County Property Tax Capitalization in U.S. Cities

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Abstract

The extent to which changes in local property taxes are capitalized into housing prices is an ongoing empirical debate. Estimates of the capitalization rate for property taxes vary in magnitude and typically depend heavily on the setting, if capitalization is found to occur at all. This paper contributes to the empirical literature on property tax capitalization by demonstrating varying responses to statutory property tax rate increases and decreases along the distribution of house prices in counties containing large U.S. cities. The empirical setting uses novel data on county-level statutory property tax rates for around one hundred and fifteen counties. Within-county standardized decreases are more influential than increases by about 1.5 times. Decreases in the statutory property tax rate tend to increase house prices around 1.3%, and increases tend to decrease house prices around 0.9%. Using recentered-influence functions (RIFs) that analyze unconditional quantile regressions, the responsiveness of households is shown to vary across the distribution of house prices. Specifically, house prices respond to increases in property tax rates by larger percentages on the lower end of the house price distribution, and house prices are unaffected by rate hikes on the high end of the distribution. House prices also respond to decreases in property tax rates, and house prices respond by larger percentages on the lower end of the distribution. The impacts of statutory property tax rate changes are economically significant in either direction, though only increases are statistically different along the distribution.

Keywords: Property Tax Capitalization, Difference-in-Differences, Quantile Regressions

JEL Codes: C22, D15, H72, R31

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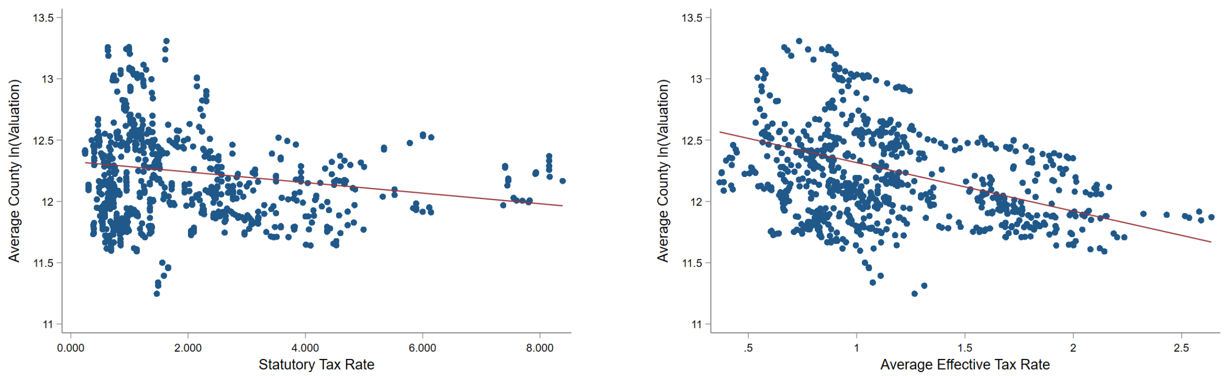
1 Introduction

As of January 2024, the Bureau of Labor Statistics (2024) (BLS) reports that homeowners' equivalent of rental expenditures for primary residences is the largest single expenditure category at 25.44% of the entire representative consumption basket used to construct the BLS Consumer Price Index for urban residents (CPI-U). Property taxes represent a non-negligible annual user cost of homeownership that vary widely across time and location. At the same time, local governments often rely more heavily on taxes levied against real property than other tax revenue classes. The relationship between house prices and local public finance is a crucial component to fully understanding housing markets and house price determination, and there is a long empirical debate on the magnitude of this relationship. Further, responses across the distribution of house prices may indicate differential impacts for certain households.

The main question in the property tax capitalization literature is, given two similar houses in otherwise comparable locations in terms of market forces and public amenities, whether differences in property taxes affect the price of a house. Property tax rates, in turn, affect the amount of property taxes paid by households. For households with lower income, changes in property taxes represent larger fractions of household income so they may be more affected by changes in the property tax burden. Figure 1 shows the natural log of county average house prices in counties that contain large cities from 2012 to 2018 against statutory property tax rates and county average effective property tax rates that descriptively demonstrates the inverse relationship between house prices and property tax rates. County governments provide public amenities focused on education, social services, public safety, and road maintenance and rely mainly on property tax revenue to do so. In this paper, variation in novel county-level statutory property tax rate data are used in several difference-in-differences designs to estimate the extent to which changes in statutory property tax rates are capitalized into house prices and how responses vary along the distribution of house prices.

Estimation models that include hedonic components are common when studying house price determination going back to Oates (1969), Alonso (1964), and Muth (1969) while Wales and Wiens (1974) point out that failing to account for changes in public goods can bias the estimates of the property tax capitalization rate. However, differences in house prices may not be entirely driven

Figure 1: Average Valuations by County



(a) (b)

Note: County average natural log house prices against statutory property tax rates in Panel (a) and against county average effective property tax rates in Panel (b) pooled from 2012 to 2018. Source: American Community Survey and the Lincoln Institute of Land Policy Significant Features of the Property Tax: Property Tax Rates.

by observable[1] characteristics of houses or public amenities in the hedonic models, and there is no theory-driven measure of these amenities.[2] Gibbons and Machin (2008) and Sirmans et al. (2008) survey the empirical literature to show that, while spending on schools is most common[3], almost every study varies on which public amenities to include in estimation and how to measure their chosen proxies.[4]

More recent empirical studies have used boundary discontinuity designs between adjacent fiscal districts to identify causal variation in property tax rates and local amenities including Cushing (1984), Black (1999), Davidoff and Leigh (2008), Dhar and Ross (2012), Livy (2018), and Giertz et al. (2021). Natural experimental approaches to estimate property tax capitalization rates start with Rosen (1982) and California's Proposition 13[5] that exploit variation from specific tax change

[1]Including fixed effects can reduce bias introduced by unobservables or characteristics left out of hedonic regressions, but there is little consensus as to whether observable characteristics bias hedonic regressions in the capitalization context.

[2]House prices may also be impacted by supply inelasticities of land as in Saiz (2010) that can be, at least partially, mitigated using geography-specific fixed effects.

[3]In the context of education spending, Davidoff and Leigh (2008) review and demonstrate how dramatically spending proxies can vary in a capitalization framework.

[4]In an unreported ancillary exercise, test scores in math and reading are used as controls. Importantly, these findings suggest that focusing on outcomes from school spending may under-estimate property tax capitalization estimates. Further, the findings suggest that math scores are capitalized more than reading scores.

[5]Many other papers also study this tax change as well as other event-study designs surrounding specific tax change events that are location-specific.

policies. Boundary discontinuity designs often rely on a control group that is not impacted by fiscal spillovers from the treated district, but inter-regional tax spillovers in property taxes have been shown to be present between neighboring fiscal districts in Germany in Merlo et al. (2023). Haughwout (1997), Elinder and Persson (2017), and Koster and Pinchbeck (2022) are among the few studies that focus on large geographic areas for estimating property tax capitalization in the United States, Sweden, and England respectively.

This paper complements the existing empirical literature on property tax capitalization in two ways. First, generalizing the setting to households in counties containing large U.S. cities using novel data on statutory county-level property tax rates circumvents concerns about external validity. Second, the paper demonstrates that property tax capitalization vary across the distribution of house prices using recentered-influence functions (RIFs) in quantile analysis. Increases and decreases are comparable effect magnitudes in either direction. Consistent with theory, tax rate increases cause house prices to fall, and tax rate decreases cause house prices to rise. Along the distribution, the highest quantiles of house prices are unaffected by increases in property tax rates, and there is little statistical difference along the distribution for rate decreases.

The rest of the paper is organized as follows: Section 2 discusses the main points of the conceptual model, Section 3 explains the data sources used for estimation, Section 4 explains the main empirical design, Section 5 analyzes the results along the distribution of house prices, and Section 6 briefly concludes the paper.

2 Conceptual Framework

Canonical bidding models to determine house prices with property tax capitalization go back to Brueckner (1979) and are given full theoretical treatment in Yinger (1982) and Yinger et al. (1988). The bidding framework for house prices relies on several assumptions. First, household utility depends on housing services/characteristics, public good provision and quality, and a composite consumption good. Second, households differ in their demographic characteristics but have well-defined preferences based on their income. Third, households do not face moving costs. Fourth, all households receive the same level of public goods as any other household in their fiscal district. Lastly, cities have many local fiscal districts with well-defined boundaries that finance different levels/qualities of public goods with different effective property tax rates. Households are not concerned with how the effective property tax rate or levels/qualities of public goods are determined by the fiscal district. Rather, households only care about the resulting parameters that are determined by the fiscal district so the fiscal authority's constrained problem does not factor into household utility.

Housing consumption is a vector of physical characteristics, H, that each have a specific price, P. Households discount the future at the real discount rate, r and face property tax rates, τ, set by the local fiscal district. Changes in property taxes may not offset dollar-for-dollar, and δ represents the fraction of each dollar of tax changes are reflected in house prices. Under perfect capitalization, $\delta = 1$ and existing homeowners bear all the burden of changes in property taxes because potential buyers are adjusting their offer prices. Treating property taxes as an annuity, offer prices change by the present discounted stream of future tax payments. When there is no capitalization, $\delta = 0$ and home buyers bear all the burden of the change in taxes since offer prices do not reflect any changes in present or future property tax obligations. Solving the household's problem leads to the well-known capitalization formula:

$$V = \frac{\hat{P}H}{r} - \delta\frac{\tau V}{r} \Rightarrow V = \frac{\hat{P}H}{r + \delta\tau} \tag{1}$$

From here, estimation equations can be derived using natural log transformations among others, but difficulties arise appropriately identifying variation to circumvent the entanglement of several parameters in the regression coefficients when trying to estimate δ. Section A enumerates some of these estimation difficulties, but these are not the focus of this paper. This paper measures how magnitudinal changes in the tax rate induce changes in house prices. Any increase in property tax rates should reduce house prices, and decreases should increase house prices based on Equation (1).

3 Data

The ideal data set to study property tax capitalization into house prices in the bidding theoretical framework is household-level panel data that includes house prices for housing units with repeated sales, housing unit characteristics, local amenity characteristics, property tax rates (both effective and statutory) at each fiscal district level, and local government tax-assessed valuations. Several sources are merged at the county×year level to gather the necessary components to estimate the empirical models from 2012 to 2018. This period mitigates some concerns of house price volatility from macro-level factors immediately following the Great Recession as house prices recovered and before the Covid-19 pandemic. Average national house prices are lowest in 2012 and monotonically increasing through 2018.[6] Mortgage rates for single-family homes measured by FreddieMac[7] also dropped dramatically after 2011, on average. This paper focuses almost exclusively on statutory property taxes so the estimation, results, and discussion are all about statutory rates unless otherwise specified as the effective rate.

3.1 Sources

The American Community Survey (ACS) accessed through IPUMS Ruggles et al. (2021) includes household-level repeated cross-sectional data on self-assessed house prices, demographic characteristics, and housing unit characteristics.[8] The benefits to using the ACS are the sample sizes and coverages that allow for the generalization of property tax capitalization to many cities. Summary statistics for housing characteristics are in Table 1.

The Lincoln Institute of Land Policy provides data sources on property tax rates and local government expenditure and revenue. The Significant Features of the Property Tax: Property Tax Rates[9] repository contains nearly all county property taxation reports sent to their respective state governments to be archived dating back to 1980, and statutory rates are collected from these annual records. Until now, no unified data set has been created from these annual reports so the variation provided by the statutory rates is novel. Since not every state has records for every year, the sample is limited to county×year observations for which statutory property tax rate data can be collected in at least two consecutive periods. The number of tax changes, tax increases,

[6] House price indices like the Case-Shiller Home Price Index (CSUSHPINSA) at the national level, the All-Transactions House Price Index (USSTHPI) at the national level, and the Federal Housing Finance Agency Housing Price Index (FHFA HPI) at the county level all indicate that house prices were lowest in 2012 in the post-Great Recession era.

[7] Access the Single-Family Loan-Level Dataset at https://www.freddiemac.com/research/datasets .

[8] The overall effective tax rate is also imputable using the midpoint of the property tax payment bins supplied by the ACS divided by the self-reported valuation of the house prices, but the effective rate isn't used for any substantive purpose in this paper since the variation is in the county-level statutory property tax rate. Given the magnitudes of the county statutory property tax rates and the fact that the overall effective tax rate is the sum of all statutory property tax rates, using the midpoint to impute effective tax rates from the ACS may provide underestimates. Moreover, after 2000, respondents were no longer explicitly instructed to report the full tax payment whether it was included in the mortgage payment, delinquent, or paid by another household member. It is possible that there is under-reporting due to the change in questionnaire verbiage.

[9] Access at https://www.lincolninst.edu/research-data/data-toolkits/significant-features-property-tax/ .

Table 1: Summary Statistics: Housing Characteristics

	Mean	SD	Min	Max	N
Valuation	251,844.59	161,968.81	21,635.52	2,967,157.25	667,987
ln(Valuation)	12.25	0.62	9.98	14.90	667,987
Number of Rooms	6.78	1.80	2.00	10.00	667,987
Number of Bedrooms	4.24	0.83	2.00	6.00	667,987
Built Before 1950	0.11	0.31	0.00	1.00	667,987
Built 1950-1959	0.10	0.30	0.00	1.00	667,987
Built 1960-1969	0.10	0.30	0.00	1.00	667,987
Built 1970-1979	0.15	0.36	0.00	1.00	667,987
Built 1980-1989	0.15	0.36	0.00	1.00	667,987
Built 1990-1999	0.17	0.38	0.00	1.00	667,987
Built 2000-2009	0.18	0.39	0.00	1.00	667,987
Built 2010 or After	0.04	0.19	0.00	1.00	667,987
ln(Density)	7.60	0.94	4.72	9.64	667,987
Unemployment Rate	5.42	1.69	2.00	11.90	667,987

Source: American Community Survey. Summary statistics are pooled from 2012 to 2018. Outliers below the 1st percentile and above the 99th percentile of house prices within county×years are removed as well as logical skips.

tax decreases, and the magnitudes of the tax changes are summarized in Table 2. The average county alters statutory property tax rates in more than half of the years during the sample period, increasing and decreasing twice each, and decreases in tax rates occur slightly more frequently than increases. The average yearly percentage change in the statutory rates across all counties and all tax changes is about -0.08% but can vary substantially. This table also lists within-county standardized scores of the level tax changes. The z-scores have a mean of 0 and standard deviation of 1. The t-scores have a mean of 0 with larger standard deviations, unsurprisingly.

While the data listed allow for estimation of property tax capitalization, there are drawbacks to relying only on the ACS in this context. First, the implied effective property tax rate in the ACS cannot be used to isolate the effective property tax rates from overlapping fiscal districts. As a result, only the overall level of capitalization can be measured as opposed to the capitalization rate specific to changes in county-level property taxes or other fiscal districts. Second, each yearly wave of the ACS surveys different samples of households to create repeated cross-sectional data. While natural log transformations can provide exact theoretically-derived estimation equations,

Table 2: Summary Statistics: Tax Changes

	Mean	SD	Min	Max	N
Statutory Tax Rate	2.11	1.73	0.30	8.39	667,987
Effective Tax Rate	1.22	0.70	0.16	4.05	667,987
Change in Statutory Tax Rate	-0.01	0.13	-2.64	0.49	667,987
Percentage Change in Statutory Tax Rate	-0.08	5.22	-43.01	35.41	667,987
t-Score of Change	-0.00	2.31	-6.63	6.74	667,987
Z-Score of Change	-0.00	1.00	-2.50	2.55	667,987
Number of Tax Changes	4.17	2.00	1.00	7.00	667,987
Number of Tax Increases	2.01	1.54	0.00	6.00	667,987
Number of Tax Cuts	2.16	1.48	0.00	6.00	667,987

Source: Significant Features of the Property Tax: Property Tax Rates. Standardized Z and t scores are calculated using households within the same county from 2012 to 2018. All households are in counties that experienced at least one tax change. The typical household experienced more tax rate decreases than increases, and the typical tax rate change was a decrease of 0.01%. The sample excludes percentage changes more than 50% in either direction to prevent outliers, and the attrition from this condition is around 1% of the overall number of counties.

panel data allow for other transformations that maintain heterogeneity within counties like first differences to derive other forms for estimation equations. Lastly, self-assessments of house prices from the ACS are not necessarily an analogue for market prices.[10] Models of portfolio choice typically assume that capital stock owners know with certainty the value of their property[11] which may be an overly strong assumption for self-reported house prices in the ACS. Self-assessments are useful in the context of a bidding model, and household-level observations are used in the empirical approach.

[10]The direction and magnitude of the deviations from self-assessments and market prices is an empirical debate with little consensus where variation across studies may be driven by methodological differences or measurements of market value. Overoptimism may cause overvaluations while the sample selection bias of more valuable units in sales data may cause self-assessments to tend toward undervaluation. Kish and Lansing (1954), Ihlanfeldt and Martinez-Vazquez (1986), Goodman and Ittner (1992), and Agarwal (2007) find that self-assessments overstate actual market value while Kain and Quigley (1972), Follain and Malpezzi (1981), DiPasquale and Somerville (1995), and Kuzmenko and Timmins (2011) find that self-assessments understate actual market value. The accuracy of self-assessments can also vary over time, especially when prices are changing rapidly as shown in Anenberg (2011), and Kuzmenko and Timmins (2011). Deviations in self-reported valuations from market prices can also vary by socio-economic status, demographics, and community characteristics such as education Kain and Quigley (1972), income Agarwal (2007), access to public transportation Emrath (2002), tenure in the same housing unit Kuzmenko and Timmins (2011), and network effects within neighborhoods Bayer et al. (2016). Further, recently sold housing units may be substantively different from the typical unit in the housing stock and may have more desirable traits. Homeowners also have incentives to invest in modifications or upgrades near the time of the sale to improve resale value and recuperate more money from the investment.

[11]See Davis and Van Nieuwerburgh (2015) for a survey on the literature of portfolio choice models and housing decisions. A key implication from the Tversky and Kahneman (1979) model of loss aversion is that homeowners typically overvalue their housing units relative to market prices, especially when asset prices are falling.

Any aggregations to geographic identifiers such as counties, CBSAs, CSAs, and cities may comprise many heterogeneous neighborhoods, communities, school districts, or towns even when the region of interest is geographically small. When regions are geographically large, the heterogeneity in localized effects may be even more pronounced so useful geographic variation is lost in aggregation. While county-level statutory changes are used for variation, the empirical strategy uses household-level responses to county-level changes. That way, useful heterogeneity within counties across households is preserved.

3.2 Sample Selection

Households are in the sample if reside in the county containing the city center for large U.S. cities or in a geographically adjacent county. In all specifications, results are population weighted using ACS household-level weights. House price data in the ACS is continuous after 2008, but the sample period contains years from 2012 to 2018. The sample is further narrowed to include homeowners[12] in counties where percentage changes in property tax rates that are less than 50% in either direction.

4 Generalized DiD

Household-level observations experience county-level changes in statutory property tax rates. Households are considered treated if their county experienced a statutory property tax rate change in a given year and untreated if their statutory property tax rate remained constant from the previous year.

$$ln(V_{ict}) = \alpha + \beta_1(D_{ct} \times T_{ct}) + \beta_2 D_{ct} + \beta_3 T_{ct} + \phi R_{ct} + H'_{ict}\lambda + \psi_c + \eta_t + \varepsilon_{ict} \tag{2}$$

Here, $ln(V_{ict})$ is the natural log of the house price reported in the ACS. In this formulation, D_{ct} is an indicator for whether a household is treated. This specification is run separately for statutory property tax rate increases and decreases. For increases, D_{ct} is active if a household is in a county whose rate increased from the previous year compared to households in counties whose rate remained the same. Likewise, for decreases, D_{ct} is active for rate decreases relative to no change

[12] Any respondent in the sample is a homeowner that is at least 18 years old, either own or are financing their current residence, are designated the primary respondents for their residence, have positive earned income, and have no logical skips in number of bedrooms, number of rooms, self-assessed house price, or tax payments. Further, households reporting a house price outside the 5th and 95th percentile for their county and removed after removing logical skips to reduce the potential influence of outliers.

from the previous year. To capture the intensity of the statutory property tax rate change, T_{ct} is the within-county t-score[13] of the level change in the statutory property tax rate from the previous year. The standardized t-scores measure the magnitudes of the changes relative to each county's recent history and lends to ease of interpretation. This accounts for county-specific norms[14] that might be masked with percentage changes alone. If, for instance, residents in a county were used to statutory property tax rate increases of a certain magnitude, there could a tolerance for certain percentage changes not present in other counties. There are fixed effects for county and year in ψ_c and η_t, respectively. H'_{ict} is a vector of physical characteristics of the respondent's household found in the ACS, population density, and the natural log of the unemployment rate to control for macro-level differences across counties that may not be accounted for in the fixed effects.

R_{ct} controls for the level of the statutory property tax rate to account for rate differences across counties. This further accounts for tolerance of households to the prevailing property tax rate environments across locations. In some specifications, the level is replaced with the natural log of the statutory rate in order to naively estimate a property tax elasticity with respect to the statutory property tax rate[15] which should be interpreted as descriptive only. The theoretical bidding framework indicates that the regression coefficient of such a specification is the entanglement of several other parameters including the discount rate, the capitalization rate, and the tax rate.

In this context, identifying an ATT requires a few assumptions. First, no anticipation of statutory property tax rate changes that would create the opportunity for strategic behavior surrounding house prices with the knowledge of impending changes. Second, parallel trends requires that the evolution of house prices in counties whose statutory property tax rates change would have been consistent had they not experienced the tax rate change. Identifying at ATE requires an added assumption that counties who experience the a magnitudinal change in statutory tax rates causes

[13] In an unreported exercise, z-scores are substituted. Mechanically, z-scores are smaller and lead to larger coefficients while conveying the same qualitative implications. Using t-scores is more appropriate since the sample period has relatively few years, and there is no loss of statistical variation.

[14] For example, in unreported ancillary specifications, school test scores are added as a control on the quality of public goods provision that would be funded partially through property tax revenue. School spending varies dramatically across overlapping fiscal districts and across space. The test scores are averages of all school districts that fall within a county, and are measured as the percentage of students that failed to meet minimum standards and the percentage of students who exceeded high standards for math and reading. These four variables (math and reading, low and high) do not substantially alter the signs or significance of the main results. Further, the coefficients on the test scores are mostly economically small and statistically insignificant across specifications.

[15] In an unreported exercise, this elasticity coefficient is shown to increase in negative magnitude as house prices increase to the median then stabilize thereafter around -0.35 in the upper half of the house price distribution. Another alternative could be that households with higher prices are subject to high property tax rates.

house prices to adjust on average by the same amount for any county that received the same change in statutory tax rates which is a version of parallel trends for each magnitudinal change in statutory rates.

Table 3 provides balance tests of outcomes of house prices for both states of treatment: increases and decreases. Both treatments use the same comparison group of households in counties who did not have a statutory property tax rate change at the same time. Across all groups, the statutory rate and effective rates are not statistically different. In the full sample, the average household self-assesses their house around \$207,524, or a natural log of 12.243. In the increase treatment state, there is no difference in the unconditional outcome variable means. For the decrease treatment state, self-assessed house prices are statistically larger than in the untreated state. The full sample includes a group of households in counties whose statutory rates never change. The fraction of never-treated observations is around 5%, and the counties are largely concentrated in a few states. Since these observations can not be standardized due to the lack of a defined standard deviation, they are not included in any specification of Equation (2).

Figures 2 and 3 summarize the magnitude of the largest tax rate increases and decreases experienced by households in each county by estimating Equation (3) with the statutory property tax rate on the left-hand side in the (a) panels and the overall effective property tax rate on the left-hand side in the (b) panels:

$$R_{ct} = \alpha + \sum_{\substack{-t \\ t \neq -1}}^{T} \pi_t + H'_{ict} + \psi_c + \eta_t + \varepsilon_{ct} \tag{3}$$

The (b) panels of Figures 2 and 3 have three main takeaways. First, overall effective rates follow the same pattern as county statutory rates which suggests that the tax rate change events are not being completely avoided through tax exemptions. However, the magnitudes for overall effective rates are slightly smaller[16] than county statutory rates which suggests some avoidance. Second, the similar pattern between both rates suggests high correspondence from the mechanical connection between statutory and effective rates. The overall effective rate is the sum of all effective tax rates

[16]Since the effective rates are estimated as the midpoint of the tax bins from the ACS, these are likely underestimates of true effective tax rates. Large differences between self-assessed property tax payments and actual tax payments may suggest that property taxes are not salient.

Table 3: Treatment Balance Table

Variable	Full	Control	Up=1	Down=1	Diff Up	Diff Down
ln(Valuation)	12.243	12.195	12.213	12.326	0.017	0.130**
	(0.614)	(0.606)	(0.635)	(0.595)	(0.753)	(0.026)
Statutory Tax Rate	1.949	1.853	1.863	2.141	0.010	0.288
	(1.655)	(1.748)	(1.503)	(1.664)	(0.973)	(0.226)
Effective Tax Rate	1.186	1.137	1.219	1.212	0.082	0.075
	(0.689)	(0.666)	(0.721)	(0.681)	(0.485)	(0.349)
ln(Density)	7.603	7.513	7.718	7.599	0.206	0.086
	(0.951)	(1.005)	(0.932)	(0.893)	(0.149)	(0.501)
Unemployment Rate	5.535	5.829	5.973	4.780	0.144	-1.050***
	(1.773)	(1.888)	(1.613)	(1.519)	(0.541)	(0.000)
t-Score of Change	-0.000	-0.008	1.819	-1.718	1.828***	-1.710***
	(2.306)	(1.275)	(2.001)	(1.710)	(0.000)	(0.000)
Z-Score of Change	-0.000	0.007	0.779	-0.743	0.772***	-0.750***
	(1.000)	(0.620)	(0.860)	(0.726)	(0.000)	(0.000)
Observations	794,775	296,383	242,681	255,711	539,064	552,094

Note: *** p<0.01, ** p<0.05, * p<0.10. Balance test of pooled variable means for the entire sample, the group of untreated observations, the statutory property tax rate increase treatment status, and the statutory property tax decrease treatment status. The right-most columns are the differences between the control group and treated group for each treatment status with standard errors of the t-tests in parenthesis clustered at the county level.

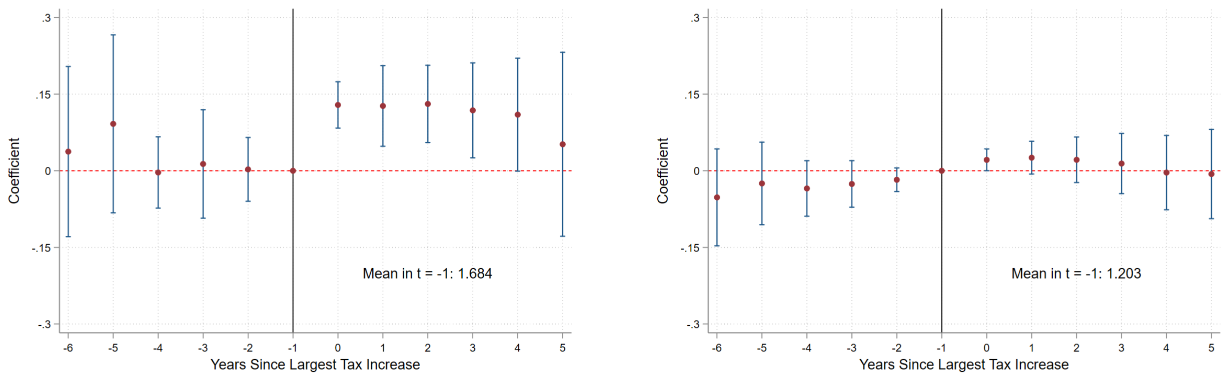
from each overlapping district[17] which are all individually highly correlated with their respective statutory rates. As such, the overall effective rate is mechanically related to county-level statutory rates. Third, the empirical design implicitly assumes that other district-level property tax rates are stable, and there is strong evidence that there is little affecting overall effective rates other than county statutory rates in this sample. At the very least, if other statutory rates are moving, they seem to be almost perfectly offsetting such that there is no observational difference in the overall

[17]The relationship between the effective tax rate for a house in county c in year t, τ^e_{ct}, and the county statutory tax rate can be expressed using the assessment ratio and the sum of all statutory tax rates, τ^s_{dt}, for each fiscal district d for a specific county:

$$\tau^e_{ct} = \frac{V^a_{ict}}{V^m_{ict}} \times \sum_d \tau^s_{dt}$$

The assessment ratio is the fraction of the assessed valuation of a housing unit to its market price which is commonly near but less than unity, but local statutes that govern reassessment vary dramatically so the ratio need not be close to unity. If any district statutory tax rate increases and the assessment ratio does not adjust immediately from a reassessment of taxable value, the overall effective tax rate increases mechanically since statutory tax rates are additively separable.

Figure 2: Evolution of Largest Tax Rate Increases



(a) County Statutory Rates

(b) Overall Effective Rates

Note: Estimates of π_t from Equation (3) with the county statutory property tax rate decreases on the left-hand side in Panel (a) and the overall effective property tax rate on the left-hand side in Panel (b). The y-axes are the magnitudes of the coefficients relative to the omitted period, $t = -1$. The average county statutory property tax rate in the reference year is 1.684% which corresponds to 16.84 millage points. Likewise, the average overall effective property tax rate in the reference year is 1.203, or 12.03 millage points. Clustered standard errors are computed at the county×year level on both panels.

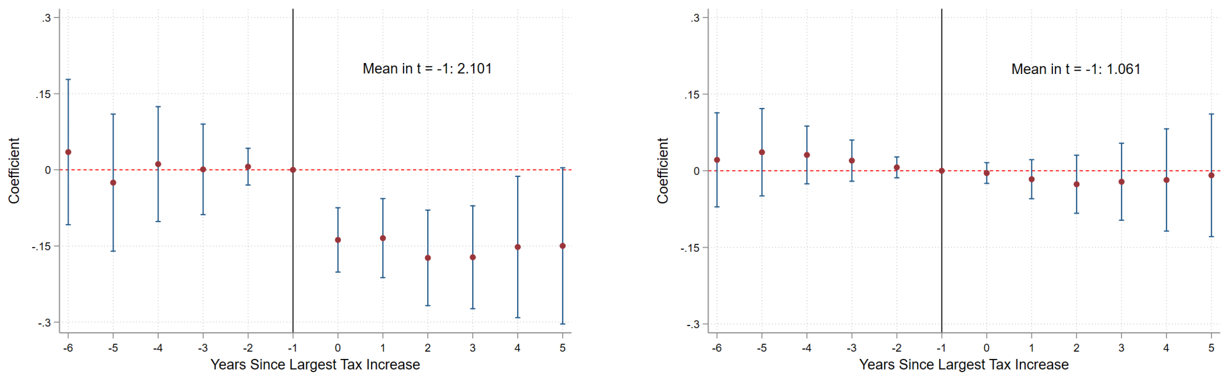
rate coming from any individual district other than the county. Further time periods from the largest tax changes are more likely to be contaminated by other tax rate changes. At least for the largest tax changes, the evidence is most consistent with unanticipated, permanent changes.

4.1 Threats to Identification

Regarding the main identifying assumptions for estimating an ATT, there are several main categories of how those assumptions might be violated. The added assumption to identify an ATE is likely to hold in the bidding framework if there is at least partial capitalization in multiple districts such that homeowners cannot sell their current house and buy another house in another county without bearing some of the cost of the present-discounted property tax burden in the sale or purchase of either houses.

Some local fiscal districts allow limited voting rights to constituents on specific spending projects that would require changes in property tax rates to fully finance. If constituents have voting rights on county-level property tax rates, the statutory county property tax rate is likely not exogenous because homeowners have the ability to strategically vote on property tax changes that may affect

Figure 3: Evolution of Largest Tax Rate Decreases



(a) County Statutory Rates

(b) Overall Effective Rates

Note: Estimates of π_t from Equation (3) with the county statutory property tax rate decreases on the left-hand side in Panel (a) and the overall effective property tax rate on the left-hand side in Panel (b). The y-axes are the magnitudes of the coefficients relative to the omitted period, $t = -1$. The average county statutory property tax rate in the reference year is 2.101% which corresponds to 21.01 millage points. Likewise, the average overall effective property tax rate in the reference year is 1.061, or 10.61 millage points. Clustered standard errors are computed at the county$\times$year level on both panels.

the house prices which violates the assumption of no anticipation. In the bidding framework, a housing unit's price is determined by market agents' willingness-to-pay for a particular unit with particular characteristics and amenities so using sale prices from transactions would be ideal. Self-assessed valuations by current homeowners who may have voting rights on some property taxation decisions in their county may not be analogues for market prices and may introduce bias if agents are strategically choosing property tax rates. Even if homeowners do not *strategically* vote for favorable statutory property tax rate changes, these votes may affect house prices through other channels such as capital changes, permanent income, and the local government budget in the future. Whether homeowners are aware of these channels may impact how they vote on such tax changes, and the housing market response is partially determined on whether homeowners are aware these channels.

Another threat to identification in terms of anticipatory effects is announcements and overall salience of future statutory property tax rate changes even if they are determined exogenously because announcements may allow adjustments to house prices in anticipation of future tax burdens as seen in the annuity capitalization formulation from Equation (1) in Section A. The frequency that county governments reassess houses to determine their taxable value is another aspect that may increase the salience of the property tax burden, particularly if these are done on an annual basis and the homeowners are made aware of the reassessment process or the reassessed value. Homeowners who are financing through mortgage have a second potential source of information about changes in property tax burdens through their mortgage provider. If mortgage providers send notices to homeowners about forthcoming property tax burden changes before the tax rate change, homeowners may anticipate the tax shock.[18] Related to announcements is whether local governments publish their spending/revenue strategies before each new fiscal year.[19]

If homeowners perceive statutory tax rate changes as both unanticipated and permanent, the measured effects may be the largest. Figures 2 and 3 suggest that the tax rate changes are permanent on average across counties for several years, but the data does not contain enough information to formally control or test homeowners' expectations or permanence of tax rate changes. If there are announcements or the statutory rate changes are seen as temporary, the results may tend toward no effects and may have anticipatory impacts. Concerns about future expectations also arise because self-assessed valuations in the ACS are not sale prices so changes in the self-assessments may come from other factors such as expectations about future prices or overall pessimism regarding housing markets. Staggered treatments and two-way fixed effects may reduce some of the possible systemic bias from changing expectations across counties and time.

Since this work aims to generalize property tax capitalization to many geographically diverse fiscal districts, this may introduce other identification issues since the statistical variation is not localized. If there are counties in the sample that have any of the characteristics listed in this section, the variation may not be fully exogenous. Further, the natural experiment assumes that homeowners are not strategically choosing county statutory property tax rates in a way that affects house prices and that other local district-level statutory property tax rates are fixed. Figures 2 and 3 support the claim that other statutory property tax rates are either stable or offsetting in a way that would allow high correspondence between statutory county-level and overall effective rates.

[18]Splitting the analysis into groups of homeowners who report their property tax payments as included in their mortgage payment and homeowners who pay their property taxes outright does not affect the signs or magnitudes of the responses, suggesting this mechanism may not play an role in anticipatory behavior.

[19]If, for example, the county government were to make known its intention to finance road maintenance with a temporary increase in property taxes for several years, homeowners in that district would be aware that the tax rate change would revert in the future so the impact of the tax rate change would not be as large on house prices.

To the extent possible, the sample excludes homeowners in counties with property tax revenue caps that would necessarily require local governments to offset rates to accommodate changes in market prices. The worry of revenue caps may be less of a concern in the ACS where house prices are self-assessments and not sale prices, but there could still be information about expectations in the self-assessments. While the ideal design would also limit identification threats through announcements of future budgetary plans and control for counties that offer limited voting rights, these facets are not taken into account in the empirical design.

4.2 Generalized Model Results

Table 4 contains descriptive results for the coefficients on the statutory property tax rate and its natural log for different sets of the sample. In general, these are the ϕ coefficients from Equation (2). The first pair of columns is the full sample, and the second pair of columns is on the set of households that are in neither treatment status. Each pair of columns is otherwise similar. These are meant to be descriptive baseline estimates for comparison and should not be interpreted causally. The level change in Column (1) indicates that a 1% increase in the statutory rate would decrease house prices by 6.43%. The descriptive elasticity with respect to the property tax rate is -0.2333 in Column (2) which should be interpreted as changes in percentage point terms of the statutory rate (e.g. a percentage change in the statutory property tax percentage rate). For households in neither treatment status in Column (3), increasing the level of statutory rates by 1% indicates a decrease in house prices by 4.953%. Columns (3) and (4) correspond to the sample in Column (2) of Table 3.

Table 5 contains the estimates of the main variables of interest that estimate β_1 from Equation (2) and is organized by treatment status. In the first two pairs of columns, the odd columns use the level of the statutory rate, and the even columns use the natural log of the statutory rate. In the last pair of columns, the control for the level or natural log of the statutory property tax rate is left out due to potential endogeneity concerns between house prices and the effective property tax rate due to the mechanical connection between statutory and effective rates. Each pair of columns is otherwise similar. The last row of coefficients is the constant term for the natural log of house prices, and the very bottom row of the table displays the implied treatment impacts in percentage terms on house prices. Each specification clusters the standard errors at the county level.

Table 4: Descriptive Results

	Full	Full - ϵ	No Treatment	No Treatment - ϵ
Statutory Tax Rate	-0.0655***		-0.0508*	
	(0.018)		(0.028)	
ln(Statutory Tax Rate)		-0.2333***		-0.2966***
		(0.064)		(0.080)
Constant	11.6151***	11.5913***	12.1252***	12.1078***
	(0.181)	(0.179)	(0.396)	(0.400)
Observations	794775	794775	296383	296383
R-squared	0.530	0.530	0.513	0.513
Year FE	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.10. Estimates of the ϕ coefficients from Equation (2) are organized by treatment status. The odd columns estimate the models that estimate the level of the statutory property tax rate, and the even columns estimate the natural log of the statutory property tax rate. The first pair of columns use the entire sample, and the second pair of columns is for households in neither treated state. These estimates are meant to be descriptive only. Standard errors are clustered at the county level.

Columns (1) and (2) contain results for the tax rate increase treatment status. The coefficient of interest is the interaction of treatment status and measure of the magnitude of the tax increase which is β_1 from Equation (2). Column (1) controls for the level of the statutory rate, and the main coefficient of interest indicates that increasing the magnitude of the tax rate increase by one standard deviation in the t-score lowers house prices by 0.912% relative to households in counties whose statutory rates did not change. This effect is marginally significant. The level of the shock and the treatment indicator both have opposite signs than would be predicted by the bidding model.

Columns (3) and (4) contain results for the tax rate decrease treatment status. Again, the coefficient of interest is the interaction between treatment status and magnitude of the tax decrease. Column (3) controls for the level of the statutory rate, and the main coefficient of interest indicates that decreasing the magnitude of the tax rate by one standard deviation raises house prices by 1.297% relative to households in counties whose statutory rates did not change. This effect is significant at conventional levels. The level of the treatment indicator does have the expected sign in this case.

Columns (5) and (6) do not control for the statutory property tax rate to address potential endogeneity concerns. The impacts of tax rate changes are slightly larger in absolute value for both

Table 5: House Price Responses by Treatment Status

	Up=1	Up=1 - ϵ	Down=1	Down=1 - ϵ	Up=1 - No Rate	Down=1 - No Rate
Statutory Tax Rate	-0.0658**		-0.0730***			
	(0.030)		(0.023)			
Increase=1	0.0092	0.0090			0.0078	
	(0.014)	(0.015)			(0.014)	
t-Score of Change	0.0057*	0.0051	-0.0116*	-0.0084*	0.0058*	-0.0156**
	(0.003)	(0.003)	(0.006)	(0.005)	(0.003)	(0.007)
Increase=1 × t-Score of Change	-0.0092*	-0.0084			-0.0101**	
	(0.005)	(0.005)			(0.005)	
ln(Statutory Tax Rate)		-0.1633*		-0.3389***		
		(0.086)		(0.055)		
Decrease=1			0.0037	0.0040		0.0021
			(0.008)	(0.007)		(0.008)
Decrease=1 × t-Score of Change			0.0129**	0.0107**		0.0154**
			(0.006)	(0.005)		(0.007)
Constant	11.4992***	11.4521***	11.4782***	11.5141***	11.3903***	11.3236***
	(0.182)	(0.159)	(0.142)	(0.132)	(0.172)	(0.136)
Observations	412276	412276	425674	425674	412276	425674
R-squared	0.541	0.541	0.559	0.560	0.541	0.559
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Estimated Effect (%)	-0.912	-0.839	1.297	1.072	-1.000	1.548

Note: *** p<0.01, ** p<0.05, * p<0.10. Estimates of the β coefficients and ϕ from Equation (2) are organized by treatment status. The odd columns estimate the models that control for the level of the statutory property tax rate, and the even columns control for the natural log of the statutory property tax rate. The first pair of columns adds a level effect for the within-county t-score of the tax rate change, an indicator for being a tax rate increase, and the interaction between the two. The second pair of columns is similar to the third for the tax rate decrease treatment status. The last two columns do not control for statutory property tax rates to circumvent some concern of endogeneity between property tax rates and the house prices. Standard errors are clustered at the county level.

increases and decreases where the impact of a one standard deviation increase in statutory rate changes leads to a 1.000% decrease in house prices, and a one standard deviation decrease in rate changes leads to a 1.548% increase in house prices.

Taken together, these results represent intuitive relationships between the magnitudes of statutory property tax rate changes and house prices in a bidding-type framework. The opposite signs in treatment status and relative comparability in magnitudes provides some evidence of internal validity. Decreases in rates have a larger impact in absolute value of around 1.5 times as much as increases across specifications, and both treatment statuses have reduced economic and statistical significance when controlling for the natural log of the statutory rate rather than the level.

5 Quantile Analysis

This section allows responses to changes in property tax rates may vary along the distribution of house prices in the main designs. Using unconditional quantile methods proposed in Firpo et al. (2009) that rely on the marginal distribution of house prices, this section investigates whether capitalization effects from shocks and responses to tax change events vary along the distribution of house prices. Unconditional quantiles are the preferred approach since the quantiles of the house price distribution are determined a priori and are therefore agnostic to the distributions of the covariates or fixed-effects, even though these factors are important when interpretation of the resulting coefficients. The essential component of estimating unconditional quantiles is first estimating the recentered-influence function (RIF). Define Y as the outcome of interest, F_Y as the associated CDF, f_Y as the PDF, then the RIF quantile value, q_θ at any quantile θ is defined as:

$$RIF(Y;q_\theta,F_Y) = q_\theta + \frac{\theta - \mathbb{I}[Y \leq q_\theta]}{f_Y(q_\theta)} \tag{4}$$

The unconditional quantile regression is then accomplished by replacing house prices with their RIF[20] quantile values, assuming linearity in the parameters. For notational ease, let the quantile θ be denoted as the Q-th percentile for the remainder of the section where the median, $\theta = 0.5$, can be notated as Q50. Further, let $\beta_{i,\theta}$ be estimates of the coefficients of interest at quantile θ. This section will use similar specifications as Equation (2) with the resulting RIF on the left-hand side to examine responses along the distribution of house prices:

$$RIF(ln(V_{ict});q_\theta,F_{ln(V_{ict})}) = \alpha + \beta_{1,\theta}(D_{ct} \times T_{ct}) + \beta_{2,\theta}D_{ct} + \beta_{3,\theta}T_{ct} + \phi_\theta R_{ct} + H'_{ict}\lambda_\theta + \psi_{c,\theta} + \eta_{t,\theta} + \varepsilon_{ict,\theta} \tag{5}$$

The regression coefficients of unconditional quantile regressions are interpreted as the marginal effect on the unconditional quantile outcome value due to a one unit change in the unconditional averages of the covariates. Put differently, if the mean of a covariate changes by one unit, the RIF

[20] For example, consider $\theta = 0.8$ at the 80th percentile of the house price distribution. The RIF function creates a new outcome variable that takes on values of $q_{0.8} + (0.80/f_Y(q_{0.8}))$ for house prices above the 80th percentile and values of $q_{0.8} - (0.20/f_Y(q_{0.8}))$ for house prices at or below the 80th percentile. The unconditional quantile regression uses the new outcome variable with the two possible values on the left-hand side. The linear combination in Equation (4) of the distributional statistic, q_θ, and the influence function (IF) is called the recentered-influence function (RIF).

quantile values will change by the quantile regression coefficient. This interpretation lends itself well to changes in statutory property tax rates that affect all homeowners in a county, but analyzing quantiles of house prices allows homeowners to respond differently across the distribution of house prices. While the distribution of house prices is unconditional, the regressions are still conditional on house characteristics and the county statutory property tax rate as in (2). Household variation is preserved in this procedure so the observational unit is still the household, and the coefficients are still relative to households who are in counties that did not change their statutory property tax rates.

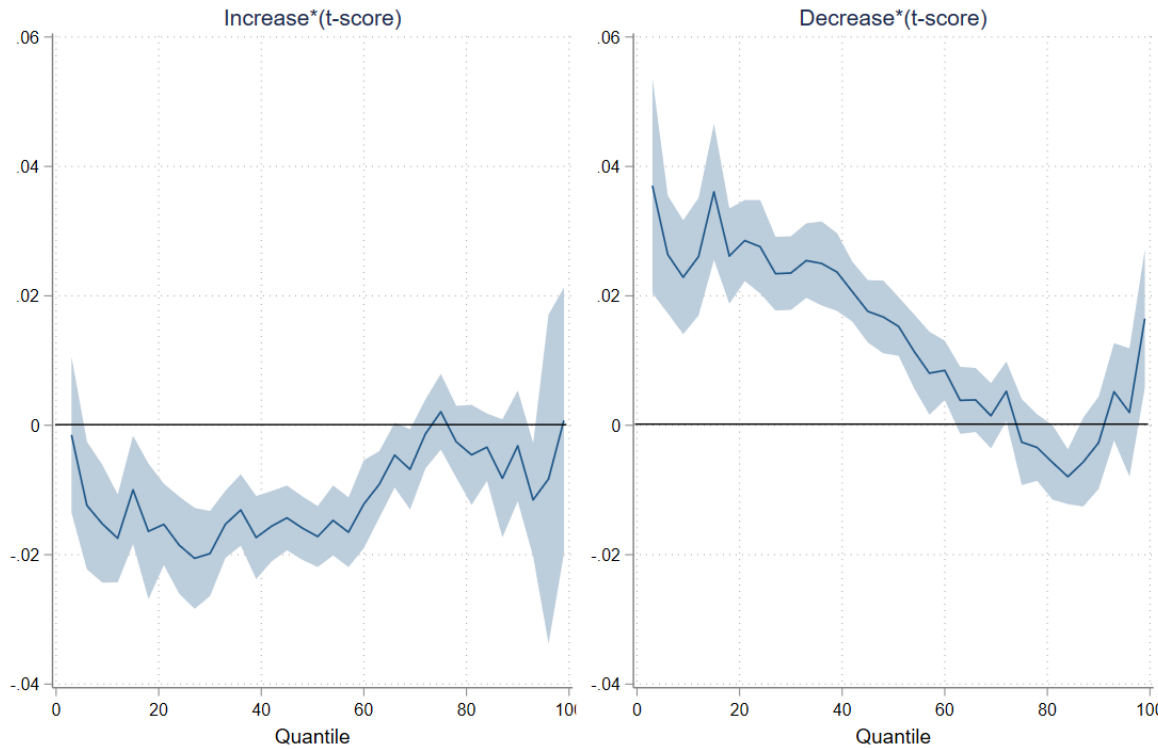
Tests of the coefficients of interquantile ranges are used to evaluate whether quantile regression coefficients are statistically different from each other along the distribution. The interquantile ranges will test whether decile coefficients are different from the seventh decile, Q70. For both increases and decreases in property tax rates, the seventh decile indicates a change in the pattern of responses as seen in Figure 4. Specifically, households are not statistically responding positively or negatively with any regularity to property tax rate changes of either kind in terms of house prices. Insignificant results relative to Q70 do not necessarily indicate that there is not heterogeneity along the distribution, and this point is chosen only because of the apparent change in behavior on either side. Interquantile ranges are differences in the RIF values at those quantiles which amount to testing the differences in the estimated coefficients.

5.1 Quantile Results

To measure differences in treatment effects from statutory tax rate changes, quantile analysis is performed on the $\beta_{i,\theta}$ coefficients from Equation (5) using the RIF as the dependent variable. Figure 4 contains the distribution of the $\beta_{1,\theta}$ coefficients at every third percentile of house prices from Q3 to Q99. The confidence bands are cluster-bootstrapped at the county level. For comparison, Tables 6 and 7 contain coefficients of $\beta_{1,\theta}$ from Equation (5) at each decile along the distribution of self-assessed house valuations. The coefficients are interpreted as the percentage change in house prices induced by increasing the size of the tax change by one standard deviation in the t-distribution. Larger increases are theoretically expected be negatively capitalized into house prices in the bidding framework, and larger decreases are expected to be positively capitalized into house prices.

In Figure 4, tax increases are negatively capitalized below the seventh decile, and tax decreases

Figure 4: Distributional Tax Rate Changes



Note: Regressions of every third percentile using the RIF approach are used to estimate the $\beta_{1,\theta}$ coefficients from Equation (5) along the distribution of house prices focused on the within-county t-scores of the statutory property tax rate increases (left) and decreases (right). Estimates are cluster-bootstrapped at the county level.

are positively capitalized below the sixth decile. This range of house prices is consistent with the implications from Section 4.2 where increases in tax rates reduce house prices and decreases in tax rates increase house prices. In either case, households in the highest third or so of house prices are statistically unaffected by changes in statutory property tax rates. In absolute value, tax rate decreases have a larger effect than tax rate increases by nearly 1% in the lower half of the distribution.

In both treatment statuses, the most striking result is that effects tend toward 0% the higher house prices become. House prices and self-assessments are highly correlated with household income, and the pattern is consistent with the idea that households become increasingly unaffected by changes in statutory property tax rates as house prices and income increase. One interpretation of this pattern is that changes in property taxes constitute larger user cost adjustments to credit

Table 6: Quantiles for Increases

	Q10	Q20	Q30	Q40	Median	Q60	Q70	Q80	Q90
Increase=1 × t-Score of Change	-0.0176**	-0.0188**	-0.0198***	-0.0161**	-0.0150**	-0.0122**	-0.0058	-0.0040	-0.0032
	(0.007)	(0.009)	(0.008)	(0.008)	(0.007)	(0.006)	(0.005)	(0.006)	(0.009)
Observations	412276	412276	412276	412276	412276	412276	412276	412276	412276
RIF(Q)	11.381	11.679	11.881	12.038	12.210	12.379	12.557	12.752	13.025
R-squared	0.161	0.245	0.301	0.344	0.368	0.375	0.377	0.373	0.355
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimated Effect (%)	-1.748	-1.861	-1.963	-1.601	-1.493	-1.209	-0.578	-0.395	-0.318

Note: *** p<0.01, ** p<0.05, * p<0.10. Regressions using the RIF approach are used to estimate the $\beta_{1,\theta}$ coefficients from Equation (5) along the distribution of house prices at each decile focused on the within-county t-scores of the statutory property tax rate *increases* as continuous treatment. Standard errors are cluster-bootstrapped at the county level.

Table 7: Quantiles for Decreases

	Q10	Q20	Q30	Q40	Median	Q60	Q70	Q80	Q90
Decrease=1 × t-Score of Change	0.0261	0.0272*	0.0235*	0.0222*	0.0149	0.0085	0.0014	-0.0028	-0.0027
	(0.018)	(0.015)	(0.012)	(0.013)	(0.011)	(0.012)	(0.010)	(0.009)	(0.009)
Observations	425674	425674	425674	425674	425674	425674	425674	425674	425674
RIF(Q)	11.454	11.760	11.950	12.135	12.291	12.445	12.616	12.789	13.036
R-squared	0.199	0.284	0.343	0.377	0.387	0.377	0.370	0.350	0.320
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimated Effect (%)	2.643	2.753	2.381	2.249	1.502	0.852	0.139	-0.279	-0.268

Note: *** p<0.01, ** p<0.05, * p<0.10. Regressions using the RIF approach are used to estimate the $\beta_{1,\theta}$ coefficients from Equation (5) along the distribution of house prices at each decile focused on the within-county t-scores of the statutory property tax rate *decreases* as continuous treatment. Standard errors are cluster-bootstrapped at the county level.

or income constrained households. As a result, they may be more impacted by changes in property tax rates and self-assess their own houses correspondingly. Consistent with that idea, households on the high end of the distribution may not care about changes in annual user costs because they are not income constrained. Mortgage lenders consider property taxes when determining the credit worthiness of borrowers so homeowners who have financed their houses may have more recent information on current property tax rates. At the extreme low end of the distribution, participation in income-based housing subsidies or other social insurance may be offsetting some of the implies changes in the property tax rates.

Tables 6 and 7 report the coefficients at each decile along the distribution in Figure 4 as well as the implied impacts on house prices in the last row. For tax rate increases in Table 6, effects are statistically and economically different than 0 below the seventh decile. The negative impacts as large as -1.963% at the third decile on house prices from a standard deviation increase in the property tax rate and vary from -1.748% in the first decile down to -0.318% in the ninth decile. The impacts are approximately U-shaped in the lower two-thirds then are not statistically different than 0 above Q70. For tax rate decreases in Table 7, impacts are economically larger in absolute value, but there is only marginal significance between the second and fourth decile. In the highest two deciles, the coefficients change sign. There is more variability in decreases since the effects range from 2.643% in the first decile down to -0.268% in the ninth decile. The overall change from the bottom to the top of the house price distribution is about twice as large for decreases which suggests more consistency in the effects of tax rate increases.

Table 8: Quantiles for Increases Relative to Q70

	IQR(70-10)	IQR(70-20)	IQR(70-30)	IQR(70-40)	IQR(70-50)	IQR(70-60)	Q70	IQR(80-70)	IQR(90-50)
Increase=1 × t-Score of Change	0.0118	0.0130	0.0140*	0.0103**	0.0092*	0.0064	-0.0058	0.0018	0.0026
	(0.009)	(0.009)	(0.008)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.008)
Observations	412276	412276	412276	412276	412276	412276	412276	412276	412276
R-squared	0.086	0.071	0.073	0.051	0.050	0.020	0.377	0.033	0.085
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.10. Regressions using the RIF approach are used to estimate the $\beta_{1,\theta}$ coefficients from Equation (5) along the distribution of house prices at each decile focused on the within-county t-scores of the statutory property tax rate *increases* as continuous treatment. Standard errors of the differences are cluster-bootstrapped at the county level.

Table 9: Quantiles for Decreases Relative to Q70

	IQR(70-10)	IQR(70-20)	IQR(70-30)	IQR(70-40)	IQR(70-50)	IQR(70-60)	Q70	IQR(80-70)	IQR(90-50)
Decrease=1 × t-Score of Change	-0.0247	-0.0258	-0.0221	-0.0209	-0.0135*	-0.0071	0.0014	-0.0042	-0.0041
	(0.026)	(0.023)	(0.014)	(0.014)	(0.007)	(0.005)	(0.013)	(0.005)	(0.008)
Observations	425674	425674	425674	425674	425674	425674	425674	425674	425674
R-squared	0.082	0.078	0.070	0.060	0.072	0.026	0.370	0.031	0.076
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.10. Regressions using the RIF approach are used to estimate the $\beta_{1,\theta}$ coefficients from Equation (5) along the distribution of house prices at each decile focused on the within-county t-scores of the statutory property tax rate *decreases* as continuous treatment. Standard errors of the differences are cluster-bootstrapped at the county level.

To investigate whether of the estimates are statistically different across deciles, Tables 8 and 9 contain the results of statistical tests of the interquantile range of the $\beta_{t,\theta}$ coefficients relative to Q70 where the "Q70" column has the same coefficients from Tables 6 and 7, respectively. Each column is the coefficient of the larger decile minus the coefficient of the smaller decile. For example, the difference between the fifth and seventh decile is calculated as Q70-Q50, and the difference between the ninth and seventh decile is calculated as Q90-Q70. Above Q70, the magnitudes are relatively stable and close to 0 so the order is less important for the sign than below Q70 where there are noticeable patterns. The signs of the differences are positive for tax rate increases because Q70 is higher than the negative coefficinets at lower deciles, and the opposite is true for differences between Q70 and lower deciles since those coefficents are positive. Tests of statistical differences from the median do not necessarily preclude heterogeneous effects along the distribution, and there are clear visual patterns in Figure 4 that demonstrate these differences. The $\beta_{t,\theta}$ tend toward 0 as house prices get higher and are not statistically different for the highest third of house prices.

For tax rate increases, there is marginally significant differences between the third decile and the median. The quantile coefficients are somewhat U-shaped in negative magnitude for rate increases. For tax rate decreases, there is only a marginally significant different at the median probably due to slightly smaller standard errors.

6 Conclusion

This paper estimates treatment effects of changes in property tax rates across the distribution of house prices, and these results generalize the capitalization framework to counties across the United States that contain large cities. These estimates do not rely on specific locations or settings. Using novel data on statutory county-level property tax rates, several strategies are used to provide both descriptive and causal estimates of capitalization elasticities and treatment effects in response to tax rate changes.

The generalized difference-in-differences approach is made possible through exploiting variation in novel statutory property tax rate data. Treatment intensity is measure by within-county t-scores in county statutory property tax rate changes. Property tax rate increases by one standard deviation cause households to reduce their self-assessed valuations by 0.912% on average, but these responses can range from 0.318% to 1.963% decreases depending on the position in the house price distribution. Similarly, property tax rate decreases by one standard deviation in the t-scores cause households to increase their self-assessments by an average of 1.297% with wider fluctuations between 2.753% increases to 0.268% decreases. These treatment effects are statistically significant, economically large, and reasonably comparable in magnitude. Using quantile analysis, these treatment effects affect households in the lower two-thirds of the distribution but show no impacts on the higher end of the distribution. Increases in property tax rates are more consistent in magnitude along the distribution while decreases almost fall toward 0% changes monotonically. The most expensive houses whose homeowners do not seem to respond to statutory property tax rate changes by adjusting their self-assessed valuations despite receiving the same magnitudinal changes to property tax rates. There is strong evidence that there is heterogeneity across the distribution in responses to property tax rate changes.

While the descriptive estimates of the property tax capitalization elasticity should be interpreted with caution, the implied capitalization elasticity is less than 1 suggesting that statutory property tax rate changes at the county level are less-than-capitalized into house prices (less than a dollar-for-dollar response). Taken together, there is strong evidence that property tax capitalization occurs in counties that contain large cities across the United States which is congruent with more convincing work in property tax capitalization. The degree of capitalization has heterogeneity along the distribution of house prices where the treatment effects are non-existent for the high-priced houses. These estimates do not depend on specific qualities of any of the 115 counties in the sample so the effects may be generalized to counties that contain large cities in the United States.

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A Theory - Household Bidding Model

There are aspects from utility maximization models and asset pricing models in this framework, and each can be used to derive similar conclusions as the bidding model.[21]

Let H be units of housing services and public amenities, P be the after-tax price of those services, and Y be household income. Define S as the quality of public goods and services and Z be a numeraire composite consumption good. The households derives utility from the numeraire, housing services and public amenities, and the quality of those housing services and amenities: $U(Z, H, S)$. The after-tax prices of housing services are an implicit function of the quality of public goods and the effective property tax rate, $P(S, \tau^e)$, that will simply be denoted as P for notational ease. Allow τ^e to be the effective property tax rate and r to be the discount rate in percentage terms across time t. The household's budget constraint[22] is then:

$$Y = Z + PH(1 + \tau^e/r) \tag{6}$$

Rearrange Equation (6) by solving for P to set up the the main question for housing bidding models which is how much a household would bid for a specific housing unit in a particular market with access to certain public goods and services provided by the fiscal authority for that market.

$$\begin{aligned} \max_{H,Z} \quad & P = \frac{Y - Z}{H(1 + \tau^e/r)} \\ \text{s.t.} \quad & U(H, Z, S) = U^0(Y) \end{aligned} \tag{7}$$

Households treat S and τ^e as given parameters, and applying the envelope theorem to the rearranged budget constraint with respect to the quality of public services and the effective property tax rate yields:

$$P_S = \frac{U_S/U_Z}{H(1 + \tau^e/r)} \tag{8}$$

$$P_{\tau^e} = -\frac{P/r}{1 + \tau^e/r} \tag{9}$$

[21] Epple et al. (1984) is one such example that uses an indirect utility derivation as a form of user cost.

[22] Ross and Yinger (1999) use alternative notation for τ^* in place of τ^e/r where $T = \tau^e V = PH\frac{\tau^e}{r} = \tau^* PH$.

Equation (8) highlights the marginal rate of substitution between the quality of local public goods and the consumption numeraire good which can be interpreted as the dollar benefits of local public goods to households in those fiscal districts. Solving the Equation (9) with the initial condition that after-tax and pre-tax prices are the same when $\tau^e = 0$ yields the basic capitalization formulation in Equation (10) which is a form of hedonic price equation. The intuition is that the willingness to pay for any housing unit is equal to the real present-discounted sum of all future housing services, H, times their after-tax prices, P, using the real discount rate, r. The present-discounted annual cost of housing services is approximately equal to the rental rate for a given year so $r = \frac{R}{V}$. The total value of a house is the numerator number of dollars added from each period for the useful life of the housing unit. In this formulation, H is a vector of all housing services or attributes that give a housing unit value and each characteristic has its own price in the price vector, P. Given enough periods the expression can be simplified algebraically[23] to a multiplicative formulation:

$$V = \sum_{t=1}^{T} \frac{PH}{(1+r)^t} \Rightarrow V = \frac{PH}{r} \tag{10}$$

The imposition of a property tax is reflected as the present-discounted value of all future tax payments and is subtracted from the present-discounted values of housing services[24] while substituting the after-tax price vector, P, for the pre-tax price vector, $\hat{P}$, which is a function of public good quality only. The tax payment is calculated by the local fiscal authority as the market value of a house times the effective tax rate, τ, so a substitution can be made where $T = \tau V$:

[23] To do this, multiply each side of $V = \sum_{t=1}^{T} \frac{PH}{(1+r)^t}$ by $(1+r)$, subtract the resulting expression from V, combine terms, and allow $T \to \infty$:

$$V(1+r) = PH + \sum_{t=1}^{T-1} \frac{PH}{(1+r)^t}$$

$$V - V(1+r) = \sum_{t=1}^{T} \frac{PH}{(1+r)^t} - \left(PH + \sum_{t=1}^{T-1} \frac{PH}{(1+r)^t} \right) = -PH + \frac{PH}{(1+r)^T}$$

$$V[1-(1+r)] = PH[(1+r)^{-T} - 1]$$

$$V = PH\left(\frac{1-(1+r)^{-T}}{r}\right) \Rightarrow V = \frac{PH}{r}$$

[24] Ross and Yinger (1999) allow this to be expressed either with after-tax prices P or pre-tax prices $\hat{P}$ and with the τ^* notation where $V = \frac{PH}{r} = \frac{\hat{P}H}{r+\tau^e} = \frac{\hat{P}H/r}{1+\tau^*}$.

$$V = \frac{\hat{P}H}{r} - \frac{T}{r} \Rightarrow V = \frac{\hat{P}H}{r} - \frac{\tau V}{r} \tag{11}$$

Equation (11) assumes that property taxes are fully capitalized into house prices. Put differently, any changes to property tax payments or property tax rates are present discounted and fully reflected in the price of a house as well as changes in housing services, the prices of housing services, and the quality of local public goods. To be more flexible and allow for less-than-full capitalization (or over-capitalization), let δ represent the degree of property tax capitalization. Solving for V then yields the well-known property tax capitalization equation:

$$V = \frac{\hat{P}H}{r} - \delta\frac{\tau V}{r} \Rightarrow V = \frac{\hat{P}H}{r + \delta\tau} \tag{12}$$

Under full capitalization[25] of property taxes, $\delta = 1$ and current homeowners bear all the burden of present and future discounted property tax payments. When there is no capitalization, $\delta = 0$ and house prices do not reflect any changes in present or future property tax obligations. Over-capitalization can occur when public good provision is below the optimal level because willingness to pay for local public goods exceeds the necessary tax revenue to provide the goods. This type of sub-optimal tax policy can occur as a result of political processes or statutory property tax rate limitations that prevent taxes from being high enough to fully finance public goods demanded by constituents.[26] Similarly, under-capitalization can occur if the supply of local public goods exceeds the demand for those public goods. No capitalization occurs if homeowners sell their houses in the fiscal district where property taxes are increasing such that the buyers in those markets would pay a higher sale price and also bear all the burden of the property tax increase.

To derive an estimation equation, use a natural log transformation[27] of Equation (1) to recover

[25] In a series of works, Brueckner (1979) theoretically allows for an imperfect Tiebout (1956) equilibrium but assumes that all tax revenues are spent on improving or providing new public goods so there are no intergovernmental transfer payments. In this framework, local fiscal districts choose tax rates that are 'efficient' in the sense of Samuelson (1954) where net benefits of the public goods enjoyed by residents in that district equal the net costs of providing those public goods. Full capitalization occurs if property tax rates are efficiently set by local fiscal districts.

[26] Work by Ross and Yinger (1999) and Hilber (2017) summarizing the theoretical and empirical literature on house price capitalization and implications of local public good provisions demonstrate that small deviations to theoretical assumptions drastically reduce the value of interpreting such deviations as efficiency gains or losses. The way house prices across districts reflect differences in underlying public goods provision is an empirical debate that is closely related to the property tax capitalization debate.

[27] Another common way to derive an estimation equation using panel data is to take first-differences of Equation (1) before the substitution of τV for T, say during a reassessment, and assume constant tax rates after reassessment.

a general form for empirical analysis:

$$ln(V) = ln(\hat{P}) + ln(H) - ln(r + \delta\tau) \tag{13}$$

Since $\hat{P}$ is not a function of the effective property tax rate, the (non-linear) effect of the property tax rate on house prices is only in the final term of Equation (13). As noted in Palmon and Smith (1998) and Ross and Yinger (1999), there are broadly four major hurdles to causal identification in empirical capitalization in estimation equations similar to Equation (13): the entanglement of the discount rate and the capitalization rate, exact functional form, endogeneity of the effective property tax rate, and which hedonic housing services to include. Sirmans et al. (2008) survey decades of property tax capitalization studies and show that many studies either use endogenous OLS functional forms or use estimation equations that are not derived from theory that often ignore the entangled discount and capitalization rates.

The first issue with an estimation equation of this form with the effective rate included is that the semi-elasticity estimation coefficient is an expression of both r and δ that cannot be algebraically separated:

$$\frac{\partial ln(V)}{\partial\tau} = \beta = -\frac{\delta}{r + \delta\tau} \tag{14}$$

Algebraically rearranging Equation (14) by solving for δ[28] yields:

$$\delta = \frac{-\beta r}{\tau\beta + 1} \tag{15}$$

If the real discount rate is strictly positive, then estimates of $\hat{\beta}$ should be sufficient statistics to determine if δ is statistically different than 0 to demonstrate at least partial property tax capitalization. Since r and δ cannot be estimated directly in this form, the usual approach to make assumptions about either r or δ to back out the other after estimation. Do and Sirmans (1994) and Koster and Pinchbeck (2022) are among the only studies to estimate the discount rate in a property tax capitalization setting finding between 3% and 4%. A theoretically-driven approximation of the

The resulting estimation equation is: $\Delta V = \frac{-\delta}{r}\Delta T$.

[28]Since theory suggests that $\beta < 0$, the capitalization parameter δ will be positive so long as the sign of the denominator is positive which occurs when $\tau < -1/\beta$.

real discount rate is the inverse of the price-to-rent ratio, $r \approx \frac{R}{V}$. The remaining three common issues are addressed in this paper by using estimation equations derived from the theoretical model, using two empirical strategies to circumvent the endogeneity of the effective property tax rate, and including a full battery of fiscal spending categories to control for changes in local public goods across counties.

The basic bidding theoretical model has many extensions that include inter-jurisdictional sorting based on differential local public good provision and quality, expectations about future house prices within fiscal districts, different discount rates for the various housing services, the imposition of other tax instruments, property tax deductions to taxable income, and zoning. Each of these has its own set of difficulties in empirical estimation in addition to the four previously mentioned, but panel data is usually required for these extensions in order to track individuals or households as they move or update their beliefs about the housing market.