Discussion Draft
Not for Citation
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The Impact of Property Reassessment on Tax Equity and Household Expectations

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Abstract

Many scholars have documented inequity in property tax assessment. This paper examines assessment disparities across racial and income groups and documents the impact of reassessment on this disparities. The paper also estimates the extent to which homebuyers expect existing property tax differentials within a jurisdiction to persist and shows how reassessment, and the announcements leading up to it, affect these expectations. We use the 2012 court-ordered reassessment in Allegheny County, Pennsylvania as a natural experiment to study these issues. We match house sales with mortgage data to analyze changes in disparities among racial and income groups. We employ local assessors' tendency to over- or under-assess properties as instruments to control for the two-way relationship between property taxes and house values, and the repeat sales housing price model to estimate the extent of intrajurisdictional tax capitalization. We find evidence that reassessment is anticipated, that tax changes are capitalized before they take place, and that households anticipate tax changes to be adjusted following an reassessment. Based on our estimate of 30 percent property tax capitalization, we illustrate tax differences in potential housing capital gains or losses and their distribution among households affected by reassessment.

Key words: property tax, assessment, valuation, inequity, capitalization, expectations

JEL codes: H23, H31, H71, H73, R51

1. Introduction

The inequitable burden of the residential property tax has long been a concern in both the practitioner and academic literatures. Residents in many lower-income minority neighborhoods often pay higher tax rates relative to their house values than those in neighborhoods where residents have higher incomes and more valuable properties. A growing number of recent studies have extensively examined existing tax differences across households by race and income groups (Amornsiripanitch, 2021; Avenancio-León and Howard, 2019; Berry, 2021). However, few of these studies have linked this inequity to property tax capitalization or examined capitalization of current differences in tax payments; none have discussed household expectations of the planned reassessments announced by local governments. This paper is designed to fill this gap.

In this paper, we focus on the capitalization of tax differences caused by reassessments. Capitalization theory is an important tool for understanding the redistributive impact of property assessment. It broadens the time horizon used to assess the benefits and costs of reassessment to homeowners; it also helps us to more accurately quantify the impact of reassessments. This study aims to shed light on house value changes by developing a method to estimate the associated changes in housing capital that arise from capitalization of the tax changes. This paper also designs a model to estimate household expectations of the tax changes arising from reassessments.

Comprehensive and regular property assessments are an integral part of optimal property tax administration. If the assessed values on record are too inaccurate, a state court may mandate reassessment, which is a systematic updating of all the property in a jurisdiction. A jurisdiction may also undertake reassessment on its own. The accuracy, and thereby equity, of a property tax system are determined largely by how assessors use available information to obtain an estimate of current market value for each property. Even with the best of intentions, assessors often lack

access to the full and updated information necessary for accurate assessment, which may result in assessment/sales ratios that vary with characteristics of the owner or the neighborhood.

This paper examines county-wide reassessment in Allegheny County, Pennsylvania. Due to long delays in reassessment before 2010, assessments in the county lagged market prices by large and varying margins, resulting in many property owners paying a lot more or less than their fair share of taxes. In such contexts, a comprehensive reassessment redistributes the tax burden away from neighborhoods where the market value has lagged to neighborhoods where home prices have increased rapidly. We focus on the changes in relative tax burden triggered by reassessment. To control for tax differences relative to public services, we consider tax variations within local-level jurisdictions inside the county, under the same jurisdiction-specific nominal tax rate and with the same (or similar) level and quality of locally provided public services. In this sense, the focus of this study is on INTRA-JURISDICTIONAL differences in property taxes – the extent to which changes in the effective tax rate on each home, relative to the jurisdiction-wide average, lead to changes in house values, relative to the jurisdiction average.

A major obstacle to identifying capitalization effects is endogeneity, reverse causality, and definitional problems in property taxes and house values – our main variables of interest. To address these issues, we employ the repeat sales method to account for time-invariant unobservables as well as disaggregated price indexes to account for time-varying neighborhood price appreciation. Our analysis draws on repeat sales of houses in Pittsburgh that occurred before and after the new assessed-value notice was sent out in the last week of December 2011. Furthermore, we leverage the plausibly exogenous variations in the assessor's influence over effective tax rates that may not otherwise affect housing values. The assumption that assessors' behavior affects intrajurisdictional tax differences motivates the use of instruments such as the

predetermined assessment ratio and variability in local conditions which are unlikely to be correlated with individual house sale prices after the reassessment. Using variation in assessors' behavioral patterns as an exogenous variable, we employ an instrumental variables approach to estimate the effect of property tax changes on house prices. We develop a novel model to estimate household expectations concerning the persistence of intrajurisditional property differences and examine the impact of reassessment on these expectations. We also explore differences in expectations across racial and income groups.

This study generates three major findings. First, we identify large disparities in effective tax rates by the race and income bracket of homeowners, which is substantial evidence of horizontal and vertical inequity favoring high-income and white households before the long-overdue reassessment. Second, our estimates suggest that there is capitalization of tax differences from the jurisdictional average and these tax differences are negatively capitalized into house prices, at a rate of about 30 percent. We consider several possible interpretations of the capitalization estimates, particularly the extent to which it may reflect households' expectations about future tax changes. This finding suggests that the market anticipates reassessment when it is long overdue, and that the reassessment impact fades over time. Lastly, we show how reassessment affects the distribution of capital gains and losses among households of different races and income levels. Specifically, we compare a variety of distributions of gains and losses as well as the associated inequity, to better understand how and to what extent reassessment affects households differently by race and income.

To our knowledge, this study is the first to link comprehensive property reassessment with tax capitalization to investigate the pattern of effective-tax-rate disparities. Using data from the Home Mortgage Disclosure Act (HMDA) on the characteristics of households, we document

how the property tax burden on each property changes during the reassessment process and how capitalization may exert differential effects on property-level tax burden. Our analysis has the potential to benefit from its highly localized setting, where the different stages of reassessment implementation may have influenced homeowners' expectations. Such expectations could be analyzed through the attributes of homebuyers with different information provided over time.

The remainder of this paper is organized as follows. Section 2 briefly reviews the tax capitalization literature. Section 3 provides the institutional background to property reassessment in Allegheny County, Pennsylvania. Section 4 deliberates on the model of property tax capitalization we use for this study. Section 5 gives an overview of our data. Section 6 presents our results, where we elaborate on whether and to what extent property taxes are capitalized as well as how comprehensive reassessment affects systematic variations in effective tax rates and capital gains and losses. Section 7 concludes the paper.

2. Related Literature

2.1. Inter- versus Intra-Jurisdictional Tax Capitalization

Some studies examine interjurisdictional capitalization of property taxes and public services—relating differences in property values among different communities to differences in the property taxes, amenities, and public services in these communities. These studies either use aggregate data on municipalities or micro-data on more than a single municipality to study interjurisdictional tax differentials. However, these studies often encounter difficulties in comparing the different levels of public services at the jurisdiction level so that the effects they find can be attributed solely to tax differentials. As a result, one of the most common issues encountered when estimating the hedonic equations for such contexts is the appropriate measure

and control of differences in public services between communities. Failure to account for or to accurately measure these differences in public services makes it difficult to interpret the coefficients on the tax rate.

One approach to controlling for differences in public services is to examine the relationship between property values and tax payments for houses within a single taxing jurisdiction in which there are presumably no differences in public services or amenities. Of course, these differences in tax payments are of a different nature than differences in tax payments across jurisdictions. For studies of intrajurisdictional capitalization differences in property tax rates among households cannot be due to different nominal rates, but to different effective rates. In other words, these differences must be due to differences in the ratio of assessed to market value within the community. Since effective tax rates are obtained from dividing tax payments by observed sales prices of each housing unit, these studies measure property taxes more accurately than is possible by using existing aggregate data.

2.2. Classical Studies

Based on the reviews and several serious econometric problems discussed in Yinger et al. (1988), our review of the classical articles reveals some trends that are particularly relevant to the focus of this study—intrajurisdictional tax capitalization. First, early studies of intrajurisdictional tax capitalization examine the impact of tax changes, which is determined by unusual market circumstances, such as jurisdiction-wide reassessment (Wicks et al., 1968; Smith, 1970) or location-based tax policy (Moody, 1974). One noticeable thing here is that since these studies rely on comparisons of sales prices before and after the tax changes, every one of these analyses is making a counterfactual prediction for sale prices after the changes. Second, some studies

examine the level of effective tax rates by utilizing unavoidable errors in assessment (Case, 1978; Hamilton, 1979; Ihlanfeldt and Jackson, 1982). These studies again predict the counterfactual of assessment value under no assessment error and see if tax differences associated with random error lead to changes in house values. They also control for variations in public service levels to a greater extent than what is possible by using existing aggregate data because public services vary more across than within jurisdictions. Third, Richardson and Thalheimer (1981) make clever use of a unique institutional feature in Fayette County, Kentucky, where the tax differential remains due to historical accidents but public services are arguably equal. This idea is on the very idea of empirical studies examining tax capitalization in controlling for the level of public service.

In sum, the classical model was undoubtedly tolerant of the multiple sources of bias and the constraints placed on causal inference. The studies reflect the emerging ways to draw causal inferences from the counterfactual model and natural experimental ideas. There was just no systematic, formal discussion of key methods available in recent methodological advances in the field.

2.3. Recent Studies

In recent empirical work, there are at least three ways to deal with endogeneity. The first is to utilize a rare institutional setting that can help isolate the tax rate effects from public service effects. To avoid the difficulties in controlling for variation in public services, Palmon and Smith (1998a, b) take advantage of unique circumstances of Municipal Utility Districts (MUDs) in Texas. These MUDs have features that are suited for estimating the extent of intrajurisdictional tax capitalization, because they provide nearly uniform public services but have varying tax rates

across homes within their boundaries. However, the key argument is that most public services were assumed to be the same despite the fact that educational services vary in level and quality. They do not account for differences in school quality within a district, namely non-MUD services, and instead make the strong assumption that observed school quality is fairly consistent across school districts. This is unlikely to be true for two reasons: (1) the provision of local public schools has been of particular interest in the capitalization literature (see Nguyen-Hoang and Yinger, 2011 for a review) as it makes up the bulk of local property tax bills; (2) school quality may vary along many difficult-to-measure dimensions (e.g., value added, accountability, pupil-to-teacher ratios, etc.) that are thought to be valued by the housing market.

The second relevant stream of literature uses border fixed effects and spatial variation across jurisdictions. This approach relies on border-segment fixed effects to examine interjurisdictional tax differences within cross-border pairs. Gallagher et al. (2013) use the overlap of school district and municipal boundaries, using house sales within a quarter mile of a school district border that intersects a single municipality, lying on either the low- or high tax side of a school district border. Thus, the key comparisons made are between houses subject to differing education property tax rates and associated services, but similar neighborhoods as well as non-education services and municipal taxes. To further control for school quality differences, they focus on a sample of small homes that pay different school property taxes but presumably do not reflect the quality differences. Two key criticisms can be brought out on this approach: (1) homeowners with children may live in small houses, so the small house sample does not simply exclude those who do not value school quality. Also, there is evidence of price premiums for higher school quality even among homeowners without children; (2) such studies may exacerbate the problem of small sample sizes by restricting the sample to an extraordinary

sample of near-boundary small homes. This group could be too small and not representative to yield significant implications for the housing market.

Furthermore, some studies utilize multiple spatial fixed effects in accounting for multiple sources of unobserved variations. Dhar and Ross (2012) combine both school district boundary and neighborhood fixed effects to examine school quality capitalization across school district boundaries. Modifying the traditional boundary analysis across school attendance zone boundaries (Black, 1999), their model controls for time invariant neighborhood attributes on either side of a district boundary to examine school quality differences across school district boundaries. While this allows them to pick up the variations across the districts, which can be successfully replicated in tax capitalization context, many challenges still remain in including a small scale for the fixed effects (neighborhood fixed effects on one side of the boundary), which may possibly take out the sorting of the demand traits.

Livy (2018) similarly employs school district and neighborhood fixed effects together but incorporates school district controls within the boundary fixed effects. The author claims that the variation left is then attributed to what is referred to as “intra-school” district differences by claiming it as the non-school differences in the tax rates; however, the author leaves out the effects of service differences across school attendance zones within the same school district, making a new defense at improving upon these measures of perceived school quality. The capitalization estimates should be interpreted as the degree to which fiscal differentials are capitalized into house values.

The third stream of literature employs quasi-experimental methods. The strategy is to use a plausibly exogenous source of spatial-temporal variation in property taxes and public services to identify how the change was capitalized into housing prices. One technique is the instrumental

variables (IVs) approach that uses historical, geographical, or political instruments. Borge and Rattsø (2014) use a variation in historical tax regulation as an instrument to estimate the impact of interjurisdictional differences in tax rates; similarly, characteristics of the local council are used as an instrument to analyze public service capitalization. However, ideally we need instruments for every amenity, not just for one amenity.

Ferreira (2010) and Bradley (2017) exploit institutional features of a property tax system based on acquisition value. The key insight from the instrumental variables developed in these papers is that because of the different property tax systems, equivalent properties may face different tax amounts. To deal with the endogeneity of housing prices, the exogenous property tax component that is not tied to the market value of the property is then used as an instrumental variable. The problem with this approach is that the exclusion restriction may be invalid if the time of purchase, as equivalent to the length of ownership, serves as a signal of homes with highly desirable or unique features, and have a direct impact on sale price.

Another technique is to apply a spatial difference-in-differences (DiD) approach. This strategy permits the comparison of differences in housing prices before and after spatial-temporal policy interventions. Hodge and Komarek (2016) utilize variations in tax benefit to examine the extent to which a new homestead exemption is capitalized into house prices. Based on the identifying assumption that sales prices in zoning and non-zoning areas exhibit similar pre-existing trends, they find houses in zoning areas sold more expensive than those in non-zoning areas on average.

3. Institutional Background

3.1. Reassessment History in Allegheny County, Pennsylvania

Most states mandate annual reassessments or on a fixed cycle of no more than ten years.[1] However, the state of Pennsylvania does not have a legislatively mandated reassessment cycle. Prior to 1982, Pennsylvania's (real property tax) assessment law required that each county assess property every year based on its current fair market value. In practice, however, most counties did not comply with the annual assessment requirement and Allegheny County was once permitted to conduct triennial assessments.[2] In 1982, the assessment law governing the counties was amended so as to allow counties to utilize either a current market value method or to adopt a base year market value. This amendment also notes that Pennsylvania does not have a state mandated regular reassessment cycle and the result, therefore, was that the role of the county government has become apparent in the reassessment process; there is supposedly no problem if uniformity of taxation is not seriously violated by county assessments – as long as all properties are valued in the same base year and at the same ratio of assessed to market value set by the county government (with a predetermined ratio of 100% for Allegheny County).

In the past 30 years, Allegheny County conducted two court-ordered assessments, on the grounds that its base year assessment practice violates the Uniformity Clause of the Pennsylvania Constitution.[3] The first one was in April of 1997: in which the court ordered a county-wide reassessment by 2001 for the 2002 tax year. The second was the reassessment process initiated in 2009. On April 29, 2009, the Pennsylvania Supreme Court ruled that the way Allegheny County has used the base year tax system was unconstitutional and required a countywide reassessment.

[1] https://taxfoundation.org/state-provisions-property-reassessment/. Accessed 8 Sept, 2020.

[2] Clifton v. Allegheny County, 969 A.2d 1197 (PA. 2009).

[3] "Timeline of Allegheny County assessment controversy," see https://www.post-gazette.com/uncategorized/2007/06/06/Timeline-of-Allegheny-County-assessment-controversy/stories/200706060208

3.2. From Announcement to Implementation

For us, it is important to track announcements that lead to actual implementation. The key question is then to identify when expectations about the implementation of reassessment process changed due to newly released information. In its implementation, the court allowed for a one-year delay in the implementation process for 2012 assessed values until 2013. In other words, Allegheny County was ordered by court to reassess all properties in the County for 2012, but the newly reassessed values were not used for 2012 tax bills. From the homeowner's perspective, the notices were supposed to be made in July 2011, but in practice the county released new reassessment values started from properties in the city and Mount Oliver in the last week of December, 2011.[4] Thus, some of the notices of 2012 tax base were made before the jurisdictions in the county finalized their millage rates for tax year 2012 and also before the 2012 municipality tax bill (typically mailed in late winter/early spring), and 2012 school district tax bill (typically mailed in mid-summer) were mailed out.

This timeline has two important implications for our analysis. First, in setting 2012 property tax millage rates, municipalities and school districts were able to consider how property values will change for tax year 2013. This was particularly important given that localities were required to set revenue neutral rates for 2013 tax bills in compliance with the Act 71 requirements.[5] As a result, the tax rate falls dramatically in 2013. In tax year 2012, however, the tax rate was among the highest because the most outdated assessed values remained at the 2002

[4] Mount Oliver, although a separate borough, is grouped with the city because it is part of the city school district. For the rest of the county, the notices were mailed in late January, 2012 (generally east of Pittsburgh); mid to late February, 2012 (generally south and west of Pittsburgh); and early March, 2012 (generally north of Pittsburgh). Allegheny county is divided into 5 assessor territories (City, East, North, South, and West) which are further divided by 9 valuation areas (Alle-Kiski Valley, City, East, Mon Valley, North, Northwest, Pittsburgh, South, and West). Ideally valuation areas are defined based on properties sharing similar economic influences.

[5] https://alleghenycontroller.com/the-controller/property-tax-watch/

base year (see Table 1). Second, until the tax rates for 2013 were set by all the taxing bodies (lastly in July of 2013), there was no way of knowing the exact amount of combined tax payment that property owners will owe.[6] At the same time, however, it was reasonable enough for homeowners to anticipate an increase (or decrease) in their property tax bills in 2012 based on their new assessed values and anticipated millage rates.

3.3. The Role of Assessors in Determining Tax Burdens

Assessors use reappraisal procedures and related policies to decide each household's tax burden. The first step in the process is the assessor's valuation of the property. During this step, the assessor or a hired contractor reviews the market prices of all recently sold properties. Just like other counties, Allegheny's properties are valued using a mass appraisal system, where the local assessors use this mass appraisal to determine each property's assessed value in relation to other recently sold properties in the same neighborhood. The assessed value for a particular property is thus essentially based on the average value of a group of properties sharing similar observable characteristics. This ensures similar properties to be assessed similarly across price levels (vertical equity) and across properties with similar values (horizontal equity).

Similarly, assessors must account for time trends in a process known as time adjustment, or "trending." Assessors adjust each property's value to reflect the trend, which is measured for the entire jurisdiction using yearly or quarterly average appreciation rates. This temporal adjustment, like any constructed measures derived from mass appraisal, tends to converge toward the mean price trends in the surrounding neighborhoods. We know that homes in some neighborhoods appreciate at a slower or faster pace than the jurisdictional average, and that a

[6] http://apps.pittsburghpa.gov/mayor/Reassessment_FAQ.pdf

house's neighborhood influences its price if there are sizeable spillover effects. Both factors (sales price of comparable property and the adjustment made to reflect any valuation differences) based on the comparable sales approach can lead to possible inaccuracy and unfair assessment practices, which will be used as instruments in our analysis to capture the likelihood of being over- or under-assessed.

Once the appraisal is completed, the appraisal results are announced and confirmed to key stakeholders. The assessor submits to the county office the resulting assessment to sales, the "ratio study" for review and approval. The ratio study looks at how well the county's assessments reflect its desired percent of fair market value, as well as how comparable such ratios are among properties in the county. Several statistical tests are conducted to ensure that the assessments are fair and treat all property owners equitably. After these tests are passed, the assessment work in the county is approved and notices of new assessed values are then mailed to all property owners, which most property owners in Allegheny receive within the first few months of the reassessment year. Briefly, most properties see increased assessments, while less than a third have their assessments reduced or remain unchanged.

One major assumption of this study is that assessors' practices will have no other impact on house prices except through its effect on tax burdens. Building on the above discussion of the process, a study may rely on multiple instruments, including key local trends and factors that may affect assessors' behaviors, which are associated with the probability of an individual household paying more or less tax than in the pre-assessment period. However, the assessors' perceptions of housing attributes are also shared by homebuyers in the housing market, implying that there could be other avenues for such factors to have a direct impact on housing prices. At this point, it is unclear how the assessors will weight certain factors in comparison to other

properties, but we focus on assumption tests which, in our opinion, tend to carry substantial benefits if they are highly robust to violations of the assumptions of the model.

4. Property Tax Capitalization Theory and Model Specification

In this section, we begin by explaining how the relationship between house values and property taxes can be derived from tax capitalization theory. We then combine the circumstances of reassessment to derive equations to focus on changes before and after reassessment, remove interjurisdictional changes, and express the final model in terms of estimable parameters. This will help us specify an econometric methodology, which will then be used to estimate the capitalization rates of the property tax rate in our identification strategy. Lastly, we discuss the different types of endogeneity issues and econometric techniques to address them, including instrumental variable strategy.

4.1. Deriving an Estimating Equation

4.1.1. Capitalization equation

This section derives an equation to estimate the degree of capitalization. Property tax capitalization occurs when a household is willing to pay more for a house with lower property taxes all other factors equal. The degree of capitalization can be estimated by measuring how much of the present value of the expected stream of tax differences is reflected in the price of a given house. Equation (1) is the well-known form of the capitalization equation where $\hat{P}$ is the pre-tax price of housing services, H is housing services, r is the real discount rate, β is the degree of property tax capitalization, and T is the annual property tax payment. The equation indicates that the value of a house equals its annual rental value (= gross rental value minus tax payment)

divided by a discount rate. In the equation, property taxes are a flow that must be paid every year – a flow that is capitalized.

$$V = \frac{\hat{P}H - \beta T}{r} \tag{1}$$

The effective property tax rate, *t*, is defined as T/V, so $T = tV$. Substituting tV for tax payment into equation (1) and solving for V leads to another well-known equation:

$$V = \frac{\hat{P}H}{r + \beta t} \tag{2}$$

4.1.2. Change form of the equation

This study estimates β using double-sales data that reveal changes in *t* associated with reassessment. To identify the impact of within-jurisdiction tax changes on housing prices, we derive a housing-price index and deflate *V* by this index. The superscript "*" is inserted to indicate this deflation. This step controls for over-time changes in *V* that affect all houses in a jurisdiction. We also express the effective property tax rate as a deviation from the municipality average, labeled *t**. This step controls for changes in *t* relative to other communities. We also conduct some of our regressions with controls for renovations or upgrades, which obviously affect house values.

Our second step is to log equation (2) and express the result in change form. The log version is:

$$\ln\{V^*\} = \ln\left\{\frac{\hat{P}H}{(r + \beta t^*)}\right\} \tag{3}$$

Adding subscripts for first and second sales, the percentage change in *V** can be written as:

$$\ln\{V_S^*\} - \ln\{V_F^*\} = \ln\left\{\frac{\hat{P}H}{(r+\beta t_S^*)}\right\} - \ln\left\{\frac{\hat{P}H}{(r+\beta t_F^*)}\right\} \quad (4)$$

which simplifies to:

$$\begin{aligned}\ln\{V_S^*/V_F^*\} &= \ln\{\hat{P}H\} - \ln\{\hat{P}H\} - \ln\{r\} + \ln\{r\} \\ &\quad - \ln\{1+\tilde{\beta}t_S^*\} + \ln\{1+\tilde{\beta}t_F^*\} \\ &\approx \tilde{\beta}(t_F^* - t_S^*) = \tilde{\beta}\Delta t^*\end{aligned} \quad (5)$$

where tilde indicates division by the discount rate. The last line of equation (5) is based on the approximation that for any expression *a*, $\ln\{1 + a\} \approx a$ when *a* is close to zero. This condition is met for the expressions $\tilde{\beta}t_S^*$ and $\tilde{\beta}t_F^*$ with an effective tax rate of 1.5 (which is typical in our data), a discount rate of 3 percent, and a capitalization rate of 30 percent, which is approximately what we estimate.

4.1.3. Estimating expectations associated with capitalization

As explained in detail in Yinger et al. (1988), the β coefficient reflects both the impact of a $1 increase in annual property taxes on house values and the length of time that this increase is expected to persist. In the case of within-jurisdiction property tax differences, the relevant expectations reflect a homebuyer's belief about the persistence of deviations between a house's effective tax rate and the average rate in the jurisdiction. In a jurisdiction with infrequent reassessments, for example, home buyers may expect current relative property tax rates to persist for a long time, thereby leading to a high estimated value of β, whereas the value of β may be much smaller when assessments are updated every three years or so. Indeed, the β that applies to intrajurisdictional property tax capitalization may go to zero when houses are reassessed upon sale, which means that all buyers can expect to pay the same effective tax rate.

To be more precise, let β' indicate the impact on housing bids for each dollar of property taxes in present-value terms, and let N stand for the number of years a current deviation from the average tax rate is expected to persist until it is adjusted to be the average. Then the present value to a household from $1 saving received each year for N years can be written as:

$$\beta = \beta' \left[1-(1+r)^{-N}\right] \tag{6}$$

This equation implies that even with $\beta' = 1$, the estimated value of β could vary, for example, from 0.137 (N = 5) to 0.256 (N = 10) to 0.772 (N = 50).

Assuming that households fully recognize the impact of current property tax differences on the value of a house (i.e., $\beta' = 1$), the logic of this equation can be reversed to solve for the value of N associated with any given value of β:

$$N = -\frac{\log\{1-\beta\}}{\log\{1+r\}} \tag{7}$$

Equation (7) assumes that expectations are the same every year, which obviously may not be the case. Expectations, and hence the estimated value of β could be affected by a proposal for a reassessment, an announcement that reassessment will occur, information on new assessed values, an actual reassessment, or a return to pre-reassessment assessment practices. Estimating a separate β for each year and then using equation (7) to calculate the expected persistence of current tax differences will indicate the pattern of expectations over time. This pattern of expectations sheds light on the impact of property taxes on house values.

Consider the case of double-sales data that all straddle a reassessment; in other words, each house sells twice, once before reassessment and once after. Let Y be the year of reassessment and YY be the last year in the sample. In this case, a separate β/r for each year can be estimated with the following equation:

$$\ln\{V_{Si}^{*} / V_{Si}^{*}\} = \sum_{y=1}^{Y-1} -\tilde{\beta}_{Sy} D_{yi}^{S}\left(t_{Syi}^{*}\right) + \sum_{y=Y}^{YY} \tilde{\beta}_{Fy} D_{yi}^{F}\left(t_{Fyi}^{*}\right) \quad (8)$$

Overall, this equation has a dummy for each year in the sample, with exactly two dummies (one for first sale and the other for second sale) switched on (i.e., equal to 1) for each house. With an assumption for *r*, this equation gives us an estimate of capitalization in each year.

For more precision, this model can be extended to cover non-straddling double sales, so long as they do not have their two sales in the same year. Define

W_{yi} = 1 if house *i* was sold for the first time in year *y*;

= -1 if house *i* was sold for the second time in year *y*; and

= 0 otherwise

Then the appropriate equation is

$$\ln\{V_{Si}^{*} / V_{Fi}^{*}\} = \sum_{y=1}^{YY} \tilde{\beta}_{y} W_{yi}\left(t_{yi}^{*}\right) \quad (9)$$

Results with the straddling sample and the more complete sample are both presented below.

The variables in this regression obviously can be interacted with household traits, such as race, ethnicity, or income. Because of the apparent long-run inequity in assessments for blacks, for example, blacks might expect property tax differences to persist longer than whites do.

4.2. Empirical Strategy

4.2.1. Repeat sales model and estimating equation

We investigate the impact of reassessment-induced tax changes on housing prices using repeat sales data from before and after new tax bills were mailed. The repeat sales model uses the change in home sales prices as a function of time-varying attributes by comparing one sale before reassessment to the next after reassessment. With this setting, we estimate equation (5)

using log changes in home prices. The final specification that we employ takes the following form:

$$ln\{\frac{V_{i,(t+\tau)}}{V_{it}}\} = \alpha + \beta(T_{i,(t+\tau)} - T_{it}) + \gamma(H_{i,(t+\tau)} - H_{it}) + \epsilon_{it,\tau} \quad (10)$$

where *V* represents the sales price of the house relative to the city average of the same property *i* occurring τ years apart where the first sale is in year *t*. The change in house value is represented as a function of the change in *T*, the effective tax rate relative to the average in the property between sales between *t* and *t*+ τ. γ accounts for changes in house characteristics (*H*) resulting from renovations, with remaining idiosyncratic components of price variability as the error term. We address potential omitted variable bias from time-invariant using repeat sales for homes where the physical and locational characteristics of the home are differenced away.

4.2.2. Concerns about identification strategy

We can address a number of concerns about the identification strategy specified above. First, unobserved time-variant variations may still bias our analysis. We should emphasize that removing interjurisdictional changes alleviates rather than eliminates potential bias due to unobserved time-variant attributes. That is, our specification implicitly assumes that the exact type of time-varying unobservables where some small neighborhoods within the jurisdiction were disproportionately impacted should be limited and thus not a major concern. However, further analysis including space by time interactions to controls for time-variant neighborhood unobservables would be necessary to verify our results.

Another issue to consider is the functional form of the specification. Our equation approximates the basic capitalization equation in a simple linear fashion. Especially, equation (5) is derived from the assumption that, after a successful reassessment, each house will have a tax

rate that is about the same as the average tax rate. The problem is that once this assumption is violated in practice, β will not be removed from the denominator and will appear as both a numerator and a denominator in the equation. This means that the estimation technique we consider should permit the flexible functional forms. Further investigation should reveal that our estimates are not largely affected by the choice of a functional form.

The last point to consider is that even if the model can be developed to address the issues mentioned above, the specification can still suffer from endogeneity. We argue that two potentially prevalent sources of bias contribute to this: simultaneity and omitted variable bias. This motivates the use of instrumental variables to ensure that the tax rate coefficient is not biased. The Technical Appendix of this paper provides the mathematical derivation of endogeneity in greater detail and how we derive instrument variables and other strategies used in our empirical work.

4.2.3. Instrumental variables strategy

We propose an instrumental variables strategy that will help us to better isolate the intrajurisdictional variation in price changes that occurred due to tax changes caused by the 2012 reassessment. That is, if we can identify a measure that embodies an exogenous source of variation affecting price changes only through tax changes, we can address endogeneity using a quasi-experimental approach. To find some exogenous source of variation in tax differences, we rely on assessor behavior and valuation methods, which we believe are critical in determining intrajurisdictional effective property tax rate variations. The basic intuition is that the change in effective tax rates is partly a function of the assessment practices specifically how assessors interpret and apply information on the market values of the properties in the jurisdiction during a

reassessment (Ihlanfeldt and Jackson, 1982; Ross, 2011). Therefore, we consider a set of instruments that are directly related to the assessors' role in keeping the assessed value up to date and equitable by considering house price changes across and within jurisdictions.

To formalize the idea, we begin deriving the variations resulting from changes in individual home prices, interjurisdictional trends, and tax components (see technical appendix for the details). The main idea behind these variations is that assessors will rely on the price trends and knowledge of recently sold properties in the areas to assign new assessed values. This process may include a variety of methods, many of which involve statistical separation or stratification of groups of properties that have similar attributes. Therefore, our estimation procedures trace the factors involved in these appraisal approaches used by assessors and employ them as instruments in our empirical setting. The exact instrumental variables we employ are as follows. First, we instrument the jurisdiction-wide average annual appreciation rate (I_{Re}/I_F), which represents how assessors infer about the rate of change in house prices over time that is plausibly exogenous to individual house specific price changes. Second, we add the year-to-year variation in nominal tax rate (m_s) derived from the exogenous source of variation in the annual tax payment. All these variations should be a useful tool for investigating tax capitalization effects. Lastly, we consider housing attributes, including comparable property value as potential additional instruments.

The conventional wisdom for IV analysis is that instruments should be proven to be both valid and strong. This implies that other possible effects of the instruments on house prices are either non-existent or limited relative to the effect through taxes. Having multiple instruments also allows us to conduct "overidentification" tests, the most common of which is the Sargan test. Under the assumption that at least one instrument is exogenous, the Sargan test tests the null

hypothesis that all the other instruments are also exogenous. On its own, the test is not sufficient to verify the validity of the instruments; however, when it is combined with strong theoretical argument and other evidence, it can increase our confidence that the instruments are likely to be valid. For this reason, in our multiple-instrument setting, we check for the sensitivity to the inclusion of additional instruments as we have enough instruments allowed. Our multiple-instrument example indicates that we should not reject the hypothesis that instruments are valid. In both tests we fail to reject validity; thus, all three of the instruments pass the tests.

We also test the strength of our instruments and find that the first-stage F-statistics of our instrument variables are all greater than ten (Staiger and Stock, 1997), implying that these instrumental variables are not poor predictors of the endogenous variables in the first-stage estimations.

5. Data and Descriptive Statistics

Our data focuses on residential home sales between 2006 and 2016, which include sales both before and after the reassessment in 2012. This paper uses data obtained from multiple sources in the Allegheny County Office of Property Assessment and the Pennsylvania Department of Community and Economic Development's (DCED) *Municipal Statistics* series, including information on home sales price, assessed value, and tax rates both in nominal and effective terms. In our data set, there are a total of 46 school districts and 130 municipal property tax districts in the county.

The data are cleaned to remove homes that sold more than once in a single year, homes that had missing information, and other observations that could be erroneous. Summary statistics for the housing sales are presented in Table 3. The data are disaggregated into three sections: the

first includes all sales in the sample period; the second includes homes that sold more than once but not in any single year; and the third contains repeat sales that straddle the reassessment year. For the entire sample, the average sale price of a home during this period is nearly $169,000. The mean house has three bedrooms and two bathrooms, with approximately 1,650 square feet of living space. The variables are comparable across the three sections. The overall similarity across the samples suggests that the homes that sold more than once are not significantly different from the population of homes sold during the sample period.

To identify the race, ethnicity, gender, and income of homebuyers, we matched loan-level records from two sources – Black Knight's (formerly Lender Processing Services (LPS)) McDash Core Database and Home Mortgage Disclosure Act (HMDA) data compiled by the Federal Financial Institutions Examination Council (FFIEC). While the McDash and HMDA data differ in emphases, they both contain homebuyer information on loan amount, loan purpose, loan origination year, loan type, property location, property type, and loan originator, which enables matching the two data sets on a transaction-by-transaction basis.

6. Results

6.1. Patterns of Property Tax Assessment Disparities

We begin with an overview of the patterns of effective tax rates to identify the extent and nature of tax inequity. There are several interesting patterns in Allegheny County's effective tax rates by race, income, as well as pre- and post-assessment periods. Table 5 compares black and white homeowners for pre- and post-reassessment periods separately. During the pre-assessment periods, black assessment ratios were slightly lower than 80 percent, compared to around 70 percent for non-Hispanic whites. Following the reassessment, the ratios increased to 89 and 86

percent for black and white homeowners, indicating that the disparity has narrowed significantly, but the differences remained significant, respectively, implying that the gap narrowed but persisted during the post-reassessment periods. This is not surprising given that assessments still deviate substantively as time passes after reassessment.

Table 6 then looks only at the pre-assessment periods, stratifying the sample by income quartiles to look at racial disparities within each income group. Except for small and non-statistically significant differences among the highest income group, racial differences were substantively consistent across the three lower income groups. However, the disparity was much more pronounced among middle-income rage, demonstrating that the long-term disparity in housing prices was not linear with income, which would be due to several other factors that may contribute to racial disparities in property values.

Table 7 shows the overall tax burdens of homeowners at different income levels. The last column calculates the tax burden as a percentage of income for each group. We find that the burden (as a proportion of income) is substantially higher for individuals at the bottom of the income distribution than for those at the top.

Moving on to horizontal equity, Table 8 shows how the reassessment changes the absolute size of the standard deviation of the tax rate within each decile. Three distinct patterns emerge. First, there was more horizontal inequity at the lower house price and income levels in both pre- and post-reassessment periods. Second, reassessing property values improved horizontal equity at all income levels, especially at the low end. Third, when comparing homeowners with similar homes to those in similar income deciles, horizontal inequities were larger in groups with similar house prices than in groups with similar income levels.

6.2. Analysis of Assessment Disparities

We proceed to explain the patterns of effective tax differentials using race, income, and reassessment periods. Table 9 shows how these variables are independently and combinedly correlated to effective tax differentials in Pittsburgh. The first three columns focus on the years before the reassessment, and the last two columns cover the years before and after the reassessment. The results shown in the first column show that for the pre-reassessment periods, black homeowners have a higher effective tax rate of 2.3 mills. Given a mean effective property tax rate of approximately 18 mills, this corresponds to a 12 percent higher additional tax burden for black homeowners. Prior to the reassessment, there are significant intrajurisdictional tax differentials between black and white households, even though the households are in the same jurisdiction with the same level of public services and intended tax level.

Next, we introduce some controls to see how much of the racial tax disparity can be explained by household and neighborhood characteristics. When we include individual income variables in Column 2, the estimated race differentials are reduced to 2.144 percentage points, indicating that race remains as the major factor that largely explains the variation in pre-assessment tax differentials. Holding race constant, there was a 0.005 percentage point decrease in effective tax rate as income increased by one unit (thousands of dollars), indicating that income differentials are significant, but on a much smaller scale than those associated with race. Interestingly, such large race differentials become insignificant when we include neighborhood (census tract) fixed effects in Column 3. Income was still significant, but to a lesser extent than in Column 2. This means that in the same neighborhood while income differences may explain some tax differences, race is no longer the primary variable that is strongly associated with tax differentials within the same tract. These suggest that much of the effect operates through

changes in house values associated with traits that describe the neighborhoods in which blacks tend to live.

In Column 4, we compare the pre- and post-assessment periods where we move the focus from differences in house price appreciation to differences in taxes due to reassessment. The findings show that overall effective tax rates are significantly lower comparing pre- and post-periods. Race and income are not significant, implying that there may be nonlinearity in pre- and post-assessment trends that cannot be fully explained by race and income solely. We attribute the significant decrease in effective tax rate in after-reassessment mainly to decreases in nominal tax rates which appear to overwhelm the increase in assessment ratios.

Column 5 explains how the changes before and after the reassessment differ for different types of households. To test this, we look for important interactions for post-assessment with the household's race and income. While the main effect in explaining pre-post differences remain significant showing decreases in tax rates over time, the interaction terms explain the household's characteristics show white, high-income households have increases in effective tax rates after the reassessment. Even within the same jurisdiction, tax differentials seem to change dramatically before and after the reassessment and significantly vary with race and income of households. While the reassessment remains significant in explaining pre-post differences and suggests lower overall tax rates compared to the pre-period, the interaction terms reflect household characteristics, as households are white and as income rises, effective tax rates increase after the reassessment. Overall, this demonstrates that tax differentials appear to change dramatically not only before and after reassessment, but also at the individual level depending on race and income of households within the same neighborhood.

Some issues that arise in models with more periods may be masked by using only the two periods (pre and post). In Figure 1, we provide a dynamic analysis of racial tax differentials. We believe the trend of tax differentials would better reflect the reassessment effects for two reasons. First, seeing the trends may help capture the expectations that arise before reassessment. Second, if house prices diverge again from the new assessed values even after the reassessment, the effects will fade over time as differential appreciation returns in the long term.

To investigate these patterns, we divide the pre- and post-2012 periods into each year and present the trend of intrajurisdictional tax differentials from 2006 to 2016. The trend highlights three major findings. First, the tax differentials decrease considerably from 2012 to 2013, which seemingly reflects the large decreases in the nominal tax rate during reassessment. It is also worth noting that standard deviations have decreased significantly, implying that the range of deviations has narrowed and become more uniform between black and white homeowners.

Second, we observe a decrease in tax differentials in 2011, which can be interpreted as the housing market responses to and predicts the tax changes. Given that there were no notable patterns in 2011 that differed from previous trends, particularly in terms of assessed value and the nominal tax rate, this evidence guides on whether households expect a reassessment, as well as the timing and direction of the response reflected in house prices. It demonstrates that the responses in differential price between homes owned by black and white homeowners are consistent with reassessment effects, implying that they correctly expect the reassessment effect to be capitalized into house prices.

Lastly, the tax differentials began to reemerge as time passed without a reassessment. This suggests that the assessment gap between black and white homeowners increases and will likely increase further as new assessment values lag and their homes appreciate at different rates.

This trend confirms that differentials before reassessment may occur very soon if tax amounts are not expected to be corrected in the near term.

6.3. Estimates of Tax Capitalization

We estimate three sets of regression coefficients: Model 1 is a simple linear model based on OLS estimator; Model 2 employs is a two-stage least-squares estimator with IVs individually or together; and Model 3 includes all the IVs as well as their combinations and powers to investigate how adding more instruments affects bias in the IV estimator.

Three tests were used to evaluate the choice of instruments: the relevance of the instruments, the Durbin-Hausman-Wu test, and overidentification tests. The first part in Table 10 (weak instruments test) shows that the instruments are very powerful, as all F-test statistics are very large. The tests displayed in the second part (endogeneity test) show that test statistics are highly significant, which indicates that the IV estimates differ significantly from the OLS estimates. We treat tax variable as endogenous. The following tests of over-identifying restrictions consider different combinations of instrumental variables (Model 3), and they suggest that a parsimonious model (Model 2) is preferable, as we do not detect any sign of instrument endogeneity in our baseline specification. The additional restrictions imposed by augmenting additional instruments turn out to be redundant (Sargan, 1958; Hansen, 1982).

The estimates in Table 11 show that the property tax capitalization rate, β, is roughly 32.1%. This estimate indicates that a reassessment-induced $1.00 increase in the present value of a house's property tax payment relative to the jurisdiction average, leads to a $0.32 decline in its house value. This estimate was significantly different from zero with a t-statistic of 2.79. Under implied assumption that households' expectations remain constant over time, people expect tax

differences from the jurisdiction average to last 14 years. Overall, we find that intrajurisdictional tax differences are capitalized at a 30% rate in house prices.

A comparison of Model 1 and Model 2 demonstrates that OLS estimates are biased downward. As noted above, this simultaneity can be traced to the negative definitional link between effective tax rates and housing prices, because by definition house value is denominator of the effective tax rate resulting in a downward bias of the capitalization estimates.

Overall, we find that property taxes are capitalized at 30% in Pittsburgh. This can be interpreted in several ways. One explanation is that a household may purchase a property with ex-ante expectation about the level of some future tax changes, and the price they pay reflects this expectation. If a homebuyer correctly predicts, this will be reflected in the pre-reassessment period, biasing the effect towards zero. Another explanation is that people expect their increased or decreased tax rates to be readjusted by future reassessment. If prospective buyers expect current tax differences to last shorter periods of time, this will underestimate the capitalization rate due to the expectation that current tax differentials will only persist for short time periods. While the models and estimates reported are preliminary to draw firm conclusions at this time, further analysis should provide a more careful investigation of what house buyers might expect at different points in time. Lastly, the tax capitalization effect depends on how much attention homebuyers give to information based on their preferences and circumstances. External factors, such as deadlines and media reports, can also influence price reactions in addition to the announcement dates of tax events. These are unresolved issues and topics for future research.

We shed further light on capitalization estimates associated with the persistence of current tax rate differences. Our approach involves interacting year dummies with the tax variable (see again sub-section 4.1.3) and seeing temporal variations in the resulting coefficients

on the tax variables in Table 12. It shows estimates conducted with β' assumed to be 1.0 and the discount rate of 3%. We first check if the degree of capitalization varies over time and whether it is affected by reassessment. The estimates show that expectations concerning the persistence of property tax rate differences decrease in pre-assessment years and increase after reassessment. The findings support the notion that homebuyers react to reassessment and anticipate and capitalize on tax changes before they are officially announced.

We next investigate the timing and expected duration of tax differences. We look specifically at when households expect tax differences to last over a longer period. The findings indicate that the expected duration of tax differences increases dramatically in 2013 and becomes infinite after 2015. This trend suggests that, following the reassessment, people quickly adjust their expectations on tax differences that will not be corrected for a long time. Altogether, these findings imply that earlier anticipation is plausible, and that this anticipation process could continue even after the reassessment is announced. This also suggest that estimating tax differences before and after reassessment may not fully capture these expectations, resulting in differences to be underestimated.

6.4. Actual Gains and Losses from Reassessment

We find that intrajurisdictional tax differences are capitalized, which means that the reassessment will impose capital gains and losses on current homeowners. The magnitude of a capital gain or loss from reassessment can be obtained by considering a specific example. If reassessment is reasonably accurate, the magnitude of the coefficient given in equation (5) indicates that the real percentage increase in the price of a home corresponds to the differences in the tax level from the average multiplied by the degree of capitalization and divided by the real

interest rate. Suppose the pre-reassessment effective tax rate for a house worth $170,000 is 2 percentage points above the average. At a discount rate of 3 percent, the value of the house would increase by (.30)(.02)/(.03)=.2, which means that the house owner in this example will experience a $34,850 of real capital gain because of reassessment.

Given black homeowner's relative effective tax rate of 0.314, expressed as a mean deviation from the average, and the average house price of 96,169, the estimated capital gains induced by reassessment for black homeowners is $302 on average, while the capital losses for white homeowners is estimated to be $3,030. This evidence confirms that the reassessment involves a real redistribution of the tax burden, showing that capitalization generates capital gains and losses for current owners in the way that systematically associated with racial tax differentials.

We summarize the distribution of gains and losses in Pittsburgh in Figure 2. The blue line represents the distribution based on a capitalization rate of 30%, which implies that tax differentials are expected to last for three years. The average house in the sample experienced 0.02% losses from reassessment, centered around zero with a standard deviation of 15%. Indeed, 79% of the houses experienced gains and losses between −15 and +15% of the house value, and 94% of the houses experienced changes between −30 and +30%. In extreme cases, some households experienced a gain of 73%, while another experienced a 50 percent loss due to reassessment tax changes. Only a small number of households, those with extremely high or low effective tax rates before the reassessment, experienced drastic changes in the value of their homes, which may partially cancel out previous gains and losses from an assessment lag.

One might ask how the distribution of gains and losses changes as households consider different time horizons for the flow of future tax payments. Although the time horizon is

potentially infinite, the expected persistence of existing tax differences can be corrected with regular reassessment cycles of five, ten, and twenty years, for example. The distribution estimated in our study (N'=3 years) can serve a conservative benchmark if homeowners truly consider a shorter time horizon, however, assuming a longer time horizon would lead to higher estimates of implied capital gains and losses from reassessment. Figure 2 clearly illustrates the distributions of capital gains and losses under three different scenarios with the corresponding expected durations of existing tax differences. Similarly, the average household is centered around 0 in all distributions, but as the expected time horizon increases, the distribution becomes less centered, implying that more households will experience considerable amounts of gains and losses. Specifically, as the duration increases from 3, 5, 10, and 20 years, households with modest capital gains and losses ranging from −5 to +5% were 46%, 30%, 19%, and 12%, respectively. For example, with a time horizon of 20 years, the reassessment will correct large assessment errors for most households, resulting in −35 percent to 35 percent gains and losses for half of the houses, while the other half will experience more. Interestingly, the distributions in Figure 2 are more likely to diverge in those who have capital losses from reassessment than in those who have capital gains, which can be interpreted as having a longer period of duration in our case affects more on households who previously experienced lower effective tax rates.

We further examine the distribution by household group. Figure 3 compares the gains and losses among black and white homeowners. We find that, when compared to white homeowners, the distribution of black homeowners has shifted to the right, implying that more black households benefit from reassessment tax changes. Extreme capital gains were more found in black households in long right tails, and modest gains ranging from 5 to 15% were especially common in black households than in white households.

We also compare the distributions estimated for each of four income groups in Figure 3. In line with previously observed patterns, most households in the upper income quartile have small capital gains and losses, indicating that there are more households with an accurate and fair effective tax rate and small tax changes caused by reassessment. Second, we also show that, except for the lowest quartile, the distribution of households that experience capital losses is qualitatively comparable, whereas one that experience capital gains is more divergent, with more households with large capital gains. This demonstrates that those with relatively high effective tax rates and lower incomes would be impacted more by the reassessment.

7. Conclusion

Residential property taxes are taxes on the dominant part of household wealth. They also form significant costs of owning a home. In 2022, home prices have risen by double digit percentages, with the median home price now approaching $400,000. Homeowners favorably see rising house prices, but not rising property taxes. Property taxes have most likely lagged behind rising property values, making reassessment process an important factor for homebuyers in capitalizing annual flows of tax expenses to keep up with rising house prices. Since property taxes are capitalized, it is difficult to generalize about how the reassessment affects the tax stream capitalized into house prices. In this paper, we investigate the capitalization of property taxes using reassessment reform as empirically relevant settings.

The objectives and results of the analysis are threefold. We begin by examining how severe assessment regressivity exists. We also offer possible explanations for variations in effective property tax rates. We find large and systematic variations in relative property tax burdens, as well as dramatic changes during reassessment, which have resulted in both equity

and redistributive effects. Second, we empirically examine whether reassessment has a capitalization effect, and estimate a capitalization rate of 30%. In addition, we present a model to account for expectations in a study of property tax capitalization and demonstrate that the expectation exists. Third, we further quantify the impact by using the estimated capitalization rate to measure the distribution of capital gains and losses. The results suggest that the changes in relative property tax rates result in capital gains and losses that vary systematically by race and income. The magnitude and distribution of gains and losses are largely determined by the expectations about the timing of future reassessment. If expectations had been shorter and more accurate, home values would have changed less than they would have otherwise.

Despite our efforts made in this paper, there are remaining issues for further research. Top the list is to run IVs with expectations for each year, from which we may be able to discern new insights. Relatedly, there may well be differences in the expectations held by racial and income groups that we have not explored in this study that may offer more perspectives. Finally, it may b e worth exploring the impact of differences in expectations across years and across groups on ho using prices—and hence on equity in the housing market. We will look into these in a sequel to t his paper soon.

Table 1. Nominal Tax Rates

Year	Municipal	School District
2006	6.311	21.958
	(4.580)	(2.770)
2007	6.296	19.856
	(4.773)	(7.500)
2008	6.245	19.992
	(4.597)	(7.509)
2009	6.437	21.497
	(4.674)	(5.273)
2010	6.593	21.651
	(4.628)	(6.433)
2011	6.761	22.212
	(4.715)	(5.614)
2012	6.678	23.043
	(4.495)	(4.464)
2013	6.101	18.261
	(4.394)	(7.600)
2014	6.064	16.781
	(4.484)	(8.789)
2015	6.201	17.026
	(4.514)	(8.901)
2016	6.379	18.100
	(4.558)	(8.937)

Note: This table is a summary of tax information from the Pennsylvania Department of Community and Economic Development's *Municipal Statistics*. In 2013, all taxing municipalities and school districts were required to set their tax millage based on the reassessed property values at a rate that yields the same tax revenue as they each received in the year prior to the reassessment.

Table 2. Assessment Ratios in Five Regions of Pittsburgh Metro Area

Region	*N*	95% Confidence Interval for Median					
		Pre-assessment			Post-assessment		
		Median	Lower Bound	Upper Bound	Median	Lower Bound	Upper Bound
City	2,555	.697	.356	1.038	1	.577	1.423
East	2,148	.878	.409	1.346	1	.559	1.441
North	3,021	.743	.435	1.052	.991	.650	1.332
South	2,988	.794	.504	1.083	1	.341	1.659
West	1,878	.779	.309	1.249	1	.526	1.474
Total	12,590	.774	.614	.934	1	.781	1.219

Note: This table compares assessment ratios just before and after the reassessment when the 2002-base- year system resulted in a decade-long divergence between assessments and market values and when the 2012-base-year system has yet to diverge from market values after the reassessment. Only sales price data for properties that were sold in the same year as the 2012 assessment were included. The resulting data set includes 12,590 records across five regions after the data were appropriately cleaned.

Table 3. Summary Statistics

Variable	All sales		Repeated sales		Straddling repeated sales	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
price	$169,024	$147,829	$156,813	$150,245	$171,619	$147,641
age	58.78	30.38	61.51	32.98	59.05	32.08
sale year	2010.90	3.28	2010.97	3.27	2011.25	3.17
stories	1.63	0.50	1.68	0.49	1.67	0.49
rooms	6.28	1.49	6.21	1.50	6.19	1.54
bedrooms	2.96	0.82	2.92	0.82	2.90	0.82
bathrooms	1.42	0.62	1.38	0.60	1.40	0.61
half bathrooms	0.52	0.56	0.49	0.55	0.51	0.56
fireplace	0.35	0.53	0.30	0.50	0.32	0.51
garage	0.74	0.82	0.66	0.80	0.71	0.80
house size	1650.07	772.21	1627.28	740.99	1621.93	743.60
air conditioning	0.62	0.49	0.56	0.50	0.61	0.49
tax 2006	22.50	8.64	22.73	9.11	21.30	7.31
tax 2007	21.10	9.20	21.54	9.80	20.20	8.26
tax 2008	21.41	9.12	21.38	10.02	20.35	7.57
tax 2009	21.49	8.44	21.35	9.06	21.06	8.26
tax 2010	20.56	9.90	20.40	10.59	19.79	9.58
tax 2011	21.12	10.52	20.77	11.79	21.90	13.05
tax 2012	26.05	9.41	25.92	9.60	24.54	8.45
tax 2013	16.97	11.15	16.41	11.04	15.68	10.20
tax 2014	15.04	10.36	14.47	10.16	13.90	9.32
tax 2015	15.47	10.56	14.99	10.40	14.38	9.63
tax 2016	16.09	10.63	15.22	10.08	15.00	9.72
observations		135,153		62,934		31,410

Note: String variables are not reported.

Table 4. Variable List and Definitions

Variable Name	Definition
A. main variables of interest	
house price	sale price of single-family and detached houses in U.S dollars
assessed value	assessed property value (land and building together) for local tax purposes (for schools and municipalities)
property tax rate	the combined school district/municipal tax rate
B. numerical covariates	
age	difference in time periods between the date of sale and construction
sale year	date of sale of a property
number of stories	story height of the main dwelling
total rooms	total number of rooms in the main dwelling
bedrooms	total number of separate rooms designed to be used as bedrooms
bathroom	number of full bathrooms (toilet, sink, and bathing facility)
half bathroom	number of half bathrooms (toilet and sink only)
fireplace	dummy variable=1 if house has a fireplace, =0 otherwise
garage	dummy variable=1 if house has a garage, =0 otherwise
living area	size of the building in square feet
air conditioning	dummy variable=1 if house has air conditioning, =0 otherwise
C. categorical covariates	
style	building style (20 types)
exterior	exterior wall type (8 types)
roof	roofing material type (5 types)
basement	basement size in relation to the main dwelling (5 types)
grade	quality of construction (21 types, 8 types)
condition	overall physical condition or state of repair of a structure, relative to its age (8 types)
D. renovation covariates	
Δtotalrooms	change in the number of rooms
Δbedrooms	change in the number of bedrooms
Δfullbaths	change in the number of full bathrooms
Δhalfbaths	change in the number of half bathrooms
Δgarage	change in the number of garages
Δlivingarea	change in the size of living area (log)

Note: covariates to account for renovations include dummy variables indicating for each measure if it is positive.

Table 5. Racial Disparities in Property Taxes, Pre- and Post-Assessment

	Black	White	Difference	t-stat
A. Pre-assessment				
sale price	96,169	161,759	-65,590	-9.68
	(5,685)	(2,047)	(6,776)	
assessed value	67,842	105,850	-38,008	-8.15
	(3,427)	(1,421)	(4,663)	
assessment ratio	.796	.704	.092	7.83
	(.013)	(.003)	(.012)	
effective tax rate	19.673	17.397	2.277	7.83
	(.317)	(.086)	(.291)	
average absolute deviation	5.401	5.017	0.384	1.99
	(.216)	(.057)	(.193)	
average deviation	.314	-1.873	2.186	7.56
	(.319)	(.085)	(.289)	
B. Post-assessment				
sale price	13,6951	205,835	-68,884	-6.74
	(8,312)	(2,470)	(10,224)	
assessed value	118,835	175,004	-56,169	-6.00
	(7,297)	(2,265)	(9,361)	
assessment ratio	.889	.859	.030	2.20
	(.013)	(.003)	(.014)	
effective tax rate	9.394	9.337	.058	0.14
	(.422)	(.097)	(.407)	
average absolute deviation	1.654	1.652	0.001	0.01
	(.133)	(.030)	(.125)	
average deviation	.047	-.520	.567	3.61
	(.164)	(.037)	(.157)	

Note: The average absolute deviation expresses the average absolute deviation of effective tax rates from the median rate divided by the median rate, which ignores the sign of the differences from the median. The average deviation tells the difference between positive and negative deviations.

Table 6. Disparities in Effective Tax Rates by Race and Income before 2012 Reassessment

	Black	White	Difference	t-stat
Income $40,000 and less	20.719	19.525	1.194	2.59
	(.443)	(.182)	(.460)	
Income $40,000-$65,000	18.548	17.279	1.269	2.44
	(.523)	(.152)	(.520)	
Income $65,000-$100,000	19.409	16.091	3.318	4.15
	(1.093)	(.176)	(.800)	
Income greater than $100,000	15.971	15.963	.008	0.01
	(.897)	(.148)	(.939)	

Table 7. Incidence by Decile of Income

Income Decile	Average house price	Average tax payment	Tax payment as % of income
1	71,171	1,073	0.048
2	84,449	1,113	0.034
3	97,857	1,063	0.027
4	112,621	1,267	0.027
5	126,856	1,265	0.023
6	147,691	1,406	0.022
7	173,603	1,679	0.021
8	217,751	2,042	0.021
9	297,332	2,763	0.020
10	491,222	4,967	0.019

Table 8. Horizontal Equity Analysis

Price Decile	Pre-assessment variance	Post-assessment variance	Income Decile	Pre-assessment variance	Post-assessment variance
1	12.76	4.42	1	5.51	2.20
2	11.77	2.88	2	4.92	1.86
3	7.24	2.01	3	4.80	1.79
4	4.86	1.92	4	4.58	1.85
5	3.97	1.67	5	4.56	1.58
6	4.01	1.58	6	4.35	1.47
7	4.72	1.66	7	4.52	1.52
8	5.08	1.45	8	4.67	1.50
9	4.66	1.27	9	4.61	1.19
10	3.74	1.00	10	3.92	1.12

Table 9. Exploratory Analysis of Tax Inequity

	(1) efftax	(2) efftax	(3) efftax	(4) efftax	(5) efftax
race	-2.277***	-2.144***	.042	-.167	-.615***
	(.291)	(.291)	(.298)	(.191)	(.238)
income		-.005***	-.002**	-.000	-.003***
		(.001)	(.001)	(.000)	(.001)
after				-11.977***	-13.413***
				(.229)	(.415)
after×race					1.197***
					(.367)
after×income					.004***
					(.001)
Constant	19.673	19.960	10.687	15.752	16.345
	(.278)	(.280)	(2.810)	(1.662)	(1.664)
Year FX	N	N	Y	Y	Y
Neighborhood FX	N	N	Y	Y	Y
Sample	Pre only	Pre only	Pre only	Pre and post	Pre and post

Note: Race is coded 0 for Black; 1 for white. Income is measured in thousands of dollars. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10. Assumption Tests

Statistical Test	Instrument(s)	F-stat
Weak instruments test [a]	I_{Re}/I_F	44.1082***
(null of irrelevant instruments)		(<.001)
	m_s	62.1678***
		(<.001)
	I_{Re}/I_F, m_s	31.0746***
		(<.001)
	I_{Re}/I_F, m_s, housing attributes	13.6056***
		(<.001)
Endogeneity test [b]	I_{Re}/I_F	13.3969***
(null of endogenous tax change)		(<.001)
	m_s	21.6405***
		(<.001)
	I_{Re}/I_F, m_s	21.5984***
		(<.001)
	I_{Re}/I_F, m_s, housing attributes	36.7925***
Overidentifying restrictions test [c]	I_{Re}/I_F	-
(null of exogenous instruments)		
	m_s	-
	I_{Re}/I_F, m_s	.1651
		(0.6845)
	I_{Re}/I_F, m_s, housing attributes	39.3888***
		(<.001)

Notes: [a] We examine the F statistic from the first stage regression by using the "firststage" test estat firststage. Low values are an indication of potentially weak instruments. [b] This implements the Durbin-Wu-Hausman test. The null hypothesis is that tax change is exogenous. Here we see that the hypothesis is rejected so in fact we can reject exogeneity of education in this model. [C] A third test is a test of overidentifying restrictions, which is often referred to as the "Hansen-Sargan" test (Sargan, 1958; Hansen, 1982). Using housing attributes (K) as additional instruments builds on the idea that assessors consistently under- or over-assess based on certain housing characteristics that are presumed to be associated with the assessor's target ratio. The results support the choice of instruments.

Table 11. Intrajurisdictional Estimates of β

Estimation	2SLS			OLS		
	(1)	(2)	(3)	(4)	(5)	(6)
β	32.1	32.3	30.7	25.7	19.4	18.7
	(2.79)	(2.73)	(2.68)	(6.65)	(5.89)	(5.67)
Control for renovations	x	x		x	x	
Control for wards	x			x		

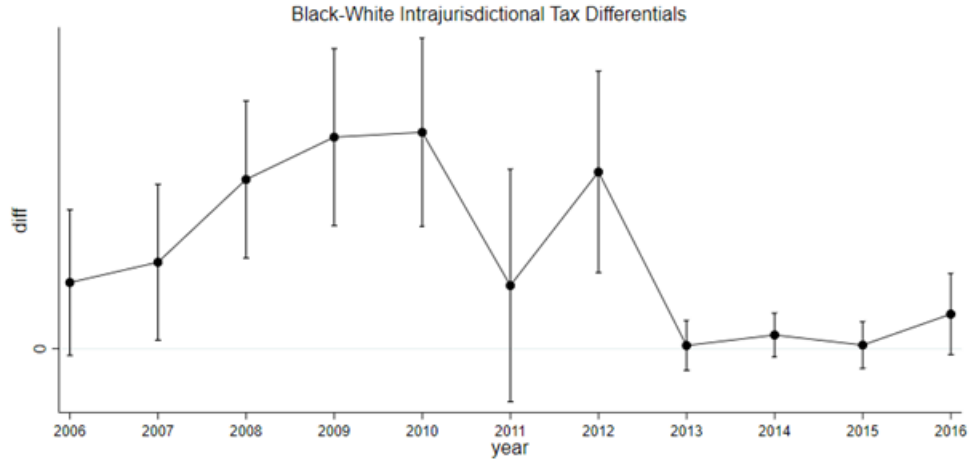
Note: The results are from the estimation of equation (10) on 2,498 pairs of sales in the city of Pittsburgh that sold more than once between 2006 and 2016 and that straddled the reassessment. It shows estimates of intrajurisdictional tax capitalization using the 3% discount rate. The specification controls for house-specific time-invariant unobservables and interjurisdictional time-varying confounders. Each cell represents the percentage at which property tax changes are capitalized into changes in sales prices. Columns (1)-(3) represent estimates based on IV-2SLS. Columns (4)-(6) represents estimates based on OLS model. Absolute values of t statistics are reported in parentheses. Robust standard errors clustered at the ward level.

Table 12. Estimates of the Expected Persistence of Tax Differences

Sales year	β	N
2006	46.5	21
2007	37.7	16
2008	17.6	7
2009	16.8	6
2010	14.6	5
2011	16.6	6
2012	29.1	12
2013	72.3	43
2014	67.7	38
2015	127.6	∞
2016	202.0	∞

Note: The results are from the estimation of equation (9) on 2,498 pairs of sales in the city of Pittsburgh that sold more than once between 2006 and 2016 and that straddled the reassessment. The results are preliminary, not yet estimated with instrumental variables. The estimates were conducted with β' assumed to be 1.0 and the discount rate of 3%.

Figure 1. Racial Disparities in Effective Tax Rates in Pittsburgh, 2006-2016



Note: A paired *t*-test was used to compare the means between Black and White homeowners. The means of the intrajurisdictional deviations (from the average effective tax rate) are plotted as a solid line. Error bars represent 95% confidence intervals for the paired t test.

Figure 2. Actual and Hypothetical Gains or Losses from Reassessment for Various Time Horizons

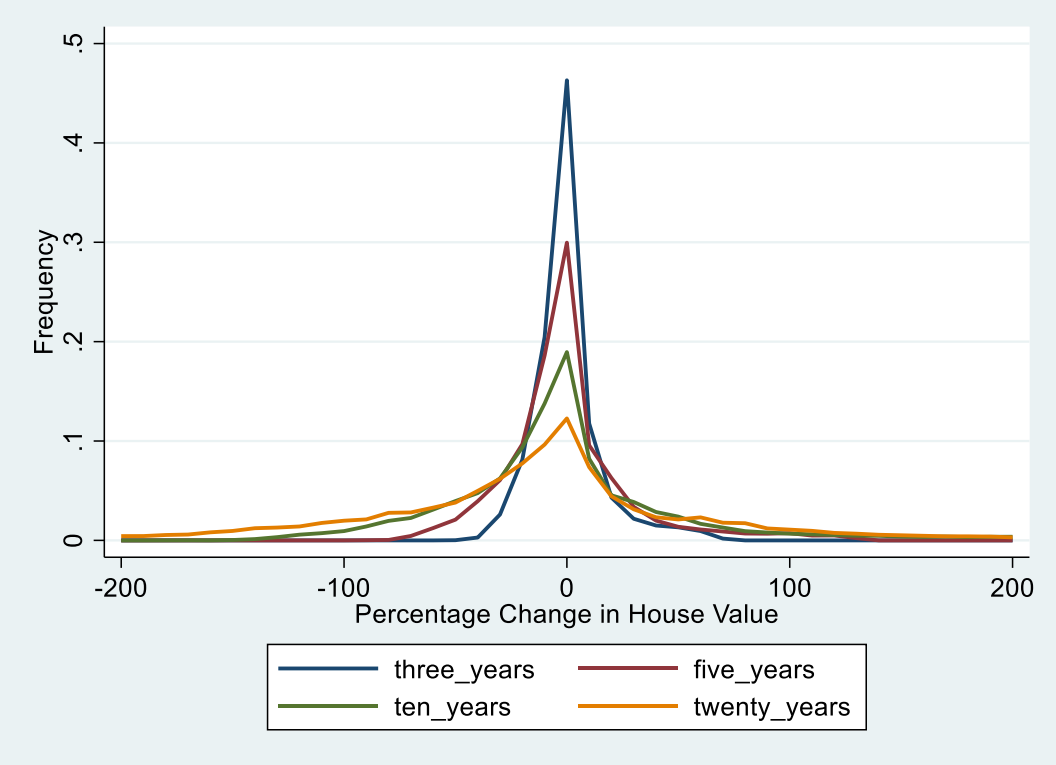
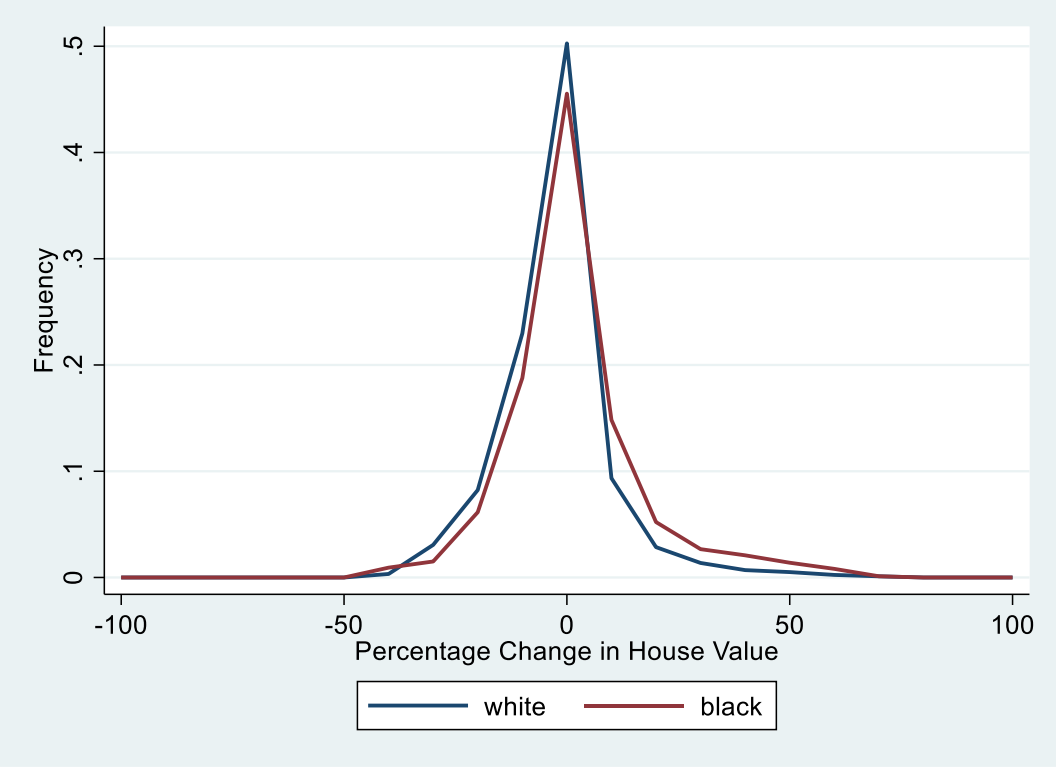
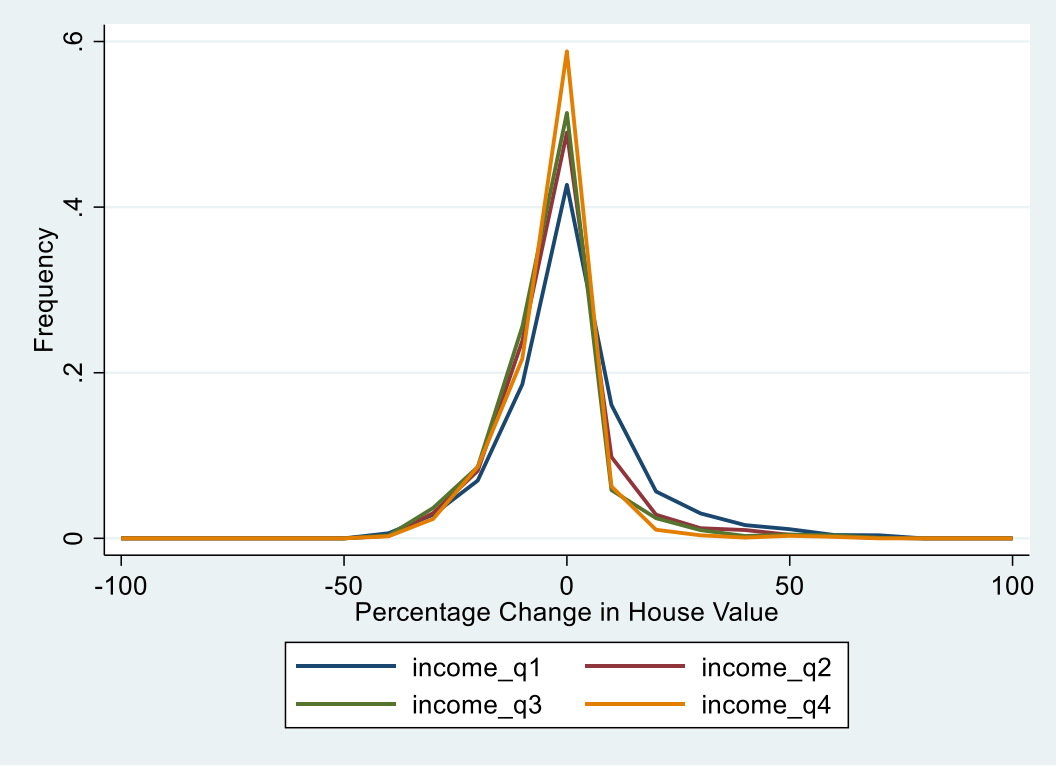


Figure 3. Distribution of Capital Gains or Losses by Race and Income in Pittsburgh





Technical Appendixes

This technical appendix includes details on the mathematical derivation used to illustrate the endogenous relationship between property taxes and house values. The following derivation is from Yinger et al. (1988). It provides more technical details on the instruments that aim to correct for simultaneity and describes empirical techniques for dealing with potential misspecification.

Correcting for simultaneity

The first technical issue we encounter is simultaneity bias. The problem arises in that house prices and the property tax are simultaneously determined. We can use two key dimensions to determine the direction of the simultaneity bias: (1) intrajurisdictional tax differentials (the effective tax rate for each property) or interjurisdictional tax differentials (the nominal tax rate in each jurisdiction), and (2) assessor's behavioral link or definitional link in the effective tax rate expression. We theorize the issue at the property level as follows:

$$t_i \equiv \frac{T_i}{V_i} = \frac{mA_i}{V_i}$$

where the effective property tax rate *t*, on property *i*, is defined to be the tax levy, *T*, as a share of the market value of property *i*, *V*, and tax levy, in turn equals the jurisdiction's nominal tax rate (in mills), *m*, multiplied by the property's assessed value, *A*.

Within the jurisdiction level, the simultaneity issue in a model of *t* on *V* takes two forms. First, the property tax variable is endogenous to the house's market value, because in principle assessors consider market values, *V*, in setting assessed values, *A*; this behavioral link will also increase tax levy, *T* and its effective tax rate, *t*. Second, house value as denominator of the effective tax rate, by definition , negatively influences *t*. Therefore, the behavioral link between tax levy and house value is likely to bias the coefficient upwards, whereas the definitional link between house value and effective tax rate likely provides a downward biased estimate.[7]

The model in this study is greatly aided by the context of this study – reassessment (or tax reform) with changes in *A* before and after the reassessment. Therefore, we will translate the simultaneity issue in a change form by introducing the time. In a model with changes in both house value and tax rate, these two types of simultaneity bias are present in one of two forms. First, relative changes in house values, dV/V_F, (a subscript "F" indicates a first sale) may be

[7] In the case of interjurisdictional capitalization, the simultaneity problem takes another form, since the tax variable is the nominal tax rate: The tax rate needed to finance a public service at a given quality depends on the average house value in the jurisdiction. Across jurisdictions, higher average property values allow a given level of services to be provided at a lower tax rate. Thus, ignoring this negative impact of *V* on *m* leads to upwardly biased estimates.

reflected in the new assessment; these changes automatically alter the denominator of the expression. Second, changes in tax rates, *dt*, arise from the second-sale (thereby the subscript t_S where a subscript "S" indicates a second sale), because house value changes do not alter a house's characteristics at first sale or the effective tax rate from the first-sale.

To identify the instruments, the second-sale effective tax rate, t_S, is decomposed into a function of assessor behavior and exogenous factors that influence the tax rate. Starting with the tax rate expression,

$$t_S = m_S \frac{A_S}{V_S}$$

Substituting the following two expressions into the above equation for effective tax rate, the parts of the denominator and numerator are:

$$V_S = V_F \frac{I_S}{I_F}\left(\frac{V_S^*}{V_F^*}\right)$$

$$A_S = KV_{\mathrm{Re}} = KV_F \frac{I_{\mathrm{Re}}}{I_F}(1+g)^{\mathrm{Re}-F} = KV_F \frac{I_{\mathrm{Re}}}{I_F}\left(\frac{V_S^*}{V_F^*}\right)^{(\mathrm{Re}-\mathrm{F})/(S-F)}$$

where the denominator—second-sale price, V_s, is explained by the first-sale price, V_F, the interjurisdictional changes, I_S/I_F, and the intrajurisdictional changes, V_S^*/V_F^*, between the first- and second-sale years. As explained earlier, the interjurisdictional changes are changes in jurisdiction average housing prices, and the intrajurisdictional changes are changes in house prices relative to the average.

The numerator—second-sale assessment, A_S, equals assessment at reassessment, which is the housing prices for the reassessment year, V_{Re}, multiplied by the assessor's target assessment-sale ratio, *K*. Since V_{Re} is not observed, it is estimated by assuming a constant annual relative growth rate (*g*%) in house value. Then we can write the second-sale tax rate expression as follows,

$$t_S = m_S \frac{A_S}{V_S} = m_S \frac{Eq(1.2)}{Eq(1.1)} = Km_s \frac{I_{\mathrm{Re}}}{I_S}\left(\frac{V_S^*}{V_F^*}\right)^{-(S-\mathrm{Re})/(S-F)}$$

This equation explains the second-sale effective tax rate variable based on assessor behavior, and also identifies the key exogenous factors that influence the second-sale effective tax rate, t_S: *K*, m_S and I_{Re}/I_S. That is, it separates the exogenous variation (*K*, m_S and I_{Re}/I_S) from the part that is jointly determined (house price, *V*).

The identification strategy we propose uses a two-stage least squares estimator to minimize the simultaneity bias discussed above. In the first stage, we regress the endogenous predictor, t_S, on the key instruments, m_S and I_{Re}/I_S, as well as a set of covariates including housing and

neighborhood characteristics that could potentially influence *K*.[8] In the second stage, the predicted values of the list of the instruments from the first-stage regression are used as instruments for the endogenous regressors to obtain a "clean" estimate of the relation between effective tax rate and housing prices.

Constructing house price indexes

To eliminate jurisdiction-wide housing inflation over time, we deflate all sales prices by a housing price index. We obtain a housing price index for each jurisdiction by estimating the Bailey et al. (1963) model for double-sales data. The basic idea is to use ordinary least squares regression analysis in which the dependent variable is the logarithm of the sales price ratio that compares a house's first sale to its second sale. The log price relatives are then regressed on a set of dummy variables corresponding with the time periods, such that

D_{it} = -1 if the first sale for house *i* occurred in period *t*,

1 if the second sale for house *i* occurred in period *t*,

with $t = 0$ as the base period. Thus, a set of dummy variables are constructed for the sample period. The first and second sales have dummy variable values of one, and zero otherwise. The estimating equation of the price index for period *t* is:

$$\log V_{ik} - \log V_{ij} = \sum_{t=1}^{T} \alpha_k D_{it} + \log u_i$$

The left-hand side expresses the sales price ratio in natural logarithm where V_{ik} is the sale price of house *i* in period *t*; *k* and *j* represent the periods in which the first and second sales occurred, respectively. On the right-hand side, α_k is the natural logarithm of the price index for period *t* to be estimated, and D_{ti} is the dummy variables with values -1, 0, and 1, as explained above. Note that a price index is estimated for each taxing jurisdiction that shares the same municipality and school district, and also is estimated by all sales, not just sales for observations that straddle reassessment but also for non-straddling observations. Each index applies to each jurisdiction pool separately, not to all observations on a countywide basis.

[8] If the first stage obtains poor predictors of the effective tax rate variable, the behavioral model will help provide an eligible list of instruments to use in a simultaneous-equations procedure. We then evaluate the relevance of each instrument to pick out relevant instruments from a set of instruments that contain redundant instruments.

Data Appendix

To identify the race, ethnicity, gender, and income of homebuyers, we matched loan-level records from two primary data sources—Black Knight's (formerly Lender Processing Services (LPS)) McDash Core Database and Home Mortgage Disclosure Act (HMDA) data compiled by the Federal Financial Institutions Examination Council (FFIEC). The LPS/McDash data provides detailed information on loan and property characteristics, however, it contains little information about borrowers. In contrast, the HMDA data contain information about borrowers' demographic and financial characteristics, although the data alone do not allow an individual to be indirectly identified. While the LPS/McDash and HMDA data emphasize different kinds of loan and borrower information, they do have some information in common. These common data items—including loan amount, loan purpose, loan origination year, loan type, property location, property type, and loan originator—allow the two data sets to be matched on a loan-by-loan basis.

The matching process begins by joining the LPS/McDash and HMDA files, based on the five matching keys: the 6-digit census tract number, year, loan amount, loan type, and lender name. This is accomplished for each year and loan type separately, and then each pair of matches was assigned a composite match score as the sum of all field-similarity scores adjusted by specified weights. We then classify these matches into four categories based on the match quality: (1) 'Perfect matches' refer to unique initial matches on the basis of all of the five matching keys; (2) 'High-quality matches' include perfect duplicate matches and matches that differ very slightly, either on the basis of small rounding differences in loan amounts (plus or minus 1) or a one-digit discrepancy of the last four-digit census tract identifiers; (3) 'Medium-quality matches' are matches that satisfy the three criteria: (a) among unmatches excluding perfect and high-quality matches, the four matching keys, except for the lender name, are the same, (b) the lender is not listed in the HMDA reporting institutions of the loan origination year but rather it appears to be involved in the securitization process as offices of affiliates or other parties such as loan brokers, and (c) the loan is unique in both data sets; (4) And 'Low-quality matches' consist of all other matches in the dataset, based on our best guess given the closeness of our matching keys.

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