Not in My Back Yard: The Local Political Economy of Residential Land-Use Regulations

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Abstract

We provide evidence that local preferences for neighborhood characteristics play an important role in shaping the political economy of residential land-use regulations and their distributional consequences. We leverage a land-use regulation reform in Houston, TX that reduced the minimum lot size—permitting denser single-family housing—while allowing incumbent property owners on individual city blocks to opt out of the change and adopt higher alternative minimum lot sizes. Initially wealthier, whiter neighborhoods were more likely to opt out and adopt higher minimum lot sizes after the reform. Supply of denser housing increased in areas that did not opt out. We develop a model where incumbents set minimum lot size. Incumbents trade off potential gains from redevelopment and local spillovers from housing density. The local nature of block-level regulatory decisions allows us to distinguish between preferences for neighborhood density and alternative political economy motives for regulation. Model estimates reveal large, negative local externalities from density that vary across incumbent socio-economic groups. Our results suggest that local control can tailor regulation to heterogeneous incumbent preferences, possibly making reform more politically feasible. However, doing so will likely limit supply in areas where housing demand is the highest.

JEL Codes: L51, L85, L88, P41, R21, R31, R52

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1 Introduction

Regulatory constraints on housing supply are ubiquitous across the United States (Gyourko, Hartley and Krimmel, 2021). Minimum lot sizes, parking requirements, zoning restrictions, and a web of other residential land-use regulations restrict the amount and type of housing that can be built in a given area. Such constraints are widely believed to increase housing prices (Glaeser and Gyourko, 2018), induce residential segregation (Gyourko and Molloy, 2015), dampen aggregate growth (Hsieh and Moretti, 2019), and reduce welfare (Albouy and Ehrlich, 2018). However, regulatory reforms designed to address residential segregation and housing affordability by allowing denser, cheaper housing often face steep political opposition.[1] These policy debates highlight the importance of understanding the political economy of restrictions on housing supply.

Limited empirical evidence distinguishes between the different political economy motives for regulatory restrictions on density. On the one hand, incumbent property owners may adopt these regulations to restrict housing supply in a market and increase their property values (Ortalo-Magné and Prat, 2014; Hilber and Robert-Nicoud, 2013). Alternatively, local governments may adopt regulations to limit congestion of public goods (Krimmel, 2022; Calabrese, Epple and Romano, 2007). In contrast, opponents of increased housing density often cite a desire to maintain their 'neighborhood character'. That is, incumbents may adopt regulations to avoid physical or aesthetic externalities from density or to exclude the types of people who sort into denser housing. It is difficult to distinguish between these three channels in part because the authority to impose land-use regulations has largely been delegated from states to municipalities, city wards, or even neighborhoods, which set varied and overlapping regulations through often opaque processes (King, 1978).

This paper provides evidence of incumbent preferences for low neighborhood housing density and the resulting political economy motives for residential land-use regulations. We leverage two policy changes in Houston, TX, that affected the minimum lot size for single-family lots. Minimum lot size regulations are present across the United States and are associated with lower housing density, higher prices, and larger houses (Gyourko and McCulloch, 2023). In 1998, Houston reduced the minimum lot size for single-family lots in the center of the city by over 70%. This policy change allowed denser housing in existing low-density single-family neighborhoods. In 2002, however, the city allowed property owners on city blocks with predominantly single-family lots to reestablish higher minimum lot sizes on their block through a formal voting process. We model incumbents' choices to adopt higher minimum lot sizes or allow denser in-fill development on their block. Our model provides a revealed preference approach to quantify incumbent preferences for density beyond the effect of density on prices. Incumbents in our sample would, on average, be willing to pay \$6,900 to avoid the average post-reform increase in density. This amount is roughly 5% of the median post-reform property value. Estimated disamenities from density are largest among incumbents in initially wealthier and whiter areas, where housing demand is the highest. This heterogeneity

[1] Recent regulatory reforms to permit denser housing have been stalled, weakened, or partially rolled back in California, Connecticut, Massachusetts, and New York, among other states.

matters for policy design. A counterfactual policy that eliminates local control of minimum lot sizes would reduce incumbent welfare by 3.7% but generate 28.7% more single-family units than the actual reform.

Houston's policy change provides several advantages to help quantify the role of local externalities as a potential driver of regulation. First, the policy change is one of the largest land-use regulation reforms in a major US city. Second, it codifies a formal voting mechanism for regulatory choices typically decided through more opaque political processes. The voting process allows us to map voting outcomes directly to the preferences of incumbent landowners. Third, the hyper-local regulatory choice mechanism allows us to differentiate between local disamenities from density and alternative political economy motives for regulation, such as restricting aggregate supply or reducing congestion of public goods that operate at a larger scale. Moreover, the variation in the adoption of higher minimum lot sizes provides insights into how preferences for land-use regulation vary across incumbent demographics.

Informed by the policy change, we develop a model of regulatory choice and housing supply that characterizes the political economy incentives for incumbents to adopt a higher or lower minimum lot size on their block. Borrowing from Turner et al. (2014), we decompose the incentives to reduce the minimum lot size for incumbent property owners into three distinct effects. (1) Own-Lot Effect: incumbents gain the ability to sell to a developer who will build denser housing. This will increase the value of an incumbent's property. (2) Externality Effect: incumbents' neighbors gain the ability to sell to a developer, increasing neighborhood density. This will decrease an incumbent's utility from their house to the extent that density is a disamenity for the incumbent. If density is also a disamenity for the marginal buyer, the increase in neighborhood density will decrease the value of the incumbent's property. (3) Supply Effect: the rest of the city gains the ability to sell to a developer, raising aggregate supply and potentially impacting the provision of public goods. This will tend to depress overall property values.

Our model provides a revealed preference approach to quantify incumbent preferences for density over and above the effect of density on property values. Following an unexpected fall in the minimum lot size, incumbents vote whether to opt out of the change. After the vote, incumbents choose to move or stay on their lot. If an incumbent moves when a block maintains a lower minimum lot size, their lot may be subdivided by a developer. If an incumbent stays, they will face potential externalities from increased density if other lots on their block subdivide. Incumbents vote to adopt a higher minimum lot sizes when the decrease in amenities and property value from the Externality Effect outweigh the increase in property value from the Own-Lot Effect. We rely on the local nature of the voting decisions—the median block contained about twenty lots prior to the reform—and assume that blocks are sufficiently small that incumbents do not directly consider the effect their vote has on aggregate supply or public goods provision through the Supply Effect.

We construct a rich dataset of the roughly six hundred thousand individual lots in Houston, allowing us to document the regulatory and supply response to the policy change. Tax assessor records identify which lots were subdivided into denser housing after the minimum lot size reduction and provide individual lot characteristics across time. We link lot records to block-level voting outcomes for establishing higher minimum lot sizes. We combine these records with data on lot transactions, including sales prices and purchaser demographics. This rich, disaggregated information allows us to model individual voting and subdivision choices to help understand the observed regulatory choices.

Four stylized facts inform the model on the effects of Houston's policy change. First, the minimum lot size regulation was largely binding before the policy change and meaningfully constrained housing density. The supply of single-family housing units increased by over 20% in the affected area in the 20 years following the reform. The new supply consisted almost entirely of houses on lots smaller than the pre-reform minimum lot size. Second, 59% of this new supply came from construction on newly subdivided single-family lots, making single-family neighborhoods denser.[2] Third, as of 2020, 19% of all eligible pre-reform single-family lots had adopted higher minimum lot sizes that prevent denser single-family housing. Higher minimum lot size adoption rates were correlated with incumbent demographics. Initially wealthier and whiter areas were more likely to vote for higher minimum lot sizes. Fourth, 13% of single-family lots subject to the 1,400 sf minimum lot size subdivided by 2020. The supply response to the minimum lot size reduction depended on the initial housing stock. Lots with lower-quality houses and higher-value land were more likely to subdivide.

We leverage the heterogeneous response to the policy change to estimate the model using data on observed sales prices, subdivisions, incumbent moving decisions, and voting outcomes. First, we estimate an equilibrium price surface that maps lot and house characteristics to prices. Next, we estimate the model using simulated maximum likelihood. The relative price difference between existing and newly subdivided lots, together with observed lot subdivisions, identify developer costs. Developer costs and lot prices govern the Own-Lot Effect, the surplus for incumbents from being able to subdivide their lot. Block voting outcomes help identify incumbent preferences for block density as incumbents trade off their Own-Lot Effect against the Externality Effect.

We find that incumbents, on average, tend to prefer lower housing density on a block. These preferences generate a negative externality from developing denser housing beyond the effects of density on prices. The average incumbent has a welfare loss equivalent to 5.0% of the median property value from the mean observed increase in block density. Estimated preferences for block density are heterogeneous and vary systematically with pre-reform lot and neighborhood characteristics. Disamenities from block density are the strongest for incumbents in neighborhoods with higher initial median incomes and shares of non-Hispanic White residents. These estimates suggest that density restrictions may be politically popular among incumbent homeowners in part because they address externalities generated by building denser housing.

Heterogeneous preferences across incumbents can have important implications for the design of regulatory reforms. Increasingly, state lawmakers and advocacy groups have sought to override local

[2] The remaining 41% was mostly built on land previously used for light industry. Conversion of single-family lots to commercial or multi-family use was rare.

or municipal control of land-use regulations to increase housing supply. However, local control may limit the geographic influence of incumbents that prefer stronger restrictions on density, leading to less uniform but overall more lax regulation (Gray and Millsap, 2020). We examine the trade-offs of local regulatory control through counterfactual policy experiments that maintain a uniformly high or low minimum lot size.

Compared to a counterfactual policy that maintained the high, pre-reform minimum lot size, expected welfare for the average incumbent affected by the policy change increased by $3,051, or 2% of the median post-reform house value. We decompose this change into the effect of the policy change on the value of incumbent lots and their disamenities from increased density on their block. The policy change increased property values by $7,294, on average. These gains dominate the average losses from increased disamenities from density of $4,275.

A counterfactual that rescinds block-level control of minimum lot sizes and sets a uniformly low minimum lot size eliminates the ability to tailor regulation to heterogeneous preferences. Aggregate incumbent welfare in this scenario falls by 3.7% compared to the observed policy. Incumbents in blocks that adopted a higher minimum lot size would be worse off by $407 on average. However, these blocks generate disproportionately more housing supply than areas that kept lower minimums. In total, the the increase in denser housing would have been 28.7% larger without local regulatory control. Blocks that adopted higher minimum lot sizes tended to be areas with higher initial incomes and shares of non-Hispanic White residents, where disamenities from density are the strongest. However, these areas also tend to have larger gains from allowing subdivision through the Own-Lot Effect. These competing effects result in relatively small welfare losses but large supply increases from reducing the minimum lot size. Our results highlight an important trade-off for policymakers. Allowing local regulatory control may tailor policy to heterogeneous incumbent preferences. However, it may also result in stricter regulation in areas that would otherwise see large supply responses to regulatory reform.

This paper provides new evidence that preferences for neighborhood housing density are an important determinant of residential land-use regulation. Alternative political economy motivations for such regulation included incumbent property owners seeking to restrict housing supply and increase prices (Ortalo-Magné and Prat, 2014; Hilber and Robert-Nicoud, 2013), prevent congestion in public goods provision (Krimmel, 2022), generate Tiebout (1956) type welfare gains by inducing an income-stratified sorting equilibrium (Calabrese et al., 2007), or for ideological motives (Kahn, 2011). Our work does not rule out these motives. Instead, we highlight the ability of regulation to correct local externalities from density as an important reason why incumbents adopt regulatory restrictions on housing supply.

Importantly, our estimates of preferences for density capture both aesthetic or physical amenities from density and exclusionary motives over people that live in denser housing. Both channels may be present. Rossi-Hansberg et al. (2010) and Fu and Gregory (2019) show that revitalizing vacant or damaged houses increases the prices of neighboring houses, in line with household preferences for local housing characteristics. On the other hand, Rothstein (2017) documents that many regulatory restrictions on housing supply were adopted to intentionally induce socio-economic segregation after explicitly race-based zoning was ruled unconstitutional by the Supreme Court. Cui (2023) provides reduced-form evidence for such exclusionary motives, finding stricter minimum lot size regulations were adopted in response to greater in-migration of Black residents but not low-income White residents during the Second Great Migration. We provide new evidence that heterogeneous preferences for local neighborhood characteristics influence the adoption of minimum lot sizes.

A key contribution of our paper is to highlight the heterogeneity in preferences for density. Our results align with those of Davidoff et al. (2022), who find accessory dwelling units decrease prices of nearby homes, with the strongest effects for higher-valued properties. Bunten (2017), Duranton and Puga (2019), and Parkhomenko (2023) develop and estimate structural models of regulatory adoption at the level of the city. These papers study how residents trade off externalities from density against other forces, such as agglomeration externalities in production, but abstract from heterogeneity in preferences. We complement this work by providing evidence on how preferences vary within a city. This heterogeneity can have aggregate consequences depending on the geographic scope of policy choices. Mast (2022), for instance, provides reduced-form evidence that switching from city-wide to ward-specific town council elections decreases permitting for additional housing units.

We also contribute new insights to a recent strand of literature that seeks to understand the distributional effects of residential land-use regulations. Evidence on consumer gains to increased density varies. Acosta (2022) and Anagol et al. (2021) find that high-skill workers gain the most from increases in density. On the other hand, Song (2021) and Mei (2022), who also studies Houston's 1998 minimum lot size reduction, find that lower-income purchasers gain when preferences are non-homothetic and regulatory reforms shift the composition of housing towards smaller units. In contrast, we explore the heterogeneous effects of regulatory reforms on incumbent property owners and their implications for regulatory choice.

The paper proceeds as follows. Section 2 provides details of the policy change in Houston and the data we use to analyze the change. Section 3 provides descriptive evidence on the effect of the policy change on housing supply and regulatory choice. Section 4 outlines a model of housing supply and regulatory choice. We discuss the estimation of the model in Section 5. Section 6 details the results of our estimation, and Section 7 describes policy counterfactuals. Section 8 concludes.

2 Policy Details and Data

In this section, we provide additional background information on residential land-use regulations in Houston. We then discuss the 1998 minimum lot size reduction and the subsequent introduction of the block-level option to opt out and adopt higher minimum lot sizes. Finally, we outline the data we use to examine the effects of the policy change.

2.1 Background

Houston, the fourth most populous city in the United States, is notable for urban sprawl: New York City has nearly four times the number of people on less than half the land. Chicago has twenty percent more people on about a third of the land. While Houston is unique among other large US cities for the absence of Euclidean zoning, a patchwork of alternative regulations contributes to its low population density. These policies include minimum lot sizes, parking requirements, maximum height restrictions, historic districts that govern architectural decisions, and a system of state-enforced but privately adopted deed restrictions that function similarly to traditional zoning.

Minimum lot sizes govern the extent to which land can be subdivided, restricting single-family housing density. These regulations play a particularly important role in shaping the housing density in Houston, where single-family units are over 40% of the housing stock. In the absence of traditional zoning, Houston does not directly regulate density by limiting the number of housing units that may be built on a lot. However, in practice, there is a strong negative relationship between lot size and housing unit density.

In addition to minimum lot sizes, Houston has a system of deed restrictions that act as a private alternative to zoning or minimum lot size ordinances. Current property owners adopt deed restrictions to limit future owners' property rights. Deed restrictions are typically adopted when developers create large, greenfield subdivisions to assure potential buyers that the neighborhood's character will not change. Today, typical deed restrictions in Houston limit land use to single-family housing, set architectural guidelines, or establish minimum lot sizes.[3] Throughout our analysis of the 1998 policy change in Houston, we take deed restrictions as predetermined. Most of the area affected by the 1998 policy change in Houston had already been developed, and we do not find evidence of large-scale adoption of deed restrictions after the minimum lot size fell. In general, it is uncommon for restrictions to be adopted after land has been initially subdivided into single-family lots. In our analysis, we identify deed restricted lots and control for these restrictions.

2.2 Policy Details

In 1963, Houston enacted its first minimum lot size and minimum setback restrictions, formalizing a set of non-binding regulations in place since 1940. The new regulation set the minimum lot size for detached single-family homes at 5,000 sf and the minimum setback of buildings from the front of a lot to 25 ft (Kapur, 2004).[4] This was a relatively restrictive minimum. It limited the development of denser town- or row-house style developments common in older US cities.

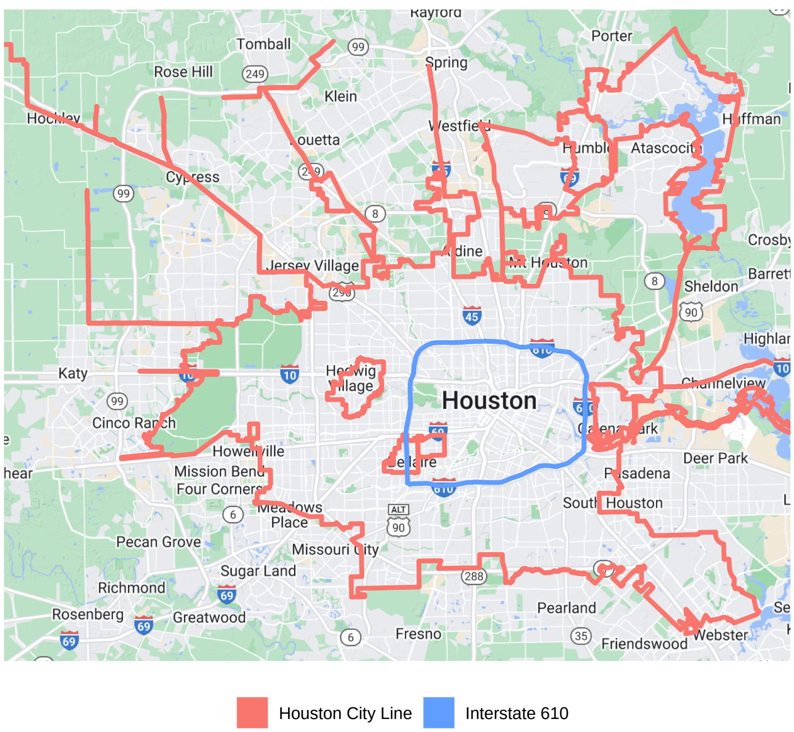
Houston reduced the minimum lot size in the 'urban core' of the city in 1998. The policy

[3] It was common for deed restrictions in Houston to ban the sale of property to Black or non-White residents before such restrictions were ruled unconstitutional by the Supreme Court in 1948. The prevalence of explicitly racist purchaser restrictions alongside restrictions like minimum lot sizes may align with an exclusionary motive for other land-use regulations.

[4] The minimum lot size was set to 7,000 sf for lots with detached single-family homes without access to a sewer line, and 2,500 sf for lots with attached single-family townhouses. Gray and Millsap (2020) notes that townhouse development was limited, with the high minimum setbacks reducing profitability.

change was partly intended to create a denser urban feel (Kapur, 2004) and partly in response to lobbying by developer organizations. Houston defined its urban core as the 96 square miles around the central business district, bounded by Interstate Highway I610. Figure 1 shows the geographic scope of the urban core. The reform reduced the minimum lot size for lots containing single-family housing to 3,500 sf unconditionally. Lots as small as 1,400 sf were allowed if a certain percentage of open space was maintained on the lot. The change also reduced the minimum setback requirement to 5 ft. Houston's policy change enabled denser green-field development of large vacant tracts of land and in-fill development in single-family neighborhoods.[5]

Figure 1: Houston City Lines and Urban Core:



Note: This figure shows a map of Houston's administrative boundaries and Interstate 610. Houston's urban core is defined as the intersection of the two polygons. Houston's administrative boundaries contain major roads extending outwards from the city. These features extend Houston's Extraterritorial Jurisdiction, the set of unincorporated land within 5 miles of Houston's administrative boundaries. Houston's limited regulatory authority in the Extraterritorial Jurisdiction includes regulations on the development and subdivision of land.

After the reform, developers could buy and raze single-family homes, subdivide the lots, and build multiple tall, narrow houses on the same land. Figure 2 provides an example of typical pre- and post-reform developments. As many incumbent residents subsequently complained, the denser

[5] Houston's Department of Planning and Development was allowed to grant exemptions, allowing for the creation of smaller lots prior to the reform. In Section 3 we provide evidence that the minimum lot size was largely binding before the reform in Houston's urban core and other previously developed areas.

townhouse-style buildings had the potential to change the look and character of a neighborhood and generate externalities on nearby lots.

Figure 2: Example Pre- and Post-Reform single-family Lots:

Note: This figure provides an example of typical pre- and post-reform developments. On the left is a 5,000-sf pre-reform lot with a bungalow-style single-family house common in Houston's urban core. On the right are two new 2,500-sf lots with townhouse-style single-family houses common post-reform.

In response to lobbying by neighborhood organizations opposed to in-fill development of denser housing, Houston weakened the initial reform by allowing property owners in the urban core to vote to raise the minimum lot size to the 'prevailing lot size' for a city block (Kapur, 2004). The city defined a block as a set of lots on one or both sides of a street from one intersection to the next, containing up to 500 contiguous lots. See Figure A1 for a typical example. To request a 'Special Minimum Lot Size' (SMLS) for a block, owners of at least 51% of the land on a block needed to sign onto a petition to the Houston Department of Planning and Development. If the block meets certain eligibility requirements, primarily that 60% of the land on a block had been developed for single-family residential use, the new SMLS would be set at the 30th percentile of lot size on a block. Lots falling below the cut-off remained unchanged but were unable to subdivide further. Lots were typically uniform in size within a block prior to the reform, preventing almost all subdivisions on a typical block that adopted an SMLS. Once enacted, an SMLS would be enforced for 20 years, later extended to 40 years. An SMLS could be revoked earlier with the approval of owners on 60% of land on a block. None had been revoked as of 2020.

Finally, in 2013, Houston extended the lower minimum lot size ordinance and the ability to adopt an SMLS across the city. This second reform added an additional mechanism that allowed areas larger than a city block to adopt higher minimum lot sizes with the approval of the owners of at least 55% of the land in an area. This additional option creates interesting questions about coalition formation in policy choices that are outside of this project's scope.

2.3 Data

We collect spatially disaggregated data from a variety of sources that allow us to explore the rich heterogeneity of multiple aspects of Houston's policy change. We link individual lot characteristics, subdivisions, transaction prices, Census neighborhood demographics, and block-level voting outcomes on minimum lot size adoption throughout the city of Houston. This section briefly summarizes each data source. See the Data Appendix for more discussion of the data sources and definitions.

Property tax records from the Harris County Appraisal District (HCAD) allow us to track lot subdivisions and new housing supply after the reform. The HCAD data contain lot and building characteristics, as well as owner names and addresses, for the universe of the 1.5 million lots in Harris County from 2005 to the present. HCAD also provides lot shapefiles. We supplement this panel with lot shapefiles from the Houston Department of Planning and Development containing data from 1989-2004. These supplemental shapefiles include information on land use and assessed value but provide less detail on housing characteristics. We use these details to extrapolate pre-reform characteristics for parcels subdivided prior to the start of the HCAD data. We use data on lot owners to construct a proxy indicator for when a parcel sells through an arms-length transaction.[6]

The Houston Department of Planning and Development provides detailed records on proposed and successful special minimum lot size petitions. These data include shapefiles of the geographic extent of the city blocks proposing a higher SMLS, the new minimum lot size, and the adoption date. The data indicates which petitions were successful but does not record which lot owners signed on to the petitions. As of 2020, 630 SMLS petitions were approved in the urban core of the city. Only one proposed SMLS was unsuccessful, suggesting applicants submit proposals after gaining support from a majority of property owners. No approved SMLS petitions were rescinded as of 2020. We use the shapefiles to link block petitions to the lot records. We construct the universe of potential SMLS blocks using lot and street grid shapefiles.

Data on lot transactions comes from CoreLogic, Inc. Unlike most states, Texas does not mandate the reporting of transaction prices. Instead, the CoreLogic data largely consists of mortgage details collected from registrars of deeds. CoreLogic imputes transaction prices from data included in mortgage documentation, along with other supplemental sources. As such, we see only a subset of transaction prices, with limited coverage of the prices developers paid to acquire existing single-family lots. We take this selection into account when developing our model in Section 4. Finally, we merge our lot-specific records with block group and tract level demographic data from the United States Census.

[6]See Appendix B for details.

3 Descriptive Evidence on Policy Change

We provide descriptive evidence on the heterogeneous responses to Houston's minimum lot size reforms that motivate our theoretical model. We begin by showing that Houston's minimum lot size constrained the supply of single-family housing in the city's urban core, and the 1998 minimum lot size reduction led to greater housing supply. Next, we document the adoption of higher local minimum lot sizes that allowed incumbent property owners to opt out of the policy change. Finally, we explore how these differential responses to the policy change vary with pre-reform lot and neighborhood characteristics.

3.1 Supply Increase and Special Minimum Lot Size Adoption

A sharp increase in single-family home supply immediately followed the 1998 reduction in minimum lot sizes in the urban core. In the decades before the reform, this area had seen relatively little new single-family development. The top left panel of Figure 3 displays the distribution of lot sizes for new single-family houses created from 1964, when the minimum lot size was established, until 1998, when the minimum lot size was reduced. The top right panel of Figure 3 shows the same distribution for the 21 years following the minimum lot size reduction. These figures show an overall increase in new single-family construction after the reform and bunching of lot sizes at the new 1,400 sf minimum after the reform. The bottom panel of Figure 3 displays the number of new single-family houses built on lots below and above 5,000 sf in the urban core by year from 1964 to 2019. New houses on lots below 5,000 sf rose sharply in 1998, the year of the reform.

The sharp increase in single-family supply starting in 1998, together with the observed bunching at the new minimum lot size of 1,400 sf, suggest the old 5,000 sf minimum lot size was a meaningful constraint on single-family housing supply in the urban core of Houston. The data show that exemptions from the minimum lot size were rare in practice, and the reform led to the development of denser housing in Houston's urban core.[7] These results expand on findings from Gray and Millsap (2020), a descriptive analysis of the reform, and Mei (2022), who studies the welfare effects of changes in the composition of new house characteristics induced by the reform.

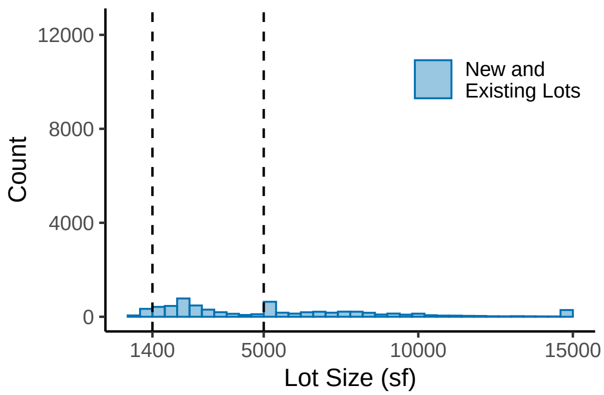
The reform caused previously lower-density single-family neighborhoods to get denser. 59% of the new 'reform style' lots below 5,000 sf were created through in-fill development of existing single-family lots. The remaining 41% resulted mostly from the redevelopment of larger lots previously used for light industry or other commercial purposes.[8] In-fill development largely took the form of developers buying lots with older, relatively smaller houses to subdivide the land and replace them with two or three taller and narrower houses. In total, over 7,000 single-family lots were subdivided by 2020. This represents about 10% of non-deed restricted pre-reform single-family lots. Notably,

[7] The minimum lot size was less binding outside the urban core. Exemptions were mostly given for large, green-field developments without immediate neighbors to protest. By 1964, much of the land in the urban core was previously developed, which limited new green-field developments.

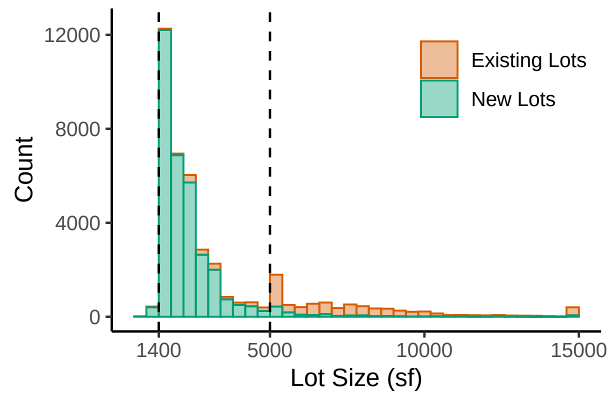
[8] By comparison, most sub-5,000 sf single-family lots outside of the urban core resulted from green-field development, both before and after the 2013 reduction of minimum lot sizes.

Figure 3: Distribution of Lot Size for New Single-Family Houses Pre- & Post-Reform

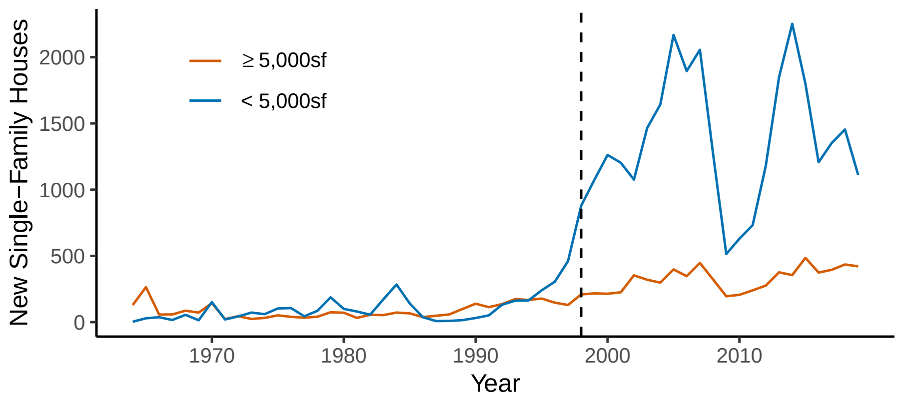
(a) Lots Size Distribution: 1964-1997



(b) Lots Size Distribution: 1998-2019



(c) Year Built By Lot Size



Note: Figure 3a plots the distribution of lot sizes for all single-family houses built inside Houston's urban core from 1964 to 1997 when the minimum lot size was 5,000 sf. Data constraints prevent us from distinguishing between houses built on newly developed lots or those that replace existing houses during this period. Figure 3b plots the same distribution from 1998 to 2019, when the minimum lot size was 1,400 sf. We differentiate between houses built on lots created before and after the 1998 reform. Figure 3c shows the number of new single-family houses created by year inside Interstate 610, broken down by those above and below the old 5,000 sf minimum lot size.

we observe relatively little conversion of single-family land to non-single-family use. A large share of conversions that we do observe were subsequently used for non-commercial uses, particularly schools. As such, we focus on the intensity of development of single-family land as the primary margin of adjustment in response to the policy change.

By 2020, 13.7% of pre-reform single-family lots were on blocks that voted to adopt a higher minimum lot sizes to prevent in-fill development of denser housing on their block. This represents 16% of eligible blocks and 19% of eligible single-family lots.[9] The partial adoption of higher

[9]Blocks already subject to private deed restrictions that set alternative minimum lot sizes, or blocks with less than 60% of land developed for single-family use were not eligible to adopt an SMLS.

minimum lot sizes suggests that preferences for block-level density restrictions among incumbent homeowners are heterogeneous. We explore these differential responses to Houston's policy change in the remainder of this section.

3.2 Heterogeneity in Lot Subdivision and Special Minimum Lot Size Adoption

In-fill development of denser single-family housing and adoption of higher local minimum lot sizes after the reform are correlated with pre-reform lot characteristics and neighborhood demographics. These divergent responses to the policy suggest that reducing the minimum lot size may have distributional consequences for incumbents. This section explores these patterns of heterogeneity in more detail.

Table 1 presents descriptive statistics for our sample of lots prior to the reform in 1998. In Columns 1-3 we display pre-reform lot characteristics for the subsample of non-deed restricted lots that were large enough to subdivide after the 1998 reform. We further divide this subsample into lots that did not subdivide (Column 1) or did subdivide (Column 2) by 2020. Lots that were subdivided tended to be in Census block groups with initially higher shares of non-Hispanic White residents, lower shares of non-Hispanic Black and Hispanic residents, and slightly higher median income, as measured by the 2000 Census. In Columns 4-6, we display similar comparisons for the subset of lots that were eligible to adopt higher minimum lot sizes. Lots on blocks that adopted an SMLS had substantially higher initial Census block group median incomes and shares of non-Hispanic White residents and lower share of non-Hispanic Black and Hispanic residents. These patterns suggest that areas with initially wealthier and whiter incumbents may benefit more from higher minimum lot sizes. In contrast, other areas may gain more from lower minimum lot sizes that allow subdivision.[10]

Next, we examine the conditional correlations between pre-reform lot and neighborhood characteristics and post-reform lot outcomes. We consider an OLS regression of the following form:

$$y_i = \alpha + X_i'\beta + \epsilon_i$$

where y_i is an indicator for lot-level outcomes in 2019. The two outcomes of interest are whether a lot was part of a block that adopted an SMLS and, conditional on not adopting an SMLS, whether a lot was subdivided. X_i is a vector of pre-reform lot characteristics. The regression sample for SMLS adoption includes all lots on blocks eligible to adopt an SMLS. The sample for lot subdivision includes all lots in the urban core eligible to subdivide based on the prevailing minimum lot size, either the city-wide 1,400 sf minimum, a deed restriction, or a block-specific SMLS. The sample for

Table 2 displays the results of these regressions. Column (1) shows that neighborhood demographics are correlated with post-reform SMLS adoption. Lots in Census block groups with higher median incomes and non-Hispanic Black residential share in 1999 were more likely to be

[10]Lot-level outcomes are also spatially correlated. Figure A2 shows the spatial correlations of post-reform outcomes. The spatial patterns of denser housing development and SMLS adoption can be explained by spatial differences in pre-reform demographics and lot characteristics, given the degree of residential segregation in Houston.

Table 1: Descriptive Statistics—Pre-Reform Lot Characteristics

Variable	Subdivision			Special Minimum Lot Size		
	Not Subdivided (1)	Subdivided (2)	Difference (3)	No SMLS (4)	SMLS (5)	Difference (6)
Demographics (Census block)						
Median Income	28,803.14	34,254.00	5,450.86***	29,456.08	44,899.33	15,443.25***
	(15,138.87)	(16,254.52)	(270.42)	(15,978.40)	(21,645.49)	(216.46)
Percent White	16.52	29.62	13.10***	18.17	38.01	19.84***
	(24.62)	(25.52)	(0.42)	(25.81)	(30.88)	(0.31)
Percent Black	27.81	15.85	-11.96***	26.37	14.25	-12.12***
	(35.00)	(23.84)	(0.42)	(34.03)	(29.21)	(0.32)
Percent Hispanic	53.84	51.67	-2.17***	53.52	44.47	-9.06***
	(34.32)	(27.00)	(0.46)	(33.90)	(32.99)	(0.35)
Lot Characteristics						
Lots Size (sf)	6,473.37	6,901.18	427.81***	5,738.05	6,518.41	780.34***
	(2,674.79)	(2,760.26)	(46.05)	(2,757.96)	(2,386.28)	(25.73)
Assessed Land Value ($/sf)	6.30	12.09	5.79***	8.58	14.06	5.49***
	(8.78)	(9.65)	(0.16)	(12.39)	(12.59)	(0.13)
House Size (sf)	1,481.94	1,461.85	-20.09	1,591.02	1,748.21	234.19***
	(973.07)	(937.58)	(18.21)	(952.69)	(848.78)	(9.55)
Assessed House Value ($/sf)	10.57	6.37	-4.20***	18.43	17.67	-0.76***
	(14.34)	(6.73)	(0.15)	(31.39)	(20.22)	(0.25)
House Age	63.19	69.69	6.50***	57.94	65.27	7.32***
	(18.45)	(14.41)	(0.29)	(24.08)	(20.05)	(0.23)
block Mean Density (lots/5000sf)	0.97	1.21	0.23***	1.10	0.88	-0.22***
	(0.33)	(0.49)	(0.01)	(0.43)	(0.27)	(0.01)
Vacant	0.19	0.26	0.07***	0.20	0.06	-0.15***
	(0.39)	(0.44)	(0.01)	(0.40)	(0.23)	(0.01)
Observations	48,886	7,039		48,754	11,258	
Percent	87.41	12.59		81.24	18.76	

Note: This table reports summary statistics for pre-reform single-family lots in Houston's urban core, disaggregated by whether lots were subdivided or were part of a block that elected to have a higher minimum lot size by 2019. Standard deviations are reported in parentheses below group means in columns 1-2, 4-5. Standard errors for a comparison of means are reported in parentheses in columns 3 and 6. Columns 1-3 include only lots eligible to subdivide based on pre-reform lot size and deed restrictions. Columns 4-6 include only lots on blocks eligible for higher special minimum lot sizes.

on a block that adopted a higher minimum lot size, all else equal. Lots with characteristics that tend to increase lot value, from lot size to building value per square foot, were also more likely to adopt an SMLS. Similarly, lots on blocks with higher initial density are less likely to adopt density restrictions.

In contrast, Column (2) shows that pre-reform, lot-specific characteristics likely to affect the relative gains to developing denser housing are correlated with post-reform lot subdivision. Larger lots and lots with higher assessed land values were more likely to subdivide. Lots with larger or higher quality houses and lots that face additional development restrictions, such as deed-restricted minimum setbacks or historical district architectural restrictions, were less likely to subdivide. Conditional on these lot-specific characteristics, we find that pre-reform neighborhood demographics are not correlated with post-reform lot subdivision.

Table 2: Lot Outcomes and Pre-reform Characteristics

	SMLS (1)	Subdivided (2)
Demographics (Census block group)		
ln(Median Income)	0.231***	-0.013
	(0.062)	(0.018)
Share White	0.016	-0.041
	(0.117)	(0.123)
Share Black	0.112**	-0.028
	(0.054)	(0.021)
Lot Characteristics		
ln(Lot Size)	0.028*	0.109***
	(0.015)	(0.016)
ln(Assessed Land Value psf)	0.054***	0.097***
	(0.021)	(0.014)
ln(Building Size)	-0.018	-0.017*
	(0.019)	(0.009)
ln(Assessed Building Value psf)	0.062***	-0.050***
	(0.011)	(0.005)
ln(Building Age)	0.092***	0.006
	(0.012)	(0.006)
Block Density	-0.242***	0.109***
	(0.029)	(0.013)
Historical District	0.118	-0.131***
	(0.082)	(0.014)
Deed Restricted setbacks	-0.067	-0.095***
	(0.076)	(0.025)
Vacant	0.361**	-0.028
	(0.150)	(0.064)
Constant	-2.640***	-0.793***
	(0.640)	(0.161)
Observations	60,012	55,925
R^2	0.240	0.137

Note: This table reports estimated coefficients of an OLS regression of lot outcomes in 2019 on pre-reform lot characteristics. Column (1) reports results for adoption of SMLS for all single-family lots on blocks eligible to adopt SMLS. Column (2) reports results for lot subdivision for all single-family lots eligible to subdivide based on their lot size and the prevailing minimum lot size based on deed restrictions, SMLS, or the city-wide minimum. Standard errors are clustered at the Census block group level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

In summary, our descriptive evidence suggests that Houston's minimum lot size was a binding constraint to the supply of single-family housing in Houston's urban core. The minimum lot size reduction in 1998 led to more and denser single-family housing supply. However, some incumbents voted to adopt higher minimum lot sizes to prevent denser housing on their blocks. Neighborhood demographics are important for explaining observed local regulatory decisions, alongside individual lot characteristics. In contrast, lot subdivisions and in-fill development do not seem to be related to neighborhood demographics. Instead, pre-reform lot characteristics associated with the profitability of subdividing an existing single-family lot are correlated with higher rates of subdivisions.

Observed patterns of local regulation and subdivision suggest that preferences for regulation vary across incumbent demographics. However, incumbent preferences can be difficult to identify. Typically, preferences for housing characteristics, such as density, are estimated through a revealed preference argument on demand: if a household purchases one house over another, we can learn something about their preferences. In the case of hedonic demand estimation, this information can be summarized succinctly by the relationship between prices and housing characteristics (Rosen, 1974). There are two issues with applying these approaches to study the preferences of incumbents. First, when incumbents initially purchased their house, the option to choose a house in a higher-density single-family neighborhood largely did not exist because of the high minimum lot size. We cannot learn about options not in the choice set with a demand-driven approach. Second, estimating demand after the reform is informative about the preferences of the marginal buyer. However, preferences for housing and location characteristics have likely changed over the last 20 years (Couture and Handbury, 2020). In general, the preferences of post-reform buyers may differ from those of incumbents.

Incumbent residents choose residential land-use regulations in Houston and in much of the United States. Overcoming the challenges to estimating incumbent preferences for density and how they vary across locations is important for understanding the political economy of regulatory choices and the impact of local regulatory control. To do so, we develop a structural model of regulation adoption and lot subdivision to estimate incumbent preferences for density and evaluate the effect of alternative minimum lot size policies on housing supply and the distributional outcomes of incumbent property owners.

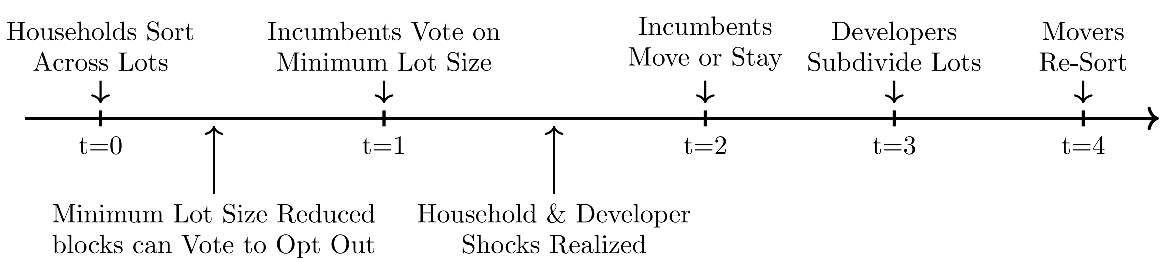
4 A Model of Regulatory Choice and Housing Supply

We develop a model of regulation adoption and lot subdivision informed by our descriptive evidence. The model leverages information embodied in observed voting outcomes and lot subdivisions to recover incumbent preferences for density. In the model, incumbent homeowners vote on local minimum lot size regulations. Conditional on the vote, incumbents choose to move or stay in their initial lots. When an incumbent moves, they sell their lot to another owner-occupier or a developer who will subdivide the lot and build denser housing. Finally, residents re-sort across available single-family lots or an outside option. The model uses a revealed preference approach to quantify potential externalities from local housing density among incumbent property owners. We estimate the monetary gains (or losses) in lot value for incumbents that allow subdivisions. Incumbents trade off changes in lot value against potential disamenities from density if they do not move following the policy change. The observed heterogeneity in the regulatory and supply response to the policy change is rationalized in the model by variation in preferences for block density and moving costs across incumbents, and variation in the opportunity cost of subdividing lots. We first review the model setup and timing before providing additional model details.

4.1 Setup and Timing

There are two types of agents in the model: households and developers. Households differ by demographic group, including race and wealth, and by preferences over housing characteristics. Before the minimum lot size reform, households sort over single-family lots and an outside option. All single-family lots are owned by households as opposed to absentee landlords. This assumption is consistent with the vast majority of ownership records for Houston's Urban Core in the Harris County tax rolls.[11]

Following the unanticipated policy change, owners on each city block collectively vote on whether to adopt a higher minimum lot size. Next, incumbent residents choose to stay or re-sort into available lots or the outside option. Newly vacant lots may be purchased by a household or a developer who will subdivide the lot and build denser housing. The model timing is outlined below:



The timing assumptions represent the policy change as a simultaneous minimum lot size reduction and introduction of a mechanism for blocks to adopt an SMLS. We collapse dynamic considerations into a two-period model to capture the impact of the reform as concisely as possible. We treat the observed set of lots in 2002, when the SMLS mechanism was introduced, as the ex-ante distribution of lots to best match the staggered implementation of Houston's policy change. Post-reform lot subdivision and SMLS outcomes are just before the introduction of the ability to adopt an SMLS over larger coalitions of blocks was introduced in 2013.

[11] Tax data do not contain detailed records of whether an owner-occupier owns a lot. We use corporate ownership, derived from owner names, and the number of lots owned by an individual, defined as an owner name and address pair, as proxies for absentee landlords. At the start of our detailed data on ownership in 2005, less than 3.6% of single-family lots in our sample were owned by corporate entities and fewer than 4.7% were owned by individuals with more than one single-family lot in the sample.

There is a mass L_0 of initial single-family lots inside and outside Houston's urban core. Lots are partitioned into a set of city blocks, B. Blocks are small relative to the larger Houston housing market. As such, we assume households do not consider how their voting decisions will affect the aggregate housing supply and lot prices. Under this assumption, we show how a revealed preference approach can be used to characterize the local (dis)amenities from density.

Lot l in block b, $l \in b(l) \subset L_0$, is defined as the tuple of characteristics $(X_l, d_{b(l)}, \xi_l)$. X_l represents observable lot characteristics, including location, neighborhood characteristics, lot size, house size, and house age. $d_{b(l)}$ is the average density of the block to which a lot belongs, $b(l)$. Block density is defined as the average number of single-family units per 5,000 sf. ξ_l represents a vertical measure of housing quality known to households but unobserved to the econometrician.

There is a mass of households. Household demand for housing follows a hedonic framework in the spirit of Rosen (1974) and Bajari and Benkard (2005). Households have quasi-linear utility over lot characteristics and a consumption composite with price normalized to one. Assuming quasi-linear utility yields significant tractability in estimating the model at the expense of not capturing wealth effects as incumbents' lot prices change post-reform. Utility is additively separable in preferences for block density. Household demand for housing before and after the reform, $t = 0$ and $t = 1$, respectively is:

$$U_{it} = \max_{l \in L_t} \; u_i(X_l, \xi_l) + g_i(d_{b(l)}) + c_t$$
$$\text{s.t. } p_{lt} + c_t \leq w_{it}$$

where i indexes households, p_{lt} is the price of lot l in period t, c_t is the consumption index, and w_{it} is household i's wealth. With a slight abuse of notation, we include in L_t an outside option with utility normalized to zero. Preferences over block density, $g_i(d_{b(l)})$, introduce a potential externality to lot subdivision: a developer may impact the utility value of other lots on a block when they subdivide a lot and build denser housing.

Bajari and Benkard (2005) show that under weak assumptions on the utility function, there exists a Lipschitz continuous equilibrium pricing function mapping each unique bundle of characteristics (X, d, ξ) to a single price: $p_{lt} = p_t(X_l, d_{b(l)t}, \xi_l)$. Since incumbents are small and take prices as given, this result does not require any supply-side assumptions. However, the pricing function is an equilibrium object and does change in response to changes in consumer preferences or supply.[12]

Households do not face credit constraints, and changes in lot value after the reform directly affect consumption, independent of whether an incumbent household sells their lot. This assumption allows us to tractably capture preferences for house price appreciation induced by changes in regulation for incumbents that do not move in our static framework.

Developers are atomistic, perfectly competitive firms that pay a fixed price to incumbents to acquire lots that they transform into denser new lots. Perfect competition implies that the

[12] Appendix C details how equilibrium prices are set for a given set of household preferences and an arbitrary level of supply across characteristic space.

incumbent lot owner extracts all the surplus from developing a lot. This is a strong assumption. As Glaeser et al. (2005) note, however, home building is a highly competitive business with few barriers to entry.[13]

We now provide additional details of the model working sequentially backward through the timing of the model.

4.2 Developer Technology and Lot Subdivision

When an incumbent household moves, they sell their initial lot to either another household or a developer. Presented with a given lot l, a developer has two decisions. First, they decide how many new lots, k, to build. Second, conditional on the number of new lots they create, developers choose building square footage to maximize surplus. All newly created lots are symmetric, consistent with the typical subdivision in the data.

We first consider the developer problem of deciding housing characteristics when subdividing a lot into k new lots. We partition the observable new lot characteristics $X(k)$ into the set of characteristics that are predetermined from the perspective of the developer, $X^{\text{exog}}(k)$, and the characteristics that are chosen by the developer, $X^{\text{endog}}(k)$. Predetermined characteristics include the size of the new lot, the age of the new house, the density of the block, and location characteristics. Developers may face a wide array of additional structural and stylistic choices, including the number of bedrooms, the number of stories, etc. We collapse these choices into a single dimension: the building's square footage. This assumption keeps the model tractable with relatively little loss of information.[14] Together, the full set of new lot characteristics are $X(k) = X^{\text{endog}} \cup X^{\text{exog}}(k)$.

We assume the unobserved quality of the new lots, ξ, is realized after the choice of lot characteristics to capture the idea that there is uncertainty in how appealing buildings ultimately will be to buyers. Under this assumption, developers will make zero profits in expectation but may realize profits or losses after the quality shocks are realized. We adopt this assumption to provide tractability in estimation, but it can be relaxed to allow for correlation with the initial lot's unobserved quality.

Developers face costs to subdivide lots and build new single-family housing. Costs depend on the characteristics of the new lots, $c(k, X(k))$, as well as an idiosyncratic component, ε_k, common to all developers and drawn from a logistic distribution. Idiosyncratic developer shocks are scaled by σ_d. For notational simplicity, we suppress time subscripts in the following exposition.

Developers trade off the expected price they get for each new lot, $E_\xi[p(X(k), d_{b(l)}, \xi)]$, against the cost of subdividing and building new single-family lots. They choose the number of new lots to create, k, and the new building square footage on each lot, $X(k)$, to maximize the expected

[13]With additional data on developer purchase prices, we would be able to estimate a bargaining model where incumbents and producers split the surplus. Incumbent bargaining weights less than one would inversely scale our welfare estimates, suggesting we may be underestimating incumbent preferences for density.

[14]In the data, we find little residual variation in such features after controlling for lot location, lot size, house age, and building square footage.

surplus:

$$p_l^{dev}(\text{mls}_{b(l)}) = \max_{\substack{k\in K_l(\text{mls}_{b(l)}) \\ X^{\text{endog}}(k)}} kE_\xi\Big[p(X(k), d_{b(l)}(\text{mls}_{b(l)}), \xi)\Big] - c\big(k, X(k)\big) + \sigma_d\varepsilon_{lk} \tag{1}$$

The feasible set of new lots is given by the correspondence $K_l(\text{mls}_{b(l)}) = \{\cdots, \lfloor\frac{\text{ls}_l}{\text{mls}_{b(l)}}\rfloor\}$, which depends on the initial lot size, ls_l, and the prevailing minimum lot size, $\text{mls}_{b(l)}$, on the block to which lot l belongs. The feasible set of subdivisions is degenerate when the minimum lot size is high. In this case, the expected surplus from subdivision is zero. Note that the post-reform block density, $d_{b(l)}(\text{mls}_{b(l)})$, depends on the block minimum lot size. The density is fixed at the pre-reform level when the minimum lot size is high.

Lots can be sold to either a developer or another household. Perfect competition among developers implies that developers will bid up the price of a lot to $p_l^{dev}(\text{mls}_{b(l)})$. A household would pay the prevailing equilibrium price for the lot $p(X_l, d_{b(l)}(\text{mls}_{b(l)}), \xi_l)$. The total value of a lot is then given by the larger of the price paid by developers or the market price among owner-occupiers:

$$\tilde{p}_l(\text{mls}_{b(l)}, \xi_l) = \max_{r_l\in\{0,1\}} r_l p_l^{dev}(\text{mls}_{b(l)}) + (1-r_l)p(X_l, d_{b(l)}(\text{mls}_{b(l)}), \xi_l) \tag{2}$$

where r_l is an indicator variable that takes a value of one if lot l would subdivide when an incumbent moves. This representation captures the descriptive evidence that lot subdivisions are correlated with pre-reform house size and quality as well as pre-reform lot size and land value. All else equal, smaller and lower quality pre-reform houses decrease the value of a lot to owner-occupiers, $p(X_l, d_{b(l)}(\text{mls}_{b(l)}), \xi_l)$, increasing the relative value of subdivision. Similarly, larger pre-reform lots on more valuable land increase surplus from subdivisions, $p_l^{dev}(\text{mls}_{b(l)})$. Importantly, the resulting housing density on a block will affect the price of subdivided lots, and lots that do not subdivide, embedding the fact that density may be a disamenity to potential buyers.

4.3 Incumbent Moving Decisions

Next, we model incumbent moving decisions after blocks have voted on adopting an SMLS. Our timing assumptions imply incumbents have previously sorted into lots prior to the reform. For an incumbent i that initially chose lot l, lot l solves:

$$U_{i0} = \max_{l\in L_0} \quad u_i(X_l, \xi_l) + g_i(d_{b(l)}) + c_0$$
$$\text{s.t. } p_0(X_l, d_{b(l)}, \xi_l) + c_0 \leq w_i$$

After the reform, the supply of single-family housing and the associated equilibrium prices will change. Incumbent households may move and re-sort across newly available lots and the outside option.

A household's post-reform utility depends on the decision to move. Let, $i(l)$ indexes the incumbent household i that initially chooses lot l. If a household $i(l)$ stays, they continue to receive the pre-reform utility value of their lot, $U^0_{i(l)}$, adjusted by any changes in density and any changes in lot value:

$$U^{\text{stay}}_{i(l)1}(\text{mls}_{b(l)}) = U_{i(l)0} + \underbrace{g_i(d_{b(l)1}(\text{mls}_{b(l)})) - g_i(d_{b(l)0})}_{\substack{\text{utility change from}\\ \text{change in block density}}} + \underbrace{\tilde{p}_l(\text{mls}_{b(l)}, \xi_l) - p_0(X_l, d_{b(l)0}, \xi_l)}_{\text{change in wealth}} \tag{3}$$

The first term represents the initial level of utility household i received from lot l. The second set of terms represents the change in utility from a potential increase in block density. This term depends on the minimum lot size on lot l's block. When the minimum lot size is high, the block density is fixed at the pre-reform level, and this term drops out. The third term is the change in household i's wealth from any increase (or decrease) in the value of i's initial lot l before and after the reform.

If household $i(l)$ moves, they solve a new sorting problem:

$$\begin{aligned} U^{\text{move}}_{i(l)1}(\text{mls}_{b(l)}) &= \max_{l' \in L_1} \quad u_i(X_{l'}, \xi_{l'}) + g_i(d_{b(l')1}) + c_1 \\ \text{s.t. } \; p_1(X_{l'}, d_{b(l')1}, \xi_{l'}) + c_1 &\leq w_i + \underbrace{\tilde{p}_l(\text{mls}_{b(l)}, \xi_l) - p_0(X_l, d_{b(l)1}, \xi_l)}_{\text{change in wealth}} \end{aligned} \tag{4}$$

This choice problem differs from the pre-reform choice in three ways. First, the choice set L_1 is now comprised of all newly subdivided lots and lots where an incumbent moved, but the lot was not subdivided. Second, there may be a new equilibrium price surface $p_1(\cdot)$. Third, household i's wealth has changed by any increase (or decrease) in the value of i's initial lot l before and after the reform.

If an incumbent moves, they pay a moving cost containing a static and stochastic component. The static component, $\text{mc}_{i(l)}$, may depend on demographic characteristics of household i. The stochastic component, $\nu_{i(l)}$, is realized after the voting process and is drawn from a standard normal distribution and scaled by σ_{mc}. Moving costs make some incumbents infra-marginal after the policy change. Infra-marginal incumbents who face high disamenities from density may not be willing to move even if density increases after the reform. Such incumbents have an incentive to vote for a higher minimum lot size. Our formulation of the incumbent moving decision when minimum lot sizes are either low or high captures this tradeoff.

In total, an incumbent's post-reform utility depends on the minimum lot size:

$$U_{i(l)1}(\text{mls}_{b(l)}) = \max_{m_l \in 0,1} m_l \underbrace{\left(U^{\text{move}}_{i(l)1}(\text{mls}_{b(l)}) - \text{mc}_{i(l)} - \sigma_{mc}\nu_{i(l)}\right)}_{\substack{\text{utility from moving}\\ \text{net of moving costs}}} + (1 - m_l) \underbrace{\left(U^{\text{stay}}_{i(l)1}(\text{mls}_{b(l)})\right)}_{\text{utility from staying}} \tag{5}$$

where m_l is an indicator variable that takes a value of one if the incumbent household on lot l moves. The first term represents an incumbent's decision to move. Moving allows an incumbent to re-sort but incurs a moving cost. The second term represents the pre-reform utility for the incumbent up to any changes in block density externalities if other lots on the block subdivide when the minimum lot size is low.

Note that quasi-linear utility ensures that an incumbent household's new lot choice l' does not depend on the minimum lot size and the value of their initial lot. As such, we can express the relative gains from moving as two terms, $U^{\text{move}}_{i(l)1}(\text{mls}_{b(l)}) - \text{mc}_{i(l)} - U^{\text{stay}}_{i(l)1}(\text{mls}_{b(l)}) = \omega_{i(l)} + g_i(d_{b(l)1}(\text{mls}_{b(l)})) - g_i(d_{b(l)0})$. The first term, $\omega_{i(l)}$, does not depend on the minimum lot size or density. The second term is the change in utility from changes in density.

4.4 Block-Level Equilibrium

The relative payoffs to moving and subdivision potentially depend on whether other lots on a block subdivide. This dependence operates through the local externality generated by post-reform density, $d_{b(l)1}$. Post-reform density affects both the surplus from allowing subdivision in equation (1), and the relative value of an incumbent staying in their initial lot in equation (5). The relative gains to subdividing a lot may be higher if other lots on a block subdivide. Similarly, the value of staying may be lower if other lots on a block subdivide.

The dependence of outcomes for one lot on those of another introduces the possibility of multiple block level equilibria from the perspective of the researcher. The spillovers in our model take the form of a scalar measure of density. Compressing the combinatorial nature of individual lot outcomes to a scalar allows us to approximate all equilibrium block densities using a fine grid when conducting counterfactuals. We assume an equilibrium selection rule that agents agree on the equilibrium that maximizes their joint welfare, following Fu and Gregory (2019) among others.

4.5 Incumbent Voting Decisions

Incumbents vote for or against a higher minimum lot size on their block to maximize their expected post-reform utility. An incumbent votes for a higher minimum lot size if the expected value of a high minimum is larger than the expected value of a low minimum:

$$E[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low})] > 0 \tag{6}$$

where expectations are taken over both developer shocks and moving cost shocks for an incumbent.

A high minimum lot size affects post-reform incumbent utility in two ways. First, it prevents lot l from subdividing. The value of lot l will not reflect any potential surplus from building denser housing, as seen in equation (2). All else equal, the larger the gains in land value from allowing subdivisions, the less likely an incumbent is to vote for higher minimum lot sizes. Second, it prevents other lots on the block $b(l)$ from subdividing and fixes the block density at its pre-reform level. If an incumbent household stays when the minimum lot size is high, they will not face any changes in externalities from block density, as reflected in equation (4). The greater the disamenities from density, the more likely these incumbents are to vote for density restrictions. We leverage this trade-off to form a revealed preference approach to capturing disamenities from density for incumbents from observed vote outcomes.

A simple majority-rule vote determines the outcome of the vote on higher minimum lot sizes for block b:

$$\sum_{l \in b} 1\Big[E[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low})]\Big] > N_b/2 \tag{7}$$

where N_b is the number of pre-reform lots on the block.[15]

5 Estimation

5.1 Estimation Overview

We estimate the model parameters in two stages. First, we estimate two auxiliary model inputs outside of the model. These model inputs include (1) the observed equilibrium price surface after the reform, $p_1(X, d, \xi)$, and (2) a reduced-form specification capturing developer choices of house characteristics. In the second stage, we jointly estimate the vector of structural parameters, θ, within the model via simulated maximum likelihood. The structural parameters consist of (1) the parameters of the developer cost function, $c(k, X(k))$, and the scale of developer shocks σ_d, (2) the distribution of incumbent relative gains from moving $U^{\text{move}}_{i(l)1}(\text{mls}_{b(l)}) - \text{mc}_{i(l)} - U^{\text{stay}}_{i(l)1}(\text{mls}_{b(l)})$ and the scale of moving cost shocks σ_{mc}, and (3) amenity spillovers from density $g_i(d)$. We simulate the likelihood over draws of unobserved lot characteristics ξ. In this section, we discuss how we parameterize the developer cost function, the amenity spillovers from density, and the distribution of preferences. We then discuss our estimation strategy in more detail.

5.2 Parameterizations

Observed subdivision choices pin down developer costs and the variance of developer shocks. We parameterize the cost of producing k new lots from an initial lot as $c(k, X(k)) = k(c_0 + c_1 X^{\text{exog}})$, where X^{exog} includes lot size and location characteristics.[16] Specifically, developer costs depend on the new lot size and its square, as well as external development restrictions. We include an indicator for historic districts that impose architectural restrictions on new houses and an indicator for deed-restricted minimum setbacks that limit the area of a lot on which a house can be built.

Observed incumbent moving decisions following the policy change help identify the relative gains from moving when the minimum lot size is low, $\omega_{i(l)} = U^{\text{move}}_{i(l)1}(\text{mls}_{b(l)}) - \text{mc}_{i(l)} - U^{\text{stay}}_{i(l)1}(\text{mls}_{b(l)})$, and the variance of the moving cost shocks. Note that because households have initially sorted across lots, we expect the distribution of relative gains from moving to differ across lot characteristics. We approximate the conditional distribution of relative gains from moving by projecting the mean relative gains from moving on the pre-reform lot and neighborhood demographic characteristics,

[15] We abstract from side payments for votes or other forms of Coasian bargaining over commitments not to subdivide since they are not a relevant margin in practice.

[16] More flexible specifications do not show evidence of meaningful economies of scale when subdividing to more lots.

$\omega_{i(l)} = \alpha X_l$. This projection allows us to capture heterogeneity in moving decisions based on an incumbent's initial housing choice. We allow the relative gains from moving to depend on pre-reform neighborhood income and share of non-Hispanic White and non-Hispanic Black residents measured at the Census block group level from the 2000 Census, as well as pre-reform lot size, house size, house age, and block density.

Block-level votes help identify incumbent preferences for density. We assume that density enters incumbent preferences linearly. As above, we project preferences for block density on pre-reform lot characteristics and Census block group demographics: $g_{i(l)}(d) = \beta X_l d$. This projection approximates the distribution of incumbent preferences conditional on their initial lot choice.

5.3 Price Surface Estimation

A key input in our model is the price at which a lot would sell to an owner-occupier after the reform. To capture this input, and consistent with our demand specification, we estimate a price surface using the CoreLogic price data following Fu and Gregory (2019).

Our sample is the set of observed prices in a five-year window centered on 2013, the year we measure block- and lot-level outcomes. Our price records are incomplete since our sales data is largely generated from mortgage records. This restriction on the available data has two implications. First, we estimate prices for sales directly to households and not developers. Second, it is likely that lots are selected into sales and further selected into our sales data in part based on unobserved lot quality. To address this concern, we account for selection following Heckman (1979) and include the inverse Mills ratio associated with a probit model predicting the probability of seeing a lot sell. We use pre-reform owner tenure as the excluded instrument in the first stage. The key assumption of the instrument is that owner tenure changes the probability a lot sells but not the price at which it sells. This would be violated if, for instance, lots with longer tenure have been less recently renovated.

The second-stage specification for estimating the price surface is:

$$p_l = P(X_l, d_{b(l)}) + \rho_p \lambda(\Phi^{-1}(\widehat{\text{sale}_l})) + \text{tract}_l + \text{year}_l + \xi_l$$

where $P(\cdot)$ is a flexible function of polynomials and interactions between observed lot characteristics X_l and block level density $d_{b(l)}$. $\lambda(\cdot)$ is the inverse Mills ratio. We include Census tract fixed effects to control for unobserved neighborhood amenities and year fixed effects to capture aggregate price trends. Note that the price surface includes the effect of density on prices. Consistent with our hedonic demand specification, the estimated price surface is informative about purchaser preferences after the reform but not incumbent preferences for density.

5.4 House Size Estimation

When developers subdivide a lot, they choose the number of new lots to create and the size of houses built on the newly created lots, as detailed in equation (1). The house size impacts the surplus from subdividing a lot. We use a reduced-form specification to capture the choice of house characteristics as a function of lot size and location. The reduced-from specification is held fixed when evaluating counterfactual policies, implying that developers would build the same size house, given a lot size and location, under alternative levels of housing supply. We adopt this reduced-form specification to ease the computational burden when calculating the likelihood over the primary structural parameters of the model. In practice, most of the variation in house size can be explained by the size of the lot on which it is built and the age of the house, limiting the potential impact on our results. The specification for estimating the price surface is:

$$X_{l'}^{\text{endog}} = G(X_{l'}^{\text{exog}}) + \zeta_{l'}$$

where $G(\cdot)$ is a flexible function of polynomials and interactions of observed lot size and location.

5.5 Likelihood

Let $\theta = (c, \sigma_d, \alpha, \sigma_{mc}, \beta) \in \Theta \subset R^N$ be a vector of the structural model parameters. We construct the likelihood of observed voting outcomes, incumbent moving decisions, and lot subdivisions in three steps.

First, we consider the likelihood of observing a lot subdivide conditional on the observed minimum lot size and the incumbent owner's decision to move. Given the parameterization of the developer cost function in equation (2), the expected value of subdividing a lot l into k new lots is:

$$\hat{p}_l(k, \xi_l) = \begin{cases} k\hat{p}_l(k) - k\big(c_0 + c_1 X^{\text{exog}}(k)\big) & k \geq 1 \\ \hat{p}_l + \xi_l & k = 0 \end{cases}$$

The expected price of each new lot, $\hat{p}_l(k)$, is estimated using the reduced-form specification of new lot characteristics and the price surface: $\hat{p}_l(k) = \hat{P}(\hat{X}_l(k), d_{b(l)1})$. Where the estimated new lot characteristics are $\hat{X}_l(k) = \hat{G}(X_l^{\text{exog}}) \cup X_l^{\text{exog}}$. The price of the existing lot that does not subdivide ($k = 0$) includes both a component estimated from the price surface, $\hat{p}_l = \hat{P}(X_l, d_{b(l)1})$, and the unobserved lot quality, ξ_l. Unobserved quality is normalized to dollar terms without loss of generality. Unobservably higher quality lots will have a lower probability of subdivision, and incumbent owners on these lots may have a higher probability of voting for an SMLS.

The associated likelihood of observing lot l subdivide into k_l new lots is:

$$\mathcal{L}_l^s(\theta, \xi_l \mid \text{mls}_{b(l)},\ m_l,\ k_l) = \begin{cases} \dfrac{\exp\Big(\hat{p}_l(k_l, \xi_l)/\sigma_d\Big)}{\sum_{j \in K_l(\text{mls}_{b(l)})} \exp\Big(\hat{p}_l(j, \xi_l)/\sigma_d\Big)} & \text{mls}_{b(l)} = low,\ m_l = 1 \\ 1 & otherwise \end{cases}$$

The likelihood takes the standard logit choice probability form when the minimum lot size is low and an incumbent moves. If the minimum lot size is high or the incumbent does not move, then the lot does not subdivide with probability one.

Next, we consider the likelihood of observing an incumbent move conditional on the block minimum lot size. From the characterization of an incumbent's decision to move in equation (5), as well as the parameterization of the distribution of the relative value of moving, the probability an incumbent on lot l moves takes the standard probit form:

$$\Pr(m_l \mid \text{mls}_{b(l)},\ \theta) = \begin{cases} \Phi\big(\alpha X_l/\sigma_{mc}\big) & \text{mls}_{b(l)} \;=\; \textit{high} \\ \Phi\big((\alpha X_l + \beta X_l \Delta d_{b(l)})/\sigma_{mc}\big) & \text{mls}_{b(l)} \;=\; \textit{low} \end{cases}$$

Where the change in utility from changes in density is expressed as $\Delta d_{b(l)} = d_{b(l)1} - d_{b(l)0}$. A high minimum lot size provides a baseline probability an incumbent moves. When the minimum lot size is low, the probability of a move is adjusted by changes in block density amenities if other lots on the block subdivide. The associated likelihood of observing an incumbent on lot l move is:

$$\mathcal{L}^m_l(\theta \mid \text{mls}_{b(l)}, m_l) = \Pr(m_l \mid \text{mls}_{b(l)},\ \theta)^{m_l} \Pr(m_l \mid \text{mls}_{b(l)},\ \theta)^{(1-m_l)}$$

Next, we consider the likelihood that a block adopts a high minimum lot size. The probability that a lot l on block b votes for an SMLS depends on the relative difference in utility as described in equation (6):

$$\begin{aligned} \Pr(vote_l \mid \xi_l, \Delta d_{b(l)}, \theta) &= \Pr\Big(E\big[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low}) \mid \xi, \Delta d_{b(l)}\big] + \sigma_v \epsilon_{i(l)} > 0\Big) \\ &= \Pr\Bigg(\hat{p}_l(\text{mls}_{b(l)} = \textit{high}, \xi_l) - \hat{p}_l(\text{mls}_{b(l)} = \textit{low}, \xi_l) \\ &\qquad + \beta X_l \Delta d_{b(l)}\Big(1 - \Pr\big(m_l \mid \text{mls}_{b(l)} = \textit{low},\ \theta\big)\Big) \\ &\qquad + \alpha X_l\Big(\Pr\big(m_l \mid \text{mls}_{b(l)} = \textit{high},\ \theta\big) - \Pr\big(m_l \mid \text{mls}_{b(l)} = \textit{low},\ \theta\big)\Big) \\ &\qquad + \zeta\Big(\Delta d_{b(l)}, \theta\Big) + \sigma_v \epsilon_{i(l)} > 0\Bigg) \end{aligned}$$

The probability of voting depends on the expectation of the difference in incumbent utility. The expectation is taken with respect to moving cost and developer shocks, conditional on unobserved lot quality ξ and the difference in density $\Delta d_{b(l)} = d_{b(l)}(\text{mls} = \textit{high}) - d_{b(l)}(\text{mls} = \textit{low})$. This expectation is comprised of four terms. The first term is the relative difference in lot value under a high and low minimum lot size. Lot values take the standard logit inclusive value form $\hat{p}_l(\text{mls}_{b(l)}, \xi_l) = \sigma_d \log \sum_{k \in K_l(\text{mls}_{b(l)})} \exp(\hat{p}_l(k, \xi_l)/\sigma_d)$. The second term describes changes in the amenity value of block density, weighted by the probability an incumbent household will not move when the minimum lot size is low. The third and fourth terms capture the relative gains from moving for marginal households that are induced to move by changes in the amenity value of block density when the minimum lot size is low. The third term is the mean difference in the value of moving for marginal movers, while the function $\zeta(\cdot)$ in the fourth term is used for notational brevity to include terms that integrate over the conditional distribution of moving cost shocks for the marginal mover.

The probability that an incumbent on lot l votes to adopt a higher minimum lot size depends on the lot's unobservable quality ξ_l and the change in density $\Delta d_{b(l)}$. Unobservably higher quality lots will have a smaller increase (or larger decrease) in lot value when allowing subdivisions and will be more likely to vote for a higher minimum lot size. Larger changes in density, when subdivisions are allowed, will make incumbents more likely to vote for a higher minimum lot size. In order to smooth the likelihood for computational tractability, we assume incumbents also face an idiosyncratic voting preference shock, $\epsilon_{i(l)}$, distributed logistic with scale σ_v that acts as a smoothing parameter:

$$\Pr(vote_l \mid \xi_l, \Delta d_{b(l)}, \theta) = \frac{\exp\Big(\frac{1}{\sigma_v}\big(E[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low}) \mid \xi_l, \Delta d_{b(l)}]\big)\Big)}{1 + \exp\Big(\frac{1}{\sigma_v}\big(E[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low}) \mid \xi_l, \Delta d_{b(l)}]\big)\Big)}$$

The smoothing parameter σ_v is calibrated to be small relative to estimated value of $E[U_{i(l)1}(\text{high}) - U_{i(l)1}(\text{low})]$. In the limit the choice probability approaches the indicator function as σ_v shrinks.

The probability that a block b adopts a high minimum lot size depends on the vote probabilities of all the incumbents on a block:

$$\Pr(vote_b \mid \xi_{b(l)}, \Delta d_{b(l)}, \theta) = B\Big(\big\{\Pr(vote_l \mid \xi_l, \Delta d_{b(l)}, \theta)\big\}_{l \in b}\Big)$$

where $B(\cdot)$ is the CDF of the Poisson binomial distribution and $\xi_{b(l)}$ is the vector of unobservables ξ_l for all lots on block b. The associated likelihood of vote outcomes is:

$$\mathcal{L}_b^v(\theta \mid \xi_{b(l)}, \text{mls}_b) = \Pr(vote_b \mid \xi_{b(l)}, \Delta d_{b(l)}, \theta)^{\text{mls}_b}\Big(1 - \Pr(vote_b \mid \xi_{b(l)}, \Delta d_{b(l)}, \theta)\Big)^{1-\text{mls}_b}$$

The likelihood of all observable decisions in the data for lot l is given by:

$$\mathcal{L}_l(\theta \mid \xi_{b(l)}, \text{mls}_{b(l)}, m_l, k_l) = \mathcal{L}_b^v(\theta \mid \xi_{b(l)}, \text{mls}_{b(l)})\mathcal{L}_l^m(\theta \mid \text{mls}_{b(l)}, m_l)\mathcal{L}_l^s(\theta, \xi_l \mid \text{mls}_{b(l)},\ m_l,\ k_l)$$

We simulate J versions of every block to construct the full likelihood. For every version, j, we draw lot level unobservables ξ_{jl} from $F_\xi(\xi_l)$. We assume $F_\xi(\cdot)$ is normal with zero mean and variance estimated from the residual distribution of our price regression. This simulation approach allows us to capture the selection of lots that do not adopt a higher minimum lot size in lot-level subdivision decisions. The log-likelihood we maximize is:

$$\ell(\theta) = \sum_b^B \sum_l^{L_b} \log \frac{1}{J} \sum_j^{J_b} \mathcal{L}_l(\theta \mid \xi_{jb(l)}, \text{mls}_{b(l)}, m_l, k_l) \tag{8}$$

6 Estimation Results

In this section, we discuss the structural parameter estimates and their economic implications. We highlight two key results. First, incumbents have substantial negative externalities from block density. Second, these externalities vary with pre-reform demographic and lot characteristics. We then explore how well our model fits observed voting, moving, and subdivision outcomes.

6.1 Parameter Estimates

Table 3 displays the estimated structural parameters that govern incumbent voting, moving, and lot subdivision decisions. These parameters are estimated by maximizing the likelihood defined in equation (8).

6.1.1 Developer Costs

Cost parameters govern the probability that a lot will subdivide when the minimum lot size is reduced and an incumbent owner moves, as outlined in equation (1). The cost per new lot is decreasing from 1,400 sf, the new minimum lot size, to about 2,660 sf. That is, it is relatively more expensive to subdivide into smaller lots on a per-house basis. This result is likely driven by higher open space requirements for lots below 3,500 sf. Additional construction restrictions raise costs substantially. Historical districts that restrict building architectural designs increase the cost of developing a 2,500 sf lot by 47%. Deed restricted minimum setbacks increase costs by 18%. These additional development restrictions make it more expensive to subdivide a lot and reduce expected increases in block density.

Cost parameters and the estimated price surface govern the pecuniary benefits to incumbents from allowing subdivision. The lower the cost and the higher the price, the more an incumbent gains from allowing subdivisions, and the more subdivisions we would expect in areas that do not adopt higher minimum lot sizes. This trade-off is summarized by the ex-ante probability a lot would subdivide if the minimum lot size were low and an incumbent moves. Panel (a) of Figure A4 plots the distribution of these probabilities separately for lots that subsequently adopt a higher block level minimum lot size and those that do not. Lots on blocks that adopted higher minimum lot sizes were 3.9 percentage points, or equivalently 43.1%, more likely to subdivide than lots on blocks that did not adopt higher minimums. These results suggest that allowing incumbents to control block-level minimum lot sizes limited housing supply in areas that were more likely to see in-fill development of denser housing.

6.1.2 Incumbent Value of Moving

We estimate parameters governing the relative gains to moving, net of moving costs, across pre-reform lot characteristics, as described in equation (4). Parameters are scaled to dollar equivalents. Incumbents in areas with a higher share of non-Hispanic White or Black residents are significantly more likely to move after the reform. On the other hand, incumbents who own larger lots, have

Table 3: Incumbent Choice Parameters

	Estimate	SE
Cost Estimates:		
c_0: per lot ($1k)	311.19	(7.79)
c_1: per lot sf ($)	-77.79	(6.57)
c_2: per lot sf^2 ($1k)	13.82	(1.34)
c_3: per lot in historic district ($1k)	94.20	(8.42)
c_4: per lot with setback restrictions ($1k)	36.64	(5.62)
σ_{dc}: scale of developer shocks ($1k)	80.21	(24.27)
Moving Estimates ($1k equivalents):		
α_1: constant	2,466.27	(325.07)
α_2: ln Census block group Income	21.79	(8.87)
α_3: Census block group Share White	342.37	(38.05)
α_4: Census block group Share Black	146.97	(19.70)
α_5: ln Lot Size	-12.51	(8.13)
α_6: ln House Size	-278.36	(32.66)
α_7: ln House Age	-171.67	(21.94)
α_8: Pre-Reform Density	48.71	(10.66)
σ_{mc}: scale of moving shocks	372.08	(45.89)
Density Estimates ($1k equivalents):		
β_1: constant	526.77	(58.65)
β_2: ln Census block group Income	-46.13	(4.37)
β_3: Census block group Share White	-167.29	(8.36)
β_4: Census block group Share Black	-97.89	(4.63)
β_5: ln Lot Size	-93.42	(4.43)
β_6: ln House Size	107.92	(3.73)
β_7: ln House Age	-5.08	(2.62)
β_8: Pre-Reform Density	1.88	(5.86)
Observations	60,012	

Note: This table provides parameter estimates from maximizing the likelihood described in equation (8). Asymptotic standard errors are given in parentheses. Standard errors for estimates that are scaled to dollar equivalents are obtained via the delta method. Estimates are given in 2013 dollars.

larger houses, or have older houses are less likely to move after the reform. All else equal, an incumbent who is less likely to move after the reform places more weight on potential disamenities from density increases when voting. Panel (b) of Figure A4 plots the estimated distribution of incumbent moving probabilities when the minimum lot size is low separately for lots that subsequently adopt a higher block level minimum lot size and those that do not. Incumbents that do not adopt higher minimum lot sizes are 1.6 percentage points, or 2.8%, more likely to move when the minimum lot size is low than incumbents that adopt an SMLS. In the model, these incumbents would place less weight on disamenities from density and, all else equal, would be less likely to vote for a higher minimum lot size.

6.1.3 Preferences for Block Density

Estimated preferences for block density point to two key findings. First, we find substantial disamenities from block density. The average incumbent has a welfare loss equivalent to 5.0% of the median property value if they do not move and their block density increases by the mean observed density increase. In dollar terms, this amounts to $6,900 for the average incumbent. The mean observed increase in block density is about 0.15, roughly equivalent to the increase in density of a 22-lot block with 5,000 sf lots where two lots each subdivide into two new 2,500 sf lots. These estimates suggest that density restrictions can correct externalities for incumbents generated by building denser housing. These preferences over density help explain some of the political opposition to proposed regulatory reforms.

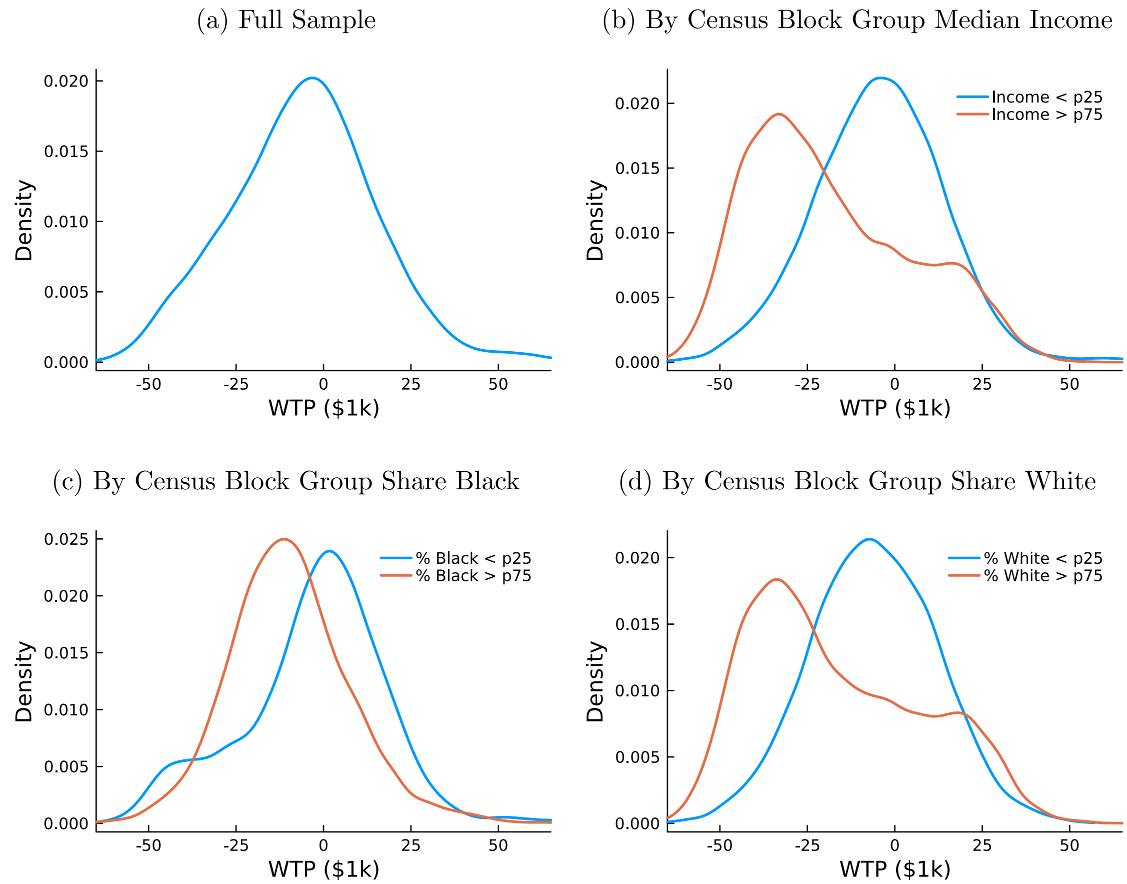
Second, we find significant heterogeneity in incumbent preferences over density. Panel (a) of Figure 4 plots the distribution of incumbent welfare losses (or gains) if they do not move and their block increases in density by the mean observed density increase. Most incumbents lose from increases in block density, while some gain. As a result, residential land-use regulations will have distributional consequences for incumbents.

Preference for density varies systematically with pre-reform lot and neighborhood characteristics. Incumbents in areas with higher pre-reform incomes and higher shares of non-Hispanic White and non-Hispanic Black residents lose more when density increases. Similarly, incumbents that own larger lots with initially older houses tend to lose when density increases. On the other hand, incumbents on lots with larger houses before the reform have smaller disamenities from increased density. One potential explanation for this pattern could be that incumbents who like green space initially sorted to larger lots with smaller houses, and increased density would reduce green space on a block.

Panels (b)-(d) of Figure 4 plot the distribution of preferences for density across different subsamples of incumbent lot owners. We report net preferences for density for demographics subsamples of incumbents since pre-reform neighborhood demographics and lot characteristics are highly correlated. Panel (b) plots the distribution of welfare losses (or gains) from the observed mean increase in block density for incumbents in the bottom and top quartile of Census block group median income. Panel (c) and (d) plot the same distributions for incumbents in the top and bottom quartile of Census block group non-Hispanic Black and non-Hispanic White residential share, respectively.

The average incumbent in the top quartile of neighborhood income has welfare losses 122% larger than the average incumbent in the bottom quartile. Similar patterns exist for non-Hispanic White residential share and, to a lesser degree, non-Hispanic Black residential share. The revealed preference approach used to identify preference heterogeneity cannot disentangle preferences for physical amenities from dense housing from exclusionary motives for disliking density. Nevertheless, these results suggest that preferences for regulations that restrict density are stronger in areas that are initially wealthier, have a higher share of White residents, and, to a lesser degree, have a higher share of Black residents. Allowing local control of regulation may limit housing supply in these areas and potentially exacerbate residential segregation.

Figure 4: Willingness to Pay for Mean Block Density Increase



Note: This figure plots the distributions of estimated incumbent willingness to pay (WTP) for the mean observed increase in block density if the incumbent does not move. Panel (a) plots the distribution of WTP for incumbents for the full sample of incumbents. Panel (b) plots the WTP distribution for the upper and lower quartile of Census block group median income. Panel (c) plots the WTP distribution for the upper and lower quartiles of Census block group share of non-Hispanic Black residents. Panel (d) plots the WTP distribution for the upper and lower quartiles of Census block group share of non-Hispanic White residents.

6.2 Model Fit

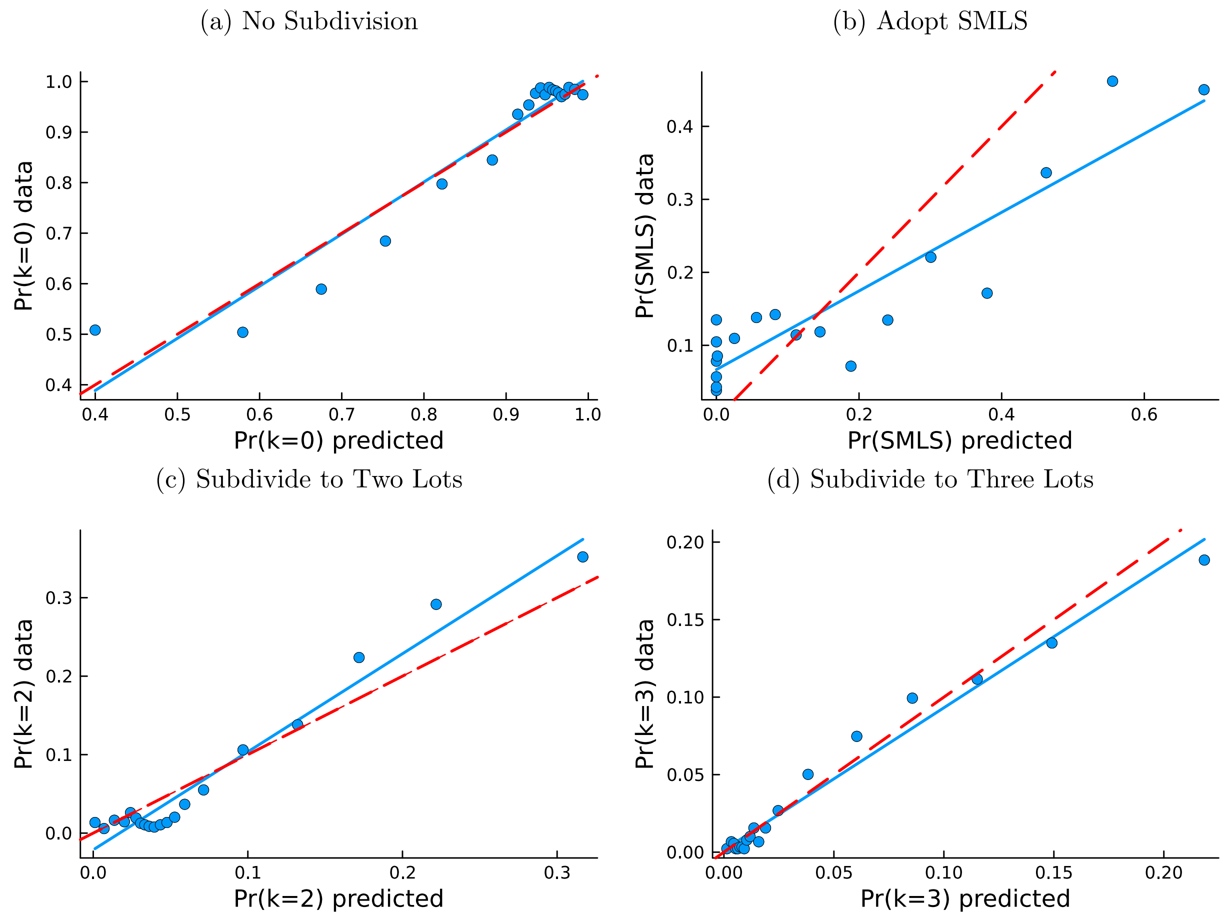
Next, we evaluate how well the model fits the data. A key component of our model and our counterfactuals is the ability to predict the likelihood that lots subdivide, conditional on a low minimum lot size and an incumbent moving. We evaluate the fit of our model in this dimension by comparing predicted and observed lot subdivision probabilities.

Panel (a) of Figure 5 plots a bin-scatter of observed lot subdivision choices against model-predicted subdivision choice probabilities. We bin lots into 20 bins based on the predicted probability that a lot does not subdivide. For each bin, we compute the observed probability that a lot does not subdivide. We tend to overestimate subdivision likelihood for the lots we predict most likely to subdivide and underestimate for those in the middle. Panel (c) and (d) of Figure

5 show similar bin-scatter plots for the observed vs predicted probability lots subdivided into two vs three new lots, respectively. Overall, using predicted sales prices and a parsimonious developer cost function, we are able to capture the fact that most lots are not economical to subdivide. On the other hand, lots with lower quality houses in higher demand neighborhoods are very lucrative to subdivide. This heterogeneity plays a key role in understanding the drivers of voting decisions in our model.

Panel (b) of Figure 5 plots a similar bin scatter on observed lot block SMLS adoption against model predicted adoption. Again, we bin blocks into 20 bins of predicted adoption probabilities and computed each bin's observed adoption rate. We tend to overestimate the probability that blocks adopt an SMLS for blocks with the highest predicted adoption rates.

Figure 5: Bin-Scatter of Predicted and Observed Likelihood of Lot Outcomes



Note: Panels (a), (c), (d) present bin-scatter plots of observed vs predicted post-reform lot subdivision outcomes, conditional on a low minimum lot size and the incumbent owner moving. Panel (b) presents a bin-scatter plot of observed vs predicted SMLS adoption decisions. For all plots, we bin lots (or blocks) into 20 bins of predicted outcome probability and compute the share of observations in each bin with that outcome. The red dashed line is the 45-degree line.

7 Quantifying the Effects of Local Regulatory Control

In this section, we consider the effect of removing local control of minimum lot size regulation in Houston. We study two alternative regulations that set a uniform minimum lot size throughout Houston's urban core. First, we compare the observed policy change against a counterfactual that maintains the pre-reform 5,000 sf minimum lot size. These counterfactuals allow us to study the distributional impacts of the reform. Next, we compare the observed policy change against a counterfactual that removes the ability for incumbents to adopt higher, block-specific minimum lot sizes and sets a uniform 1,400 sf minimum. This counterfactual allows us to study the degree to which local control can tailor policy to heterogeneous preferences for density, and evaluate the counterfactual increases in housing supply. We find that allowing local control has limited ability to tailor policy to heterogeneous incumbent preferences and produces relatively small incumbent welfare gains at the cost of relatively large reductions in supply.

We evaluate the supply response and the distributional effects on incumbent welfare for each counterfactual policy. We aim to understand how and where local preferences for density shape the political economy of residential land-use regulations. As such, we do not explicitly model gains or losses to potential buyers. As discussed below, the area affected by the policy change is small relative to the greater Houston housing market and benefits are likely to be small and diffuse. Moreover, optimal policy would ultimately depend on how a planner weights incumbent vs newcomer welfare. We leave questions about optimal policy to future work.

The expected change in incumbent welfare from reducing the minimum lot size is the expected difference in incumbent utility, in dollar terms, when the minimum lot size is high or low on their block. From equation (6), the difference in welfare for incumbent i on lot l is:

$$E\Big[\Delta W_i\Big] = E\Big[U_{i(l)1}(\text{mls}_{b(l)} = 1400)] - E[U_{i(l)1}(\text{mls}_{b(l)} = 5000)\Big]$$

where expectations are taken over unobserved lot quality, ξ_i, as well as moving and developer cost shocks. We approximate this expectation by simulation. We take draws of unobservable quality, as well as moving and developer cost shocks for every lot. We compute the block-level welfare maximizing subdivision equilibrium for each set of draws. As discussed in Section 4.4, we simulate moving and subdivision outcomes over a grid of potential post-reform block densities for each block. Every grid cell that induces moving and subdivision choices that result in a post-reform density in the same grid cell constitute an equilibrium. We then select the equilibrium that maximizes joint incumbent welfare.

We can decompose the effect of minimum lot size reduction into three channels:

$$
\begin{aligned}
E\Big[\Delta W_i\Big] = &\underbrace{E\Big[p_l(\text{mls}_{b(l)} = 1400, \xi_l) - p_l(\text{mls}_{b(l)} = 5000, \xi_l)\Big]}_{\substack{\text{Lot Value} \\ \text{Channel}}} \\
&+ \underbrace{E\Big[\beta X_l \Delta d_{b(l)} \Big(1 - \Pr\left(m_l \mid \text{mls}_{b(l)} = 1400\right)\Big)\Big]}_{\substack{\text{Incumbent Externality} \\ \text{Channel}}} \\
&+ \underbrace{E\Big[\alpha X_l \Big(\Pr\left(m_l \mid \text{mls}_{b(l)} = 1400\right) - \Pr\left(m_l \mid \text{mls}_{b(l)} = 5000\right)\Big) - \zeta\Big(\Delta d_{b(l)}\Big)\Big]}_{\substack{\text{Marginal Mover} \\ \text{Channel}}}
\end{aligned}
$$

The first change is the 'lot value' channel. This channel captures the relative difference in the value of a lot when subdivisions are allowed or not allowed. This channel includes the potential surplus from allowing a lot to subdivide and any decrease in price from higher block density. The second channel is the 'incumbent externality' channel. This channel captures the disamenity from density for incumbents that do not move, weighted by the probability they do not move. Finally, the third channel is the 'marginal mover' channel. This channel captures utility difference for incumbents induced to move when the minimum lot size is reduced. It contains two terms. The first captures the relative value of moving for marginal movers. The second term captures the expected moving cost shock for marginal movers. The marginal mover channel is small relative to the first two channels.

We hold equilibrium prices fixed when computing expected incumbent welfare. In practice, these counterfactual policies will shift the total supply and composition of single-family housing in Houston. However, the effects of these changes on prices are likely to be small since Houston's 1998 minimum lot size reduction only applied to non-deed restricted property in Houston's urban core. Maintaining a higher minimum lot size would have decreased the number of housing units in Houston by less than 1% and an even smaller share relative to the housing market of Houston's commuting zone. While this increase is spatially concentrated, Piazzesi et al. (2020) show that the nature of housing search spreads the effect of local shocks across a housing market and reduces local effects. To test the robustness of this assumption, we estimate an auxiliary model of housing demand in Appendix D to solve for equilibrium lot prices under our estimated counterfactual housing supply. The average price change across lots under a counterfactual with no minimum lot size reductions is less than \$400. A counterfactual that removes the ability of incumbents to adopt higher minimum lot sizes has price effects an order of magnitude smaller. We do not find quantitatively different subdivision outcomes under price changes of this scale.

7.1 Incumbent Welfare Impact of Minimum Lot Size Reduction

The impact of minimum lot sizes on incumbent welfare is an important determinant of the political economy motive for adopting higher minimum lot sizes. Column (1) of Table 4 reports the total change in welfare for incumbents, as well as the mean and median change. Across all incumbents, decreasing the minimum lot size from 5,000 sf to 1,400 sf increases welfare by $116 million. The average incumbent gains $2,290 from the reduction. This is equivalent to 1.6% of the median post-reform lot price. These results suggest that the typical incumbent in our sample gains from lower minimum lot sizes, consistent with the majority of incumbents not adopting higher minimum lot sizes.

Increased lot values drive the welfare gains to lowering minimum lot sizes from allowing subdivisions. In total, reducing the minimum lot size increases the value of lots by $406 million, or about 3.5% of the total post-reform value of all lots in the sample. This increase highlights how density regulations can reduce land value by restricting productive use.

Increased disamenities from density off set gains from the lot value channel. The average household would be willing to pay $5,743 to prevent other lots on their block from subdividing. This amounts to 4% of the median post-reform lot price. Aggregate losses from increased density for incumbents are $291 million. These losses highlight the role of regulations restricting density as a mechanism for incumbents to address local externalities from developing denser housing. However, our results indicate that such regulations were too strict in the affected areas of Houston's urban core on net.

The aggregate welfare effects mask significant heterogeneity. Panel (a) of Figure 6 plots the distribution of net incumbent welfare changes from a reduction of the minimum lot size. While the majority of households gain from a reduction, 31.4% of incumbents lose when the minimum lot size falls. This heterogeneity is key for understanding the heterogeneous adoption of higher special minimum lot sizes.

The distribution of welfare changes features long tails, suggesting some incumbents stand to gain a lot while others lose a lot when the minimum lot size falls. The two primary welfare channels drive these extreme outcomes. Panel (b) of Figure 6 plots the distribution of welfare changes from the lot value channel. We see a small number of lots that stand to increase in value significantly more than others when allowed to subdivide. These lots tend to have lower initial quality housing stock in areas with higher land value.

On the other hand, panel (c) of Figure 6 plots the distribution of welfare change from the externality channel. The long left tail indicates that a small number of incumbents stand to lose significantly more than others when the minimum lot size falls. These larger losses are generated by incumbents with strong preferences for lower density on blocks likely to see more subdivisions and higher density.

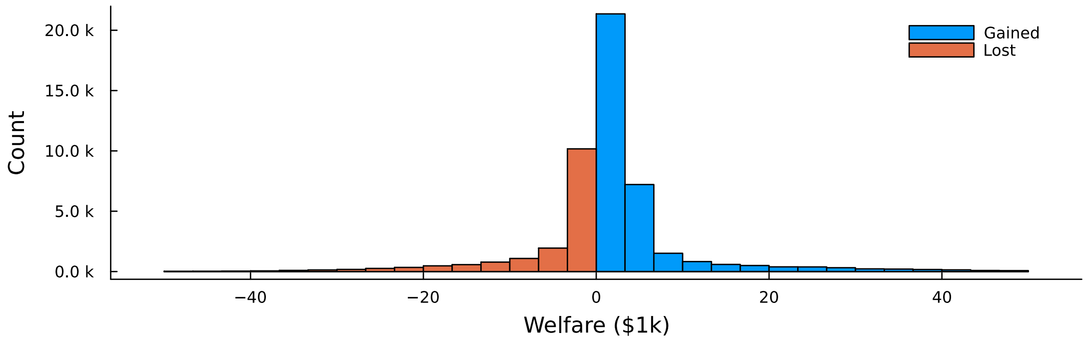
Table 4: Net Welfare Impacts

	Full Sample (1)	No SMLS (2)	Adopted SMLS (3)
Welfare Change			
Total ($M)	116.0	120.6	-4.5
Mean ($)	2,290.5	3,051.5	-407.6
Median ($)	1,224.7	1,572.6	-241.0
Lot Value Channel			
Total ($M)	406.3	288.1	118.2
Mean ($)	8,022.7	7,293.9	10,606.4
Median ($)	3,158.8	3,080.8	3,702.5
Externality Channel			
total ($M)	-290.9	-168.9	-122.0
Mean ($)	-5,743.9	-4,275.0	-10,951.4
Median ($)	-1,831.1	-1,499.3	-4,001.6
Mover Channel			
Total ($M)	0.6	1.3	-0.7
Mean ($)	11.6	32.6	-62.6
Median ($)	0.0	5.3	-23.5

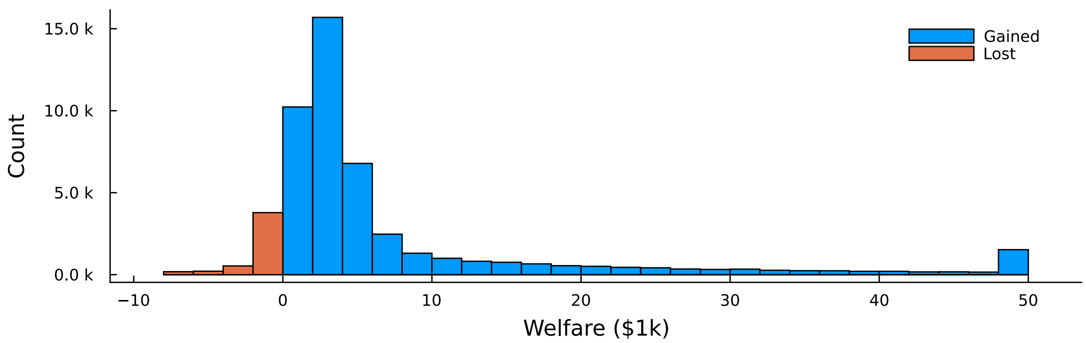
Note: This table presents compares net incumbent welfare changes in dollar terms from a 5,000 sf vs. 1,400 sf minimum lot size for the sample of incumbents eligible to adopt an SMLS. Column (1) presents aggregate welfare changes. Columns (2) and (3) present welfare changes for the set of incumbents that did not adopt an SMLS and those that did, respectively. We report the total welfare changes and decompositions for the three welfare channels for each subsample. For each channel, we report the aggregate welfare change in dollars, as well as the mean and median for change.

Figure 6: Distribution of Impact of Low Minimum Lot Size on Incumbent Welfare

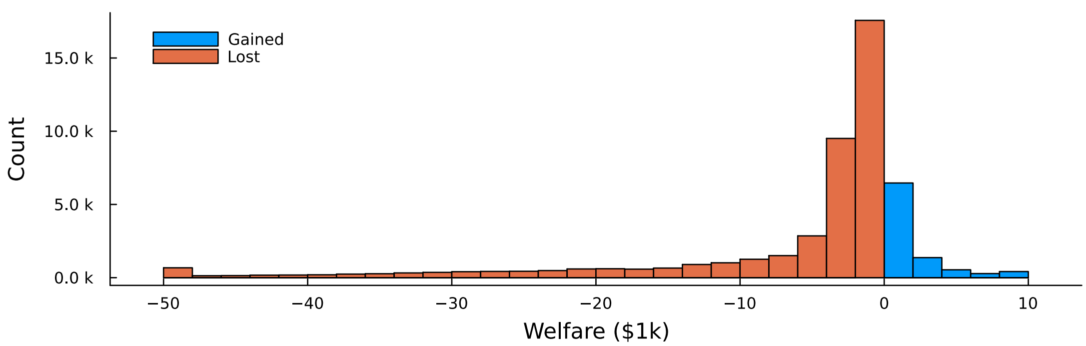
(a) Total Difference



(b) Lot Value Channel



(c) Externality Channel



Note: This figure plots the distribution of the effect of a reduction of minimum lot size on expected incumbent welfare for the sample of single-family lots eligible to adopt an SMLS. Panel (a) plots the distribution of the total expected welfare change. Panel (b) plots the contribution of expected changes in lot value from allowing subdivision. Panel (c) plots the contribution of expected changes in incumbent welfare from staying as a block gets denser.

Incumbent Welfare Impact of Local Control

Local control of regulation may help tailor regulation to the heterogeneous impacts of increased density. In columns (2) and (3) of Table 4, we display the welfare effects of reducing the minimum lot size for the set of incumbents that did not adopt a higher block-specific minimum lot size and those that did, respectively.

Column (2) of Table 4 shows welfare gains among incumbents on lots that did not adopt a higher block-specific minimum lot size. This column captures the welfare effects for incumbents of the policy as it was implemented. Among this subsample of incumbents, average welfare gains are 33% larger than for the full sample. This difference is driven primarily by the externality channel, where average losses from increased density are 26% smaller than in the full sample.

However, reducing the minimum lot size decreases welfare for the average incumbent on blocks that did adopt a higher minimum lot size. Column (3) of Table 4 shows the welfare effects of reducing the minimum lot size for incumbents that adopted an SMLS. This column captures the effect of removing local regulatory control. Reducing the minimum lot size for this subsample of incumbents reduced welfare on average by $407, or 0.3% of the median post-reform lot price. The decomposition of the welfare changes shows that incumbents that adopted an SMLS forgo larger increases in lot value to avoid larger disamenities from density. The average incumbent that adopts an SMLS sees 45% larger gains in lot value than the average incumbent that does not adopt an SMLS. However, losses for the average incumbent that adopts an SMLS are 156% larger and outweigh these gains.

These results highlight the ability of local control to tailor regulation to local incumbent preferences. This may allow policymakers to implement regulatory reforms that allow greater density across more areas while preventing political opposition where the externalities from density are the strongest. However, the ability to target regulations may be limited. Figure A5 plots the distribution of welfare changes from reducing the minimum lot size for incumbents that do and do not adopt an SMLS. We still find significant heterogeneity in welfare effects. This heterogeneity is driven largely by with-in-block differences in gains to subdivision and preferences for density. This suggests that allowing local control has limited ability to tailor policy to local preferences.

Importantly, the total effect of allowing local control on incumbent welfare is small, raising aggregate incumbent welfare by just $4.5 million, or 3.9%, compared to a uniform minimum lot size reduction. Doing so reduced the aggregate change in lot values by $118 million, or 29%. This highlights the role of local control in limiting supply where the surplus is greatest. In total, removing local control would have increased the total number of single-family housing units in Houston by close to 2,500. This represents a 28.7% increase over the estimated response to the policy change in our sample.

8 Conclusion

In this paper, we study the role of local preferences for housing density in determining residential land-use regulations. Disamenities from density generate externalities from developing denser housing. Restrictive land-use regulations can help reduce these externalities for incumbents who may influence regulatory choice.

We draw on evidence from a regulatory reform in Houston that reduced the minimum lot size for single-family lots. However, Houston also allowed a form of local regulatory control by which property owners on individual city blocks could effectively opt out of the reduction. We show that the reform led to an increased supply of single-family housing and increased housing density in some single-family neighborhoods. However, the policy response was heterogeneous. Neighborhoods that were initially more affluent and predominantly White exhibited a stronger propensity to opt for stricter land-use regulations.

We develop a structural model to quantify incumbent preferences for regulation using a revealed preference approach based on observed block-level regulatory choices and lot subdivisions following the reform. We find large disamenities from increases in housing density on a city block. Disamenities are strongest in more affluent and predominantly White areas, leading to higher rates of adoption of restrictive minimum lot sizes in these areas.

Our results show that local control of regulation may better tailor regulation to heterogeneous incumbent preferences. However, doing so decreases supply in the areas most likely to have seen the development of denser housing.

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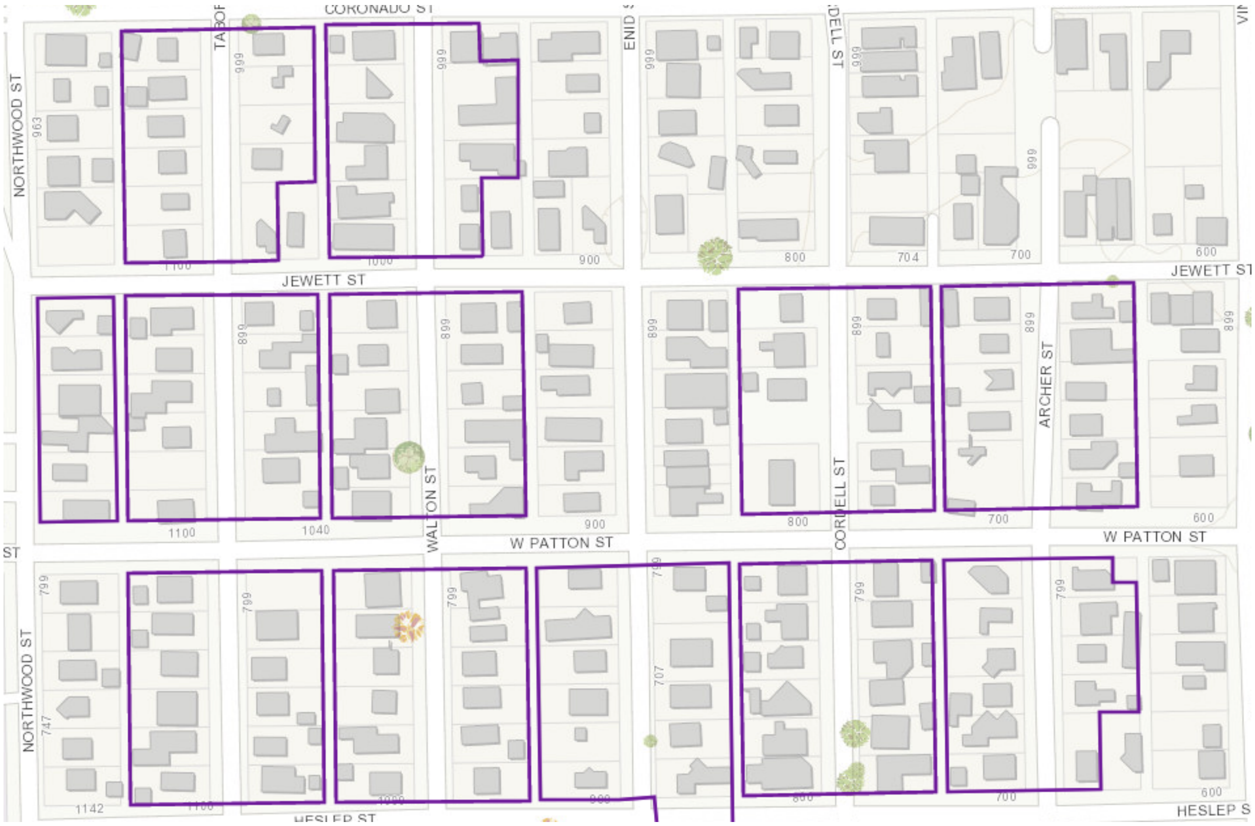
A Tables and Figures

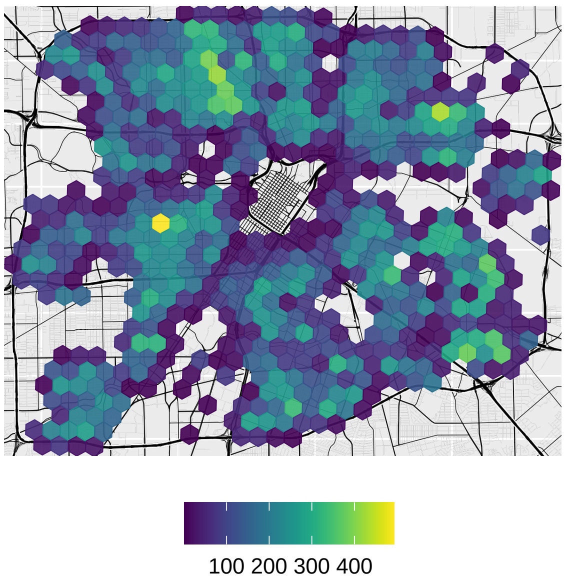
Figure A1: Example Special Minimum Lot Size Blocks:



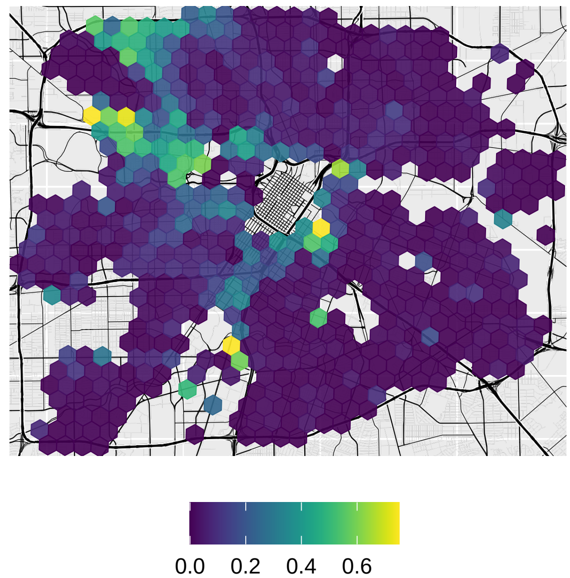
Note: This figure plots an example of observed SMLS boundaries, overlaid on a map of lots and streets. Prior to 2013, the set of houses on one or both sides of a street, from one intersection to the next, were eligible for vote to adopt a higher minimum lot size for the block. After 2013, groups of blocks were eligible to vote to adopt a higher minimum lot size.

Figure A2: Clustering of Response to Policy Change

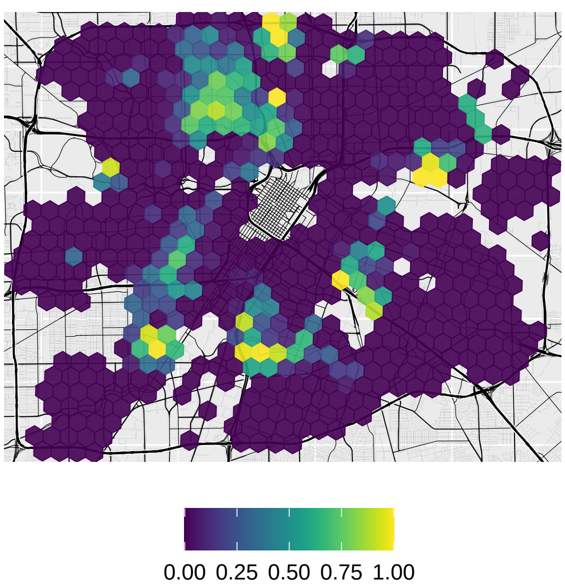
(a) Pre-Reform Single Family Lots



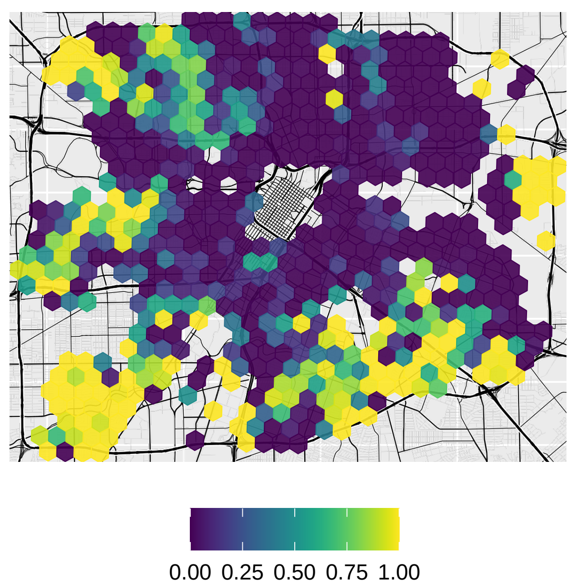
(b) Share that Subdivided



(c) Share with SMLS



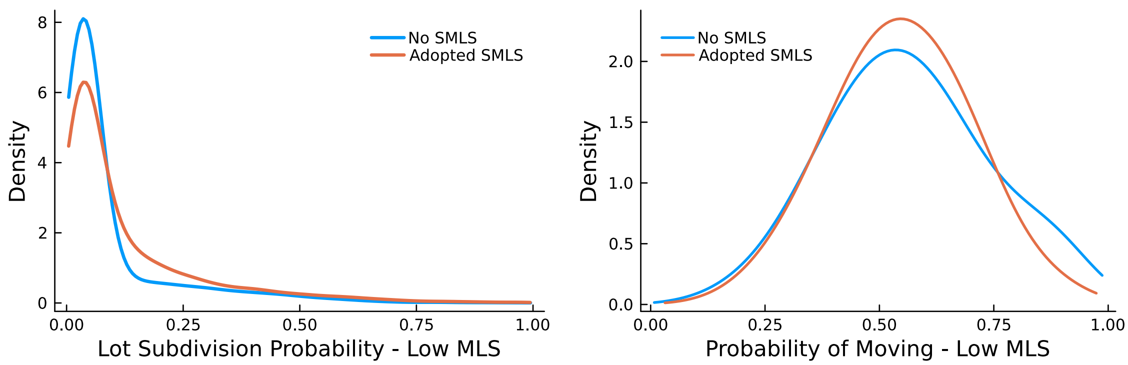
(d) Share with Deed Restrictions



Note: Figure A2a plots a heatmap of single-family lots inside Houston's urban core prior to the reform. Figure A2b plots the share of pre-reform single-family lots that subdivided by 2020, Figure A2c plots the share that were on a block that voted for a higher 'special minimum lot size'. Figure A2d plots the share subject to deed restrictions that limit subdivisions.

Figure A3: Model Predicted Lot Outcomes by Voting Choice

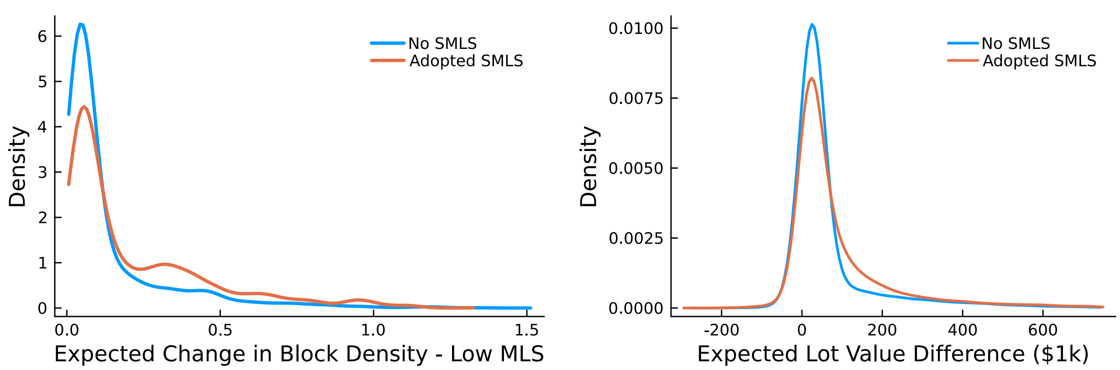
(a) Lot Subdivision Probability (b) Incumbent Moving Probability



Note: This figure plots the distributions of model predicted, payoff relevant outcomes for lots and incumbents prior to voting for an SMLS. Panel (a) plots the distribution of probabilities that a lot subdivides when the minimum lot size is low, conditional on an incumbent moving. Panel (b) plots the distribution of probabilities that an incumbent moves when the minimum lot size is low. Outcomes are plotted separately for lots on blocks that did or did not adopt an SMLS.

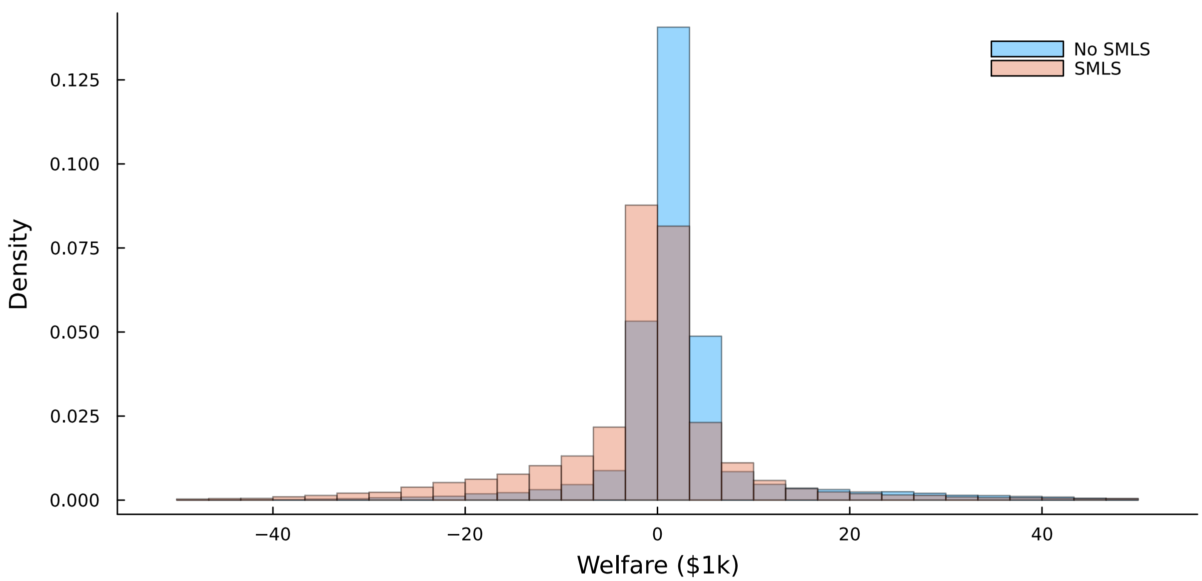
Figure A4: Decomposition of Expected Incumbent Payoffs by Voting Choice

(a) Expected Change in Density (b) Expected Lot Value - Low vs High MLS



Note: This figure plots the distributions of model predicted incumbent payoffs that influence voting decisions. Panel (a) plots the expected change in block density when the minimum lot size is low. Panel (b) plots the distribution of the expected change in lot value when the minimum lot size is low vs high. Payoffs are plotted separately for lots on blocks that did or did not adopt an SMLS.

Figure A5: Impact of Low Minimum Lot Size on Incumbent Welfare by SMLS Choice



Note: This figure plots the distribution of the effect of a reduction of minimum lot sizes on expected incumbent welfare for the sample of single-family lots eligible to adopt an SMLS. Welfare impacts are disaggregated by lots on blocks that adopted an higher minimum lot sizes and those that did not.

B Data Appendix

This appendix provides additional details on the construction of the data for the analysis.

B.1 Lot Panel Construction

Property tax records from the Harris County Appraisal District (HCAD) provide a panel of lot characteristics from 2005-2020 for all lots in Harris County. These data include a unique lot ID, lot address, lot size, building characteristics, owner name and address, and assessed land and building values. The Houston subset of this data provides the basis of our analysis data.

We extend the lot panel to 1995 by incorporating data from a GIS shapefile developed by the Houston Department of Planning and Development in 2004. This file contains a sub-set of lot characteristics for lots inside the Houston city limits for the ten year period from 1995-2004. These data contain lot size, land use code (eg. single- vs multi-family), assessed land values, and assessed building values. Detailed data on initial housing characteristics are missing for lots that were re-developed prior to 2005.

B.1.1 Linking Subdivided Lots

We link lots that subdivide or merge with newly created lots based on over-lapping geographic lot boundaries. To do so, we incorporate lot boundaries from multiple GIS shapefiles. We use the 2004 shapefile developed by the Houston Department of Planning and Development, as well as a one created in 2009. We supplement these with shapefiles developed by HCAD for the years 2014-2020. Together, these files provide the lot boundary lines for the near universe of single-family lots in our panel. We also extract the latitude and longitude of lot centroids.

We use the lot panel to identify the first or last year a lot appears in our data, or if the size of a lot changes, to track when lots are subdivided or merged. We then identify parent-child linkages across lots using overlapping lot boundary lines for these lots. In a small number of cases multiple contiguous lots were subdivided at the same time. When, for instance, two lots were subdivided into three, we randomly assign one of the parent lots to two of the new lots. The HCAD data also contains a subset of the parent-child linkages when parcels are subdivided or merged. We use these data to check verify our linkages when available.

B.1.2 Additional Data Sources

The Houston Department of Planning and Development provides a GIS shapefile with the boundaries of every special minimum lot size petitions. For every petition, the shapefile includes data on whether the petition was successful, the new minimum lot size, the data of the petition, and the data the new minimum lot size goes into effect. We link these records to the lot panel using the overlap between petition boundaries and lot boundaries. We collect data on house sales prices and mortgage details from CoreLogic, Inc. We link these data with the lot panel using unique Harris County Appraisal District lot ID code, which is included in the CoreLogic data. We match addresses from the HCAD data and the CoreLogic data to ensure the quality of the match. Finally, we merge US Census data on neighborhood characteristics to the lot panel using the overlap between Census tract and block group shapefile boundaries and lot boundaries.

B.2 Constructing Counterfactual SMLS Blocks

The Houston Department of Planning and Development provided details on the geographic extent of blocks that adopt higher minimum lot sizes. For our analysis, we construct the set of blocks that could have adopted higher minimum lot sizes but did not. Importantly, blocks are defined by the street grid: the set of houses on one or both sides a street facing each other, from one intersection to the next, qualify as a block that may be able to adopt a higher minimum lot size.

We construct these blocks using GIS shapefiles of the street grid in 2000 from the US Census Department. We the street grid with the lot boundary GIS files. The following procedure is used to link lots together to form blocks: First, we identify all street sections between intersections. If a lot has frontage on that street section, defined by the street name on the lot address, we link the lot to the street section. Lots where the lot address does not match any of the nearby street names (possibly due to typos or idiosyncratic naming conventions) are linked to the closest street previously linked to a positive number of lots. This assignment rule capture block definitions well for the majority of lots in the data, which tend to lie on grided streets.

B.3 Defining Arms-Length Transactions

An important component of the analysis is capturing if incumbent residents move after the reform. We define a move as the existence of an arms-length transition in our data after the reform. We classify an arms-length transaction as a change in lot ownership, excluding changes that do not result in a change in owner surname or to a corresponding family trust. We match owner names before and after a transfer of ownership by first cleaning and standardizing the name fields, followed by a fuzzy string matching procedure. Our classification captures the vast majority of observed lot sales from CoreLogic Inc.'s transaction data but may overestimate the number of arms-length transactions if within-family transfers result in a change in surname.

C Price Setting in Pure Characteristic Space

Bajari and Benkard (2005) show that a hedonic model of demand will yield a unique equilibrium price for every bundle of product characteristics when (1) consumers are small in the sense they take prices as given, (2) utility is continuously differentiable and strictly increasing in consumption, (3) utility is Lipschitz continuous in observable and unobservable characteristics and (4) utility is strictly increasing in unobservable characteristics. This result does not rely on any additional supply-side assumptions. In this section we show how equilibrium prices are set under these assumptions.

Consider a set of products J. Product $j \in J$ is defined by it's location in characteristic space $(x_j, \xi_j) \in \mathcal{R}^{n+1}$, where n denotes the number of observable characteristics x_j. There is a mass of supply of each product. Note that two lots with the same observable and unobservable characteristics would be the same product from the perspective of consumers.

For expositional clarity, we let utility be quasi-linear. Consider the consumer i's maximization problem for the choice of products:

$$\max_{j \in J, c} \beta_i x_j + \alpha_i \xi_j + c \quad \text{s.t.} \quad p_j + c \leq y_i$$

We can write (normalized) indirect utility for each good as $u_{ij} = \beta_i x_j + \alpha_i \xi_j - p_j$. Let consumer preferences over characteristics be drawn from an arbitrary distribution $(\beta_i, \alpha_i) \sim F(\beta, \alpha)$ such that $\alpha_i \in R^+$. Consumers can choose not to purchase a good (or equivalently purchase an outside option in infinite supply), $j = 0$, with utility normalize to zero: $u_{i0} = 0$.

Given an arbitrary level of supply and consumer preferences, our goal it to find the equilibrium prices that equalize supply and demand. We can characterize supply for each product in terms of shares of consumers, s_j, such that $s_j \geq 0$ and $\sum_{j \in J} s_j = 1$.

Consumer i purchases good j if and only if $u_{ij} \geq u_{ij'} \;\; \forall j' \in J$. For a given set of prices $\mathbf{p}$, the set of consumer preferences that result in product choice j is:

$$A_j(\mathbf{p}) = \left\{ (\beta, \alpha) \mid \beta_i x_j + \alpha_i \xi_j - p_j \geq \max_{j'} \beta_i x_{j'} + \alpha_i \xi_{j'} - p_{j'} \right\}$$

We can express consumer demand in terms of shares as a function of price:

$$s_j(\mathbf{p}) = \int_{(\beta,\alpha) \in A_j(\mathbf{p})} dF(\beta, \alpha)$$

In equilibrium, prices equate supply and demand: $s_j(\mathbf{p}) = s_j \; \forall j$.

Pang et al. (2015) show that the problem of solving for prices can be recast as a feasible linear program over individual choice probabilities, π_{ij}:

$$\begin{aligned} \max_{\pi_{ij}} & \int \sum_{j \in J} \pi_{ij} \left(\beta_i x_j + \alpha_i \xi_j \right) di \\ \text{s.t.} & \int \pi_{ij} di = s_j \;\; \forall j \\ & \sum_{j \in J} \pi_{ilj} \leq 1 \;\; \forall i \\ & \pi_{ij} \geq 0 \;\; \forall i, j \end{aligned}$$

where equilibrium prices p_j are the multiplier on the aggregate supply constraints: $\int \pi_{ij} di = s_j$. This formulation is equivalent to solving the planner's problem of allocating scarce goods to consumers.

Consider a stylized example. Let there be a mass of consumers of size one. There are two products and an outside option. Each product has a single quality attribute. The high type product has quality of 20 and market share of 20%. The low type product has quality 10 and market share of 40%. There are two types of consumers. High type consumers value quality at 2 and make up 30% of consumers. Low type consumers value quality at 1 and make up 70% of consumers. The outside option has value normalized to zero for both consumer types.

We present the resulting equilibrium prices and choice probabilities in Table A1. In equilibrium, the low type product price is such that low type consumers are indifferent between the low type product and the outside option. The high type product price is such that the high type consumers are indifferent between high type products and low type products. Consumer choice probabilities equalize supply and demand at these prices.

Table A1: Stylized Supply and Demand in Pure Characteristic Space

Products	Consumer Values		Prices	Consumer Choice Probabilities		
	high	low		high	low	total
high	40	20	30	$\frac{2}{3}$	0	0.2
low	20	10	10	$\frac{1}{3}$	$\frac{3}{7}$	0.4
outside option	0	0	0	0	$\frac{4}{7}$	0.4

Note: This table presents equilibrium prices and choice probabilities for a stylized set of consumer preferences and product supply.

D Alternative Housing Demand and Counterfactual Prices

In this section we propose and estimate an alternative model of demand for single-family housing similar to Bayer et al. (2007). This alternative model will allow us to solve for counterfactual prices under alternative vectors of housing supply. We use this alternative model to check to robustness of our counterfactuals that assume prices do not change when the minimum lot size changes in the urban core of Houston, given the relative size of the Houston's urban core to the greater Houston housing market. We find counter-factual price changes are small and have limited quantitative impact on our results.

D.1 Alternative Demand Assumptions

We impose additional structure on household preferences in Section 4.3 to estimate demand for single-family lots in Houston. We make four additional assumptions to arrive at an alternative model for housing demand. Importantly, we allow purchasers to have different preferences than incumbents to capture the fact that the marginal buyer of a lot may have different preferences than incumbents as prices and density change.

First, we assign house types by binning lots on observed lot characteristics $(X_l, d_{b(l)})$ and location for computational tractability when calculating counterfactual prices. We assume that unobservable characteristics ξ are constant within bin h. Second, we assume preference for lot characteristics take the form $u_i(X_h, \xi_h) + g_i(d_h) = \gamma_i \tilde{X}_h + \nu_i d_h + \zeta_h + \xi_h$. Where we decompose observed lot characteristics, X_h, into a component that is valued differently across households, including house size, lot size, and house age, and a location-specific fixed effect, ζ_h, valued uniformly across households. Third, we assume households have idiosyncratic preferences across lot types, denoted ϵ_{ih}. This deviates from the hedonic demand we adopt in our main analysis and allows us to tractably compute counterfactual prices. Fourth, we bin households into race-by-income groups. The demographic vector z_i contains household demographics for household i.

The household choice problem can then be written as:

$$U_{h1} = \max_{h \in H_1} \; \gamma_i \tilde{X}_h + \nu_i d_h + \xi_h + \zeta_h + \frac{1}{\iota_i}\epsilon_{ih} + c \tag{9}$$

$$\text{s.t. } \; p_1(X_h, d_h, \zeta_h, \xi_h) + c \leq y_i \tag{10}$$

where preferences depend on household demographics z_i:

$$\begin{pmatrix} \gamma_i \\ \nu_i \\ \iota_i \end{pmatrix} = \begin{pmatrix} \gamma \\ \nu \\ \iota \end{pmatrix} + \Pi z_i$$

Where the matrix Π maps household demographics into demographic-specific preferences for housing characteristics. These assumptions compress the potentially rich heterogeneity in preferences across lot characteristics into demographic-specific mean preferences.

D.1.1 Demand Estimation

We estimate demand parameters via two-step GMM following Calder-Wang (2021). First, we match market shares of houses that transact and micro-moments on the covariance of purchaser demographics and lot characteristics derived from HMDA records. Second, we estimate mean preferences using a model derived price instrument.

In the first step we recover $\delta_h = \iota(-p_h + \gamma \tilde{X}_h + \nu d_h + \zeta_h + \xi_h)$ and Π. The parameter δ_h is the mean utility from lot type h. The parameters in the matrix Π govern demographic-specific preferences. We recover these parameters by matching the following moments:

$$E_i\left[\Pr(h \mid z_i, \delta, \Pi)\right] = s_h \quad \forall h$$
$$\text{Cov}\left(E_i\left[z_i \mid h, \delta, \Pi\right], \{\tilde{X}_h, d_h\}\right) = \text{Cov}(\bar{z}_h, \{\tilde{X}_h, d_h\})$$

The first set of moments matches market shares, s_h, for every lot type h. The second set of moments matches the covariances of mean purchaser demographics for a lot type, $\overline{z}_h$, and the observed characteristics of that lot type, $\tilde{X}_h,\ d_h$. The identifying assumptions are that households maximize utility, and lot prices and lot type characteristics are exogenous from the perspective of individual household choices.

In the second step we recover γ, ν, ι. We worry that price p_h is correlated with unobservable quality ξ_h. We construct model derived price instruments following Berry et al. (1999) and Bayer et al. (2007). First, we set the unobserved quality ξ is set to zero. Second, we solve for the alternative price vector p^{iv} that equalizes demand with the observed level of supply. This instrument implicitly uses the characteristics of other lot types and their relative scarcity to instrument for the price of any particular lot type. Formally:

$$E_i\left[\Pr(h \mid z_i, p, \tilde{X}, d, \zeta, \xi, \Pi)\right] = s_h \quad \forall h$$
$$E_i\left[\Pr(h \mid z_i, \hat{p}^{iv}, \tilde{X}, d, \zeta, \xi = 0, \Pi)\right] = s_h \quad \forall h$$
$$E\left[\xi_h \hat{p}_h^{iv}\right] = E\left[\xi_h \tilde{X}_h\right] = E\left[\xi_h d_h\right] = E\left[\xi_h \zeta_h\right] = 0$$

The identifying assumptions are that observed lot characteristics $\tilde{X},\ d,\ \zeta_h$ are independent of the unobservable ξ. This is a strong assumption. To help address identification concerns we include location fixed effects, ζ_h, at the level of the ZIP code to capture unobserved location quality.

D.1.2 Demand Results

Table A2 displays estimated demand parameters. The coefficient on price is -30.1 using instrumented prices. The increase in magnitude of this coefficient when we instrument for prices suggest that prices are positively correlated with unobservable lot type quality. The first-stage F-stat is 16.9. Instrumenting for prices is important, with the sign on preferences for house age changing sign in a way that aligns with our priors that households tend to prefer newer houses.

We allow preferences for lot characteristics to vary by purchaser income and the race of the head of household. Columns (3)-(5) of Table A2 report the parameters that govern demographic specific preference shifters. We find that higher income houses have a significantly lower disamenity from prices and higher preferences for larger houses. Households with a non-Hispanic White head prefer smaller and older houses and higher density. This result contrasts with our findings that incumbent households in areas with higher pre-reform White residential share face larger-disamenities from density. These differences highlight the importance of identifying incumbent preferences for understanding the political economy of land-use regulations. Regulation is determined by incumbents and incumbent preferences may differ from newcomers. Households with a non-Hispanic Black head have higher disamenities from prices and have lower preferences for lot size and house age. Overall, demographic specific preferences suggest land-use regulations will affect residential sorting as the regulations change the composition of new housing supply.

Finally, column (6) of Table A2 reports estimated willingness to pay for lot characteristics,

Table A2: Demand Parameters

	δ		Π			WTP
	OLS (1)	IV (2)	ln Income (3)	White (4)	Black (5)	(\$100k) (6)
Price (\$100k)	-0.160	-30.125	0.263	0.025	-1.320	
	(0.020)	(7.329)	(0.046)	(0.039)	(0.078)	
ln Lot Size	0.041	4.923	-0.049	-0.013	-0.256	0.160
	(0.021)	(0.988)	(0.028)	(0.072)	(0.071)	(0.097)
ln House Size	0.245	8.257	0.452	-0.607	-0.022	0.261
	(0.015)	(1.588)	(0.054)	(0.101)	(0.060)	(0.050)
ln House Age	0.101	-5.148	0.005	0.191	-0.328	-0.168
	(0.015)	(1.064)	(0.019)	(0.045)	(0.062)	(0.150)
Density	-0.041	-2.677	0.001	0.131	0.064	-0.086
	(0.017)	(0.565)	(0.027)	(0.071)	(0.065)	(0.110)
Location FE	Yes	Yes				
Estimator	OLS	IV				
N	8,855	8,855				
First-stage F statistic		16.907				

Note: This table provides parameter estimates for household lot type demand. The dependent variable in columns (1) an (2) is the estimated mean preferences for lot types δ_h. Columns (3)-(5) display demographic specific preference shifters. Log household income is normalize to mean zero for numerical stability during estimation. Column (3) reports estimated willingness to pay for each characteristic $(\gamma/\iota, \nu/\iota)$ for the average household. Willingness to pay estimates are given in 2013 dollars. Asymptotic standard errors are given in parentheses for columns (1)-(5). Standard errors for willingness to pay are computed via the delta method.

$(\gamma_i/\iota_i,\ \nu_i/\iota_i)$, for the average household. We find the average household is willing to pay \$26,000 for a 1% increase in house size, and \$16,000 for a 1% increase in lot size. Willingness to pay estimates for a change in density are noisy, but of a comparable magnitude to our mean estimated disamenities from density for incumbents.

D.2 Implications for Counterfactuals

When the minimum lot size is kept at 5,000 sf in Houston's urban core, we find there would be 2.2% fewer single-family homes, and less than 1% fewer total housing units in the city as a whole. These shares would be even smaller for the Houston MSA. Ignoring compositional changes, our alterative model of demand suggests that the average single-family lot would have been \$380, or 0.16% more expensive. The standard deviation of price changes is \$402. We find that price changes on this order of magnitude do not quantitatively affect our counterfactual results.