Housing Availability and Affordability: Evidence from a National Estimate and Effects of a Local Rezoning*

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Abstract

During the past few years, many groups have suggested that the United States is experiencing a housing crisis marked by a supply deficit and affordability problems. This paper argues for a better understanding of housing availability and the drivers of house price appreciation. It further contributes to the debate in two ways. First, it provides an alternative estimate of housing availability that suggests the U.S. housing market has not been in a crisis during the past two decades. Second, to estimate the price response of relaxing regulatory restrictions in a city, it provides a robust statistical analysis of zoning changes in Denver in 2010. While there is some evidence supporting a positive effect of rezoning, the findings do not suggest that increased supply is the sole determinant of price effects. These results do not imply, in any way, that local governments should refrain from the types of reforms that will reduce regulatory costs and increase construction. They do, however, suggest that officials should temper their expectations for exactly how much added construction will slow the growth in home prices. The findings implore the need for more refined research on housing market dynamics—especially on the demand side—to precede policy prescriptions aimed at solving housing-related problems through increased construction.

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1 Introduction

For the past several years, various organizations have called for policies to boost the number of homes built in the United States. These groups regularly characterize the U.S. housing market as facing a shortage, though they typically are referring to a market where the quantity supplied is less than some preferred measure, not a market where the quantity demanded exceeds the quantity supplied at the equilibrium price by their quoted amounts. Nonetheless, some groups claim that the U.S. is experiencing both a housing supply and affordability crisis.[1] While there seems to be a consensus that this supply deficit has been the primary culprit of the affordability crisis, there is still a vast spread of opinions on exactly how to define the "shortage." Furthermore, the range of estimates of this "shortage" has varied considerably.

The National Association of Home Builders' (NAHB) estimated a shortage of 1.5 million homes for 2021, while a study for the National Association of Realtors (NAR) estimated the shortage was 5.5 million.[2] Freddie Mac, one of the two large housing government sponsored enterprises (GSEs), estimated the shortage was 3.8 million homes.[3] In 2022, the tech-based real estate firm Zillow estimated that the U.S housing shortage grew to 4.5 million homes.[4] These estimates create a substantial shortage range of approximately 1 million to 5 million units, making it difficult for policymakers to design targeted policies that account for dynamic nuances in the housing market and to judge their efficacy over time.

Some quantifications of the housing shortage have involved construction of statistical models that suggest what the supply of new homes should be compared to other contemporaneous and relevant housing market variables. Freddie Mac's model, for instance, includes household formation rates, current vacancy rates (the share of homeowner inventory that is vacant/for sale), the exist-

[1]For instance, National Association of Realtors president Leslie Rouda Smith recently stated that "Urgent action is needed to tackle our nation's housing supply crisis." National Association of Realtors, "Biden Administration Takes Aim at America's Housing Shortage," Realtor Magazine, May 16, 2022. Also see Adewale Maye and Kyle Moore, "The Growing Housing Supply Shortage has Created a Housing Affordability Crisis," Economic Policy Institute, July 14, 2022; Orphe Divounguy, "Affordability Crisis: Housing Shortage Worsened Despite Pandemic Construction Boom," Zillow, June 18, 2024; and Daniel McCue and Sophie Huang, "Estimating the National Housing

[2]National Association of Home Builders, "The Size of the Housing Shortage: 2021 Data," Eye on Housing, December 16, 2022; and, Kenneth T. Rosen et al., "Housing is Critical Infrastructure: Social and Economic Benefits of Building More Housing," Rosen Consulting Group, June 2021,

[3]Freddie Mac, "Housing Supply: A Growing Deficit," Research Note, May 7, 2021,

[4]Orphe Divounguy, "Affordability Crisis: Housing Shortage Worsened Despite Pandemic Construction Boom," Zillow, June 18, 2024. Freddie Mac, "The Housing Supply Shortage: State of the States," Insights, February 27, 2020.

ing housing stock, and a target vacancy rate of 13 percent.[5] While models estimating shortages computed with vacancy rates appear to have become a standard way of measuring housing market trends, the lack of a clear answer as to what should be the recommended vacancy rate (and why) makes it difficult to evaluate the estimates these models produce. Still others, for example Corinth and Dante (2022), estimate the shortage based on what would have been built in the absence of zoning and other regulatory constraints. [6] NAR's online "Housing Shortage Tracker" estimates the shortage for major U.S. metro areas by comparing the number of new construction permits issued to every new job.[7] There is no objectively correct method for making such shortage estimates because they are, by nature, subjective. This study provides an alternative estimate of housing availability that does not require subjective adjustment. It argues that a change in resident population is superior to job creation as a proxy for housing requirement, and refrains from setting arbitrary target vacancy rates or the timing and manner of household formation.

While the new metric is limited in terms of lacking a general equilibrium framework incorporating demand and supply variables, not unlike its peers, it provides a broad understanding of how housing construction has kept up with simple population-based demand, accounting for location and time-based variations. The metric is similar to some metrics used previously in the literature in relation to housing stock (e.g. Jackson (2016), Green, Malpezzi, and Mayo (2005)). Based on the evidence that follows, using a measure of housing availability spanning 362 US counties from 2000 to 2022, it appears that not only is there no evidence of an appalling housing shortage, but housing availability has been improving in recent years. For instance, housing availability was at its lowest around the 2008 financial crisis when a 100 unit increase in population was associated with only 52 housing units permitted. This rate increased to approximately 79 units for every 100 residents after the crisis. Overall, between 2000-2021, the average building units permitted per 100-unit change in resident population is approximately 93 housing units, hardly indicative of a major shortage. Put differently, in the full period, U.S. housing construction has kept up with U.S.

[5] Freddie Mac, "The Housing Supply Shortage: State of the States," Insights, February 27, 2020

[6] Corinth and Dante (2022) estimate that the United States had a housing shortage of 20.1 million homes in 2021, a total representing the number of homes that (according to their methodology). Their work is something of an outlier in terms of the estimated quantity and in methodology. Unlike the other groups, the key variable in their model is the land share, a variable that they assume will fall to approximately 20 percent without regulatory constraints.

[7] National Association of Realtors, "Housing Shortage Tracker," 2024. Separately, the above-mentioned NAR study presents an alternative estimate of the shortage (6.8 million units) with the following calculation: Demand-Supply Gap = Household Formation + Lost Housing Stock – New Completions). Rosen et al., "Housing is Critical Infrastructure," p. 3.

population increases. We wish to emphasize that while more housing may still benefit some people in specific locations, our measure helps answer, broadly, whether the housing market generally provides housing for people.

As alluded to earlier, many of the shortage estimates, which range from approximately 1 million to 5 million units, depend on a comparison of current vacancy rates–the number of vacant homes as a share of all housing units–to their long-term average.[8] Relying solely on such supply-side metrics to call for new construction is problematic for several reasons. First, these metrics do not answer the key question of whether, over the long run, housing construction tends to keep up with population growth, such that people are generally not lacking a place to live. Our analysis contributes in this aspect by discussing an availability metric that incorporates population changes. Additionally, these metrics generally do not estimate specific demand factors (income growth, consumer preferences, interest rates, lending policies, etc.) that could still lead to home price increases even in markets with additional construction.[9] Finally, because these metrics ignore equilibrium supply conditions, attempts to make up even the most conservative of these "shortages" could constrain basic supply factors (labor, materials, land, etc.) so much that it leads to higher home prices.

Without an adequate understanding of the various demand and supply factors that drive housing market dynamics, policies designed to improve housing affordability could be ineffective or even counterproductive. If, for instance, housing demand factors such as income growth, wealth, and preferences for larger (better equipped) homes, tend to outweigh supply factors, home prices might continue to rise even in the face of above-average new home construction. For instance, Albouy et al. (2016) estimate housing demand in a novel theoretical framework and find that falling household sizes may have increased demand. They show that households have shrunk in size by almost 30

[8]The NAHB relies on a parsimonious comparison of the difference between the current vacancy rate and "the 'natural,' or long-run average" vacancy rate. See National Association of Home Builders, "The Size of the Housing Shortage: 2021 Data."

[9]It is well documented that federal policies made a concerted effort to increase home mortgage lending at various points during the past century. In the 1950s, for example, the Federal Housing Administration (FHA) began to reduce the downpayment required to take on a home loan through its single-family mortgage program. Eventually, Congress passed the Federal Housing Enterprises Financial Safety and Soundness Act of 1992, a law that required the secretary of the U.S. Department of Housing and Urban Development (HUD) to establish three broad affordable housing goals for Fannie Mae and Freddie Mac, thus expanding their lending support. In 2000, HUD increased those goals. For a history of FHA downpayment requirements see M. Carter McFarland, "FHA Experience with Mortgage Foreclosures and Property Acquisitions," Federal Housing Administration, January 1963, p. 23. For a description of the increase in the affordable housing goals see U.S. Department of Housing and Urban Development, "HUD's Affordable Lending Goals for Fannie Mae and Freddie Mac," Issue Brief No. v, January 2001.

percent. This has reduced economies of scale in housing consumption, thereby increasing per-capita demand for housing.[10] Thus, while many policymakers may incentivize more construction to help make homes more affordable (as they should), for instance by relaxing zoning requirements, the price responses from such policies could be disappointing.[11]

In line with the preceding discussion, the literature reveals a complex interplay between housing demand and supply, as discussed in detail by Freemark (2023). In fact, several studies show that controlling for demographics and density suggest both housing prices and homeownership may be driven more by demand than supply, (Brookings Report (2002), Glaeser and Ward (2009), Fisher and Gervais (2011)). This finding is reiterated by Anenberg and Ringo's (2022) housing search model that emphasizes the significant role played by housing demand (and its underliers) on the overall housing market dynamics. Still others (Schill (2005) and Glaeser & Gyuorko (2018) to name a few) agree that low supply may be causing affordability issues. These studies generally argue that supply restrictions, in the form of land use and/or zoning, are the primary factors causing the low supply. We agree that government officials should relax rules and regulations that make building unnecessarily difficult and expensive, but they should exercise caution when promising substantial reductions in prices as a result of those regulatory changes. Policy prescriptions, the majority of which are geared towards improving affordability through boosting construction, need to critically examine the extent to which higher supply increases affordability. To address that, the second part of this paper examines the relationship between zoning changes and prices by analyzing a case study in supply-based regulation changes in Denver, Colorado.

Estimating price responses from these kinds of regulatory changes is not always straightforward. For instance, Quigley and Rosenthal (2005) discuss some common issues that arise when studying supply regulation and housing prices. These issues include identification of endogeneity between regulation and price (wealthier, more expensive communities may have stronger tastes for regulation), and recognizing the complexity of local policymaking and regulatory behavior (many

[10]They integrate a demand equation into a utility function that models housing consumption and provides cost-of-living indices across space and time for different income, household sizes, and amenity levels, which account for income and substitution effects. They find evidence of economies of scale in housing, in proportion to the square-root of housing size. A 30-percent reduction in residents per household reduces household housing consumption by only 15 percent, increasing per-capita consumption by the same percentage.

[11]Zillow, for instance, claims that "The growing housing shortage is the primary reason for the affordability crisis." Divounguy, "Affordability Crisis." Some groups make more subtle claims about affordability. See, for example, Rosen et al., "Housing is Critical Infrastructure," pp. 11-12.

projects may be implemented simultaneously, some of which may make zoning more restrictive). In this paper, as we study the impact of the rezoning change implemented in 2010 in Denver, we confirm that Denver's rezoning episode does not coincide with any other growth or development projects. Additionally, our primary outcome variable is a price appreciation measure derived from a Federal Housing Finance Agency (FHFA) House Price Index that considers repeat sales, correcting for well-known biases in price means and medians typically reported.

The data in this paper spans 48 counties in Colorado from 2000-2018, with the rezoning occurring in 2010 at Denver, which acts as an exogenous shock to Denver's housing supply.[12] A two-way fixed effects model is employed to isolate the impact of the zoning change in permits and prices, controlling for other geographic and temporal variations. The average annual house price appreciation in Denver was about 4.53% before rezoning (averaging between 2000 and 2009), which increases to about 6.6% after rezoning (average between 2010-2018), with a high degree of volatility marked by a 5.5% standard deviation for the full period.

Controlling for permits issued both in the past year and the year before, based on our estimates, rezoning is found to have reduced the average house price appreciation from potentially 8.55% to the realized value of 6.6%. Note that given the average house price appreciation in Denver from 2000-2018, this translates to rezoning being associated with a continued rise in prices, albeit at a rate slower than it would have otherwise been in the absence of rezoning. The presence of rezoning is associated with a significant increase in building permits issued as well, but the findings show that the relationship between an increase in permits and a reduction in house price appreciation is ambiguous. Still, the Denver rezoning presents a unique opportunity to study the effect of a regulation change to the number of permits on house price appreciation. It allows us to separate the supply-based outcomes and estimate how much supply singularly may affect affordability, while controlling for some of the demand-variation (those that can be captured by fixed effects). Naturally, we cannot control for all the demand-variation, and the ambiguity in our finding suggests that studying more detailed demand-dynamics might provide a clearer answer.

Our analysis of rezoning contributes to a growing literature studying new zoning changes both in the US and abroad (e.g. in Zurich (Buechler & Lutz (2021), Auckland (Greenaway-McGrevy

[12]We acknowledge that policy changes do not happen in vacuum and there might have been expectations of a zoning change in Denver before 2010. However, the 2010 zoning change created an exogenous increase in the number of permits issued in Denver to the extent that any such shift can be exogenous.

and Phillips (2022), Brisbane (Limb and Murray (2022)). While studies about zoning changes within the US almost unanimously agree that relaxing zoning restrictions leads to higher building permits and supply (although the effect on supply of low-cost housing is mixed), the findings on price-effects are more ambiguous. For instance, a host of studies find that some rezoning efforts have led to increasing housing prices. These studies include Angotti & Morse (2016) and Liao (2022) analyzing New York upzoning, Freemark (2019) discussing Chicago upzoning, Dong & Hanz (2019) analyzing rezoning in Portland and Stacy et al. (2023) analyzing cross-city panel dataset of land use reforms. However, another set of studies finds that zoning changes can reduce price growth, aligning with our finding with respect to Denver. These studies include Anagol, Ferreira & Rexer (2021) studying rezoning in Sao Paolo, a paper that reports rezoning led to a 1.9% increase in housing stock and a 0.5% reduction in prices, with substantial heterogeneity across neighborhoods. Separately, Buechler & Lutz (2021) analyze rezoning in Zurich and discuss how increased housing production may reduce prices in the region overall due to increased supply, but with limited effect at the city level due to changes in amenities from construction.

The sections that follow analyze the motivation, data, methodology and results pertaining to our new housing availability metric. Section 3 starts with a basic explanation of the 2010 Denver zoning change, which is then followed by details of the data, methodology, and results from the rezoning analysis.

2 New Housing Availability Metric

Rather than focus on an existing metric of the housing shortage, we present more details on housing availability. As Figure 1 demonstrates, annual housing units completed followed an upward trend from 1992 to 2005, while the population change was falling, and then declined for several years. Since 2011, however, units completed have been on the rise. To study how units started (or completed) compared to the change in population nationally during the past several decades, Figure 2 shows the annual change in population divided by the number of units started (in blue) and the annual change in population divided by the number of units completed (in orange). The trends account for housing volume relative to population change, attempting to formulate an objective measure of how construction has fared alongside the "need" for it. As either of these ratios shown in blue and orange decreases, it implies that there is a relatively higher volume of housing being built compared to the demand created by annual population.[13]

As Figure 2 demonstrates, from approximately 2009 to 2018, yearly units completed and started increased with annual population changes (a downward trend in the orange and blue lines for both periods). The population change per units started (or completed) was the highest following the financial crisis.[14] However, since then, population change relative to building units dropped continuously, to hit an all-time low of 0.35 in 2021, before rising slightly in 2022. The 2021 ratio is symbolic of a lower change in population than housing unit starts (and completes) and the magnitude itself was lower than it was at any point during the past five decades. As such, in the absence of clear evidence showing a shortage in supply, from here on, we refer to our housing supply related metric as a "housing availability" metric, departing from the widely used terminology of "housing shortage".[15]

While the national trends in the long time-series graphs are not indicative of any major decrease in housing supply, it is also important to study similar availability metrics for geographically smaller regions. Also, given that so many aspects of the housing market have also changed since the 1970's, it is important to undertake a more granular analysis on a shorter period. Hence, this section describes a novel analysis of housing availability starting from 2000. It is based on annual housing supply and annual changes in population using a 22-year panel of 362 counties. The county-level data allows a more in-depth analysis that considers housing availability across time, categorized by building types and variation in population density across locations. The supply metric at the county level is measured best (based on data availability) by the building permits issued annually in each county, and hence, from here on out, our analyses employ building permits and population changes as the primary variables of interest.

[13] In the context of resident population, the word "demand" used here and in the entire New Housing Availability Metric section serves to provide a sense of the general requirement of housing; it should not be confused with an estimate of economic demand generated out of any econometric model.

[14] Apart from population change, the change in the number of households may also serve as a proxy for housing demand. However, the aggregate count of households exhibits much more variation than the population series (especially in Census years), owing to both underlying variations and methodological revisions. Due to this volatility, the ability of individuals (both family and non-family members) to move in and out of households on a regular basis, and the lack of a county-level household count time-series, we use population change here and in the panel analyses shown in the following sections.

[15] As Corith and Dante (2022) mention, researchers often misuse economic terminology by defining the "housing shortage" in the United States as the difference between the number of homes that would be built in the absence of supply constraints and the actual number of homes; instead of estimating a gap between the number of homes demanded and supplied.

2.1 Data

The two major data sources used for this analysis are: (1) county-level annual numeric change in resident total population from the U.S. Census Bureau, Population Division; and (2) Building Permits Survey county-level data on the number of units for which permits are issued in single family and multifamily (2-4 units and 5+ unit) buildings. This data is geographically restrictive and the lack of consistent locations over time limits the sample to a panel of 362 counties. Using these data, we construct an availability ratio, defined as the ratio of resident population change to units permitted (of all building types). This index is very similar to one of the primary outcome terms used by Jackson (2016), to understand the effect of regulations on housing. In similar lines, Green, Malpezzi, and Mayo (2005) proxy for percentage change in the housing stock using the number of annual permits issued, multiplied by an average household size of 2.5, divided by population (differing in scale from our index in the inclusion of a constant average household size).

In case of our index, while a higher ratio implies a higher number of residents allotted to a single housing unit, alluding to lower housing availability, a lower ratio implies more availability. The ratio can take negative values and positive values corresponding to population reductions and increases in a county, at any point in time. If the annual number of units permitted is 0, a value of 1 is assumed and the ratio takes the value of the population change. Housing availability varies both across time and geographic location, but we first provide a basic overview of how the data looks across time, aggregated over all the available counties.

Table 1 shows the ratio of median population change to median units permitted (of all building types) each year. Among positive values, the ratio can take values less than or greater than 1. A value less than 1 implies that more housing units are permitted annually relative to the population change, suggesting a higher housing availability. A value greater than 1 implies that the resident population change is higher than the annual housing units permitted, suggesting a lower housing availability. We use the ratio of median values to help ensure that extremities in large urban areas do not bias the central tendencies. Based on the median ratios, availability has been improving steadily since 2013, with a ratio of less than 1 since 2020. Likewise, based on the average ratios, availability has been improving steadily since 2009, with a ratio less than 1 since 2020.

Figure 3 reports the ratio of the medians from the above table. This graph shows that housing availability worsened during the financial crisis and was the lowest (corresponding to the highest ratio) immediately following the crisis. Also, while availability slightly worsened in 2022, it has fared better than the average since 2016, with the trend improving almost steadily starting in 2010.

2.2 Methodology

For a more robust study of the associations between annual changes in population and yearly building permits issued, we estimate several regression models. The regression models are listed below with the advantages of each subsequent model explained briefly.

The base model is a simple panel regression with 13 years and 362 counties:

$$\Delta P_{c,t} = \alpha + \beta\, U_{c,t} + \epsilon_{c,t} \tag{1}$$

where

$\Delta P_{c,t}$ = Change in population between year t and year $t-1$ in county c $\forall t = 2010, 2011 \ldots .2022$

$U_{c,t}$ = Total units permitted in county c in year t

Then, we add year-fixed effects to the base model. The year-fixed effects account for any time-specific changes that happen over the years:

$$\Delta P_{c,t} = \alpha + \beta\, U_{c,t} + \gamma_t + \epsilon_{c,t} \tag{2}$$

where γ_t = year dummies

Next, we add state-fixed effects to the second model. The state-fixed effects account for any state-specific changes that happen over the years:

$$\Delta P_{c,t} = \alpha + \beta\, U_{c,t} + \gamma_t + \gamma_s + \epsilon_{c,t} \tag{3}$$

where γ_s = state dummies

The following model adds county-fixed effects to base model along with year-fixed effects. The state-fixed effects account for any state-specific changes that happen over the years, while the county-fixed effects are more granular, controlling for county-specific changes over time. This model is known as a two-way fixed effects model owing to the inclusion of fixed effects of the individual unit and time:

$$\Delta P_{c,t} = \alpha + \beta U_{c,t} + \gamma_t + \gamma_c + \epsilon_{c,t} \tag{4}$$

where γ_c = county dummies

2.3 Results

The numbers in the tables report the amounts by which changes in population are associated with one additional housing unit permitted to be built. So, the value 1.08 in column 4 of table 2 implies that between 2000 and 2021, with state and year fixed effects, an additional unit permitted is associated with a 1.08 increase in resident population. This estimate provides a more robust version of the availability metric introduced earlier. It can also be interpreted as an 100 unit increase in resident population being associated with approximately 93 more housing units permitted for construction.

Table 2 shows the changing association between population and units permitted across multiple subsamples. Columns (1), (2) and (3) pertains to the pre-pandemic periods, 2000-2005, 2006-09, and 2010-2019. Column (4) looks at all the years except the most recent year, while column (5) isolates the relationship for only the most recent year of observation (2022) to enable a comparison of other results to those in the post-pandemic market. In 2022, the value is negative implying that while population decreased, building permits issued increased at the rate of 100 residents to 185 housing units. The housing availability was at its lowest around the financial crisis when a 100 unit increase in population was associated with only 52 housing units permitted. This rate increased to approximately 79 units for every 100 residents after the crisis. Overall, between 2000-2021, the average building units permitted per 100-unit change in resident population is approximately 93 housing units.

Table 3 and Table 4 follow similar organizations. The units permitted are subdivided into units in single family, all multifamily buildings, and multifamily buildings with 2-4 units. It appears that while there's significant correlation between population change and units permitted in single family and 2-4-unit multifamily buildings, there's no significant association between population change and units permitted in all multifamily buildings.

Single family units permitted have varied significantly across the pre-pandemic periods. However, in 2022, housing availability in single family buildings was relatively low, with a 100 unit increase in resident population being associated with an increment of 47.6 single family units permitted for construction. Multifamily permits issued in 2-4-unit buildings, however, more than made up for the 2022 deficit in single family housing. For 2–4-unit multifamily buildings, the metric is negative 11.72, implying that each of those housing units permitted is associated with about a 12-unit decrease in resident population during 2022. Put differently, during 2022, a 100 unit decrease in resident population is associated with an 8.5 unit increase in unit permits in 2-4-unit multifamily buildings.

Table 4 shows the association between population change and total units permitted in various periods before the pandemic, and in 2022, grouped by locations that have above and below median population density. The availability of housing in counties below median density is slightly worse in 2022 than the entire pre-pandemic era. In 2022, a 100 unit increase in resident population is associated with an approximately 55 unit increase in housing units permitted in low density counties. For high density counties in 2022, the result is statistically insignificant. Historically, housing availability in high density counties has fared better than in low density counties (evidenced by a lower estimate across the 1st row in Table 4, relative to the 2nd row, up until column 4), however there's no conclusive evidence to say that the same still holds true in 2022. These results show that building is keeping up with population changes, even in higher density areas. Indeed, given this relationship in high-density areas, the results suggest that consumer demand—the choice to live in a high-density area—tends to outweigh supply factors and push prices up.

3 Denver Rezoning: Effects on Permits and Prices

The preceding sections of this paper provide evidence that, throughout the past few decades, new housing construction has kept up with population growth. The findings in the last section are also consistent with demand outweighing supply in a high-density location, such that housing price growth may respond mildly to increased home construction. To further investigate such a price response, this section of the paper studies a 2010 rezoning in Denver.

Denver adopted the new zoning code in 2010, replacing an older code, known as Former Chapter

59 (FC59) of the Denver Revised Municipal Code. The new code was adopted by the City and County of Denver on June 21, 2010 and became effective on June 25, 2010.[16] It involves 13 articles defining seven new neighborhood contexts—Suburban, Urban Edge, Urban, General Urban, Urban Center, Downtown, and Special—based on the unique characteristics of a neighborhood, such as existing building types, uses, and street patterns.[17] According to HUD, the code addresses affordability and sustainability by reducing minimum lot sizes, parking requirements for residential developments and increasing opportunities for developing diverse housing types in proximity to transit and employment centers.[18] Using data that spans up to 8 years after the adoption of the new code, this section studies the differential impact of the code change on permits issued and house price appreciation.

To begin, it is important to note some nuances in what has become standard terminology regarding zoning changes. The zoning literature commonly refers to "upzoning" or "downzoning" as a zoning change resulting in an increase or decrease in building, respectively. Zoning codes across US municipalities are very complicated, and code changes may have unintended or unpredictable consequences with respect to housing supply, so it is often difficult to identify such changes as a true net "upzone" or "downzone." For example, a zoning change may lead to an increase in single family units but a decrease in multifamily units. Judged by the number of permits, the change may appear to be an "upzoning," but from the perspective of the change in total units, it would be a "downzoning."

In the case of Denver's 2010 zoning code change, with the lack of a clear comparison between the older code and the introduction of the new neighborhood contexts, and given that some properties retained the older zoning, we do not wish to presume the change was an "upzone" or a "downzone."[19] We avoid this post-hoc application of terms and merely use the term "rezoning."

3.1 Data & Methodology

We use annual data from FHFA and colorado.gov for counties in Colorado (including Denver, which is a contiguous city and county) from 2000 to 2018 containing the following data series: annual

[16] Denver's zoning code change is summarized in the official Government website of Denver.

[17] Zone district definitions available here.

[18] As summarized in the U.S. Department of Housing and Urban Development's online newsletter published on July 2011.

[19] A discussion and further details on areas that did not implement the new code is available here.

home price change calculated from a home price index based in the year 2000, population, vacancy rate, and number of permits issued. We limit our analysis to the 48 Colorado counties for which there is data in every year in our selected period. From the above listed data series, we create one- and two-lag variants of the annual home price change and permits variables to control for any lagged effects.

We estimate several regression models to study the effects of Denver's 2010 rezoning. Analogous to the two-way fixed effects model used in the preceding section, we now use the following regression specifications to measure the effect on permits and prices, respectively.

Impact of Rezoning on Permits issued

$$U_{c,t} = \alpha + \beta_1 \, R_{c,t} + \gamma_c + \gamma_t + \Delta P_{c,t} + U_{c,t-1} + U_{c,t-2} + \epsilon_{c,t} \tag{5}$$

where

$U_{c,t}$ = Total units permitted in county c in year t

$R_{c,t}$ = Rezoning indicator assuming the value of 1 for Denver between 2010-2018, 0 otherwise

$U_{c,t-1}$ = one-period lag of $U_{c,t}$

$U_{c,t-2}$ = two-period lag of $U_{c,2}$

$\Delta P_{c,t}$ = annual population change in county c in year t

Impact of Rezoning on house price appreciation

$$\Delta HP_{c,t} = \alpha + \beta_1 \, R_{c,t} + \gamma_c + \gamma_t + \Gamma X_{c,t} + \Delta HP_{c,t-1} + \Delta HP_{c,t-2} + U_{c,t-1} + U_{c,t-2} + \epsilon_{c,t} \tag{6}$$

where

$\Delta HP_{c,t}$ = Annual change in home price between year t and year $t-1$ in county $c\,, \forall t = 2000$, 2011 $\ldots.$2018

$R_{c,t}$ = Rezoning indicator assuming the value of 1 for Denver between 2010-2018, 0 otherwise

$X_{c,t}$ = vector of contemporaneous controls including vacancy rates, annual population change, and permits issued.

$\Delta HP_{c,t-1}$ = one-period lag of $\Delta HP_{c,t}$

$\Delta HP_{c,t-1}$ = one-period lag of $\Delta HP_{c,t}$

In the following section where we discuss results, the county fixed effects control for characteristics that are specific to each county and remain constant over time (e.g., baseline housing demand, geographic features, long-standing policies). The rezone coefficient with inclusion of county fixed effects measures the impact of rezoning within Denver County, relative to its own baseline trends before rezoning, and not against other counties' levels directly. The addition of year fixed effects controls for statewide or macroeconomic factors that affect all counties in a given year (e.g., economic booms, recessions, interest rate changes). This ensures that the rezone coefficient reflects the effect of rezoning on Denver's house price appreciation, net of broader trends affecting all counties in Colorado.

The primary coefficients of interest from the preceding regression specifications are β_1 and β_2, the coefficients for permits issued and annual change in home price, respectively, for the rezoning treatment across counties and years. The two-way fixed effects model controls for variation across counties and years, as well as for factors changing across counties and years that may be affecting our outcome variables. Consequently, a positive β_1 identifies an increase in permits because of rezoning, while a negative coefficient identifies a reduction in permits. Similarly, a positive β_2 identifies an increase in average annual house price appreciation because of rezoning, while a negative coefficient identifies a reduction in average house price appreciation.

3.2 Results

Table 5 shows that the Denver rezoning is associated with a statistically significant increase of 1,427.46 new housing units permitted. For context, the average number of permits issued in Denver from 2010-2018 is approximately 6163.22 with the rezoning in effect during those years. Hence, controlling for lags of permits and population change, without the zoning change, the average new permits issued would have been approximately 4735, which is 1428 less than the realized value of 6163 permits. In terms of percentages, rezoning is found to be associated with about 30 percent more permits issued relative to what would have been the case in the absence of rezoning.

Table 6 shows the effect of rezoning on the annual change in home prices. It is important to note that a negative coefficient implies a reduction in the home price growth, and not a decrease in prices themselves. The first column of results includes controls like concurrent annual population change, vacancy rates, and lagged house price appreciation, but does not include controls for permits (contemporaneous or lagged). These results correspond to the effect of the presence of rezoning on house price appreciation, without accounting for change in permits. The second column adds contemporaneous permits, while the 3rd and 4th column include the addition of permits lagged by a year and permits lagged by 2 years, respectively. These results correspond to the impact of rezoning, controlling for the rise in permits issued (with the lagged permits possibly accounting for occupancy, following issuance of new permits). The 5th column provides results including all the preceding control factors. Of the contemporaneous control variables, population changes and vacancy rates are statistically significant determinants of changes in house price appreciation. Meanwhile, increases in population are associated with increased house price appreciation, and increases in vacancy rates are associated with reductions in house price appreciation.

Most importantly, the rezone coefficient is statistically significant at the 5 percent level without inclusion of any permits at all, and with the inclusion of lagged permits. To put the results from this table into context, before the zoning change in 2010, the average annual house price appreciation between 2000 and 2009 was about 4.53%, with a standard deviation of about 3.34%. After 2010 and the zoning change, Denver's average annual house price appreciation increased to 6.602 percent from 2010 to 2018, with a standard deviation of about 4.64%. Over the whole period under consideration, house price appreciation is quite volatile in Denver, with a standard deviation of about 5.5%. It is also important to note that Denver's house price index (as calculated by FHFA) based in 2000, shows that prices have been on an upward trend in a majority of the years, with large magnitudes of increases following 2012 (Refer to Table A2 in the Appendix). We wish to emphasize that with our outcome of interest being house price appreciation, we are not discussing the effect of rezoning on prices themselves, but rather on the rate of growth of prices.

With the rezone coefficients from all the columns being negative, the results help in estimating how much more (than 6.602 percent) the average annual house price appreciation would have been without the zoning change, based on county and yearly trends, and controlling for population change and vacancy rates. Column 1 suggests that the presence of rezoning is associated with a 1.102 percent reduction in average annual house price appreciation, without controlling for permits. In other words, without accounting for changes in permits, rezoning appears to have reduced Denver's house price appreciation from potentially 7.7 percent to about 6.6 percent. Column 3 shows that, when controlling for permits issued in the prior year, the average house price appreciation would have been 8.55 percent in the absence of rezoning. In this case, the zoning change reduces house price appreciation to 6.6 percent. This result does not change substantially when accounting for lagged changes in permits from 2 years prior (column 4), instead of one year. The addition of contemporaneous permits (as shown in columns 2 and 5) renders the rezoning treatment insignificant, possibly suggesting that the time lag between permit issuance and occupancy plays a pivotal role in the impact of rezoning on house price appreciation.

Comparing columns 2 and 5 to columns 1, 3 and 4, it appears that controlling for permits and their lags diminishes the apparent impact of rezoning, suggesting that the effect of rezoning might overlap significantly with the dynamics of permitting or that the residual effect of rezoning alone is small or difficult to detect with the current specification. Comparing column 1 to columns 3 and 4, it appears that the lower absolute magnitude of the coefficient in column 1 as compared to that of column 3 implies that rezoning has a more negative effect on house price appreciation when lagged permits are included. In column 1, the exclusion of permits likely biases the rezone coefficient because some of the effects of permit-induced increased supply following rezoning are conflated with some direct effect of rezoning itself.

In columns 3 and 4, the model isolates this direct effect of rezoning on house price appreciation in column 1 by controlling for its effects mediated through permits or increased housing supply. This adjustment allows the rezone coefficient to more accurately capture non-supply-related effects of rezoning, which are found to be more strongly negative. Hence, the regression results interestingly show that not only is there a net effect of rezoning itself on house price appreciation beyond its response through increased permits, but also that the difference in magnitudes imply that the effect of rezoning alone (possibly arising from some contemporaneous demand-based forces) is higher than what is achieved through greater supply of housing.

There are two key takeaways to note from the preceding results. First, although rezoning substantially increased the number of permits issued and helped reduce house price appreciation, it did not reverse house price appreciation. Based on average house price appreciation rates approximately 10 years before and after the zoning change, the reduction in house price appreciation did not reduce price levels. More importantly, holding every other factor constant, variation in coefficient size and significance originating solely from the inclusion or exclusion of contemporaneous and/or lagged permits implies uncertainty in the role that increased supply played in the reduction of house price appreciation.

So, while rezoning did seem to slow the growth in home prices, it is not clear how much of that reduction stemmed from higher construction, raising questions about the general idea of more construction reversing house price appreciation. While the models presented above attempt to control for as many of the demand factors as can be captured through fixed effects, we speculate that demand-based outcomes that change across time and space simultaneously that are difficult to (and hence we cannot always) account for, might be important and often overlooked driving factors in the pricing story.

4 Conclusion

This paper addresses some questions related to housing availability and affordability that we believe can lead to better policy outcomes. It contributes to discussions regarding housing shortages, and it provides a robust statistical analysis of zoning changes in Denver in 2010. In terms of prices, while there's some evidence here supporting a positive effect of rezoning, the findings suggest exercising caution when interpreting the results from changes in regulations and consequently in policy prescriptions that follow. These results do not suggest, in any way, that local governments should refrain from the types of regulatory reforms that lead to increased construction. But they do suggest that expectations for how much added construction will slow the growth in home prices should be placed carefully in the context of the multitude of forces driving the housing market.

More broadly, this research demonstrates the critical need for robust analysis of housing markets in a rigorous demand-supply framework that can account for multiple simultaneous factors. Housing markets are generally supply-constrained, and demand-side factors can outweigh supply innovations, leaving prices to rise even in the face of added construction. Few of the analyses of housing shortages examine these kinds of factors, so the paper argues for a better understanding of housing availability and the drivers of house price appreciation. At the very least, our findings underscore the need for more refined research on housing market dynamics to precede policy prescriptions aimed at solving housing-related issues.

5 Tables and Figures

5.1 Tables

Table 1: Summary Statistics of Housing Availability

Year	Average Total Units Permitted	Average Population Change	Median Population Change	Median Total Units	Average Pop-Change/ Average Units Permitted	**Median Pop-change/ Median Units Permitted**
2000	2157	1195	432	878	0.55	0.49
2001	2209	4906	1577	951	2.22	1.66
2002	2312	4131	1403	968	1.79	1.45
2003	2512	3698	1314	1077	1.47	1.22
2004	2612	3840	1272	1066	1.47	1.19
2005	2337	3372	921	718	1.44	1.28
2006	2011	3123	1116	606	1.55	1.84
2007	1511	3733	962	490	2.47	1.96
2008	978	3656	903	270	3.74	3.34
2009	567	3302	681	224	5.82	3.04
2010	602	3162	690	191	5.25	3.61
2011	653	3127	497	179	4.79	2.78
2012	950	3335	413	217	3.51	1.90
2013	1165	3181	596	271	2.73	2.20
2014	1254	3301	594	285	2.63	2.08
2015	1450	3366	591	283	2.32	1.83
2016	1413	3136	581	364	2.22	1.60
2017	1499	2622	625	368	1.75	1.70
2018	1582	2191	545	406	1.39	1.34
2019	1644	1949	474	431	1.19	1.10
2020	1696	1501	380	460	0.89	0.83
2021	2005	-96	447	574	-0.05	0.78
2022	1920	1284	432	490	0.67	0.88

Source: US Census Bureau and Building Permits Survey

Table 2: Panel Regression Results for year-based sub-samples

Population Change	**2000-2005**	**2006-2009**	**2010-2019**	**2000-2021**	**Only 2022**
Units Permitted	1.50***	1.94***	1.26***	1.08***	-0.54***
	(0.04)	(0.08)	(0.05)	(0.04)	(0.20)
Year FE	Yes	Yes	Yes	Yes	-
State FE	Yes	Yes	Yes	Yes	Yes
R-squared (Adj. where applicable)	0.53	0.43	0.60	0.45	0.24

Notes: Standard errors are robust to heteroscedasticity. Asterisks indicate statistical significance at the following levels: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

Table 3: Panel Regression Results for year-based and building-based subsamples

Population Change	**2000-2005**	**2006-2009**	**2010-2019**	**2000-2021**	**Only 2022**
Single family units permitted	1.93***	1.69***	0.92	1.13***	2.10***
	(0.43)	(0.51)	(0.73)	(0.16)	(0.25)
Multifamily units permitted in 2-4-unit buildings	-1.81	0.13	-32.37**	-1.28	-11.72***
	(4.34)	(6.36)	(15.36)	(4.34)	(3.42)
All multifamily units permitted	-0.75	-0.82	-0.78	-0.54	0.00
	(0.85)	(2.02)	(0.49)	(0.58)	(0.21)
Year FE	Yes	Yes	Yes	Yes	-
State FE	-	-	-	-	Yes
County FE	Yes	Yes	Yes	Yes	No

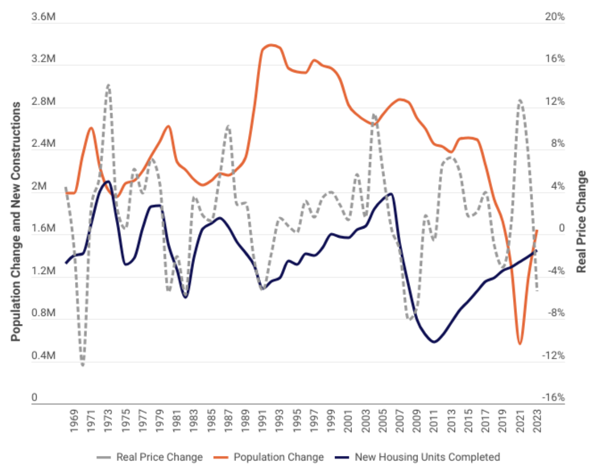
Notes: Standard errors are robust to heteroscedasticity. Asterisks indicate statistical significance at the following levels: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

Table 4: Panel Regression Results for year-based and population-density based sub-samples

Population Change	**2000-2005**	**2006-2009**	**2010-2019**	**2000-2021**	**Only 2022**
Total units among high pop. density locations	1.22***	1.54***	0.99***	0.82***	-0.11
	(0.08)	(0.14)	(0.07)	(0.06)	(0.23)
Total units among low pop. density locations	1.83***	2.01***	2.66***	1.76***	1.82***
	(0.04)	(0.05)	(0.05)	(0.02)	(0.11)
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are robust to heteroscedasticity. Asterisks indicate statistical significance at the following levels: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

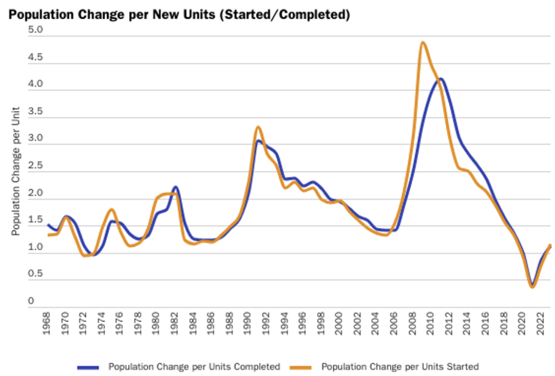
Figure 1: Population Change, New Constructions and Price Change



U.S. Census Bureau and U.S. Department of Housing and Urban Development, Median Sales Price of Houses Sold for the United States [MSPUS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/MSPUS, October 28, 2024, and U.S. Bureau of Economic Analysis, Personal Consumption Expenditures Excluding Food and Energy (Chain-Type Price Index) [PCEPILFE], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/PCEPILFE, October 28, 2024, U.S. Census Bureau and U.S. Department of Housing and Urban Development, New Privately-Owned Housing Units Completed: Total Units [COMPUTNSA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/COMPUTNSA, October 28, 2024, U.S. Bureau of Economic Analysis, Population [POPTHM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/POPTHM, October 28, 2024.

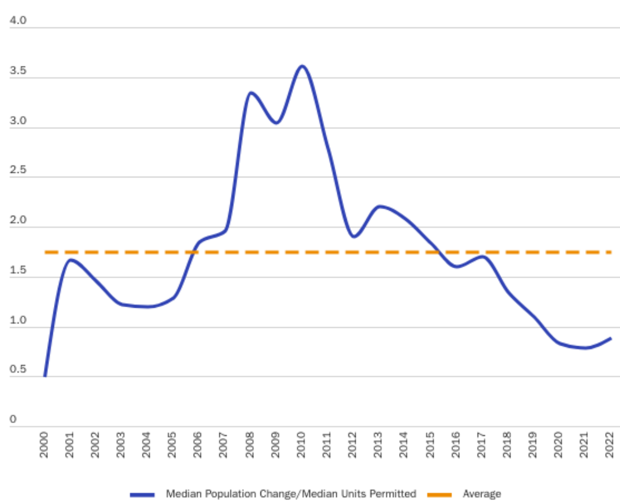
5.2 Figures

Figure 2: Population change relative to units started and completed



Source: U.S. Census Bureau and U.S. Department of Housing and Urban Development, New Privately-Owned Housing Units Completed: Total Units [COMPUTSA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/COMPUTSA, October 31, 2024, U.S. Census Bureau and U.S. Department of Housing and Urban Development, New Privately-Owned Housing Units Started: Total Units [HOUST], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/HOUST, October 31, 2024, https://fred.stlouisfed.org/series/COMPU1USA, October 31, 2024, U.S. Bureau of Economic Analysis, Population [POPTHM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/POPTHM, October 31, 2024.

Figure 3: Median Population Change/Median Units Permitted



Note: 2001, 2007-2009 and 2020 are recession years according to NBER.

Source: U.S. Census Bureau Population Division and Building Permits Survey.

Table 5: Rezone Effect on Permits

Variable	**Coefficient**
Rezone	1,427.464***
	(216.985)
Lagged Permits	0.480***
	(0.064)
Two-Lag Permits	0.092***
	(0.017)
Population Change	0.027
	(0.024)
County Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	912
$\mathbf{R}^2$	0.371
Adjusted $\mathbf{R}^2$	0.334

Notes: Standard errors are robust to heteroscedasticity. Asterisks indicate statistical significance at the following levels: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

Table 6: Rezone Effect on Home Prices

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Rezone	-1.102**	-0.969	-1.945**	-1.928**	-1.512
	(0.507)	(0.881)	(0.765)	(0.767)	(0.938)
Lagged Annual Change	0.511***	0.512***	0.510***	0.511***	0.516***
	(0.081)	(0.082)	(0.081)	(0.082)	(0.083)
Two-Lag Annual Change	0.070	0.071	0.061	0.060	0.062
	(0.070)	(0.070)	(0.072)	(0.072)	(0.072)
Permits		-0.00005			-0.0003
		(0.0002)			(0.0002)
Lagged Permits			0.0003*	0.0004**	0.0005***
			(0.0002)	(0.0002)	(0.0001)
Two-Lag Permits				-0.0001	-0.0001
				(0.0002)	(0.0002)
Population Change	0.0002**	0.0002**	0.0002**	0.0002**	0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Vacancy Rate	-0.512***	-0.511***	-0.531***	-0.525***	-0.527***
	(0.081)	(0.080)	(0.084)	(0.085)	(0.085)
County Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	912	912	912	912	912
$\mathbf{R}^2$	0.349	0.349	0.350	0.351	0.351
Adjusted $\mathbf{R}^2$	0.310	0.309	0.310	0.310	0.310

Notes: Standard errors are robust to heteroskedasticity. Asterisks indicate statistical significance at the following levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

References

Albouy, D., Gabriel, E., and Liu, Y. 2016. Housing Demand, Cost-of-Living Inequality, and the Affordability Crisis NBER Working Paper No. w22816, November 2016. https://ssrn.com/abstract=2868914.

Anagol, S., Ferreira, F. V., and Rexer, J. M. 2021. Estimating the economic value of zoning reform. Working Paper 29440. National Bureau of Economic Research, October 2021, Revised March 2023.

Anenberg, E., and Ringo, D. 2022. Volatility in home sales and prices: Supply or demand? Finance and Economics Discussion Series 2022-041. Washington: Board of Governors of the Federal Reserve System, 2022. https://doi.org/10.17016/FEDS.2022.041.

Angotti, T. and Morse, S. 2016. *Zoned Out! Race, Displacement, and City Planning in New York City.* New York University Press. https://nyupress.org/9781613322086/zoned-out/.

The Brookings Institution. 2002. The link between growth management and housing affordability. February 2002. Available here.

Buechler, S., and Lutz, E. 2021. The local effects of relaxing land use regulation on housing supply and rents. MIT Center for Real Estate Research Paper No. 21/18, November 2021.

City of Denver. 2024. Denver Zoning Code. Community Planning and Development. Accessed December 3, 2024. https://www.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Community-Planning-and-Development/Denver-Zoning-Code.

City and County of Denver. 2024. Zone district descriptions and definitions. https://www.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Community-Planning-and-Development/Denver-Zoning-Code/Zone-Descriptions.

Corinth, K., and Dante, H. 2022. The understated 'housing shortage'in the United States. IZA Discussion Paper No. 15447, Institute of Labor Economics, July 2022.

Divounguy, O. 2024. Affordability crisis: Housing shortage worsened despite pandemic construction boom. Zillow, June 18, 2024. https://www.zillow.com/research/affordability-housing-shortage-34153/.

Dong, H. & Hansz, J. A. 2019. Zoning, density, and rising housing prices: A case study in Portland, Oregon. *Urban Studies*, **56**(16), 3486–3503. https://www.jstor.org/stable/26958653.

Edelberg, W. 2024. What can the next administration do about the US housing shortage? Brookings, October 24, 2024. https://www.brookings.edu/articles/what-can-the-next-administration-do-about-the-us-housing-shortage/.

Environmental Systems Research Institute (Esri). The importance of wetlands. ArcGIS StoryMaps. https://storymaps.arcgis.com/stories/2f00e0f23e8d481d832790ea8eba3a26.

Fisher, J. D. M., and Gervais, M. 2011. Why has home ownership fallen among the young? *International Economic Review* 52(3): 883-912.

Freddie Mac. 2021. Housing supply: A growing deficit. Research Note, May 7, 2021. https://www.freddiemac.com/research/insight/20210507-housing-supply.

Freddie Mac. 2020. "The Housing Supply Shortage: State of the States." *Insights*, February 27. Available at: https://www.freddiemac.com/research/insight/20200227-the-housing-supply-shortage.

Freemark, Yonah. 2019. "Upzoning Chicago: Impacts of a Zoning Reform on Property Values and Housing Construction." *Urban Affairs Review*. Available at: https://yonahfreemark.com/wp-content/uploads/2019/01/Freemark-Upzoning-Chicago.pdf.

Freemark, Yonah. 2023. "Zoning Change: Upzonings, Downzonings, and Their Impacts on Residential Construction, Housing Costs, and Neighborhood Demographics." *Journal of Planning Literature*, 38(3), 297–315.

Glaeser, Edward L., and Bryce A. Ward. 2009. "The Causes and Consequences of Land Use Regulation: Evidence from Greater Boston." *Journal of Urban Economics*, 65(3), 265–278.

Glaeser, Edward, and Joseph Gyourko. 2017. "The Economic Implications of Housing Supply." *National Bureau of Economic Research Working Paper Series*, No. 23833.

Green, Richard K., Malpezzi, Stephen and Mayo, Stephen K. 2005. "Metropolitan-Specific Estimates of the Price Elasticity of Supply of Housing, and Their Sources." *American Economic Review*, 95 (2): 334–339.DOI: 10.1257/000282805774670077

Greenaway-McGrevy, Ryan, and Peter C. B. Phillips. 2022. "The Impact of Upzoning on Housing Construction in Auckland." *Cowles Foundation Discussion Papers*, No. 2689. Available at: https://elischolar.library.yale.edu/cowles-discussion-paper-series/2689.

Jackson, Kristoff. 2016. "Do land use regulations stifle residential development? Evidence from California cities." *Journal of Urban Economics*, Volume 91, Pages 45-56, ISSN 0094-1190. Available at: https://www.sciencedirect.com/science/article/pii/S0094119015000789.

Liao, Hsi-Ling. 2023. "The Effect of Upzoning on Housing Supply and Residential Mobility: Evidence from New York City." *Working Paper*, July 14. Available at: https://papers.hsilingliao.com/Upzoning_Liao_JMP.pdf.

Maye, Adewale, and Kyle Moore. 2022. "The Growing Housing Supply Shortage Has Created a Housing Affordability Crisis." *Economic Policy Institute*, July 14. Available at: https://www.epi.org/blog/the-growing-housing-supply-shortage-has-created-a-housing-affordability-crisis/.

McCue, Daniel, and Huang, Sophie 2024. "Estimating the National Housing Shortfall." *Joint Center for Housing Studies of Harvard University*, January 29. Available at: https://www.jchs.harvard.edu/blog/estimating-national-housing-shortfall.

McFarland, M. Carter. 1963. "FHA Experience with Mortgage Foreclosures and Property Acquisitions." *Federal Housing Administration*, January. Available at: http://babel.hathitrust.org/cgi/pt?id=mdp.39015008723499.

Murray, Cameron, and Megan Limb. 2023. "We Zoned for Density and Got Higher House Prices: Supply and Price Effects of Upzoning over 20 Years." *Urban Policy and Research*, 41(2), 129–147. Available at: https://doi.org/10.1080/08111146.2022.2124966.

National Association of Home Builders. 2022. "The Size of the Housing Shortage: 2021 Data." *Eye on Housing*, December 16.

National Association of Realtors. 2022. "Biden Administration Takes Aim at America's Housing Shortage." *Realtors Magazine*, May 16. Available at: https://www.nar.realtor/magazine/real-estate-news/biden-administration-takes-aim-at-america-s-housing-shortage.

National Association of Realtors. 2024. "Housing Shortage Tracker." Available at: https://www.nar.realtor/research-and-statistics/housing-statistics/housing-shortage-tracker.

Poverty & Race Research Action Council. 2017. "Poverty & Race." January-March. Available at: https://www.prrac.org/newsletters/janfebmar2017.pdf.

Rosen, Kenneth T., David Bank, Max Hall, Scott Reed, and Carson Goldman. 2021. "Housing is Critical Infrastructure: Social and Economic Benefits of Building More Housing." *Rosen Consulting Group*, June. Available here

Schill, Michael H. 2005. "Regulations and Housing Development: What We Know." *Cityscape*, 8(1), 5–19. Available at: https://www.huduser.gov/periodicals/cityscpe/vol8num1/ch1.pdf.

U.S. Census Bureau. 2023. "Income in the United States: 2023." Available at: https://www.census.gov/library/publications/2024/demo/p60-282.html.

U.S. Department of Housing and Urban Development. 2002. "Durability by Design: A Guide for Residential Builders and Designers." *PATH (Partnership for Advancing Technology in Housing)*, May. Available at: https://archives.huduser.gov/rbc/archives/newsletter/vol10iss4_2.html.

U.S. Department of Housing and Urban Development. 2001. "HUD's Affordable Lending Goals for Fannie Mae and Freddie Mac." *Issue Brief No. v*, January.

U.S. Department of Housing and Urban Development. 2011. "The Evolution of HUD's Public-Private Partnerships." *Regulatory Barriers Clearinghouse*, Vol. 10, Issue 4, July.

Appendix

Table A1: Full Panel Regression Results

Population Change	(1)	(2)	(3)	(4)
Units Permitted	0.99***	1.10***	0.98***	0.39
	(0.04)	(0.04)	(0.04)	(0.30)
Year FE	No	Yes	Yes	Yes
State FE	No	No	Yes	-
County FE	No	No	No	Yes
Adjusted R^2	0.37	0.35	0.37	0.12

Table A2: Summary Statisticss for Denver

Year	HPI (base 2000)	Year-over-Year Increase in HPI	House Price Appreciation
2000	100.00	-	18.67
2001	109.88	9.88	9.88
2002	115.09	5.21	4.74
2003	116.43	1.34	1.16
2004	120.07	3.64	3.13
2005	126.25	6.18	5.15
2006	129.89	3.64	2.88
2007	130.28	0.39	0.30
2008	129.69	-0.59	-0.45
2009	130.32	0.63	0.49
2010	128.60	-1.72	-1.32
2011	126.80	-1.80	-1.40
2012	129.69	2.89	2.27
2013	141.24	11.55	8.91
2014	157.27	16.03	11.35
2015	172.79	15.52	9.87
2016	192.52	19.73	11.42
2017	211.46	18.94	9.84
2018	229.39	17.93	8.48