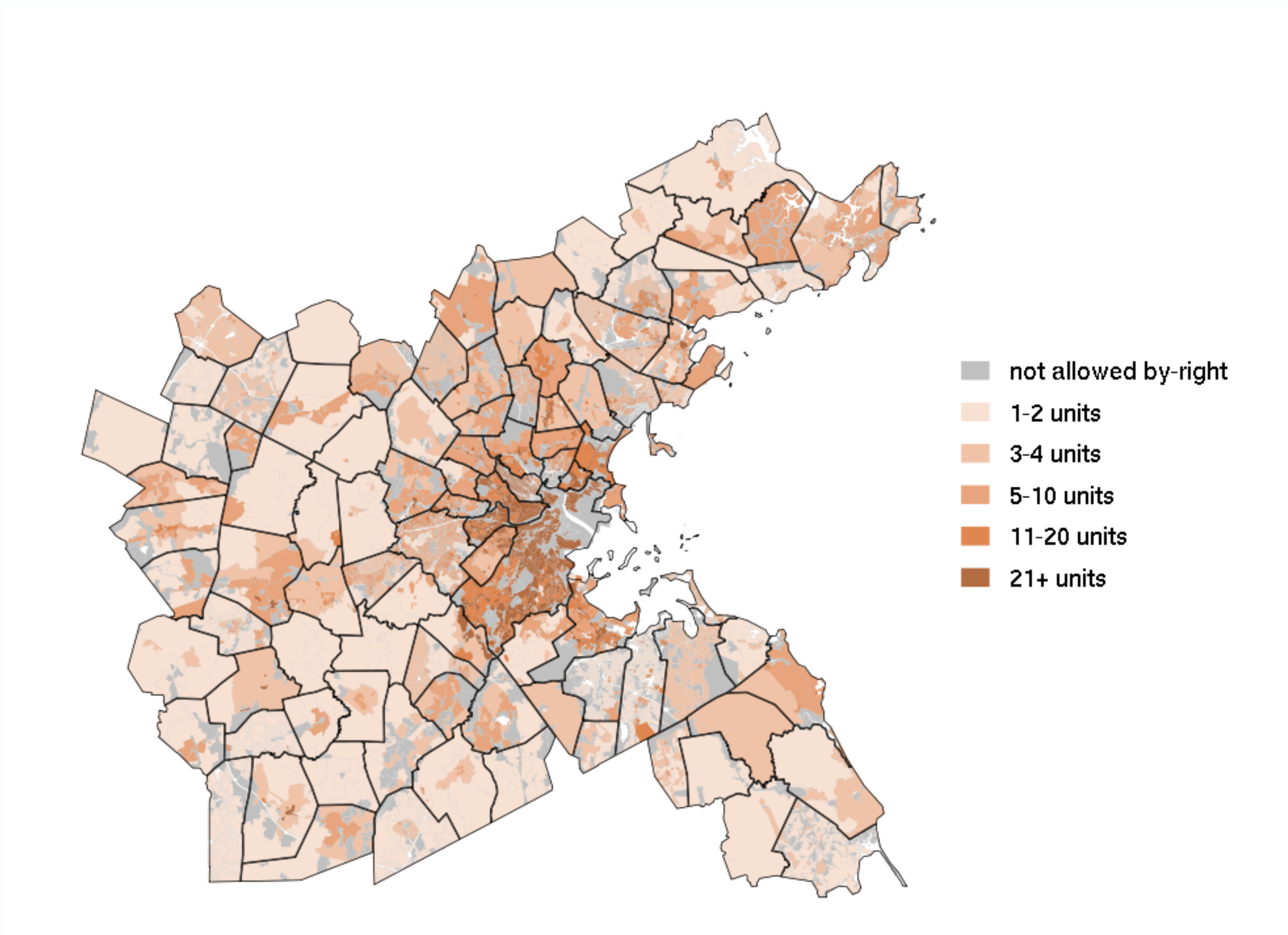
Note: This figure plots the multifamily zoning in Greater Boston Area. Allowed includes areas where multifamily construction is allowed by right and by special permit.

Figure B.2: Maximum Height Restrictions in Greater Boston Area



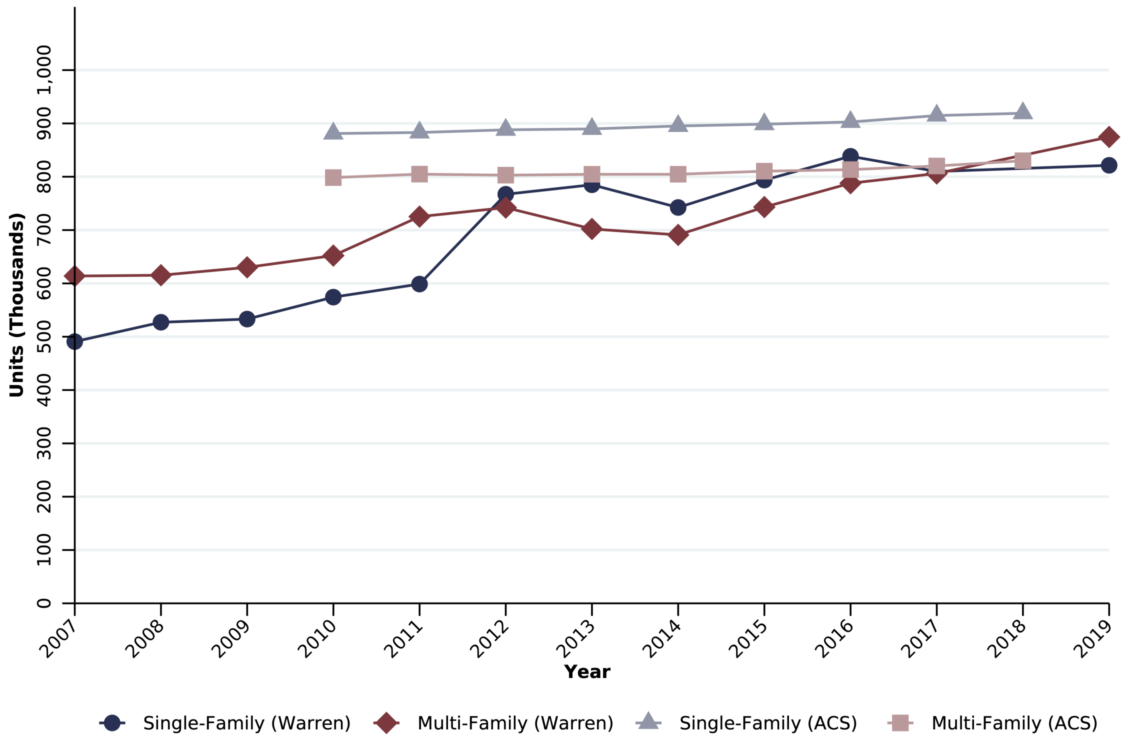
Note: This figure plots the maximum height restrictions in Greater Boston Area in feet.

Figure B.3: Maximum Density (DUPAC) Restrictions in Greater Boston Area



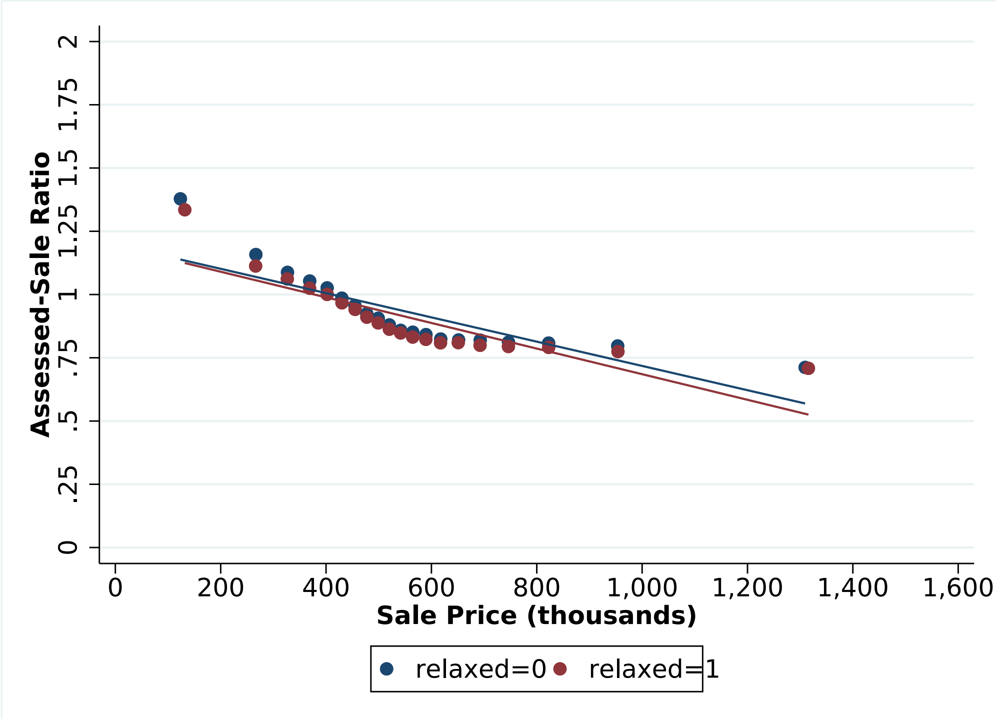
Note: This figure plots the maximum DUPAC (dweelng units per acre) restrictions in Greater Boston Area.

Figure B.4: Total Units by Housing Type: Warren and ACS Data



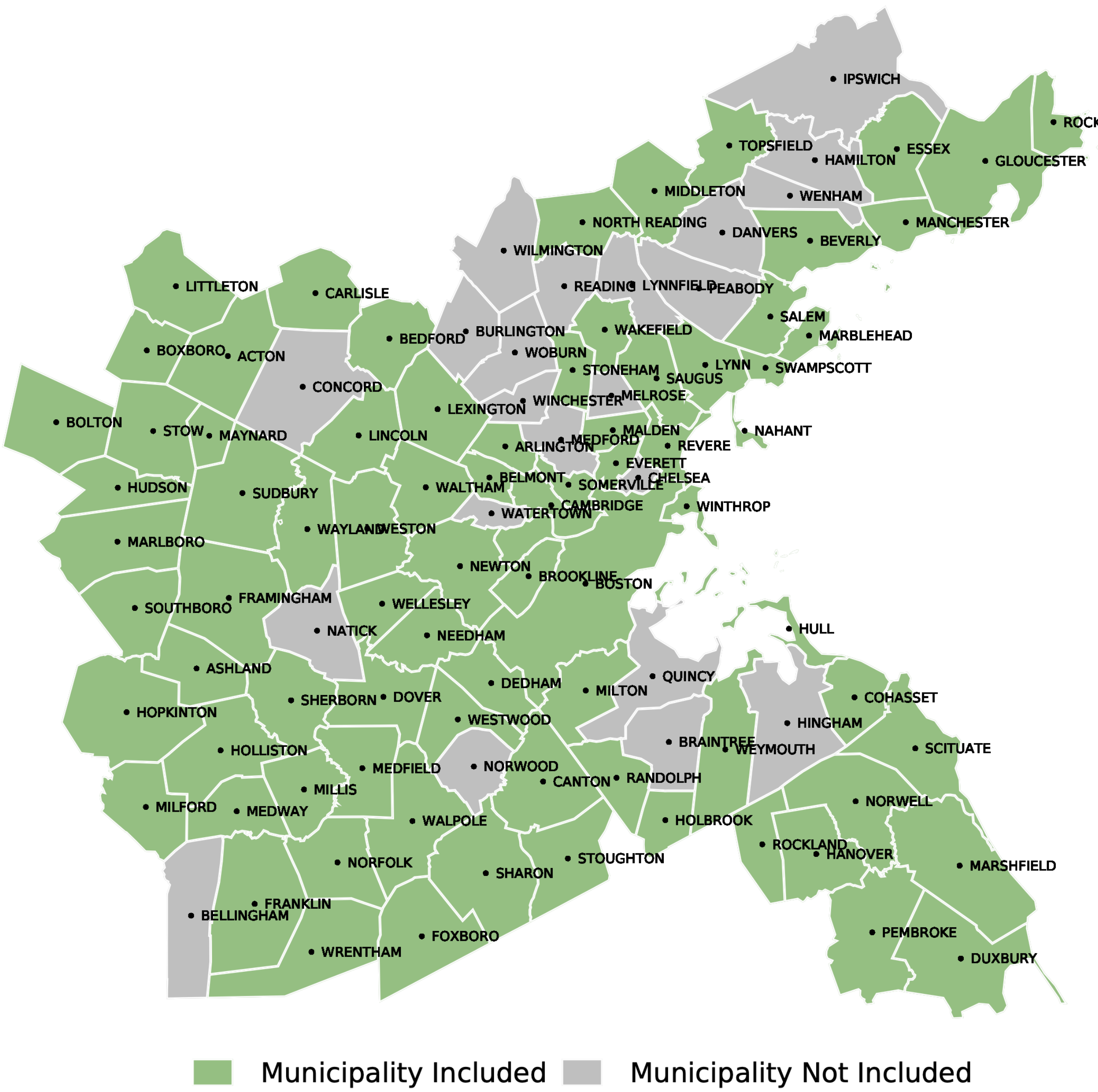
Notes: Single-family units from ACS include all 1 unit housing units (attached and detached). Single-family units in Warren include property addresses with 1 unit listed. All other types counted as multifamily. Counts only Massachusetts counties for the Boston-Cambridge-Newton MSA (2007-2019).

Figure B.5: Sales and Assessed Values for Single-Family Houses



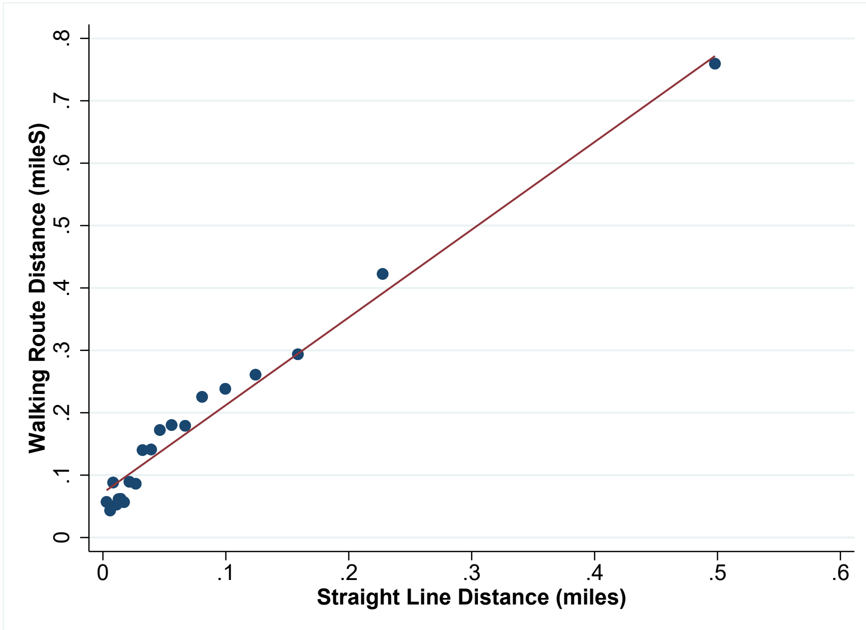
Note: Plots assessed-sales ratio against sale prices for single-family houses sold 2010-2018 in Greater Boston Area for houses on relaxed (relaxed=1) and restricted (relaxed=0) side of the regulation boundary. Town and year fixed effects are included. Following the literature (Berry, 2021), we drop the top and bottom 2% of the sample.

Figure B.6: Towns Included in Sample



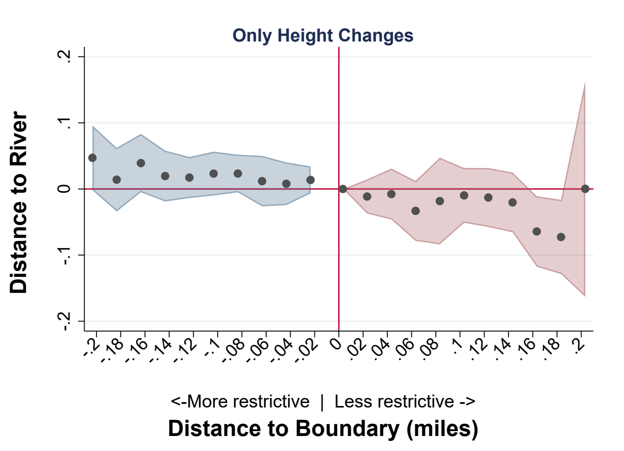
Note: Municipalities are included if they either had open enrollment school attendance policies or had elementary school attendance boundary data included in the 2016 School Attendance Boundary Survey (SABS). Municipalities were excluded if they lacked school attendance boundary data and did not have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

Figure B.7: Correlation between straight line and walking distance

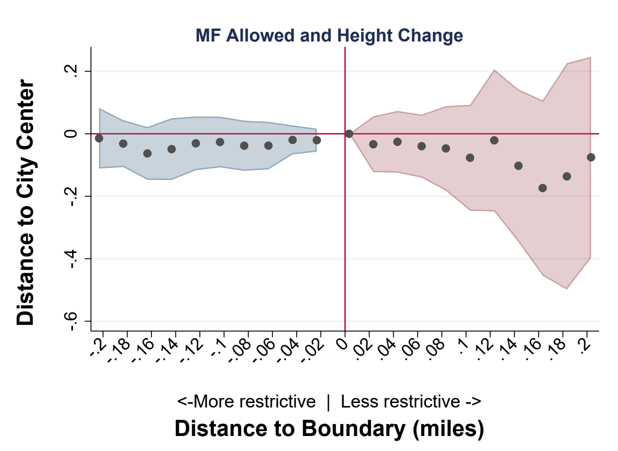


Note: This figure plots the straight line distance against the walking distance between the closest property on the less restrictive side of a regulation boundary and the closest property on more restrictive side. The straight line distance is the direct path between two properties (in miles), while 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.

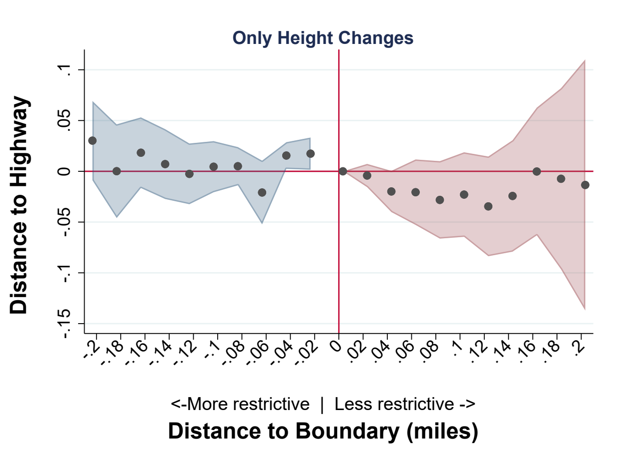
Figure B.8: Amenities at Regulation Boundaries (Continued)



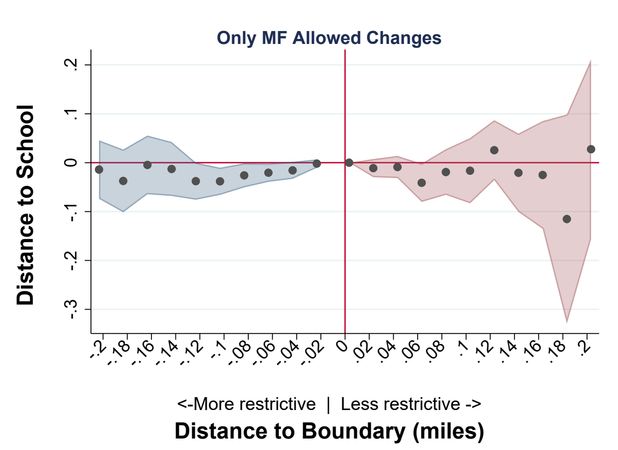
(a) River/Lake RD estimate = 0.014, (t stat = 1.32)



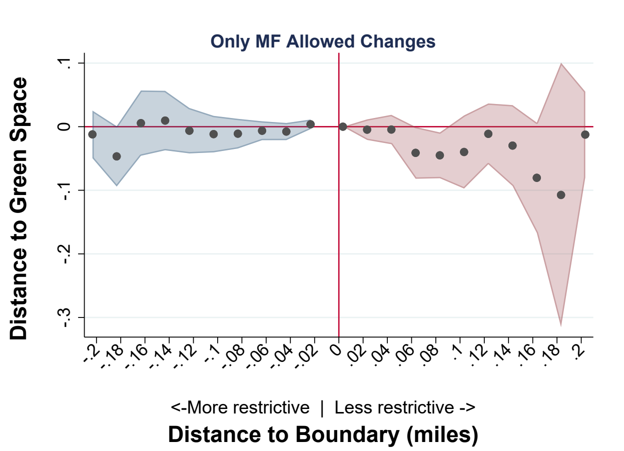
(b) Center RD estimate = -0.021, (t stat = -1.11)



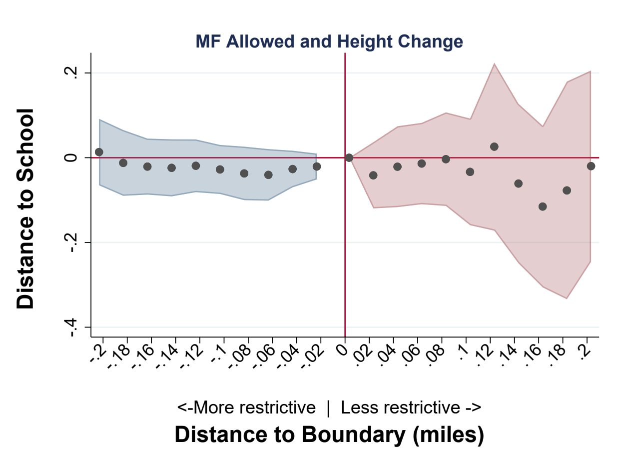
(c) Road RD estimate = 0.017, (t stat = 2.17)



(d) School RD estimate = -0.002, (t stat = -0.43)



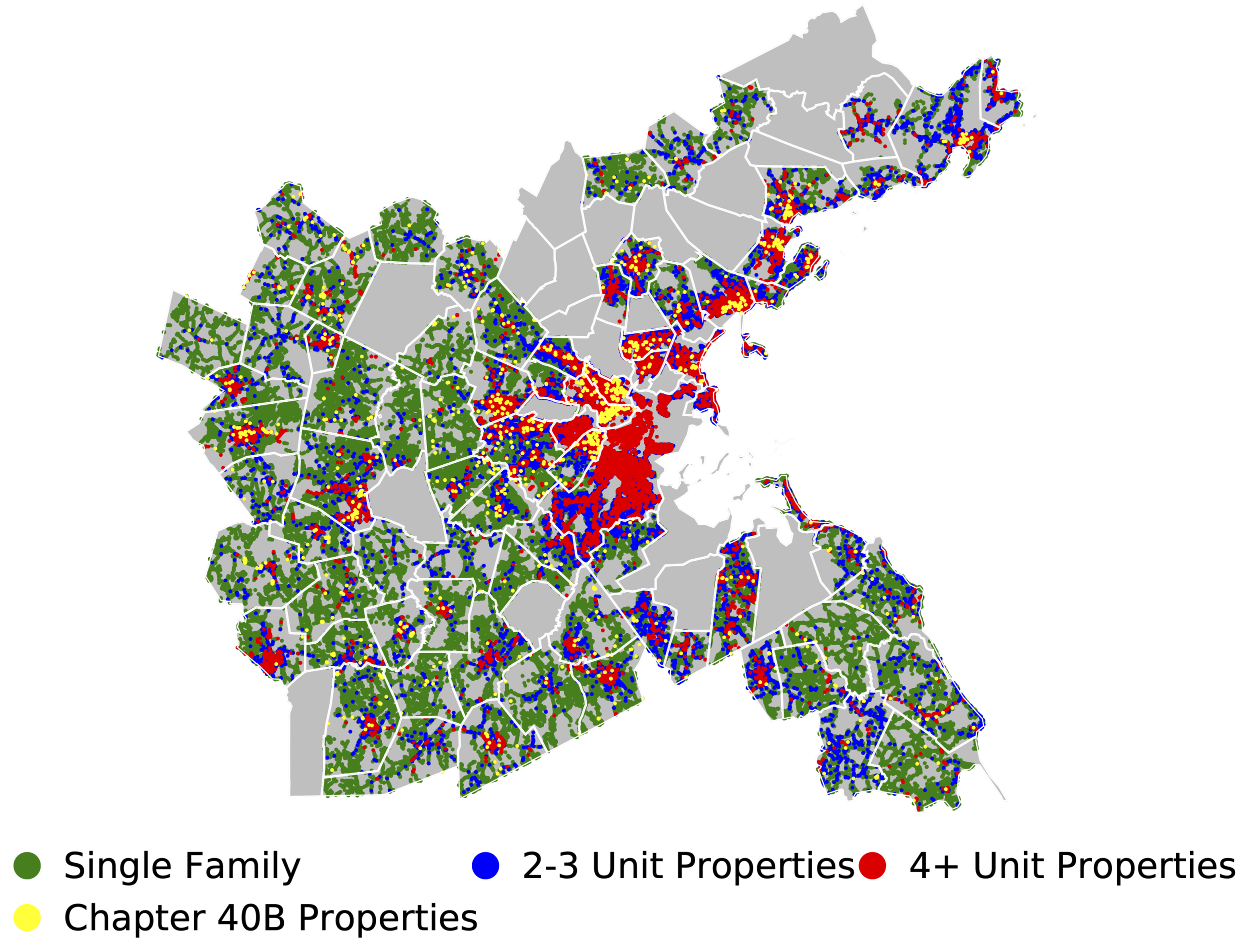
(e) Open Space RD estimate = 0.004, (t stat = 0.98)



(f) School RD estimate = -0.021, (t stat = -1.36)

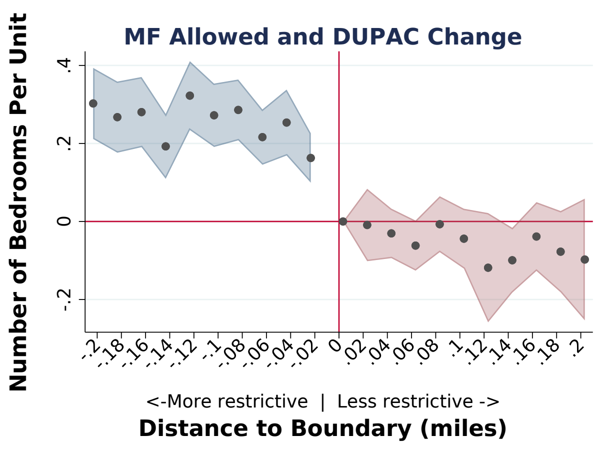
Note: Plots are created by regressing distance to various amenities on boundary fixed effects and bins of distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. Negative distances indicate more regulated side of boundary. The bin closest to the boundary on the less regulated side (0-0.02 miles to boundary) is normalized to 0. 95% confidence intervals are shown. DUPAC is Density units per acre and MF is multifamily zoning boundaries. Standard errors are clustered at the boundary level.

Figure B.9: Housing Types over Space

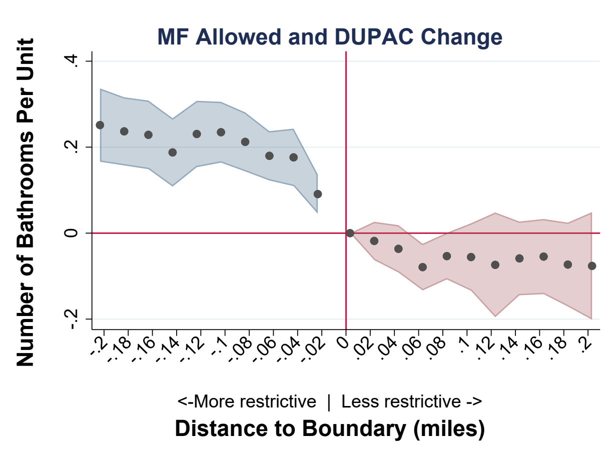


Note: Single-family properties are those classified as single-family on their 2018 tax assessment record. Two-to-three and four plus unit properties are those classified as such on their tax assessment record, or mixed use or other residential properties with two-to-three or four or more units, respectively. Chapter 40B properties are buildings built under Massachusetts inclusionary zoning law. Chapter 40B properties are magnified for better illustration. Properties shown include only those within 1 mile of a zoning boundary. Excludes municipalities that were not included in the analysis.

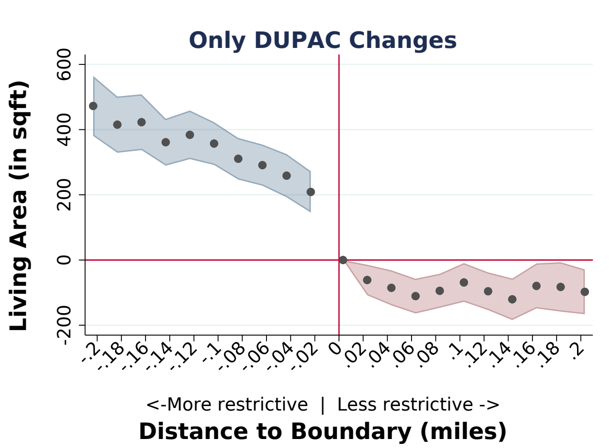
Figure B.10: Housing Characteristics at Regulation Boundaries: Continued



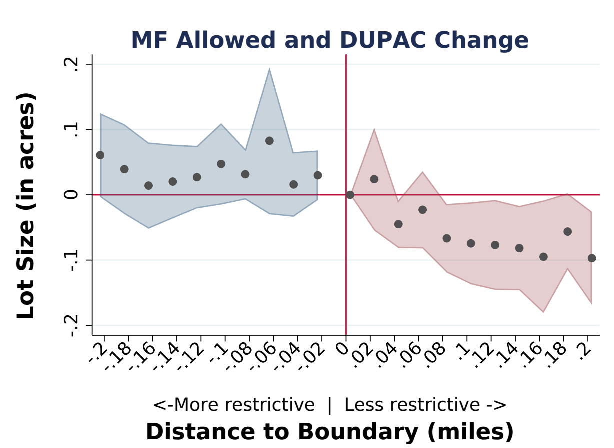
(a) RD est. = 0.163 (t-stat = 5.04), n = 29,871



(b) RD est. = 0.091 (t-stat = 3.90), n = 30,493



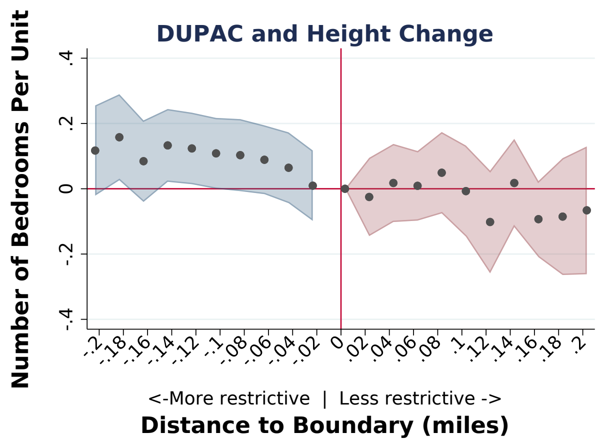
(c) RD est. = 208.9 (t-stat = 6.47), n = 77,782



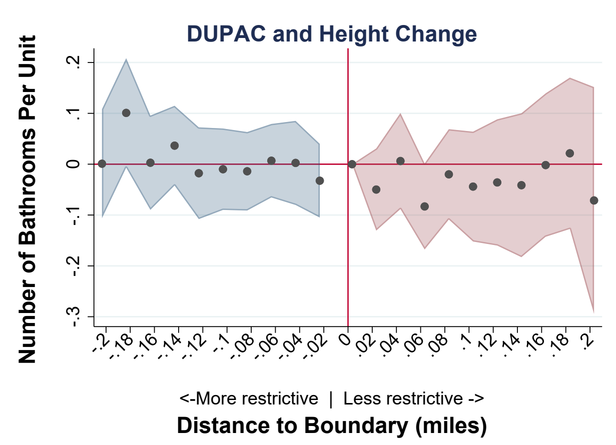
(d) RD est. = 0.03 (t-stat = 1.54), n = 31,186

Note: This figure plots building characteristics across regulation boundaries. 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 more regulated side. Bin closest to boundary on less 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 zoning.

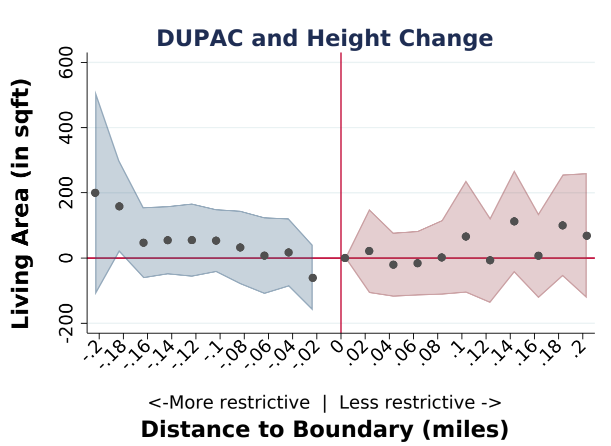
Figure B.11: Housing Characteristics at Regulation Boundaries: Continued



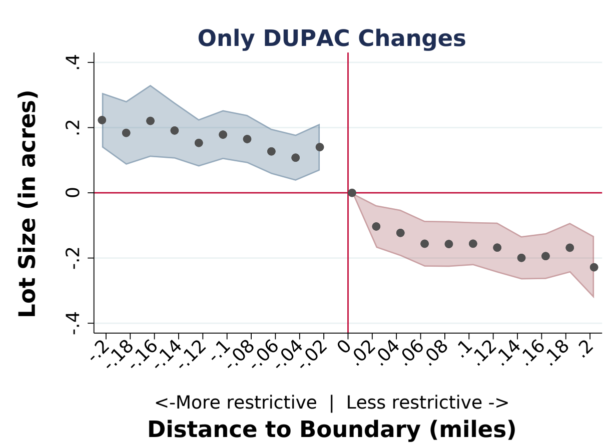
(a) RD est. = 0.009 (t-stat = 0.17), n = 11,506



(b) RD est. = -0.33 (t-stat =-0.88), n = 11,615



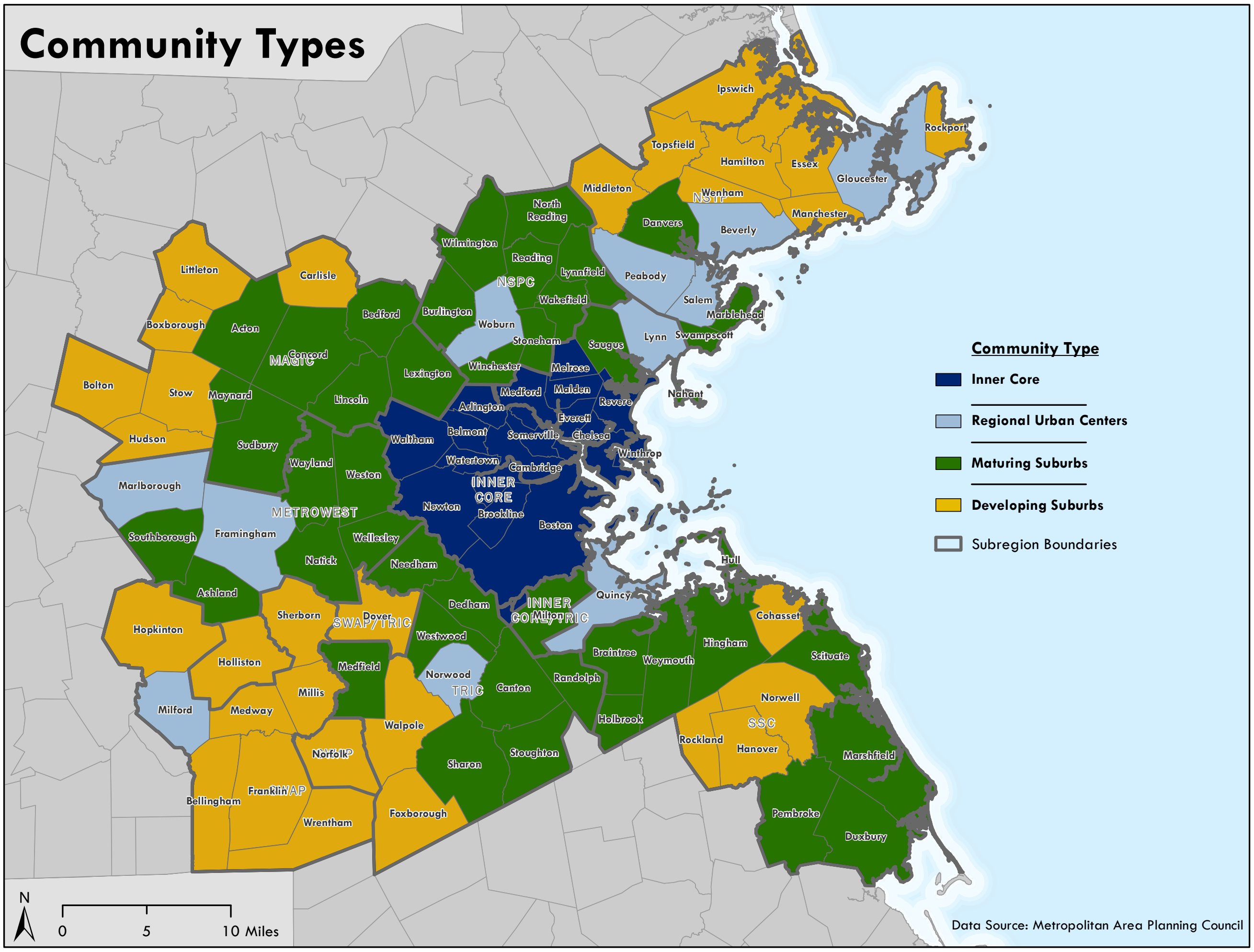
(c) RD est. = -60.79 (t-stat = -1.18), n = 12,013



(d) RD est. = 0.140 (t-stat = 3.83), n = 78,977

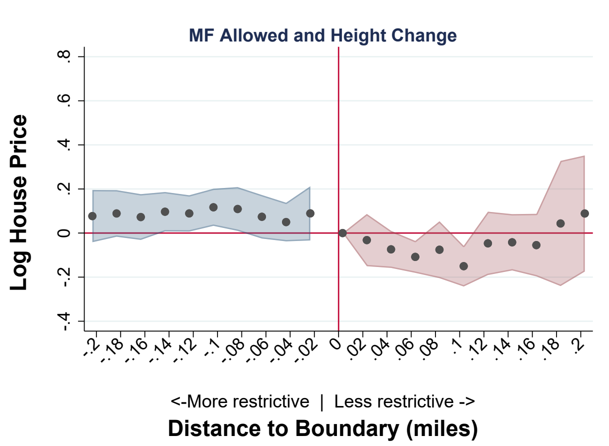
Note: This figure plots building characteristics across regulation boundaries. Plots are created by regressing unit characteristics on boundary fixed effects and distance to boundary (bins of 0.02 miles). Coefficients on distance bins are plotted. Negative distances indicate more regulated side. Bin closest to boundary on less 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 zoning.

Figure B.12: Greater Boston Area Community Types

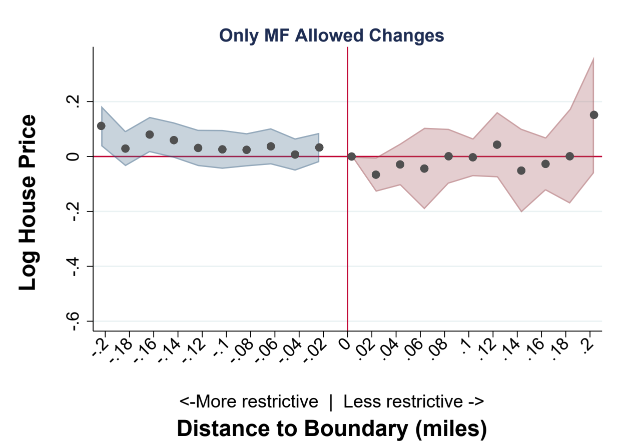


Notes: This figure highlights how Metropolitan Area Planning Council (MAPC) divides towns in Greater Boston Area into four distinct community types. Source: Metropolitan Area Planning Council

Figure B.13: Effects of Height and Multifamily Regulation on Housing Costs

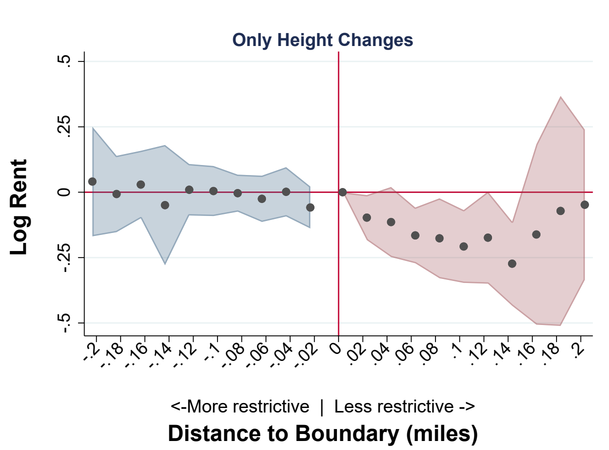


(a) RD est. = 0.068 (t-stat =0.46), n = 19,393

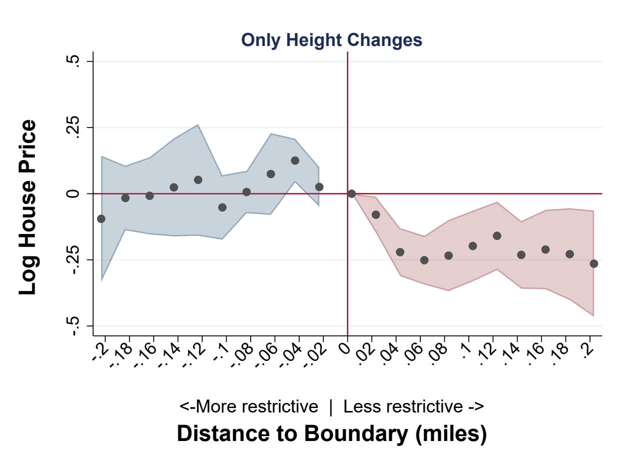


(b) RD est. = 0.033 (t-stat =1.22), n = 49,957

Change in Only Multifamily or Multifamily and Height Regulation



(c) RD est. = -0.058 (t-stat =-1.44), n = 15,092

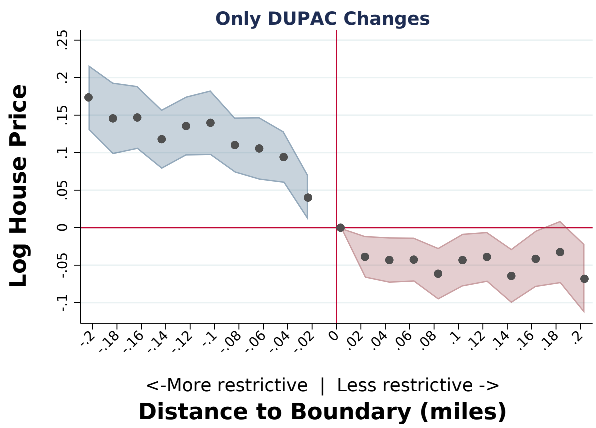


(d) RD est. = 0.026 (t-stat =0.67), n = 39,069

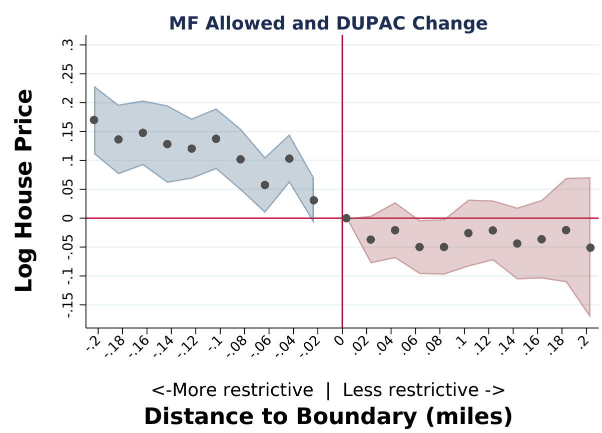
Change in Only Height Regulation Boundaries

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.

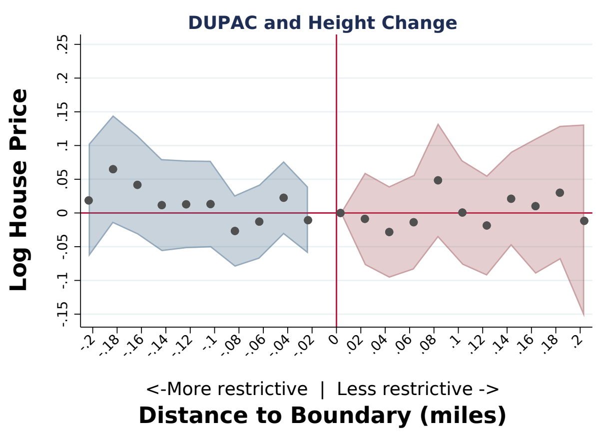
Figure B.14: Effects of Regulations on Sales Prices and CoStar Rents



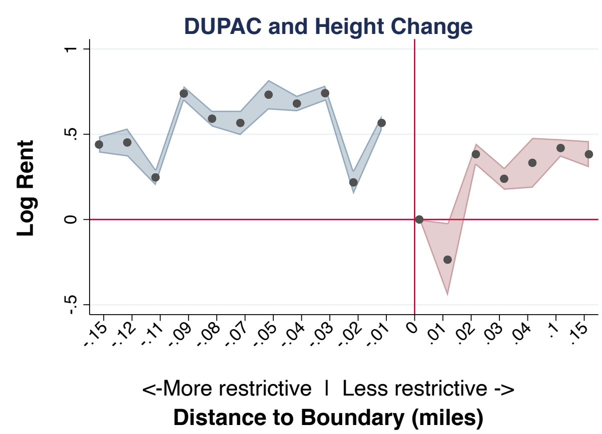
(a) RD est. = 0.040 (t-stat =2.60), n = 132,892



(b) RD est. = 0.031 (t-stat =1.53), n = 51,514



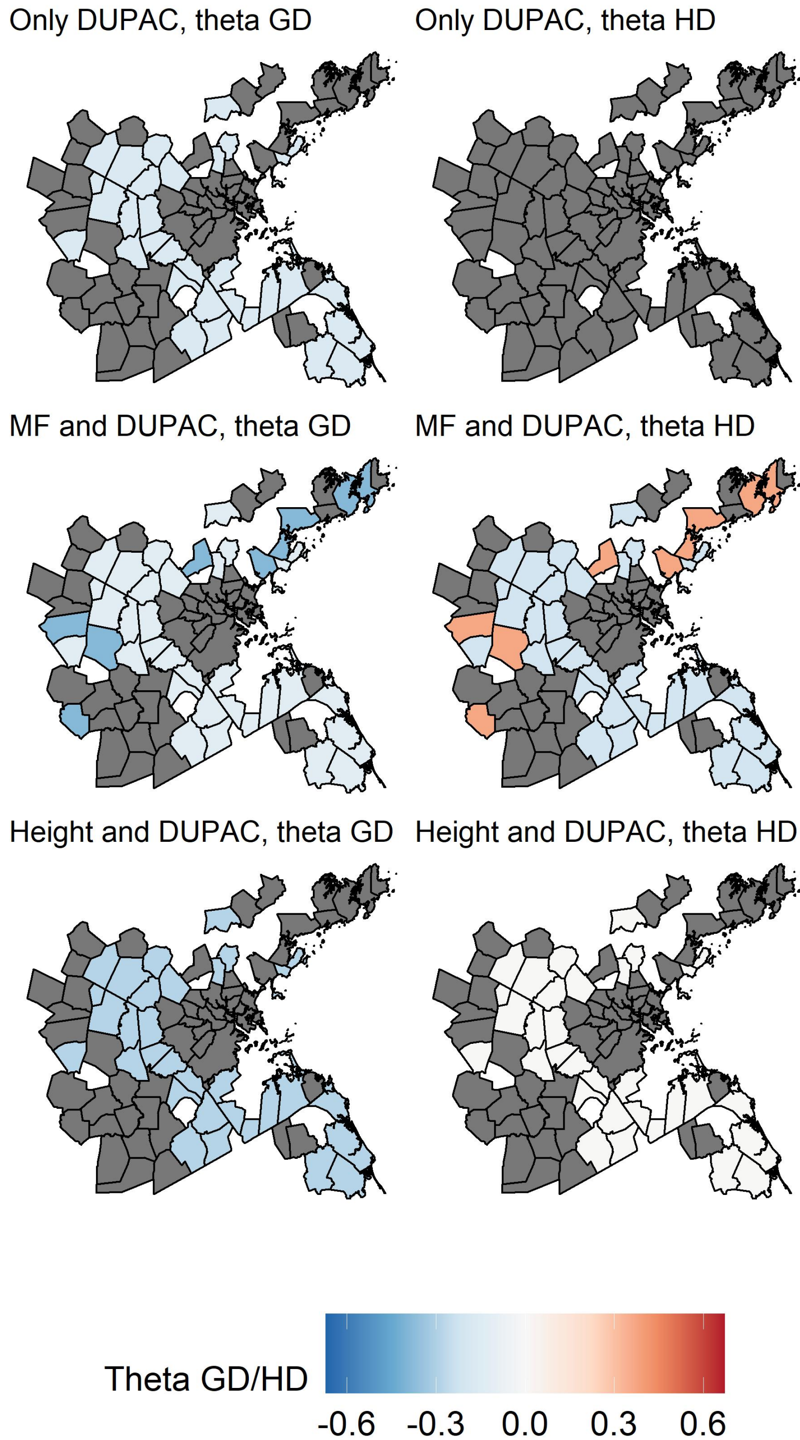
(c) RD est. = -0.011 (t-stat =-0.42), n = 22,500



(d) RD est. = 0.57 (t-stat = 25.09), n = 273

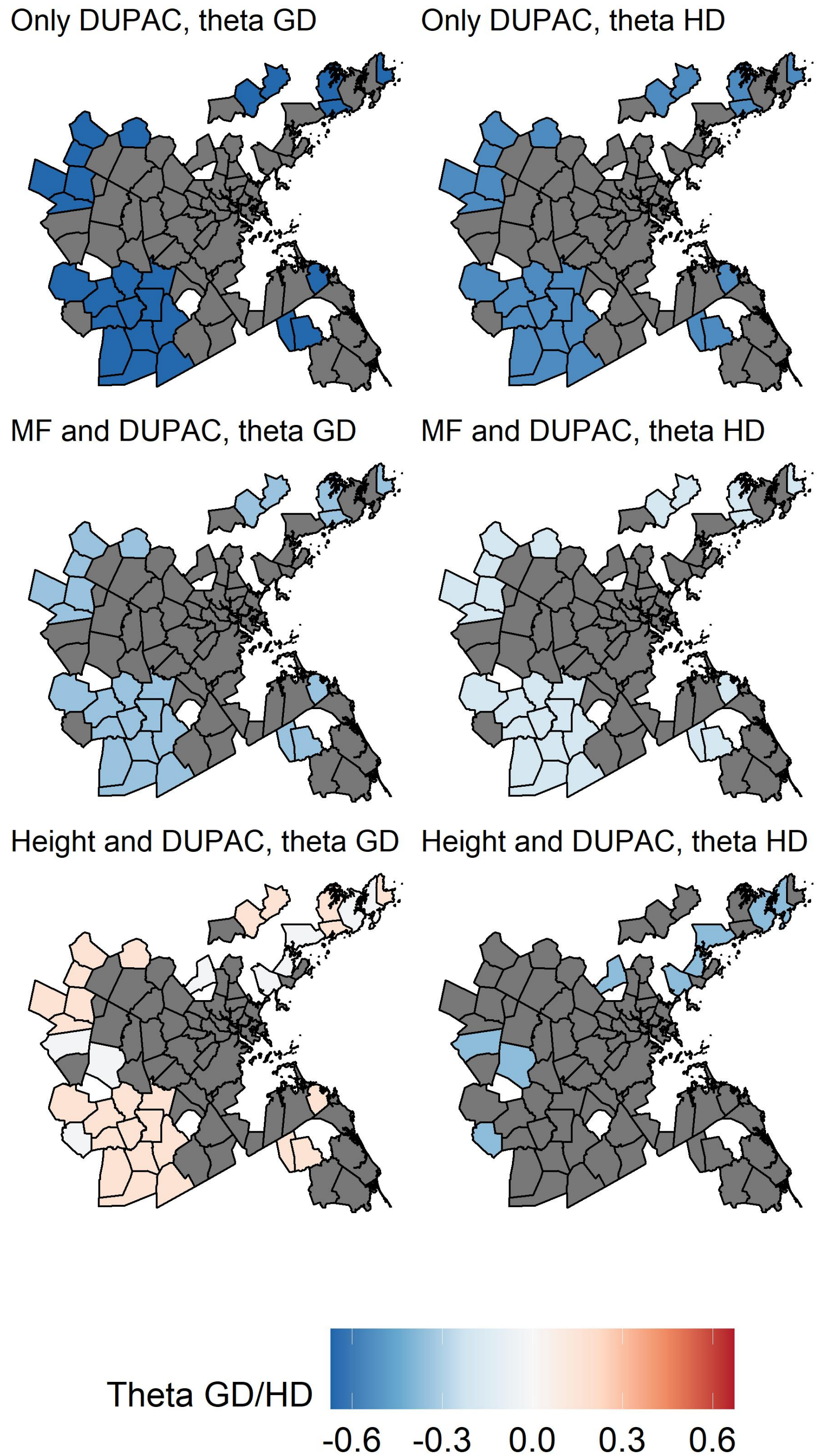
Note: Plots are created by regressing log sales prices or log CoStar rent on boundary fixed effects, year fixed effects [2010-2018], and 0.02 miles bins of distance to boundary. Coefficients on distance bins are plotted. Negative distances indicate the more regulated side of a boundary. The bin closest to the boundary on the less regulated side (0-0.02 miles) is normalized to 0. 95% confidence intervals are shown. Panels (a), (b), and (c) indicates the effect on monthly owner cost of housing for single-family houses and panel (d) indicates the effect on CoStar monthly rent. The unit on DUPAC (dwelling units per acre) is in 1 housing unit. Standard errors are clustered at the boundary level. Note that figure in panel (d) includes only residential buildings and excludes rents from mixed-use buildings.

Figure B.15: Indirect Effects of Gentle and High-Density on Single-Family Houses



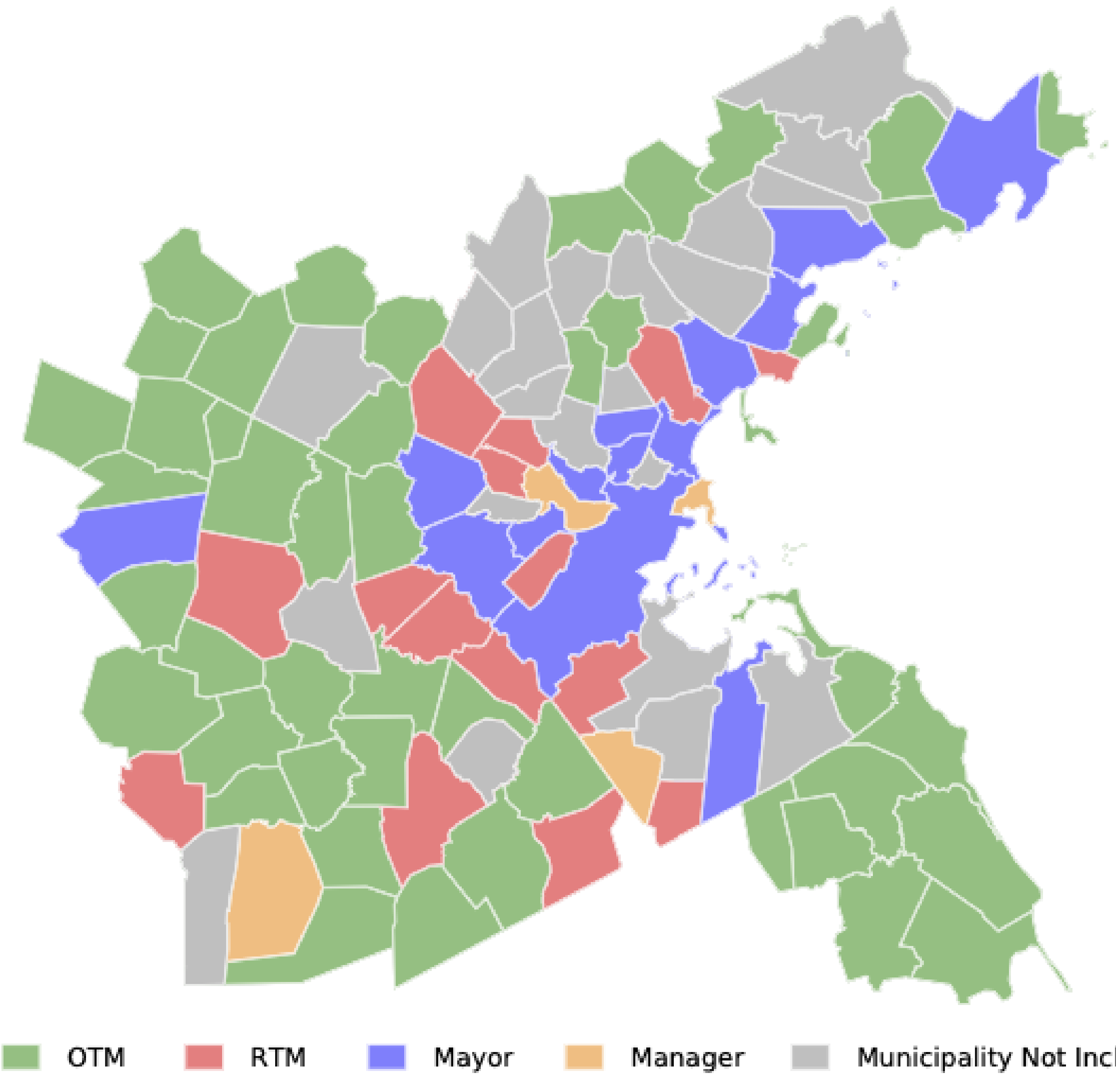
Note: These figures plots coefficients (θ^{GD}, θ^{HD}) of the indirect price effects from Equation 5 of only DUPAC (dwelling units per acre), DUPAC and Height, and DUPAC and multifamily (MF) regulations on log monthly owner cost of housing for single-family houses for increases in gentle-density (2-3 units) or high-density (four or more units) in 0.1 radius around the house on left and right, respectively. Grey areas represent no statistically significant results.

Figure B.16: Indirect Effects of Gentle and High-Density on Multifamily Renters



Note: These figures plots coefficients (θ^{GD}, θ^{HD}) from Equation 5 of the indirect price effects of only DUPAC (dwelling units per acre), DUPAC and Height, and DUPAC and multifamily (MF) regulations on log monthly rents for multifamily houses for increases in gentle-density (2-3 units) or high-density (four or more units) in 0.1 radius around the house on left and right, respectively. Grey areas represent no statistically significant results. Standard errors are clustered at the boundary level.

Figure B.17: Systems of Local Town Governance



Notes: This figure plots the different forms of local town governance in Greater Boston Area. OTM is open town meeting structure. RTM is representative town meeting structure. Other two local governance system is Mayoral and Town Manager (Manager) system.