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Property tax capitalization, a case study of Dallas County

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ABSTRACT

We estimate the degree to which local property taxes are capitalized into house prices using administrative data from the Dallas Central Appraisal District (DCAD) from 2014 to 2016. Capitalization rates are measured using a hedonic price regression model. To control for unobservable neighborhood characteristics, we employ a border discontinuity research design, restricting our sample to homes within half-mile blocks of jurisdictional boundaries. With respect to school district taxes, we estimate that more than 70 percent of the increase in the present value of property tax liabilities resulting from a tax increase is capitalized into current house prices. The null hypothesis of full capitalization cannot be rejected. For city taxes, capitalization rates are even larger. We also estimate the willingness to pay for public schools, finding that a one standard deviation increase in test scores results in a roughly four-percent increase in house prices.

1. Introduction

1.1. Contrasting views of tax capitalization

Hamilton (1975 and 1976) depicts the local property tax as a de facto benefit tax resulting from Tiebout (1956) competition, where property values reflect not only houses' physical characteristics but also the bundle of local amenities, disamenities, and tax packages offered by local governments. As a result of competition, local taxes represent the price of local public services and are nondistortionary so long as the market price equals the cost of public good provision. Under this *benefit tax view*, changes to property taxes, holding constant local public good provision, are fully capitalized into property values.[1,2]

In contrast to the benefit view, under the *traditional* (or *excise tax*) *view*, which dates to Simon (1943), the property tax is viewed as a tax on (perfectly inelastic) land plus an excise tax on (perfectly elastic) housing capital. The excise tax component dominates so that the majority of the property tax is shifted forward to consumers (i.e., prospective home buyers and renters) in the form of higher housing prices. In sum, the traditional view holds that local capital escapes the tax burden by migrating to other jurisdictions, reducing the local housing stock.

A third view, the *new* or *capital tax view*, was developed by Mieszkowski (1972). According to this general equilibrium approach, the property tax is a distortionary tax on the local use of capital (i.e., a profits tax on capital income). Mieszkowski argues that, while housing capital is mobile (within a country), it cannot completely escape property taxation because all jurisdictions have a property tax.[3] Thus, the owners of housing (or capital owners more generally) must bear the average (or "national") level of property tax within a country. In this respect, therefore, the capital tax view is similar to the benefit view. However, capital responds to deviations between the rates for the "national" property tax and the local property tax. This residual deviation is borne by consumers who pay more in high-tax areas and less in low-tax areas. Thus, local tax differentials represent an excise tax (i.e., the traditional view).

Because our focus is on variation in tax rates within a metro area, we are not able to assess the capital tax view. Our analysis is, however, relevant to the benefit and excise tax views. The benefit tax view is

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[1] The original Tiebout model assumes no inter-jurisdictional spillovers and that public services are financed with a head tax (instead of a property tax). However, when relaxing these assumptions, a strong benefit tax component could remain.

[2] Capitalization effects may not always push markets towards efficiency. For example, Yinger (1982) develops a model in which mobility responses to capitalization effects do not result in efficient local governments.

[3] Capital will flow to low-tax jurisdictions until the after-tax rate of return on investment is equal across jurisdictions.

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consistent with full capitalization, whereas the excise tax view is consistent with much lower capitalization. These predicted tax capitalization effects are predicated on controlling for benefits from public expenditures that are financed by property taxes. Despite five decades of investigation, there is no consensus on the degree to which property taxes are capitalized into housing values.[4] For example, research by Oates (1969), Reinhard (1981), and Gallagher et al. (2013) supports full capitalization – i.e., they find that current owners bear approximately 100 percent of the tax in the form of lower prices. On the other hand, Pollakowski (1973) and Wales and Wiens (1974) find almost no property tax capitalization, suggesting that the current owners shift taxes fully to new homebuyers. Wales and Wiens (1974) believe that zero capitalization may reflect buyers' limited knowledge about the housing market or the systematic biases in estimating future tax payments. Other studies, such as King (1977), Yinger et al. (1988), and Palmon and Smith (1998) find support for neither extreme. Instead, they find that property taxes are partially capitalized, meaning that the tax burden is shared between current and future homeowners.

1.2. Tax capitalization in Dallas County

We revisit the issue of property tax capitalization, focusing on Dallas County. We rely on administrative sales and appraisal data from the Dallas Central Appraisal District (DCAD), which spans 47 local (school and city) tax jurisdictions, in order to estimate the incidence of property taxes levied by both school districts and city governments. We employ a regression discontinuity research design (see Lee and Lemieux, 2010) to exploit discontinuities in property tax rates for neighborhoods spanning jurisdictional boundaries.

A major obstacle to identifying capitalization effects is neighborhood heterogeneity, which often can only be imperfectly accounted for using Census measures. To address this, we use ArcGIS mapping software in order to restrict our sample to properties in close proximity to jurisdictional boundaries. This allows us to compare homes located on opposite sides of ISD or city boundaries (an approach employed by Black, 1999).[5] While local amenities and disamenities are fairly homogeneous around a boundary, residents face different property tax rates. Our preferred specifications include block fixed effects. This approach assigns properties along boundaries into "blocks" that we create. Because some jurisdictional boundaries span many miles, block fixed effects are employed to control for neighborhood heterogeneity along these boundaries. We further include Census block group (CBG) variables to account for residual variation in neighborhood quality and school test scores to account for variation in school quality. We then show how our estimated tax coefficients relate to capitalization rates – i.e., the share of revenue from a tax increase that is capitalized into property values – by developing a model that accounts for both tax capitalization, as well as revenue feedback effects from capitalization.

We find that a 10-basis point (i.e., 0.1 percentage point) increase in the ISD property tax rate leads to a 2 to 2.5 percent reduction in housing values. Assuming that the tax increase remains in perpetuity, this implies that at least 70 percent and possibly more than 100 percent of the present value of increased tax liabilities are capitalized into current market prices. We strongly reject the null hypothesis of no tax capitalization, while we cannot reject the null hypothesis of full (100-percent) capitalization. We discuss the sensitivity of these results to the choice of discount rate and other assumptions.

We find even higher capitalization rates with respect to city property taxes. For example, we find that a 10-basis point increase in the city property tax rate results in a 4-percent reduction in property values. This suggests that property tax rates in Dallas County are near the revenue-maximizing rate with respect to changes to city taxes. However, because city property tax rates are only about one quarter of overall property tax rates, our estimates suggest that increases to city property tax rates would still raise substantial revenue for cities, but this added revenue would be almost entirely offset by losses in revenues in overlapping jurisdictions sharing the same property tax base.

The fact that estimated capitalization rates are greater for city (as opposed to ISD) property taxes is puzzling. The difference in capitalization rates may be partially explained by fiscal adjustment by overlapping tax jurisdictions. Because, on average, city property tax rates in Dallas County are a little more than half ISD rates, capitalization effects from changes to city tax rates impart much greater fiscal externalities – i.e., reductions in tax revenues due to contraction of the tax base – for overlapping jurisdictions. Suppose homeowners expect overlapping jurisdictions to adjust their property tax rates so as to be held harmless from changes in overlapping jurisdictions. If so, this fiscal adjustment will be twice as large for ISDs responding to cities than vice versa. Thus, the difference in capitalization effects could be partially explained if the market is pricing in this future fiscal adjustment.

A good study for comparison to this one is Livy (2018), who estimates house-price responses to property taxes for school districts in Ohio's largest county, Franklin County. In an approach that closely resembles our block fixed effects, he estimates that a 10-basis point increase in the property tax rate results in a 1.5 to 3.8 percent decline in property values, with estimates increasing when the sample is increased from observations within 0.2 miles to a boundary all the way to observations within 1 mile of a boundary. It is noteworthy that our estimates (with respect to school district taxes) for Dallas County and Livy's for Franklin County are very close when restricting samples to within 0.2–0.5 miles of a district boundary.

The remainder of this paper is organized as follows: Section 2 addresses property taxation in Dallas County and presents an overview of our data. Section 3 details our property tax capitalization model. Section 4 presents our empirical methodology. Section 5 presents our results, and Section 6 concludes the paper.

2. Property taxation in Dallas County

2.1. Institutional background

2.1.1. Local tax jurisdictions

Within Texas, local property taxes are collected by four taxing units: counties, municipalities, ISDs, and special districts. Dallas County includes portions of 31 city governments, 16 ISDs, and 12 special districts. City property taxes finance local public services such as libraries, parks, police, fire stations, etc. Special district taxes finance water and sewer systems, junior colleges, etc. (Gilliland, 2011). ISD property taxes finance K-12 education.

In Texas, as in most states, a family's address determines the public schools that their children may attend. Thus, public schools are, in reference to the theory of public goods, in some sense excludable in that families must live within a district. That is, families pay ISD taxes (explicitly for owners and implicitly for renters) in exchange for access to district schools. On the other hand, city property taxes are collected to finance local public goods, many of which carry substantial spillover effects.[6]

Our data include houses purchased from 2014 to 2016 within Dallas County. Therefore, we have cross-sectional variation in ISD, city, and

[4] Many of the earlier studies on property tax capitalization are reviewed in Yinger et al. (1988).

[5] Black (1999) looks at a related issue, studying the effect of school quality on housing values. She limits her sample to homes located around school attendance boundaries where public services and property taxes do not vary across boundaries, while school quality does.

[6] Negative spillovers are a possibility as well. For example, increased spending on police protection may cause criminal activity to shift to adjoining jurisdictions with laxer protections.

special district taxes but not county taxes. However, because just 2.2 percent of observations are within special districts, we focus on ISD and city property taxes. These represent a large share of overall tax payments by homeowners and vary substantially across jurisdictions within Dallas County.

2.1.2. Tax liability determination

Within each taxing entity, a property's tax liability is partially determined by two factors: the mill rate and the property's assessed value. However, tax liabilities are also affected by exemptions or deductions offered by local governments.[7] Exemptions and deductions vary by taxing jurisdiction as well as by the owner's age, disability status, and veteran status. Owners are eligible for a homestead exemption on their primary residence. Furthermore, homeowners may deduct property tax payments, if they choose to itemize, from federal taxable income.

In this study, we generally assume that prospective homebuyers are only eligible for the homestead exemption. A prospective homebuyer is eligible for this exemption regardless of age, disability status, veteran status, and filing status. Note that not all city jurisdictions within Dallas County offer a homestead exemption.[8] Among cities that do offer them, exemptions range from 1 to 20 percent of assessed value. By contrast, at the ISD level, all jurisdictions offer a "general" homestead deduction. The general deduction was $25,000 in 2015 and 2016, up from $15,000 for 2014. Also, ISDs may offer an add-on to the homestead exemption. For example, Dallas and Richardson ISDs allow residents to exempt 10 percent of their assessed values from taxation; Highland Park ISD allows residents to deduct 20 percent of their assessed values, on top of the general homestead exemption.

2.1.3. Effective property tax rates

On an annual basis, taxpayers in our dataset deducted an average of $25,088 from the ISD property tax base and $25,886 from the city property tax base.[9] In addition to exemptions, the effective tax rate (ETR) may be lower than the statutory tax rate because of the underassessment of property values. Changes to assessed values often lag changes to market values. Lutz et al. (2011) argue that properties may be underassessed by statute during periods of high house-price growth via caps on increases to assessed values. And even when not required by statute, they find that properties are generally appraised at below market value during periods when market values are increasing.

These factors imply both that ETRs are likely lower than statutory rates and that deviations between the statutory and effective rates are likely to vary across jurisdictions and over time, depending on house-price cycles and local economic conditions. Given this reality, using nominal tax rates to estimate the degree of property tax capitalization is problematic. Therefore, we focus on the relationship between effective property tax rates and house prices.[10]

2.1.4. State aid to education in Texas

Public K-12 schools in Texas are funded by a complex system that has been heavily shaped by a litany of court rulings over the past several decades. The Texas Constitution states that "it shall be the duty of the legislature of the State to establish and make suitable provision for the support and maintenance of an efficient system of free public schools." In *Edgewood v. Kirby* (1989), the Texas Supreme Court, in overturning an appellate court ruling, interpreted this to mean that:

> There must be a direct and close correlation between a district's tax effort and the educational resources available to it; in other words, districts must have substantially equal access to similar revenues per pupil at similar levels of tax effort. Children who live in poor districts and children who live in rich districts must be afforded a substantially equal opportunity to have access to educational funds.[11]

While local property tax revenues account for the majority of the funding for Texas public schools, court rulings (such as in *Edgewood*) have necessitated that the state play an important role in assisting property-poor districts.[12]

To achieve "similar revenues per pupil at similar levels of tax effort" in the face of stark differences in property wealth per pupil across districts, the state relies on the Foundation School Program (FSP). FSP allocates state aid to education through two tiers. Tier I finances the basic cost of education and Tier II finances program enrichment. Tier I entitlements are determined based on district and student characteristics, relying on formulas that adjust for differences in the cost of delivering education across districts, as well as for differences in student needs, and differences in the local resources available to each school district.[13]

In accord with FSP, Chapter 41 of the Texas property tax code redistributes local property tax revenues – the portion of local ISD taxes raised for maintenance and operations (M&O) – from property-wealthy school districts and toward property-poor school districts.[14] This redistribution of property tax revenues across districts is often called "recapture" and amounted to $2.1 billion for the 2017–2018 school year.[15] Recapture can take various forms, including direct payments between districts and payments to the state, which are then allocated via FSP.

In our sample, three ISDs (Coppell, Grapevine, and Highland Park) paid recapture taxes in years 2014–2016. (By 2018–2019, a couple of other ISDs in the county, including Dallas ISD, were subject to recapture taxes.) It is not known how recapture affects local decision-making with respect to setting ISD tax rates. On one hand, ISDs harmed by recapture must enact higher tax rates in order to finance a given level of spending. On the other hand, the marginal revenue (or price effect) to the ISD from raising tax rates is reduced, pushing the ISD toward lower tax rates. As long as the provision of public services is adequately controlled for, recapture does not pose a problem for estimating capitalization effects. However, if changes in tax rates are correlated with (unaccounted) future changes to school quality, estimated capitalization effects could be larger with recapture.

[7] See Section 11.13 of the Texas Property Tax Code.

[8] Property tax exemptions by year and taxing unit can be found at http://dallascad.org/TaxRates.aspx.

[9] Note that these values are actual exemptions and thus include taxpayers who are eligible for special deductions, as well as those who are not eligible for the homestead deductions. For a representative home buyer – who is under age 65, not disabled, and qualifies for the homestead exemptions – we estimate mean eligible exemptions of $42,718 for ISDs and $42,038 for cities.

[10] Itemization could also alter effective property tax rates since itemizers are allowed to deduct local property tax payments. As a result, they are effectively reimbursed for property tax payments in proportion to their federal marginal tax rate on income. We do not account for itemization in our estimation because this would require income tax information at the household level for each property – or for the market of prospective buyers. To the extent that this is important, variation in effective tax rates would be somewhat smaller and estimated semi-elasticities would likely be somewhat larger.

[11] See https://law.justia.com/cases/texas/supreme-court/1989/c-8353.html.

[12] Over the period of our study, state and local spending for education in Texas totaled approximately $50 billion per year. Excluding federal grants (for things like child nutrition programs), local property taxes finance roughly 60 percent of school spending in Texas, with the state government providing the other 40 percent (Texas Comptroller, 2019).

[13] TTARA (2018, pp 9–17) outlines the steps used to determine a school district's entitlement under Tier 1.

[14] ISD budgets are often divided between M&O expenditures and interest and sinking (I&S) costs used for debt financing of ISD facilities.

[15] For detailed discussions, see *An Introduction to School Finance in Texas* (https://ttara.org/wp-content/uploads/2018/09/IntrotoSchoolFinance_2018.pdf).

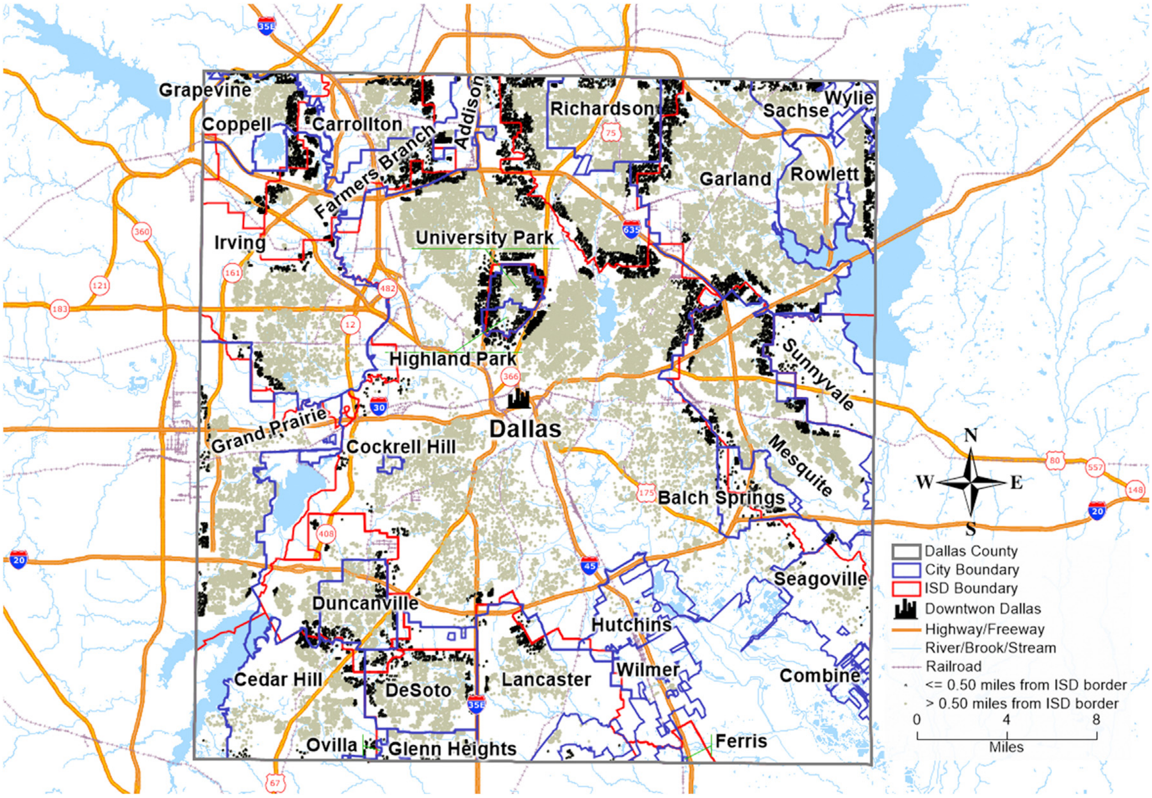

Fig. 1. Homes purchased in Dallas County from 2014 to 2016.
Notes: Each dot represents one home purchased in Dallas County from 2014 to 2016. The total number of homes purchased equals 61,907. The red lines are ISD boundaries, and the blue lines are city boundaries. City names are included on the map.

2.2. Data and summary statistics

2.2.1. Home sales

Fig. 1 presents the geographic distribution of homes purchased in Dallas County from 2014 to 2016, highlighting proximity to ISD boundaries. This includes 61,907 owner-occupied home sales within Dallas County. Among the county's 16 (included or overlapping) ISDs, Dallas ISD, with 20,073 observations, had the highest number of sales; Sunnyvale ISD, with 202 observations, had the fewest sales.[16]

Our dataset includes assessed values, sales prices, and physical characteristics, such as year built, internal area, the number of bedrooms and bathrooms, etc. The dataset also includes property addresses, which are crucial to identifying homes located around boundaries. We add municipality and ISD mill rates and exemption values to the dataset.[17] These data are merged with information from two other datasets: (1) public school STAAR (State of Texas Assessments of Academic Readiness) test scores from the Texas Education Agency (TEA),[18] and (2) CBG data from the Census Bureau's (United States Census Bureau) American Community Survey (ACS). STAAR test scores serve as proxies for public-school quality. CBG variables serve as controls for neighborhood characteristics.

2.2.2. Geographical information

To further control for neighborhood heterogeneity, we focus on homes located along ISD boundaries. We consider three subsamples by restricting the data to houses within 0.5 miles, 0.35 miles, and 0.20 miles of an ISD boundary such that each home is associated with only one boundary.[19] Fig. 1 highlights home sales falling within 0.50 miles of ISD boundaries.[20] The largest subsample includes 66 boundaries with at least one observation on both sides. In our empirical analysis, we exclude homes located in rural areas; homes with no counterparts on the other side of the boundary; homes with zero tax liability; and observations with missing explanatory variables. In the rare instance where a home is sold multiple times in a year, only the latest sale is used.

2.2.3. Summary statistics

Table 1 presents summary statistics for the full sample and three subsamples. The full sample includes house sales irrespective of distance to ISD borders. The average sales price for the full sample is $294,000 (and the median is $190,000) with a standard deviation of $334,000. Both market and assessed values are normalized to 2014 dollars using the annual Consumer Price Index (CPI). The mean assessed value is less than the mean market value for each subsample. For the full sample, the mean assessed value is $280,000 (with a median of $184,000). Both mean sales prices and assessed values increase markedly as the sample is restricted to properties bordering an ISD boundary. Moving from the full sample to the sample within 0.2 miles of a boundary, sales prices increase 46 percent, from $294,000 to $428,000, while assessed values for these properties increase by 45 percent, from $282,000 to $409,000.

The Park Cities are an oddity that contributes to the increase in mean house prices as we restrict our sample. The Park Cities refers to the

[16] This excepts the portions of the Ferris and Grapevine-Colleyville ISDs that fall within Dallas County in which no home sales were reported.

[17] The ISD and city mill rates and homestead exemptions are available at http://www.dallascad.org/TaxRates.aspx.

[18] See https://tea.texas.gov/student.assessment/staar/aggregate/.

[19] If a home is near multiple ISD boundaries, ArcGIS matches the home to the closest boundary. We also explore narrower boundaries but usually do not include these estimates in our tables.

[20] In our pooled sample, 4730 homes are located within 0.20 miles, 4036 homes are located within 0.20–0.35 miles, and 4232 homes are located within 0.35 and 0.50 miles from the ISD boundaries.

Table 1
Summary statistics.

Distance from ISD boundary:	Full Sample		0.50 miles		0.35 miles		0.20 miles	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
House Price ($1000s)	294	334	391	455	417	469	428	470
Assessed Value ($1000s)	282	317	374	431	398	444	409	449
Property Tax Rate	2.21	0.36	2.18	0.36	2.16	0.36	2.15	0.37
ISD Property Tax Rate	1.08	0.22	1.09	0.21	1.09	0.21	1.08	0.21
City Property Tax Rate	0.61	0.13	0.57	0.16	0.56	0.16	0.55	0.17
County Property Tax Rate	0.51	0.07	0.51	0.07	0.51	0.07	0.51	0.07
Test Score	1663	40	1677	48	1681	49	1685	50
Building Characteristics:								
Age of Building	38	23	34	21	34	21	33	21
Internal Area (100 sq. ft)	22	10	24	11	25	12	25	12
Bedrooms	3.34	0.82	3.40	0.83	3.42	0.83	3.41	0.82
Bathrooms	2.40	0.92	2.61	1.01	2.67	1.05	2.70	1.05
Stories	1.54	0.86	1.73	0.94	1.75	0.95	1.78	0.99
Sauna	0.01	0.11	0.02	0.13	0.02	0.13	0.02	0.12
Pool	0.14	0.35	0.18	0.38	0.18	0.39	0.18	0.38
Garage	0.87	0.33	0.91	0.29	0.91	0.29	0.90	0.29
Carport	0.04	0.20	0.03	0.17	0.03	0.18	0.03	0.18
Neighborhood Characteristics:								
Median Household Income ($1000s)	79.11	43.32						
Hispanic	0.28	0.23						
Non-Hispanic White	0.46	0.28						
Non-Hispanic Black	0.18	0.22						
Population Density (1000s per sq mile)	4.58	2.84						
Dist. to CBD (miles)	10.89	4.14						
At Least College Degree	0.28	0.19						
Observations	59,334		12,585		8454		4574	

Notes: The summary statistics are based on the pooled cross sections for the years from 2014 to 2016. Homes with zero property tax liability are excluded. The market price and assessed value are in 2014 dollars. Tax rates are effective rates (i.e., tax liability divided by sales price). The test score equals the average of eighth-grade mathematics and reading STAAR test scores. The number of bathrooms refers to the number of full bathrooms plus 0.5 times the number of half bathrooms. The other-race category is omitted. Distance to CBD is the linear distance between home and downtown Dallas.

adjacent cities of Highland Park and University Park – enclaves surrounded by the City of Dallas, which together form the Highland Park ISD. The Park Cities are very small both geographically and in terms of population. Their area is less than six square miles. They are also one of the richest areas in Dallas County (and in Texas more generally). Many neighborhoods bordering on the Dallas side (of the Park Cities) are similarly wealthy. For example, Dallas Cowboys owner and billionaire Jerry Jones resides in Highland Park. In Preston Hollow, on the Dallas side of the border, both former President George W. Bush and billionaire Dallas Mavericks owner Mark Cuban have homes. Restricting the sample to areas within 0.5 miles of ISD borders causes us to drop most of the Dallas ISD while, based on our ArcGIS analysis, keeping the majority of homes in the much smaller Highland Park ISD. Furthermore, a disproportionate share of properties that are within Dallas ISD and kept in our restricted sample are in very wealthy neighborhoods surrounding Highland Park ISD. In our dataset, the mean house price in Highland Park equals $1.45 million. When we drop Highland Park ISD from our sample, mean house prices fall 12 percent from $294 thousand to $260 thousand (see Table A1 in the appendix). Now consider the subsample within 0.2 miles of an ISD boundary. When dropping properties along the Dallas-Highland Park boundary, mean house prices fall 34 percent from $428 thousand to $281 thousand. The same phenomenon is observed when examining assessed values across subsamples.

Turning to our tax variables, the average overall effective property tax rate (i.e., the summation of ISD, municipality, and county effective rates) for our full sample equals 2.21 percent with a standard deviation of 0.36 percent. The ISD-, city-, and county-level components are 1.08 percent, 0.61 percent, and 0.51 percent, respectively. For properties that fall into both the City of Dallas and Dallas ISD, statutory (marginal) rates average 2.73 percent (whereas average effective rates for this area is 2.08 percent).

Both property taxes and school quality (as proxied by test scores) vary across ISD boundaries. Previous studies find that public-school quality plays an important role in location decisions. For example, Black (1999) and Dhar and Ross (2012), both of which employ boundary fixed effects to control for neighborhood heterogeneity, find a strong positive relationship between willingness to pay and public-school quality.[21] ACS data for Dallas County, for years 2014–2016, show that 87.9 percent of all K-12 students (including 93.1 percent of middle-school students) attended public schools.

We use a three-year moving average of eighth-grade STAAR test scores (averaged by school) as a proxy for school quality. The Texas STAAR test includes mathematics, reading, social studies, and science. Passing it is required for entry into the ninth grade. We merge the test scores into our main dataset by matching homes to 84 middle-school attendance zones. For zones with more than one middle school, we average the test scores over schools.

Fig. 2 shows the location of middle schools along with middle-school attendance zones and school districts in Dallas County.[22] The thick lines are ISD boundaries and the thin lines are attendance-zone boundaries. (Note that attendance zones do not cross ISD boundaries.) We calculate average combined math and reading test scores by middle-school attendance zone. This measure varies substantially across jurisdictions. The mean score across all school zones equals 1663 with a standard deviation of 40 for the full sample. These values remain relatively stable across our three subsamples. For some perspective on student test scores, DeSoto ISD has the lowest average score, at 1632, while Highland Park

[21] Dhar and Ross (2012) also include boundary-side fixed effects to control for the effects of sorting into either side of school district boundaries. They argue that if school district boundaries have been in place for a long time, neighborhood quality differences will develop across a district boundary even though they are close in physical distance.

[22] Each school district includes at least one attendance zone.

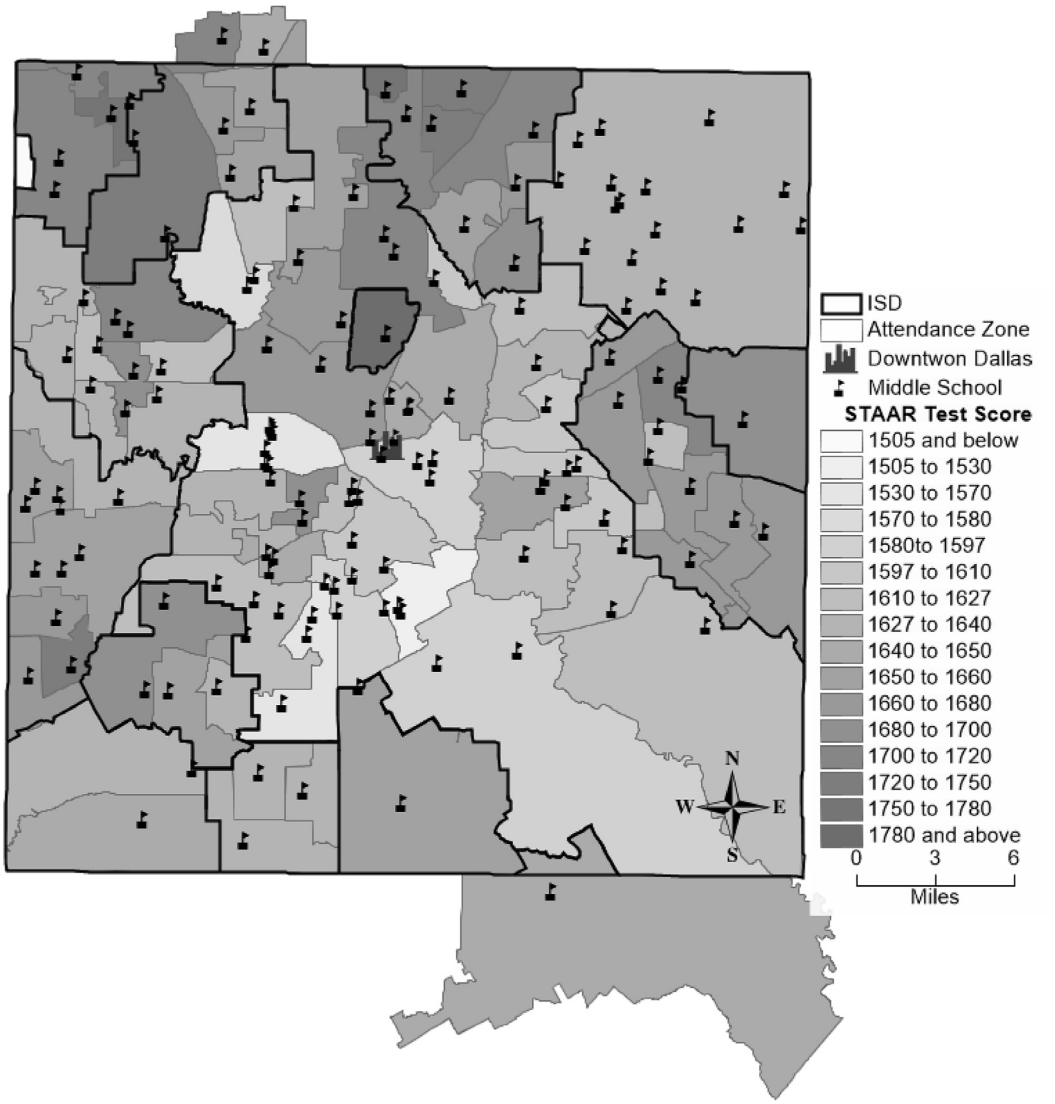

Fig. 2. STAAR test score.
Notes: The average test score equals the mean of 3-year moving averages of eighth-grade mathematics and reading test scores. For attendance zones with more than one school, the test score is averaged over schools.

ISD has the highest score, at 1789.

We control for neighborhood heterogeneity using CBG variables. These include median household income, population density, and dummies for race and education (for those 25 years old or older). These variables are merged into the main dataset via matching homes to our 1669 block groups. In addition, the linear distance from each home to the Dallas city CBD (i.e., the downtown of the City of Dallas) is measured using ArcGIS software.

For our pooled dataset, each property is assigned the median income of its Census block group. The mean of this variable equals $79,110. With respect to race and ethnicity, Dallas County is 46 percent non-Hispanic white, 28 percent Hispanic, 18 percent non-Hispanic black, and 8 percent are of other races. Dallas County's average population density is 4580 people per square mile, and 28 percent of those aged 25 or older have at least a four-year college degree.

3. Capitalization model

3.1. Market value

According to the canonical housing bid-rent model, potential home-buyers consider the value of housing services along with property taxes when choosing between alternative locations (Yinger, 1982). Theoretically, a house's price should equal the present value of housing services net of tax liabilities (see also Oates 1969; Yinger et al., 1988).[23] That is, the market value of a typical property is:

$$P = \sum_{l=1}^{L} \frac{R_l(X, Z, Q)}{(1+r)^l} - \sum_{l=1}^{L} \frac{T_l}{(1+r)^l}, \tag{1}$$

where $R(.)$ is a hedonic function of pre-tax real housing services, which is assumed to be a function of housing characteristics, X (such as age of dwelling, internal area, number of bedrooms, number of bathrooms, etc.), neighborhood characteristics, Z (such as public services, location, crime, population density, traffic congestion, etc.), and public-school quality, Q. For simplicity, let us further assume that property taxes, T,

[23] We are assuming that housing services are net of other costs associated with homeownership (such as maintenance). Note that, in competitive equilibrium, the market value of a property should also equal the present value of user cost, where user cost equals all costs associated with homeownership (such as taxes, maintenance, depreciation net of capital gains, insurance, a risk premium, etc.).

are the only other cost of homeownership. Note that, $T = \tau' P' = \tau P$, where τ' is the statutory mill rate (divided by 1000), P' is the (post-exemption) assessed value, τ is the effective tax rate, and P the market value. Finally, L is the building's useful lifespan and r is the real discount rate.

Equation (1) implies that, holding housing benefits constant, the present value of future property tax payments is fully capitalized into house prices. Therefore, the price differential between two identical properties with the same annual benefits is exactly equal to the difference between their discounted future tax liabilities. This is consistent with the benefit view. The assumption that local public good provision is held constant (across jurisdictions) implies that tax revenues in excess of those spent in the lower-tax jurisdiction are wasted – or that the cost of efficiently providing local public goods differs across the jurisdictions. If, on the other hand, all tax revenues were efficiently spent on prospective improvements to public services, then the benefit view suggests less than full capitalization since expected housing benefits would not be held constant. Note that, under the benefit view, an optimizing jurisdiction is expected to increase (or decrease) taxes until the marginal social benefit from another dollar of public expenditure equals the sum of the marginal private benefit of a dollar plus the marginal excess burden from raising revenue.[24] Thus, a pure benefit tax is a de facto user fee, and thus the marginal excess burden is 0.

3.2. Allowing for partial capitalization

A complication in measuring capitalization is to what degree public benefits are held constant. With only cross-sectional variation, the assumption that observed benefit levels are relatively constant seems tenable. However, time-series variation may signal both a change in prospective taxes and prospective benefits. We will discuss the implications of this in more detail as we proceed.

Empirical studies (discussed earlier) find that the degree of property tax capitalization is not always consistent with equation (1) and may, in fact, also depend on factors such as information asymmetries, expectations about future taxes and benefits, etc. Furthermore, because property taxes are imperfect proxies for user fees, differences in taxes may influence housing capital flows, leaving a reduced effect on house prices. This suggests that, instead of full capitalization, we should consider a capitalization range $\delta \in [0,1]$, such that

$$P = \sum_{l=1}^{L} \frac{R_l()}{(1+r)^l} - \delta \sum_{l=1}^{L} \frac{T_l}{(1+r)^l}. \tag{2}$$

δ equal to 0 implies that the burden of property taxes are fully transferred to new homebuyers, while δ equal to 1 implies that the burden of property taxes are fully borne by current homeowners in the form of reduced market prices.

In other words, δ equals the average per dollar reduction in property values in response to an increase in the present value of tax liabilities. Thus, an increase in property taxes (resulting from an increase in the statutory tax rate) from period 1 to period 2 implies that

$$\delta = -\frac{P_2 - P_1}{\tau_2 P_2 / r - \tau_1 P_1 / r}, \tag{3}$$

where, as defined above, τ is the effective property tax rate, P is the market value of the property, and r is the discount rate. The numerator shows the house-price change brought about by the property tax increase. The denominator shows the change in the present value of tax liabilities from the property, where the property is assumed to exist in perpetuity.

We can replace the numerator with the initial price multiplied by the house-price semi-elasticity, which measures the percent change in house prices associated with a one percentage-point increase in the tax rate, and then multiply by $d\tau$, which is the percentage-point increase in the tax rate. In the denominator, we substitute $\tau_1 + d\tau$ for τ_2 and express P_2 in terms of P_1, where P_2 equals P_1 plus the change in the price brought about by $d\tau$. Thus,

$$\delta = -r \frac{P_1 \frac{dP_1}{d\tau} \frac{1}{P_1} d\tau}{(\tau_1 + d\tau)\left(P_1 + P_1 \frac{dP_1}{d\tau} \frac{1}{P_1} d\tau\right) - \tau_1 P_1}. \tag{4}$$

This further simplifies to

$$\delta = -\frac{r d\tau P_1}{d\tau P_1} \frac{\frac{dP_1}{d\tau} \frac{1}{P_1}}{1 + \tau_1 \frac{dP_1}{d\tau} \frac{1}{P_1} + \frac{dP_1}{d\tau} \frac{1}{P_1} d\tau} = \frac{-r\beta}{1 + \beta(\tau_1 + d\tau)}, \tag{5}$$

where β represents the semi-elasticity of house-prices with respect to a percentage-point increase in the property tax rate. β is the key parameter from our regression analysis and, as shown here, is a sufficient statistic for assessing the capitalization effect from a change in property tax rates. Note that δ should be thought of as a marginal effect. I.e., it applies to the effect of a change in tax rates or to the differential in tax rates between jurisdictions. This effect may be very different from the average capitalization effect, in which the capital tax (i.e., "new") view must also be considered.

4. Empirical methodology

4.1. Hedonic price equation

Consider the following hedonic price equation applied to repeated cross-sectional data,

$$\ln(P_{ht}) = \alpha + \beta \tau_{ht} + X_{ht}^{'} \gamma + \theta Q_{ht} + Z_h^{'} \eta + \lambda_t + \varepsilon_{ht}. \tag{6}$$

$\ln(P_{ht})$ is the natural log of the sales price of house h in year t. τ_{ht} is the corresponding effective property tax rate.[25] Matrices X, Z, and (vector) Q include variables that contribute to housing desirability as defined in equation (1). λ_t is a vector of time fixed effects (including month and year dummies). Finally, ε_{ht} is the regression error term.

4.2. Obstacles to identification

As discussed in the preceding section, our primary parameter of interest is β, which is central to calculating the overall degree of capitalization. β is a semi-elasticity measuring the change in house prices (in percent form) resulting from a one basis-point increase in the property tax rate. A complication in identifying β arises because some neighborhood characteristics are either unobservable or difficult to quantify (such as public services and local amenities and disamenities). This could bias estimates of β if changes to property taxes directly influence public services. Furthermore, the baseline ordinary least squares (OLS) model suffers from simultaneous-equations bias because the effective property tax rate equals the nominal tax rate times the post-exemption assessed value divided by the market price,

$$\tau = \frac{\tau' \cdot P'}{P}. \tag{7}$$

In other words, τ may be negatively or positively correlated with the dependent variable (and thus the error term), with the direction of the bias depending on the relationship between assessed and market

[24] This follows from the Samuelson condition, where private expenditures represent the opportunity cost of public spending.

[25] Unless otherwise noted, τ_{ht} is the overall ETR accounting for city, ISD, and county property taxes. In many cases, we will instrument for this variable (with a base-specific statutory rate) in order to isolate the effects from a particular taxing jurisdiction.

values.[26] In one scenario, if the post-exemption assessed value (P') is held constant, OLS applied to equation (6) is likely to yield an overestimate of the degree of capitalization, i.e., a $\hat{\beta}$ that is negatively biased. In a second scenario, if the assessed and market values perfectly track each other, then τ increases with the sales price. This implies the standard endogeneity issue encountered with graduated tax schedules. Because the degree of graduation is relatively modest with the property tax, reverse causality from this correlation is much weaker, and thus not nearly as problematic, than in studies looking at income taxes.

To address the issue of unobserved neighborhood characteristics, we follow Black (1999) by first limiting our sample to houses within a short distance (for example, a half mile) of ISD boundaries. Then, we add to equation (6) the full set of boundary fixed effects. This also helps address ambiguities that may arise in measuring the distance to the central business district (CBD) when there are multiple employment and recreational centers (Cushing, 1984). The modified model becomes

$$\ln\left(P_{hbt}\right) = \alpha + \beta\tau_{ht} + X_{ht}^{'}\gamma + \theta Q_{ht} + \varphi_b + \lambda_t + \varepsilon_{ht}, \quad (8)$$

where φ_b is an indicator variable denoting house location with respect to boundary b.[27] In other words, one dummy is included per boundary.

Note that ISD boundaries within Dallas County are sometimes long such that houses may be miles apart along a boundary, even though they are close to the boundary.[28] Thus, neighborhood heterogeneity along a boundary is likely. To account for this heterogeneity, we create half-mile blocks along ISD boundaries using ArcGIS mapping software. Then, we include a full set of block fixed effects, or "block" dummies, in place of "boundary" dummies to control for neighborhood heterogeneity.[29] See Fig. 3 (created using Maptitude and ArcGIS software) showing blocks along the Dallas-Highland Park ISD boundary. Blocks are 0.5 miles in width, where one side of each block coincides with a district boundary. Smooth adjustments are made to the block borders to account for nonlinearities in jurisdictional boundaries. Properties may only fall into a single block. Thus, some blocks are truncated so as not to overlap.

By including block fixed effects, we relate deviations from boundary-side mean housing values on opposite sides of ISD boundaries to differences in property tax rates while controlling for physical characteristics, neighborhood characteristics, and public-school quality. Block fixed effects (φ_{block}) capture the hedonic value placed on the bundle of characteristics unique to that block and relative to the reference block (Gallagher et al., 2013).

Following Yinger et al. (1988), we instrument for the effective property tax rate using the statutory rate. Instrumenting is important for two reasons. One, even with a flat statutory tax rate, exemptions make for a graduated tax system. Instrumenting allows us to isolate the effect of an increase in tax rates on house prices, as opposed to the mechanical effect of increasing house prices on tax rates. Second, we instrument in order to separately isolate the effects of city and ISD property taxes.[30] Given that the effective rate equals the nominal rate times the property's post-exemption assessed value divided by the sales price (i.e., $\tau = \tau' P' / P$), this instrument is strongly correlated with the endogenous variable. The first-stage test rejects the weak instrument hypothesis with 99-percent confidence. (See Appendix A, Table A2 and A3.) Moreover, since changes to the nominal property tax rate are independent of changes to property values, the instruments should be exogenous.[31]

5. Results

5.1. ISD property tax capitalization

5.1.1. ISD elasticity estimates

Table 2 includes OLS and two-stage least squares (2SLS) regression results. Row 3 reports the estimated semi-elasticity of house prices with respect to the property tax rate. Column (1) shows baseline OLS estimates (from equation (6)) for the full sample, controlling for neighborhood and housing characteristics, as well as school test scores. Column (2) presents analogous results after instrumenting for the overall effective property tax rate using statutory ISD property tax rates.[32]

In column (1), the OLS estimated coefficient on the property tax rate is −0.21 when including CBG controls for neighborhood quality. Because our dependent variable is in log form and the tax rate variable is measured as a percentage – as opposed to log or decimal form – our estimates show the effect of a one basis point (i.e., a 0.01 percentage point) increase in the effective property tax rate on the percent change in house prices.[33] Thus, the estimate in column (1) implies that a 10-basis point increase in the property tax rate decreases housing values by 2.1 percent. Moving to column (2), where we continue to use the full sample but now instrument for the ETR using the statutory ISD tax rate, a 10-basis point increase in the ISD property tax rate decreases housing values by 2.8 percent.[34] The estimates for OLS and 2SLS are similar, but they measure different effects. In addition to controlling for endogeneity in the ETR, the instrument allows us to isolate the response from the ISD tax rate apart from the city tax rate. Thus, column (1) shows the estimated effect from changes to both the city and ISD tax rates, whereas column (2) shows the effect from variation in only the ISD tax rate. We will see later that the capitalization effects from ISD and city taxes may be quite different.

An important strand of the tax-capitalization literature, as discussed earlier, questions whether observable neighborhood characteristics are sufficient to capture neighborhood quality. In column (3), we address this issue by restricting the sample to houses within 0.5 miles of ISD boundaries, where neighborhoods tend to be more homogeneous. When restricting the sample to bands around boundaries, we continue to include CBG controls to account for heterogeneity on the boundary, which could result from sorting (Bayer et al., 2007). (However, excluding CBG variables has virtually no effect on our ISD estimates when also restricting the sample to properties within 0.5 miles of a boundary.)

Here, the estimated capitalization effect is lower (compared to the corresponding full sample estimate in column (2)), implying that a 10-basis point increase in the property tax rate lowers property values by

[26] Note that division bias is not present in our model because we use actual sales prices (and not estimates).

[27] The focus here is on property tax capitalization from ISD taxes. We also apply an analogous approach to estimate property tax capitalization from city taxes by restricting the sample to houses located along municipality boundaries.

[28] For example, the length of the Dallas-Richardson boundary is about 21 miles. The length of the Dallas-Carrolton boundary is 16 miles, while the Sunnyvale-Mesquite boundary is 10 miles.

[29] This yields 166 half-mile blocks around ISD boundaries within Dallas County. See Gallagher et al. (2013) who employ a similar approach.

[30] In one set of analyses, we instrument for the overall ETR using the ISD statutory rate. This exercise is then repeated, focusing on city and instrumenting for the overall ETR using the city statutory rate.

[31] According to Lutz et al. (2011), local policymakers may "adjust the effective property rates by altering the statutory tax rate or by altering the way in which property is assessed for tax purposes." However, this adjustment process often occurs with a three-year lag.

[32] Neighborhood controls include median household income, population density, race and ethnicity, and the percentage of those aged 25 or over with at least a college degree. Property-specific controls include dwelling age, internal square footage, number of bedrooms, number of bathrooms, and indicator variables for the pool, sauna, garage-carport, AC, and heat.

[33] An equally valid, but less practical, interpretation of the tax coefficient is the percent change in *decimal form* associated with a one-percentage point increase in the property tax rate. I.e., a one-percentage-point increase in the property tax rate lowers property values by 21 percent.

[34] Estimates on our control variables are generally consistent with theoretical predictions. For example, house prices increase with neighborhood median income and decrease with distance to CBD. Housing prices increase with population density.

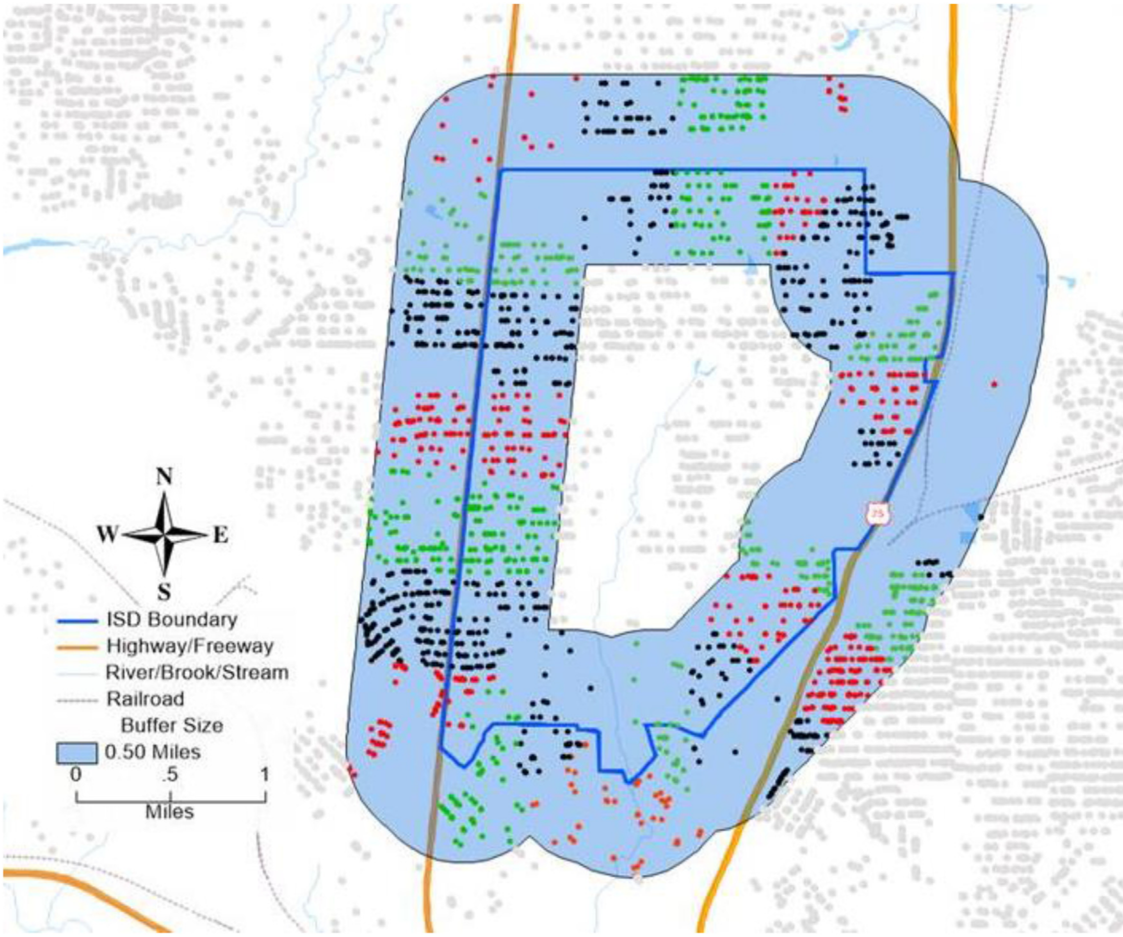

Fig. 3. Half-mile blocks around the Highland Park and Dallas ISD boundary.
Notes: Authors' calculations using Maptitude and ArcGIS software and DCAD data. Light gray dots represent properties more than 0.5 miles from the boundary and thus not included in any blocks. Black, red, and green dots represent properties within 0.5 miles of a boundary. Property colors are alternating from block to block. Properties may fall within only one block. A property falling within 0.5 miles of boundaries for more than one block is assigned to the block with the nearest boundary.

2 percent. Also, the estimated coefficient on school test scores nearly doubles (compared to column (2)) to 1.91. This estimate implies that a one standard deviation increase in eighth-grade test scores results in a 4.5 percent increase in house prices.[35] This is a hedonic estimate of the value that homeowners place on increases in school quality. Estimated coefficients for the physical characteristics remain statistically unchanged.

Column (4) includes half-mile block fixed effects (instead of boundary fixed effects) to account for possible neighborhood heterogeneity along district boundaries. Before estimating this specification via 2SLS, we present OLS estimates for comparison. Thus, in column (4), we include the actual ETR without instrumenting. This implies that a 10-basis point increase in ISD property tax rates is associated with a 2.8 percent decline in property values. This result is robust to narrowing the blocks below 0.5 miles. These stronger controls, when also instrumenting for the ETR, yield a very similar estimate – showing that a 10-basis-point tax increase is associated with a 2.5 percent decline in property values (column (5)). Continuing to employ block fixed effects, while narrowing the sample to properties within 0.35 or fewer miles from an ISD boundary, the estimated tax coefficient stabilizes at about −0.2 (or −2 percent for a 10-basis-point tax increase). Also of interest, with block fixed effects, the estimated hedonic value of a one standard deviation change in school test scores ranges from 3.7 to 4.2 percent of house prices. Excluding the school test score from the right-hand side of the regression results in larger estimates (in absolute magnitude) on the tax variable. This suggests that the effects of tax changes are partially offset by changes in school quality.

The fact that the specification in column (5) includes strong controls and that the estimates are robust to narrowing the boundary below 0.35 miles suggests that it is identified. While the corresponding OLS estimates are similar, we maintain that instrumenting is important. We instrument using statutory tax rates partly because ETRs and property values are simultaneously determined (as discussed earlier). But we also instrument in order to isolate responses to ISD taxes apart from city taxes. Without instrumenting, our key independent variable includes a mixture of variation from ISD and city taxes. If ISD and city boundaries are rarely close together, block fixed effects would still separate responses from the two taxes. However, since city and ISD boundaries often overlap, OLS estimates may pick up the effects of variation in both tax rates (even with block fixed effects).

To examine this further, we re-estimate our OLS specifications while including separate ETRs, one for the city and one for the ISD. When imposing block fixed effects along ISD boundaries, estimated semi-elasticities (with respect to the ISD ETR) are often positive and sometimes statistically different from zero.[36] This is consistent with the presence of endogeneity, where ETRs and property values are

[35] Note, the regression estimates the effect of a one percent increase in test scores. A one standard-deviation increase in the test score variable is equivalent to a 2.35 percent increase (relative to the sample mean).

[36] These results are not included in our tables.

Table 2
Regression results: ISD property tax capitalization.

Dep. variable: ln(house price)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	2SLS	2SLS	OLS	2SLS	2SLS	2SLS
ISD Boundary Restriction:	Full Sample	Full Sample	0.50 miles	0.50 miles	0.50 miles	0.35 miles	0.20 miles
$\hat{\delta}_\tau$ – capitalization rate (full)	0.80	1.54	0.70	1.45	1.12	0.73	0.85
$\hat{\delta}_{ISD}$ – capitalization rate (ISD)	0.55	0.83	0.50	0.80	0.69	0.52	0.58
Tax Rate	−0.212**	−0.284**	−0.197*	−0.278**	−0.250**	−0.201**	−0.219*
	(0.005)	(0.011)	(0.096)	(0.021)	(0.062)	(0.070)	(0.092)
ln (Test Score)	1.107**	1.005**	1.915**	1.712**	1.832**	1.915**	1.675**
	(0.061)	(0.061)	(0.610)	(0.482)	(0.509)	(0.522)	(0.625)
Age (10s)	−0.132**	−0.134**	−0.130**	−0.103**	−0.102**	−0.088**	−0.099**
	(0.002)	(0.002)	(0.026)	(0.014)	(0.015)	(0.016)	(0.020)
Age-squared (100s)	0.015**	0.015**	0.015**	0.012**	0.012**	0.010**	0.011**
	(0.000)	(0.000)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Living Area (100s)	0.033**	0.033**	0.031**	0.030**	0.030**	0.029**	0.028**
	(0.000)	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Bedrooms	0.067**	0.067**	0.074**	0.088**	0.087**	0.083**	0.086*
	(0.007)	(0.007)	(0.018)	(0.019)	(0.019)	(0.020)	(0.035)
Bedrooms-squared	−0.013**	−0.012**	−0.012**	−0.013**	−0.013**	−0.012**	−0.013*
	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)	(0.003)	(0.006)
Bathrooms	0.274**	0.279**	0.254**	0.220**	0.218**	0.205**	0.218**
	(0.008)	(0.009)	(0.019)	(0.020)	(0.020)	(0.027)	(0.031)
Bathrooms-squared	−0.034**	−0.035**	−0.032**	−0.028**	−0.027**	−0.025**	−0.027**
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Median household income ($1000s)	0.009**	0.009**	0.004**	0.005*	0.005*	0.003	0.006*
	(0.000)	(0.000)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
Population density (1000s)	0.013**	0.013**	−0.004	−0.005	−0.005	−0.006	−0.008
	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Dist. to CBD (miles)	−0.019**	−0.017**	−0.018**	−0.004	−0.005	−0.012	0.016
	(0.000)	(0.000)	(0.005)	(0.012)	(0.012)	(0.011)	(0.021)
Hispanic	−0.141**	−0.133**	−0.063	−0.061	−0.057	−0.073	−0.011
	(0.013)	(0.013)	(0.072)	(0.078)	(0.080)	(0.080)	(0.104)
Non-Hispanic white	0.247**	0.260**	0.112	−0.046	−0.046	−0.142*	−0.109
	(0.011)	(0.011)	(0.065)	(0.067)	(0.067)	(0.071)	(0.090)
Non-Hispanic black	−0.430**	−0.416**	−0.048	−0.003	−0.001	−0.056	−0.041
	(0.011)	(0.011)	(0.097)	(0.080)	(0.080)	(0.099)	(0.110)
At least college degree	1.125**	1.132**	0.415**	0.271**	0.271**	0.241*	0.129
	(0.014)	(0.014)	(0.066)	(0.085)	(0.086)	(0.093)	(0.105)
Observations	59,334	59,334	12,517	8952	8952	6098	3253
R-squared	0.871	0.870	0.754	0.700	0.699	0.689	0.666
Boundary FE	NO	NO	YES	NO	NO	NO	NO
Block FE	NO	NO	NO	YES	YES	YES	YES

Notes: For 2SLS specifications, the effective tax rate is instrumented with the ISD statutory tax rate. The "other-race" category is omitted as the reference group. Estimates on some building characteristics (such as sauna, pool, garage-carport, number of stories, AC, and heater), and boundary (or block) fixed effects are suppressed. Year and month fixed effects are included in all columns. Robust standard errors in parentheses. Standard errors are clustered at the boundary or block level where appropriate. $^{**}p < 0.01$, $^{*}p < 0.05$.

simultaneously determined. With respect to the city tax rate, these specifications yield estimates that are negative and greater than −1 (in absolute magnitude). However, here, when identifying based on ISD boundaries, city ETRs are better viewed as controls not designed to yield identified semi-elasticities.

5.1.2. *Exploring additional controls*

Smooth price trends that extend across blocks and through boundaries could complicate our identification strategy (Turner, Haughwout, and van der Klaauw, 2014). For example, such trends might reflect transportation costs to some desired location (that lies beyond the blocks of observations used in the sample). If unaccounted for, our approach could misinterpret such trends as a boundary effect. To test for this possibility, we re-estimated our model, adding a trend variable that accounts for distance to a boundary. The trend variable equals the negative distance to the boundary on one side and the positive distance to the boundary on the other side. This variable was not statistically significant and had almost no impact on our estimated tax effects, implying that such price trends were not contaminating our core estimation strategy.

By including test scores, along with other controls, our intent is to measure the capitalization effect of tax changes, holding constant school quality. However, the housing market may account for expected changes to school quality that are not captured by these controls. For example, it may take a number of years before an improvement to the school system results in appreciably higher test scores. To address this issue, we re-estimated Table 2 after adding the log of fifth-grade class size. This variable is arguably a forward-looking measure, possibly capturing changes to school quality in advance of changes to test scores. The estimated coefficient on the log of fifth-grade class size is negative and statistically significant for the full sample, but it is not statistically significant for any of the samples using boundary or block fixed effects. For the full sample, the tax semi-elasticity is almost the same (−0.27 versus −0.28 in Table 2). Results are similarly robust for columns 1–6 (of Table 2). The exception is column 7, where the estimate falls in size by half and is no longer statistically significant. Note, column 7 may be more sensitive since it relies on so few observations – excluding almost 95% of observations from the full sample.

5.1.3. *ISD capitalization rates*

Our preferred semi-elasticity estimate, with respect to the property tax rate, is between −0.2 and −0.25, which is consistent with a capitalization rate of between 70 and 112 percent, where the rate of capitalization (defined as δ in Section 3) equals the ratio of the change in property values over the change in discounted property tax payments. See row (1) of Table 2. We will define this capitalization rate, with respect to the total (as opposed to a jurisdiction-specific) property tax rate, as δ_τ. (I.e., it includes changes to discounted property tax liabilities owed to city or county authorities, not just those owed to the ISD.) In calculating δ_τ, we assume a discount rate of 2 percent, a starting effective tax rate equal to the overall mean property tax rate (of 2.2 percent), and a one-percent increase in the overall property tax rate.[37] δ_τ relies not only on the inputted discount and tax rates but also on the assumption that the model fully captures future amenities. Assumptions regarding future amenities and costs are discussed in greater detail later in this section.

The choice of discount rate is important for our estimates. Our choice of 2 percent is in line with the Council of Economic Advisors (CEA, 2017), who report that real rates of return and discount rates have fallen considerably in recent decades. However, some, such as Koster and Pinchbeck (2018), suggest a higher range of between 3 and 4 percent. Note that $\widehat{\delta}$ is directly proportional to the choice of discount rate. Thus, readers can easily adjust our numbers based on their preferred discount rate. For example, a discount rate of 1 percent would cause $\widehat{\delta}$ to fall by 50 percent, whereas a discount rate of 4 percent would cause $\widehat{\delta}$ to double.

In a related paper, Livy (2018) reports semi-elasticities between -0.15 and -0.38 based on variation in school district taxes within for Franklin County Ohio.[38] Livy calculates a capitalization rate of 58 percent for his semi-elasticity estimate of -0.29, when assuming a 2-percent discount rate. Applying our capitalization measure to this estimate yields greater than full capitalization. This highlights an important difference between our measure and Livy's. Livy's measure is independent of the property tax rate and does not account for revenue feedback effects (from capitalization). That is, he estimates the capitalization effect from raising one additional dollar of revenue through the property tax, assuming no second-order revenue effects from the contraction in the tax base. The difference between our measures, thus, increases with the elasticity of the tax base *and* with the overall level of the property tax rate.[39] For example, our measures would be identical when considering the introduction of a small property tax in an area with no existing property taxes. However, in Dallas County, where combined property tax rates often exceed 2 percent, even modest elasticities imply substantial feedback effects, offsetting much of the revenue gain from a rate increase.[40]

In another related study, Gallagher et al. (2013) use half-mile block fixed effects along ISD boundaries to estimate property tax capitalization in Cook County, Illinois (excluding the City of Chicago). They report a semi-elasticity of -0.34. Assuming a discount rate of 1 percent, they estimate close to full capitalization. However, this estimate is sensitive to their assumptions. Given our assumptions, their estimate would imply that overall property tax rates in Cook County were beyond revenue-maximizing rates.

As a reference point, consider the semi-elasticity associated with full capitalization. This value is easily derived from equation (5) by setting $\delta_\tau = 1$. Therefore, full capitalization implies that

$$\beta^* = \frac{-1}{(\tau^* + d\tau) + r}. \tag{9}$$

Given our assumptions, full capitalization yields a β^* of -0.237. For most of our specifications, point estimates imply that, at the margin, the incidence of the tax is shared between current homeowners and prospective homebuyers; however, the null of full capitalization cannot be rejected. This coupled with the fact that the null hypothesis of no capitalization effect (i.e., $\beta = 0$) is soundly rejected, suggests that the benefit view likely plays an important role for the ISD tax – at least for a large urban area such as Dallas with numerous school districts in close proximity.

The sensitivity of our capitalization rates with respect to τ and r is easy to assess, as long as one is willing to assume that these rates are constant over time. As equation (5) makes clear, a change to r will have a direct and proportional effect on δ_τ. With regard to the tax rate, holding r constant, δ_τ increases with τ because, while capitalization (i.e., the numerator of δ_τ) is assumed linear, revenues from increasing τ (i.e., the denominator of δ_τ) increase at a diminishing rate, until the revenue-maximizing property tax rate (i.e., $\tau^{MAX} = -1/\beta$) is reached. For example, if τ were reduced by 25 percent, from 2.2 percent to 1.65 percent, δ_τ in column (6) would fall from 0.73 to 0.60.

Interpreting the estimates of δ_τ in row 1 as the reduction in property values associated with a one-dollar increase in school district property taxes is not quite accurate. This is because the capitalization effect means that city and county property tax revenues fall somewhat in response to the increase in ISD tax rates. Thus, a one-dollar increase in property tax revenue from increasing the rate on the ISD portion of the property tax must raise somewhat more than one dollar for schools in order to offset losses in the overlapping tax bases. With overlapping tax bases, each property tax jurisdiction imposes a fiscal externality on the other overlapping jurisdictions whenever it changes its tax rate.

An alternate formulation, labeled δ_{ISD} and associated with a one dollar increase in ISD property tax revenue, is presented in row (2). Here, the denominator (from equation (5)) is no longer the change in overall property tax revenue but rather the change in jurisdiction-specific property tax revenue. Thus, for an exogenous one dollar increase in ISD property tax revenue, property values fall by 52 cents (column (6)). The β^*, full capitalization rate, with respect to only the ISD tax is -0.32. Thus, we can reject both the null hypothesis of the $\delta_{ISD} = 0$ and the null of $\delta_{ISD} = 1$. It is plausible that the jurisdiction-specific capitalization rate, δ_{ISD}, may be more revealing than the measure with respect to overall revenue changes, δ_τ. This is because δ_τ accounts for revenue effects from overlapping tax bases but does not account for benefit changes in these overlapping bases (assuming that the revenue feedback effects from capitalization lag tax changes).

As noted by Bradley (2017), less than full capitalization can occur for several reasons. First, the traditional view predicts this because it treats the property tax as an excise tax falling mainly on mobile capital. Second, recent tax rate changes may be perceived as temporary. Third, the ability to deduct state and local taxes from federal taxable income reduces the property tax burden. Fourth, property taxes may signal prospective changes to public services (not captured in contemporaneous control variables). Fifth, tax rate differentials (between jurisdictions) may not be fully salient to homebuyers, attenuating tax responses (e.g., see Chetty et al., 2009).

5.1.4. *δ and the benefit tax view*

The property tax as a pure benefit tax implies that local taxes should be fully capitalized into property values, provided that benefit levels are held constant. While this view, of the ISD property tax as a pure benefit tax, cannot be rejected, other views of shared incidence also cannot be rejected. While a pure benefit tax implies full incidence on current

37 Larger tax increases imply somewhat larger capitalization rates because marginal revenue declines with τ (as the tax base contracts).

38 He reports an estimate of -0.39 when employing property-level fixed effects to a sample restricted to repeat sales.

39 Ignoring second-order effects understates the true capitalization rate (for anything more than an infinitesimal change to the tax rate); however, it does have the virtue that the measure is not distorted as tax rates approach the revenue-maximizing rate. For example, our measure becomes undefined as the revenue-maximizing rate is approached.

40 Note some other distinctions between this paper and Livy's. Livy's data span 15 years, allowing for much greater time-series variation in tax rates (and for the possibility of property-level fixed effects). Livy does not produce estimates with respect to other tax bases, such as for cities. In terms of methodology, Livy appears to include the statutory tax rate directly in his regressions instead of using it as an instrument for ETR.

homeowners, the traditional or excise tax view does not imply 100-percent incidence on new buyers.[41] Because land is an important component for housing, the excise tax view implies at least some incidence on current homeowners.

And, while capital, the major component of housing, is quite mobile between jurisdictions, this mobility is far from instantaneous. It takes time for new housing to be built or for existing housing to depreciate. Because of adjustment costs, current homeowners may still bear a substantial share of property tax changes – even for the capital component – under the excise tax view. See Auerbach (2006), who demonstrates that the speed adjustment (i.e., capital mobility) can have important implications for the long-run incidence of changes to capital taxation.

5.1.5. δ and ISD services

The benefit view prediction of full capitalization is predicated on the assumption that differences in public services are fully taken into account. Test scores may be a good indicator of school quality and a measure available to parents. However, to the extent that this measure is incomplete, unobserved differences in school quality across ISD boundaries may remain.[42] It thus follows that variation in ISD taxes could be picking up effects from these unobserved differences.

Another assumption of our model is that tax changes do not affect prospective benefits from public schools – or that tax changes are not influenced by changes to expected costs. At one extreme, a change in ISD taxes may alter expectations of future benefits from schools without having any effect on current period benefits. Under this scenario, the benefit tax view – rather than predicting full tax capitalization – predicts that house-price changes will equal the residual between changes to tax liabilities and the changes to future benefits (both measured in present value terms). Thus, efficiency is maximized when the marginal effects are exactly equal, implying no change to house prices (for small changes in taxes).

Thus, under this scenario (where tax changes always lag changes to public benefits), $\delta_{ISD} = 0.52$ (Table 2, column (6)) implies that homeowners are worse off by \$0.52 for the marginal dollar transferred from private to public ISD spending. If tax rates in overlapping jurisdictions are set optimally, then no fiscal externalities exist (via the envelope theorem) since the costs and benefits from small changes to spending in these jurisdictions exactly offset. If taxes in overlapping jurisdictions are above (below) the optimum level, then the net cost to homeowners from increasing ISD revenue by \$1 would be less (greater) than \$0.52.

5.1.6. Confidence intervals for $\widehat{\delta}$

Table 3 presents 95-percent confidence intervals for $\widehat{\delta}$ assuming a discount rate of 2 percent. Like our point estimates, the confidence intervals are also proportional to the choice of discount rate. Thus, a discount rate of 1 percent would cut the range of our confidence interval in half, while a discount rate of 4 percent would double it.

Note that even high statistical significance on our semi-elasticity estimates still results in confidence intervals (for $\widehat{\delta}$) that span a wide range of possibilities. When employing block fixed effects (columns (5)–(7)), lower-bound estimates – where the denominator includes revenue offsets from overlapping tax bases) – always suggest substantial tax capitalization. However, less than full capitalization cannot be ruled out.

When the denominator of δ includes only revenue from the ISD tax base, $\widehat{\delta}$ ranges from 0.69 to 1.27 when including 0.5-mile block fixed effects. Narrowing the blocks (columns (6)–(7)) results in larger standard errors and thus wider confidence intervals. It is noteworthy that our lower bounds always rule out the possibility of no capitalization.

5.1.7. δ and endogenous property tax changes

We instrument to control for endogeneity between property tax rates and property values. (Since exemptions make for a graduated system, increasing property values, all else equal, increase effective property tax rates.) However, it is possible for property tax rate changes themselves to be endogenous. Tax elasticity interpretations may be very different if, for example, a tax increase were not random but instead were in response to an unobserved shock that raises expected costs for providing the same services. Likewise, an unobserved factor that causes property values to rise could lead to a cut in property tax rates since the same revenue (and services) could now be raised with lower rates.

The likelihood of bias from endogenous tax changes is lessened by our research design. Any county-specific shock will impact all ISDs in our sample, so should not bias estimates unless these effects have a heterogeneous effect across ISDs. Likewise, restricting the sample to properties near ISD boundaries and including boundary or block fixed effects further lessens potential biases from endogenous tax changes. For example, an unobserved exogenous shock is likely to have similar effects over a small area along a boundary.

However, the possibility of an impactful (and unobserved) ISD-specific shock that influences property taxes cannot be completely ruled out. For example, suppose one ISD discovers asbestos in many of its school buildings that must be remedied. These added and unexpected costs from remediation may result in an ISD tax increase, while adjacent ISDs are unimpacted. While we cannot rule out such ISD-specific shocks, we suspect that these are not the norm and that it is reasonable to view our estimates as responses to exogenous tax changes.

5.2. City property tax capitalization

5.2.1. City elasticity estimates

Here, we investigate the effect of city property taxes on house prices. Following a procedure analogous to the one applied in Section 5.1 (to examine the effect of ISD property taxes on housing values), we restrict the sample to homes within 0.5 miles of city (as opposed to ISD) boundaries. Note that our tax-rate variable is constructed in the same manner as in the previous (ISD) analysis. However, here, we instrument using the statutory city tax rate.

We first run 2SLS on the full sample, which yields a semi-elasticity of −0.09. See Table 4, column (1). This is about half the size of the full sample estimate when using the ISD-specific tax instrument. When applying boundary fixed effects (column (2)) and restricting the sample to properties within 0.5 miles of city boundaries, the semi-elasticity estimate is −0.22.

We next explore block fixed effects, our strongest control for unobserved heterogeneity. As with the ISD-based analysis, we first present OLS estimates for properties within 0.5 miles of city boundaries. This yields an estimate of −0.28 (see Table 4, column (3)). This is about the same as the corresponding OLS estimate for focusing on ISD boundaries, but, as we shall see, this estimate is very different from our corresponding 2SLS estimates for cities using block fixed effects.

With the strongest set of controls, block fixed effects produce larger and stable semi-elasticity estimates of between −0.41 and −0.45, depending on the distance restriction around city boundaries. These estimates (with block fixed effects) are roughly twice the size of estimates for the comparable ISD specifications in Table 2.[43]

[41] Because we measure the effects of small changes to property tax rates, we can only assess the effects of property taxes at the margin and, for example, cannot assess whether the overall property tax is borne by capital owners more generally.

[42] Identification does not rely on the ability of test scores to explain the overall willingness to pay for schools, but rather the differential in scores across boundaries should explain the differential in willingness to pay.

[43] As with our ISD estimates, we also tried adding a trend variable to account for the possibility of smooth price trends extending across blocks and through boundaries. Here too the estimated coefficient on this trend variable was statistically insignificant and our estimated tax effects were not impacted.

Table 3
Capitalization rates ($\hat{\delta}$) and 95% confidence intervals.

Dep. variable: ln(house price)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	2SLS	2SLS	OLS	2SLS	2SLS	2SLS
Boundary Restriction:	Full Sample	Full Sample	0.50 miles	0.5 miles	0.5 miles	0.35 miles	0.2 miles
ISD Boundaries							
Full Tax Base							
$\hat{\delta}_\tau$, $r = 0.02$	0.80	1.54	0.70	1.45	1.12	0.73	0.85
Upper Bound, $r = 0.02$	0.87	1.90	5.34	2.19	4.26	2.72	7.09
Lower Bound, $r = 0.02$	0.73	1.26	0.02	1.00	0.36	0.15	0.08
ISD Tax Base Only							
$\hat{\delta}_{ISD}$, $r = 0.02$	0.55	0.83	0.50	0.80	0.69	0.52	0.58
Upper Bound, $r = 0.02$	0.59	0.93	1.35	0.99	1.27	1.08	1.44
Lower Bound, $r = 0.02$	0.52	0.74	0.02	0.64	0.30	0.14	0.08
City Boundaries							
Full Tax Base							
$\hat{\delta}_\tau$, $r = 0.02$	0.80	0.23	0.92	1.45	99.24	43.88	8.97
Upper Bound, $r = 0.02$	0.87	0.37	114.02	1.94	−3.73	−3.76	−4.34
Lower Bound, $r = 0.02$	0.73	0.13	0.02	1.11	1.78	1.63	1.13
City Tax Base Only							
$\hat{\delta}_{city}$, $r = 0.02$	0.55	0.20	0.53	0.67	1.24	1.22	1.10
Upper Bound, $r = 0.02$	0.59	0.30	1.77	0.93	3.48	3.46	3.08
Lower Bound, $r = 0.02$	0.52	0.12	0.02	0.69	0.90	0.86	0.69
Boundary FE	NO	NO	YES	NO	NO	NO	NO
Block FE	NO	NO	NO	YES	YES	YES	YES

Notes: Confidence intervals are produced for capitalization rate point estimates reported in Tables 2 and 4.

5.2.2. δ and city property taxes

The estimated tax coefficients from the specifications that include block fixed effects imply that the overall property tax rate (of 2.2 percent) is very close to the revenue-maximizing tax rate. Thus, δ_τ (the change in property values, in absolute magnitude, divided by the change in tax revenues) is not meaningful. That is, the denominator is close to 0 yielding huge capitalization rates that are extremely sensitive to small changes to parameters.

Here, the null hypothesis that property tax rates are less than or equal to the rate associated with full capitalization is rejected (for columns (4)–(6)), while the null hypothesis that rates are less than or equal to the revenue-maximizing tax rate cannot be rejected.[44] The fact that rate increases appear to not even raise revenue at the margin suggests that tax rates are well above optimal.

One possible explanation for such large effects is that market participants perceive changes in tax rates not as a shift to a new steady state but as a signal of more changes to come. Mean-reverting tax changes, where a tax increase now is associated with a tax reduction later, is one possibility. Controlling for public services expectations of mean-reverting tax changes should result in a lower capitalization rate than otherwise. Alternatively a tax change could signal a trend, raising expectations of future tax changes in the same direction. Under this scenario, traditional methods would overstate the degree of capitalization (by failing to account for changes in expectations regarding future tax rates). We tested for this possibility, employing a panel unit root test, proposed by Levin et al. (2002). We strongly rejected the null hypothesis of a unit root in city statutory rates.[45] In fact, statutory tax rates within Dallas County appear to follow a random walk.

Another factor that could make identification more difficult is if city boundaries tend to coincide with geographical boundaries. This would attenuate our assumption that areas on either side of a boundary are homogeneous. It is not unusual for neighborhoods to differ greatly when crossing an impassable boundary, such as an expressway. However, by including geographical boundaries in Fig. 1, it appears that this is not a major issue. In general, the correlation between city and geographic boundaries is weak, with the exception primarily of boundary segments between the City of Dallas and cities, such as Farmers Branch, University Park, and Highland Park.

5.2.3. δ and fiscal externalities

After controlling for neighborhood and property characteristics, it would seem that responses to an exogenous increase in property taxes would be the same independent of the source. However, note that the city property tax rate within Dallas County is, on average, a little more than half the rate for the ISD property tax.[46] As a result, fiscal externalities from the city tax – i.e., costs borne on overlapping tax bases – are more pronounced than for ISD taxes. Fiscal externalities from an increase in the tax rate in one jurisdiction impart either reductions in public services or tax increases in overlapping jurisdictions.[47] Both of these are costs that could have a second-order capitalization effect on house prices. And for taxing jurisdictions with lower rates (such as cities), these effects are larger. When accounting for second-order effects, a more relevant capitalization measure is δ_{city}, the capitalization rate where the denominator is the change in city property tax revenues only – instead of city property

[44] These hypothesis tests are conducted indirectly with respect to the estimated tax coefficient. In the second case, for example, consider the null $H_0 : \tau \leq \tau^{MAX}$, where, as noted earlier, $\tau^{MAX} = -1/\beta$. Thus, rearranging the hypothesis test to focus on the estimated parameter yields $\beta^{MAX} = -1/\tau$ and the null hypothesis of $H_0 : \beta \geq -0.455$. In the first case, the hypothesis test is $H_0 : \beta \geq -0.237$, where based on equation (9), the full-capitalization tax coefficient $\beta^* = -0.237$.

[45] To conduct the panel unit root test, we used a panel of city statutory tax rates spanning years 2000–2020. Although the data for our analysis spans just a few years, it is important to examine this longer time period in order to assess reasonable expectations of patterns in tax rates, which may be accounted for in market prices.

[46] The sample mean effective property tax rate is 0.61 percent for cities versus 1.09 percent for ISDs.

[47] See Buettner and Wildasin (2006) who examine fiscal responses by municipalities to exogenous shocks.

Table 4
Regression results: City property tax capitalization.

Dep. variable: ln(house price)	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	OLS	2SLS	2SLS	2SLS
City Boundary Restriction:	Full Sample	0.50 miles	0.50 miles	0.50 miles	0.35 miles	0.20 miles
$\hat{\delta}_{\tau}$ – capitalization rate (full)	0.23	0.92	1.45	99.24	43.88	8.97
$\hat{\delta}_{city}$ – capitalization rate (City)	0.20	0.53	0.67	1.24	1.22	1.10
Tax Rate	−0.093**	−0.227*	−0.278**	−0.446**	−0.441**	−0.409**
	(0.019)	(0.112)	(0.015)	(0.075)	(0.077)	(0.081)
ln (Test Score)	1.276**	2.417**	2.147**	1.037	1.010	0.965
	(0.064)	(0.757)	(0.595)	(0.664)	(0.757)	(0.922)
Age (10s)	−0.128**	−0.120**	−0.102**	−0.106**	−0.094**	−0.090**
	(0.002)	(0.021)	(0.012)	(0.012)	(0.012)	(0.016)
Age-squared (100s)	0.014**	0.014**	0.012**	0.012**	0.011**	0.010**
	(0.000)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Living Area (100s)	0.032**	0.032**	0.029**	0.030**	0.029**	0.027**
	(0.000)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Bedrooms	0.067**	0.071**	0.052**	0.050**	0.065*	0.037
	(0.007)	(0.018)	(0.015)	(0.015)	(0.028)	(0.035)
Bedrooms-squared	−0.013**	−0.010**	−0.007**	−0.007**	−0.009*	−0.006
	(0.001)	(0.003)	(0.002)	(0.002)	(0.005)	(0.006)
Bathrooms	0.266**	0.271**	0.237**	0.243**	0.226**	0.217**
	(0.008)	(0.018)	(0.019)	(0.021)	(0.025)	(0.031)
Bathrooms-squared	−0.032**	−0.035**	−0.031**	−0.031**	−0.028**	−0.027**
	(0.001)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
Median household income ($1000s)	0.010**	0.005	0.007**	0.005	0.004	0.003
	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Population density (1000s)	0.013**	−0.001	−0.005	−0.006*	−0.007*	−0.006
	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)
Dist. to CBD (miles)	−0.022**	−0.003	0.027	0.045	0.024	0.033
	(0.001)	(0.014)	(0.026)	(0.028)	(0.033)	(0.063)
Hispanic	−0.155**	−0.252	−0.173*	−0.161	−0.162	−0.181
	(0.013)	(0.196)	(0.085)	(0.085)	(0.107)	(0.154)
Non-Hispanic white	0.227**	−0.056	−0.011	0.015	−0.024	−0.091
	(0.012)	(0.163)	(0.074)	(0.074)	(0.095)	(0.126)
Non-Hispanic black	−0.453**	−0.266	−0.081	−0.071	−0.081	−0.142
	(0.011)	(0.197)	(0.093)	(0.092)	(0.113)	(0.147)
At least college degree	1.114**	0.469**	0.307**	0.313**	0.286**	0.228*
	(0.014)	(0.096)	(0.071)	(0.072)	(0.078)	(0.101)
Observations	59,334	13,807	8799	8799	6217	3164
R-squared	0.869	0.741	0.707	0.692	0.680	0.644
Boundary FE	NO	YES	NO	NO	NO	NO
Block FE	NO	NO	YES	YES	YES	YES

Notes: For 2SLS specifications, the effective tax rate is instrumented with the city statutory tax rate. The "other-race" category is omitted as the reference group. Estimates on some building characteristics (such as sauna, pool, garage-carport, number of stories, AC, and heater), and boundary (or block) fixed effects are suppressed. Year and month fixed effects are included in all columns. Robust standard errors in parentheses. Standard errors are clustered at the boundary or block level where appropriate. **$p < 0.01$, *$p < 0.05$.

taxes net of the reduction in revenues from overlapping tax bases. Our estimates of δ_{city}, when including block fixed effects, range from 1.10 to 1.24. None of these estimates are statistically different from 1.

Fiscal adjustment is not the only factor that may explain the differences between our ISD and city capitalization estimates. It may be that ISD boundaries are more fluid than city boundaries – although our maps do not show evidence of this. Furthermore, for cities, tax changes may represent less of a signal (compared to ISD tax changes) of prospective changes to public services in the years to come. Or prospective changes to city public services may be more susceptible to spillovers. As a result, capitalization effects (from the public services) would spread across boundaries and thus be less affected by a property's jurisdiction. Unlike with public schools, those just outside a city border may be able to free ride on public parks or better roads.

6. Conclusion

In this paper, we examine the effect of two sources of property taxes in Dallas County on the market value of owner-occupied housing: (1) the property tax that is used to finance public schools (i.e., ISD property tax); and (2) the city property tax that is used to finance other local amenities such as roads, emergency response services (police and fire), libraries, parks, etc. With respect to ISD property taxes, we control for variation in neighborhood quality across jurisdictions by focusing on houses that fall into half-mile blocks around ISD boundaries. Within each block, neighborhood quality is likely homogeneous, while houses on opposite sides of the boundary are subjected to different tax rates. Following an analogous strategy, we examine the effect of city property taxes on house prices by limiting observations to homes that fall into half-mile blocks around city boundaries.

Controlling for neighborhood heterogeneity, we find that raising another dollar of revenue (in excess of revenue reductions in overlapping tax bases) through ISD taxes lowers property values by $0.73 and $1.12, and the null of full capitalization cannot be rejected. With respect to city taxes, estimated capitalization rates are greater. With respect to school quality, and when employing our strongest controls, we find a one standard deviation increases in eighth-grade test scores results in a 3.7 to 4.2 percent increase in house prices.

It is not clear why capitalization rates are greater for city taxes when holding other factors constant. We hypothesize that fiscal externalities, which are more pronounced for the city tax, could help explain the difference. Another contributing factor may be that added taxes precede increases in public services and that this relationship may be stronger for ISD taxes. Furthermore, free riding on prospective changes to public services, which is likely more prevalent for city services than for schools, might also contribute to the greater rate of capitalization for city taxes. These are unresolved issues and topics for further investigation.

Declaration of competing interest

We have no relevant or material financial interests that relate to the research in this paper, although one of us has an independent contract with an agency for a totally separate project that allowed us to access to some of the data used in this paper.

Appendix A

Table A1
Summary Statistics: House Sales Price ($1000s) and Assessed Values ($1000s)

Distance from ISD boundary:	(1)		(2)		(3)		(4)	
	Full Sample		0.50 miles		0.35 miles		0.20 miles	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
With Highland Park ISD								
House Price	294	334	391	455	417	469	428	470
Assessed Value	282	317	374	431	398	444	409	449
Observations	59,334		12,585		8454		4574	
Without Highland Park ISD								
House Price	260	256	263	214	275	222	281	221
Assessed Value	250	243	253	205	264	212	268	209
Observations	56,971		10,558		7031		3804	

Notes: The first three rows are from Table 1. The last three rows are based on the subsample excluding observations that fall into the Highland Park ISD and 0.5 miles from the Dallas-side of the Highland Park-Dallas border.

Table A2
First-stage Regressions: ISD Tax Capitalization

Dep. variable: Effective Tax Rate	(2)	(3)	(5)	(6)	(7)
	First Stage	First Stage	First Stage	First Stage	First Stage
ISD Boundary Restriction:	Full Sample	0.50 miles	0.5 miles	0.35 miles	0.2 miles
ISD Statutory Rate	1.425**	1.717**	1.587**	1.500**	1.387**
	(0.018)	(0.230)	(0.143)	(0.146)	(0.149)
ln (Test Score)	−1.969**	−2.223**	−3.046**	−3.049**	−3.010**
	(0.065)	(0.772)	(0.465)	(0.548)	(0.638)
Age (10s)	−0.034**	−0.018	−0.019	−0.025	−0.000
	(0.002)	(0.010)	(0.017)	(0.020)	(0.020)
Age-squared (100s)	0.004**	0.002	0.002	0.002	−0.000
	(0.000)	(0.001)	(0.002)	(0.002)	(0.002)
Living Area (100s)	0.006**	0.005**	0.004**	0.004**	0.004*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)
Bedrooms	0.011	0.015	0.026	0.032	0.038
	(0.008)	(0.024)	(0.016)	(0.021)	(0.026)
Bedrooms-squared	0.001	−0.000	−0.002	−0.004	−0.005
	(0.001)	(0.003)	(0.002)	(0.003)	(0.005)
Bathrooms	0.068**	0.051	0.056**	0.041	0.031
	(0.008)	(0.032)	(0.021)	(0.022)	(0.032)
Bathrooms-squared	−0.012**	−0.007	−0.009**	−0.006*	−0.005
	(0.001)	(0.004)	(0.003)	(0.003)	(0.004)
Median household income ($1000s)	−0.003**	−0.007**	−0.007*	−0.005	−0.004
	(0.000)	(0.002)	(0.003)	(0.004)	(0.005)
Population density (1000s)	0.001	−0.002	−0.011**	−0.013**	−0.015**
	(0.001)	(0.002)	(0.003)	(0.004)	(0.004)
Distance to CBD (miles)	0.010**	0.009	0.007	−0.002	0.003
	(0.001)	(0.007)	(0.009)	(0.009)	(0.018)
Hispanic	−0.036**	0.047	0.015	−0.022	0.027
	(0.014)	(0.031)	(0.079)	(0.088)	(0.108)
Non-Hispanic white	0.139**	0.149*	0.034	−0.025	0.017
	(0.012)	(0.055)	(0.072)	(0.090)	(0.115)
Non-Hispanic black	0.000	−0.034	0.008	−0.004	0.026
	(0.012)	(0.067)	(0.096)	(0.108)	(0.134)
At least college degree	0.031*	0.090	0.029	−0.065	−0.067
	(0.015)	(0.084)	(0.099)	(0.107)	(0.129)

(continued on next page)

Table A2 (*continued*)

Dep. variable: Effective Tax Rate	(2)	(3)	(5)	(6)	(7)
	First Stage	First Stage	First Stage	First Stage	First Stage
ISD Boundary Restriction:	Full Sample	0.50 miles	0.5 miles	0.35 miles	0.2 miles
Observations	59,334	12,517	8952	6098	3253
R-squared	0.275	0.192	0.209	0.208	0.193
Weak Identification F-statistic	6251.91	55.67	123.33	105.51	86.13
Boundary FE	NO	YES	NO	NO	NO
Block FE	NO	NO	YES	YES	YES

Notes: Column numbers correspond to 2SLS columns in Table 2. The ISD statutory tax rate is used as an instrumental variable for ETR. The "other-race" category is omitted as the reference group. Estimates on some building characteristics (such as sauna, pool, garage-carport, number of stories, AC, and heater), and boundary (or block) fixed effects are suppressed. Year and month fixed effects are included in all columns. Robust standard errors in parentheses. Standard errors are clustered at the boundary or block level where appropriate. **p < 0.01, *p < 0.05.

Table A3
First-stage Regressions: City Tax Capitalization

Dep. variable: Effective Tax Rate	(1)	(2)	(4)	(5)	(6)
	First Stage	First Stage	First Stage	First Stage	First Stage
City Boundary Restriction:	Full Sample	0.50 miles	0.5 miles	0.35 miles	0.2 miles
City Statutory Rate	0.753**	0.871**	0.828**	0.833**	0.829**
	(0.015)	(0.096)	(0.062)	(0.064)	(0.058)
ln (Test Score)	0.119	−0.867	−2.361**	−2.505**	−2.388**
	(0.074)	(0.776)	(0.519)	(0.534)	(0.650)
Age (10s)	−0.026**	−0.019	−0.019*	−0.025*	−0.041**
	(0.003)	(0.011)	(0.008)	(0.010)	(0.015)
Age-squared (100s)	0.003**	0.002	0.002*	0.003**	0.004*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)
Living Area (100s)	0.005**	0.005**	0.003**	0.002*	0.004*
	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)
Bedrooms	0.006	0.008	−0.007	−0.023	−0.018
	(0.008)	(0.019)	(0.021)	(0.033)	(0.051)
Bedrooms-squared	0.001	0.001	0.002	0.005	0.004
	(0.001)	(0.003)	(0.003)	(0.005)	(0.008)
Bathrooms	0.059**	0.053	0.025	0.037	0.026
	(0.008)	(0.027)	(0.027)	(0.031)	(0.043)
Bathrooms-squared	−0.012**	−0.009*	−0.003	−0.005	−0.005
	(0.001)	(0.004)	(0.004)	(0.004)	(0.006)
Median household income ($1000s)	−0.002**	−0.004	−0.005**	−0.004*	−0.003
	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)
Population density (1000s)	0.000	0.001	−0.003	−0.002	−0.003
	(0.001)	(0.003)	(0.004)	(0.004)	(0.005)
Distance to CBD (miles)	0.029**	0.043**	0.101**	0.111**	0.146**
	(0.001)	(0.011)	(0.022)	(0.029)	(0.048)
Hispanic	0.042**	−0.013	−0.001	−0.049	−0.120
	(0.014)	(0.106)	(0.085)	(0.098)	(0.116)
Non-Hispanic white	0.079**	0.135	0.155*	0.110	0.123
	(0.012)	(0.088)	(0.074)	(0.089)	(0.102)
Non-Hispanic black	0.083**	−0.063	−0.035	−0.072	−0.110
	(0.012)	(0.110)	(0.092)	(0.106)	(0.129)
At least college degree	0.009	−0.032	0.020	0.032	−0.120
	(0.015)	(0.085)	(0.069)	(0.078)	(0.098)
Observations	59,334	13,807	8799	6217	3164
R-squared	0.224	0.181	0.230	0.249	0.242
Weak Identification F-statistic	2552.2	82.98	176.58	169.73	201.00
Boundary FE	NO	YES	NO	NO	NO
Block FE	NO	NO	YES	YES	YES

Notes: Column numbers correspond to 2SLS columns in Table 4. The city statutory tax rate is used as an instrumental variable for ETR. The "other-race" category is omitted as the reference group. Estimates on some building characteristics (such as sauna, pool, garage-carport, number of stories, AC, and heater), and boundary (or block) fixed effects are suppressed. Year and month fixed effects are included in all columns. Robust standard errors in parentheses. Standard errors are clustered at the boundary or block level where appropriate. **p < 0.01, *p < 0.05.

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