A Third Dimension of Equity: Temporal Discontinuities in Property Assessments

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Abstract

The cycle of property revaluation in a municipality inevitably creates tax bill discontinuities for individual property owners, as market values change. However, any form of statistical analysis carries a risk that analyst assumptions will color the results. Data from Providence, Rhode Island suggest that standard assessment techniques frequently produce onerous tax bill discontinuities, not because of shifts in market values, but because of the techniques in use and the assumptions behind them. Large numbers of tax bill discontinuities are not reliably associated with rapid changes in property value, with highly variable property values, or with property value, even if the last is common. The random nature of these discontinuities are particularly onerous for renters and for households at the low end of the income spectrum. Because these effects are statistical artifacts and not inherent in the real estate market, they permit some degree of amelioration. A case is presented that current assessment techniques emphasize an elusive standard of accuracy over stability, and suggest a greater focus on temporal consistency as an indispensable component of fairness.

1 Introduction

Mass assessment of property values for tax purposes is one of the fundamental chores of a government whose funding derives from property taxes. The dual imperatives of fairness and consistency have led practitioners to use sophisticated statistical regression techniques to glean a valuation model from sales data. And yet, beyond that base-level consensus, there is little in the way of consensus about the details. Across the US, there is a startling level of heterogeneity in assessment practice. The length of a revaluation cycle, the bounds of acceptable changes for individual properties, and the selection of appropriate parameters for an appraisal model all vary significantly even across US governments [NYSDTF, 2022].

This is perhaps because poor administration of assessment can add a layer of arbitrariness that can exacerbate claims of unfairness. This potential might be said to have motivated the many different forms of property tax assessment limitations seen in jurisdictions around the country [Winters, 2008]. Such variety in legislative response would seem the natural outcome of an opaque and seemingly arbitrary process whose outcomes are widely seen as frequently unfair, but where the definition of fairness is not widely shared. The potential might also have motivated the creation of IAAO assessment standards [IAAO, 2017]. These standards exist to promote accuracy in assessment, but

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also equity. However, as in most matters involving equity, there is not widespread agreement on how to achieve it and at what cost. Is a three-year cycle of re-assessment a good tradeoff between expense and equity? Five? One? Communities differ and as a result, practice differs, too.

Assessment practice often references concepts of horizontal equity, where properties of similar value should have similar assessments, and vertical equity, which demands that properties of different value should have a similar ratio of purchase price and assessment [e.g. Hou et al., 2021, IAAO, 2017]. But there is also a case to be made for what we will call temporal equity. That is, though a property's value obviously must change over time as the markets evolve, it is important to avoid sudden jumps in imposed taxes for an individual property, at least within the context of a continuity of ownership, relatively recent assessment, and a lack of externalities such as lawsuits, delinquencies, or other past deficiencies. Sudden large increases in tax bills can impose disproportionate burdens even on owners of valuable property because of the lack of time to prepare. Sudden jumps down are also to be avoided, if only because they imply the existence of sudden jumps up somewhere else in the community. Concerns about temporal equity are more or less orthogonal to the vertical and horizontal directions, but seem no less important since a breach can have the effect of putting people out of their homes.

Concerns about temporal equity have led, in recent years, to an increase in the frequency of revaluations, as in Rhode Island, where a ten-year cycle of assessment was changed by the legislature to three years in 1997. Similar reforms have been enacted around the country, so the most common cycles are in the 3-5 year range [NYSDTF, 2022]. Unfortunately, though these reforms have been enacted in the hope of ameliorating sudden changes in value and the concomitant changes in tax bills, the record since shows they have often failed to improve the temporal equity of the system, and possibly even made it worse, as the current analysis will show.

To begin with, one must acknowledge some of the perils of subjectivity in any kind of statistical analysis [Berger and Berry, 1988]. When one adopts hedonic pricing theory to represent a residence as a collection of bedrooms, bathrooms, and other features, one is implicitly assuming that the range in quality of bedrooms is small compared to the range of the houses that contain them. When one chooses a linear regression to fit sales data, one is making an assumption about how prices should vary. And when one excludes time on the market from consideration of value, one is assuming a certain level of economic efficiency in real estate markets. Awareness of such assumptions is vital to the validation of a model in any domain, not just real estate valuation.

In fact, each of these assumptions can be shown to be weak. Bedrooms and bathrooms vary considerably among houses, a consolidated city block is often worth much more than the sum of its lots, and real estate markets are fraught with the kinds of information asymmetries and irrationalities that tend to undercut broad claims of market efficiency [Kurlat and Stroebel, 2015, Levitt and Syverson, 2008]. Even sales ratios, commonly used to evaluate dimensions of equity, are not immune. When used as a standard of accuracy, they embody an assumption of independence between assessment and sales price that is not beyond question [e.g. Garmaise and Moskowitz, 2004]. However, the weakness of these assumptions is beside the point if the resulting assessment can be considered fair, by the citizens affected.

1.1 Smoothing the bumps by increasing revaluation frequency

One of the important assumptions in an assessment is about what matters. Which of the many possible variables are the important ones to the price of a house? The number of bedrooms? The view? The EV charging station in the garage? Though it is tempting to be complete, and to include any variable that seems important to a potential buyer, too many variables can compel even a linear regression to fit the noise rather than the signal. This overfitting, because it varies over time, can destroy temporal equity by producing inexplicable large jumps in property values from one assessment to the next.

In 1997, the state of Rhode Island abandoned its 10-year property revaluation cycle in favor of a 3-year cycle, where every third revaluation includes an audit of house condition and improvements and the other two are purely statistical in nature, using current sales data, but assuming the assessment data about each property are unchanged from the last revaluation. According to legislators at the time, this was done primarily to address the complaints that revaluations often produced large jumps in tax bills. The first item in the list of legislative findings in the statute confirms this, reading "Up-to-date property values are maintained through more frequent property revaluations."[1] In other words, the reform was enacted to promote, and protect, temporal equity.

We received and analyzed 21 years of tax roll data from the City of Providence Tax Assessor's office covering the years 2003–2023, including seven revaluations, every three years. Property taxes are administered by the cities and towns in Rhode Island. (There are no county governments.) The revaluation of 2003 was used in the 2004 tax bills, 2006 for 2007 bills, and so on.[2] The revaluations were conducted by two different vendors contracted to the city assessor's office. The median changes in assessed value for the three categories of residential property are shown in Table 1.

%	03-04	06-07	09-10	12-13	15-16	18-19	21-22
Single-Family	77.5	35.0	-29.9	-9.6	7.6	30.1	43.0
Multi-Family	91.9	54.9	-43.2	-17.3	13.0	41.8	58.3
Apartments	54.9	60.3	-23.1	-6.1	14.2	8.4	53.7

Table 1: Median percentage changes in assessed value for the revaluation years shown for three residential property classes. "Multi-Family" includes buildings with 2-5 units, and "Apartments" have 6 or more.

Typically, the tax rates in a city will be adjusted as a result of a revaluation. Holding total tax collections constant, individual properties whose change in assessment is near the average will see the smallest changes in their tax bill. We used median instead of mean for the average, to reduce the effect of outliers, though we also tried to exclude them by other means. Assuming the change at the median is zero, if the median change in assessment is ΔV, a property whose assessment changes by $\Delta V + \delta$ will see a tax bill increment of $\delta / \Delta V$, before accounting for any of the assortment of tax exemptions available to some property owners in Providence, which we ignore for this analysis. We will refer to such increases and decreases as changes in the assumed taxes.

Obviously the city has not always held tax collections constant. The goal here is to isolate the effect of the assessment from budgetary decisions. In the following, discussion of tax increases and decreases are meant to refer to changes in the assumed tax bills, independent of tax rate changes imposed by demands of the city budget.

[1] RI General Laws, §44-5-11.5, https://webserver.rilegislature.gov//Statutes/TITLE44/44-5/44-5-11.5.htm

[2] Data files for each year can be downloaded at https://data.providenceri.gov/browse?q=Roll.

We note that a large number of properties, especially in less affluent neighborhoods, saw their assessments rise dramatically at some point in our study period. Many of these represent properties that were abandoned or have had substantial renovations. Because our interest is in exogenous influences on assessed value, we omitted these from consideration by excluding from the study properties whose valuations went up by more than 150% at a revaluation. Table 2 shows mean tax bill changes and standard deviations for three classes of residential property over each of the revaluations in the study period. For comparison, there were an average of 13,866 total properties in the Single-Family class over the study period (13,839 in 2004 growing to 13,881 in 2023), 13,785 Multi-Family properties (13,921 declining to 13,626), and 608 Apartment properties (640 to 583).

%	03-04	06-07	09-10	12-13	15-16	18-19	21-22
Single-Family	0.249 (11.8)	1.88 (14.2)	0.180 (21.5)	0.568 (12.1)	0.256 (8.87)	0.0251 (13.1)	1.01 (13.1)
N	13,750	13,832	13,857	13,857	13,880	13,868	13,858
Multi-Family	0.104 (12.6)	0.0760 (12.8)	6.39 (27.4)	0.583 (20.0)	1.03 (10.8)	0.325 (14.4)	-0.0268 (12.7)
N	13,525	13,767	13,791	13,736	13,756	13,726	13,577
Apartment	2.74 (22.5)	0.386 (23.2)	1.49 (23.0)	-1.98 (30.6)	0.797 (14.6)	4.81 (15.3)	-2.15 (15.1)
N	611	604	608	594	608	594	582

Table 2: Mean (standard deviation) of assumed tax bill changes for the revaluation years shown. Most of the means are fairly close to zero, but the variances are often quite large. The distributions for single-family houses are shown in Figure 1.

2 Results

A visual depiction of the distribution of assumed tax changes for single-family houses is shown in Figure 1. As in Table 2, the change in variance from one revaluation to the next is substantial. The 2009 revaluation is notable for its broad, almost tri-modal, distribution, but the 2015 distribution is notable, too, for its narrow distribution, that minimizes the abrupt changes in assumed taxes.

2.1 Hypothesis testing

Having established that the distribution of assumed tax bill changes varies significantly from one revaluation to the next, one might hypothesize that this is caused by one or more of several circumstances that also vary from one year to the next. For example, it is possible that high variance in assumed tax bills is associated with rapidly changing prices, or with high levels of heterogeneity in prices, or just with high prices. We can use plat-level data to test these hypotheses. This is appropriate since sales figures tend to be geographically linked, with values rising in favored neighborhoods, and falling, at least in a relative sense, in the unfavored areas.

The Providence tax rolls reference 130 different plats, maps covering areas ranging from two to 1,009 properties. Our interest in residential property excludes a dozen or so from consideration, but there are still 118 plats with more than 10 residential properties in them, ranging up to 701. There are 258 properties in the median plat, with a mean of 268. Note that residential “properties” includes single-family, multi-family, and apartment buildings.

Though plat maps tended to be drawn to respect physical boundaries, they are not exclusively so. They tend be smaller than what residents might think of as a neighborhood. However, they are

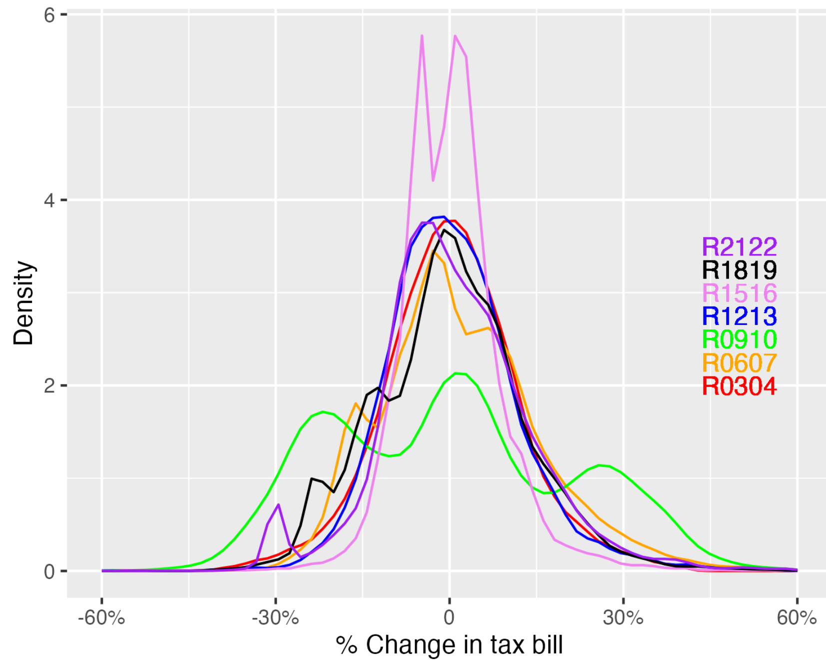

Figure 1: Distribution of assumed tax changes. The width and height of the peaks varies considerably during the study period. For the 09-10 change, the figure shows a tri-*modal distribution.*

large enough and numerous enough to provide a ground for rough tests of the suggested hypotheses, and we approach them in turn.

2.1.1 Rapidly changing prices

One possible hypothesis is that a wide range of changes in assumed tax bills is associated with rapidly changing prices. Figure 2 shows assumed tax bill changes as a function of the mean rate of change in each plat in the city, over the study period. For some of the revaluation years (2007, 2019, 2022) there is a weak association, with enough of a correlation that a linear regression explains as much as 37% of the variance. However, in four years of the seven, the analysis cannot reach the 10% mark. Table 3 shows the R^2 values. It is perhaps significant that the two best fits are the two most recent years, but those are results from two different vendors, neither of whom has reported changes in their methodology from previous revaluations.

2.1.2 Price heterogeneity

It seems plausible enough that simple heterogeneity of properties in a plat might be associated with a high variance in assumed tax bill changes. We have no metric for heterogeneity of properties beyond the assessments themselves, but it seems plausible that heterogeneous assessments might create heterogeneity in assumed tax bill changes.

Figure 3 shows this relationship, again for each plat in the city with more than 10 properties, and limiting the universe to properties whose change in assessment was less than 150%, in order to avoid

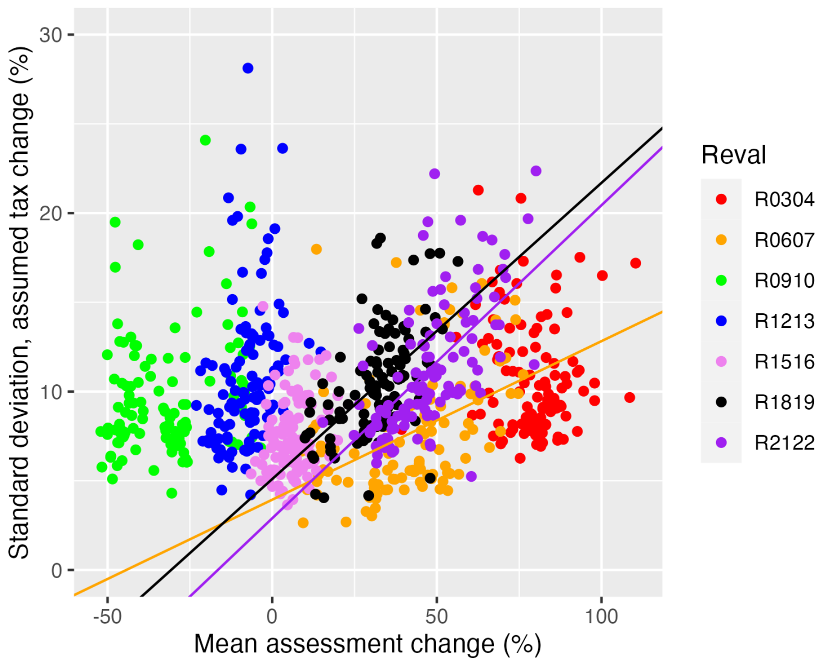

Figure 2: Mean rate of change in assessments vs. σ for assumed tax changes. Each point represents all the Single-Family units in a different city plat. The fitted lines are shown where they produced a multiple R^2 value of more than 10%, only three of the seven revaluation years. See Table 3.

	R0304	R0607	R0910	R1213	R1516	R1819	R2122
Single-Family	.0015	.208	.043	.098	.036	.318	.372
Multi-Family	.0042	.382	.0013	.134	.076	.217	.306
Apartment	.040	.181	.048	.023	.116	.794	.0068

Table 3: Multiple R^2 values for linear fits between mean rate of change in assessments and σ of assumed tax changes, for the years in Figure 2 . The high value for Apartments in 2019 seems only to underscore the randomness of the results, since none of the other years break 20%, and three years are close to zero. (N=19).

including properties whose value changed due to internal factors such as extensive renovations. There are no obvious trends, as can be seen in the R^2 values in Table 4, where the regression lines do not seem to predict much more than a mean value would.

	R0304	R0607	R0910	R1213	R1516	R1819	R2122
Single-Family	.140	.010	.057	.021	.0015	.033	.0015
Multi-Family	.0498	.0128	.122	0	.0868	.004	.0439
Apartment	.0363	.0821	.175	.0343	.0005	.0029	.134

Table 4: Multiple R^2 values for linear fits between σ for per-plat prices and tax bill increments, for the years in Figure 3 (Single-Family property) as well as the other property classes studied here.

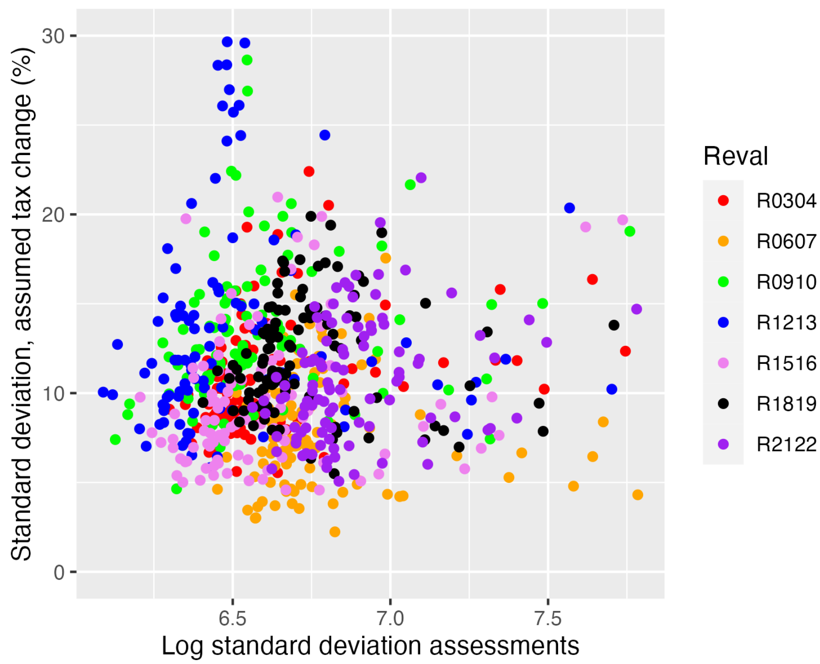

Figure 3: Mean σ of assessments vs. σ assumed tax changes for Single-Family class property. (The horizontal axis is a log axis, to expand the viewable area, but the analysis was on the raw values.) Each point represents a different city plat. None of the sets of points show an obvious trend, as can be seen from the R^2 values in Table 4.

2.1.3 Property prices

When plats are ranked by the variance in the jump in tax bills, it seems consistently true that the higher ranked neighborhoods are the lower-income parts of the city. In fact, there is a weak correlation (0.249) between the rank of plats ordered by mean value and by the variance in the increment of assumed tax bill over the entire study period for single-family properties, with the variance in assumed tax bills inversely related to the property values. For Multi-Family properties, the correlation is slightly higher (0.342). The Apartment properties show no comparable correlation (0.0253), but these results suggest examination of the relationship between property value and assumed tax bill change.

Broadly speaking, there is often a negative relationship between property values and the span of assumed tax bill changes, so that low property values are often associated with high incidence of large jumps in assumed tax bills. Figure 4 shows the relationship between assessed value and the size of jumps, for all seven revaluation episodes. For all but the 2003-2004 revaluations, there is a line of value above which the σ of assumed tax bill jumps becomes substantially smaller. But the same figure also shows a substantial variability among the cases, and in fact there is little consistency in the correlation. For single-family properties, over the course of the study period, the correlations of plat rank in these two categories for any specific revaluation year range from -0.08 in 2010 to 0.47 in 2013. See Table 5.

	All	R0304	R0607	R0910	R1213	R1516	R1819	R2122
Single-family	.249	.029	.431	-.0799	.477	.121	.369	.393
Multi-family	.342	.276	.571	.151	.453	.374	.366	.204
Apartments	.0253	-.0268	.518	-.384	-.0221	.237	-.161	-.0562

Table 5: Correlations between plat rank and σ for assumed tax bill increments. Positive correlations imply low plat values are associated with high values of σ. Correlations are often modest but significant, but for single-family homes, three times out of seven they are not.

Though there is often a correlation between low property value and high jumps in assumed tax bills, this speaks more to the size of the jumps than the number of them. Figure 5 counts the number of large assumed tax bill jumps for each property and compares them with property values, across all the study years. It shows very little in the way of a trend between property values and the number of jumps.

Comparing revaulation records for individual properties shows occasionally significant relationships between the size of the assumed tax bill change and the property value. But the pattern is not consistent, and though there are a few years and categories where the R^2 for a linear fit exceeds 0.1, it does not seem to indicate any kind of underlying pattern, as in Table 6.

	R0304	R0607	R0910	R1213	R1516	R1819	R2122
Single-Family	.030	.119	.419	.120	.0887	.148	.123
Multi-Family	.0004	.128	.472	.0173	0	.0069	.0535
Apartment	.0466	.00014	.0265	.0121	.0011	.0059	.0637

Table 6: Multiple R^2 values for linear fits between per-plat mean price and σ for tax bill increments.

Note that since the plats experience a certain amount of stability in their rank in property values, this also demonstrates that the pattern of high variability in assumed tax increases is not stable geographically from one revaluation to the next. Overall, when staying within the bounds of the assessment data, it seems difficult to find a consistent correlate to the span of assumed tax bill increases.

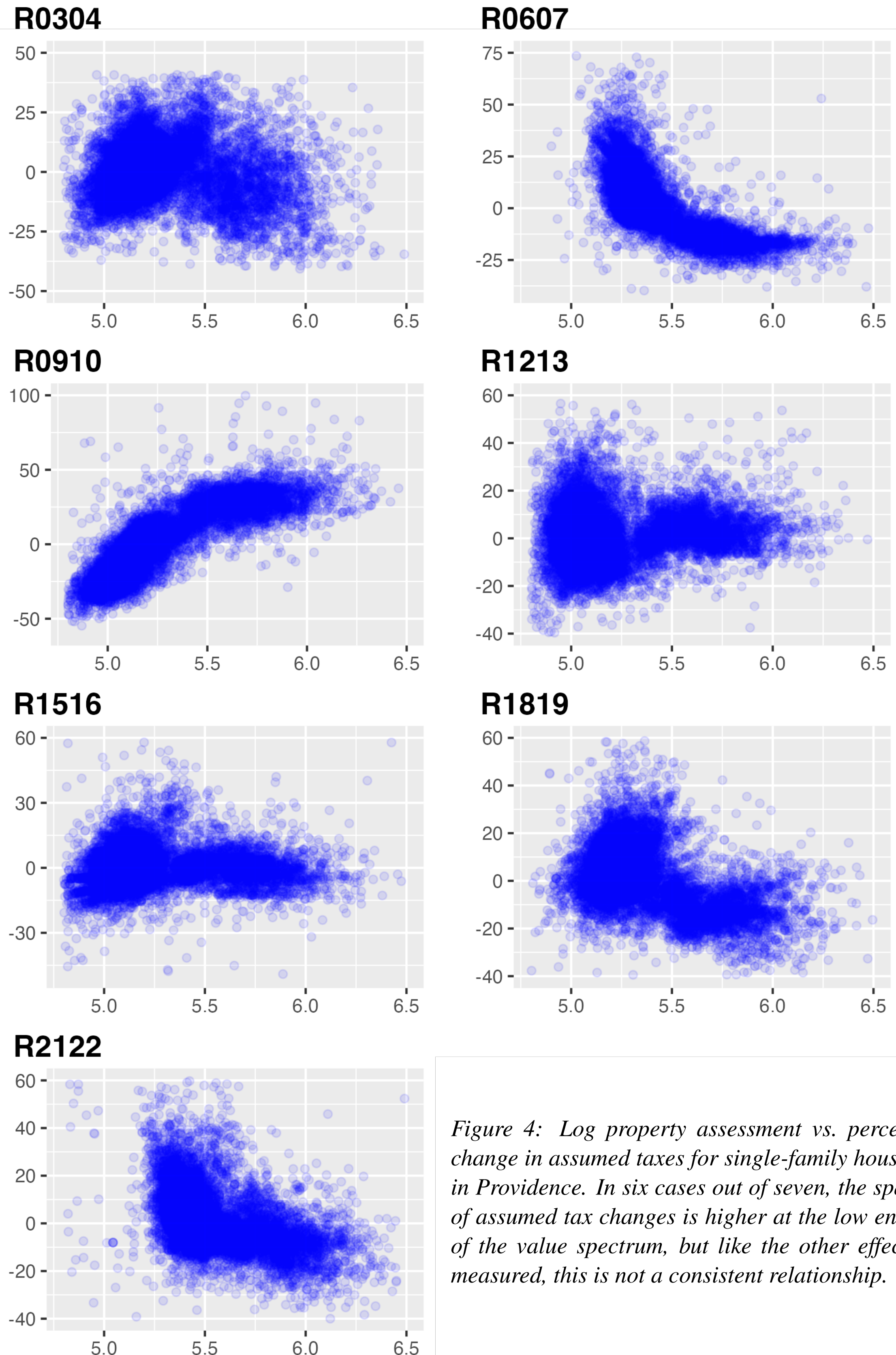

Figure 4: Log property assessment vs. percent change in assumed taxes for single-family houses in Providence. In six cases out of seven, the span of assumed tax changes is higher at the low ends of the value spectrum, but like the other effects measured, this is not a consistent relationship.

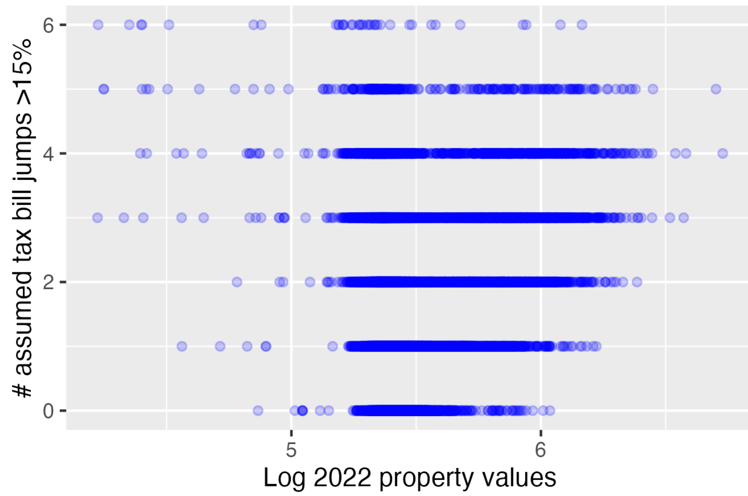

Figure 5: Log property values vs. number of large jumps in assumed tax bills for single family properties over the study period. All properties are subject to these jumps, though as seen in Figure 4, there is often a relation between property value and the size *of assumed tax bill jumps.*

2.2 Taxpayer impact

We turn to the question of the impact of the assumed tax bill changes on property owners. For each property, we counted the number of revaluations out of the seven episodes that resulted in assumed tax bill increases over the study period, and the number of assumed tax bill changes that exceed 15%, either up or down. This is an arbitrary threshold, chosen out of a subjective conviction that it was a small proportion that would still be considered a startling jump to a property owner. We use it as a gauge of impact, but no findings here depend on this choice of number, even if the counts will be obviously larger or smaller for a different choice of threshold. Heat maps for these two dimensions, for each of the three property classes, are shown in Figures 6, 7, and 8.

The heat maps clearly show that the bulk of properties are in the middle of the X axis, implying that most properties were above the average assessment increase as often as they were below it. But in the vertical direction, the main mass of properties is well above the X axis, meaning that most properties experienced a change in assumed taxes of at least 15% at least once. In fact, most saw more than that in the course of the study period. For single-family homes, 59% saw this size change two times or more, and 19% saw four or more such jumps. Almost exactly the same numbers apply to multi-family houses (61% and 19%, respectively), and apartments (62% and 19%).

3 Discussion

Whether data are overfit is a subjective matter because the proper shape of the functional relation fit to any data is generally an assertion of the analyst, not an observable fact of the data itself. In science, the exact relation between independent and dependent variables is generally the hypothesis being tested by a regression analysis, not something a regression analysis defines [Sykes, 1993]. However, we can make some observations from the analysis presented here.

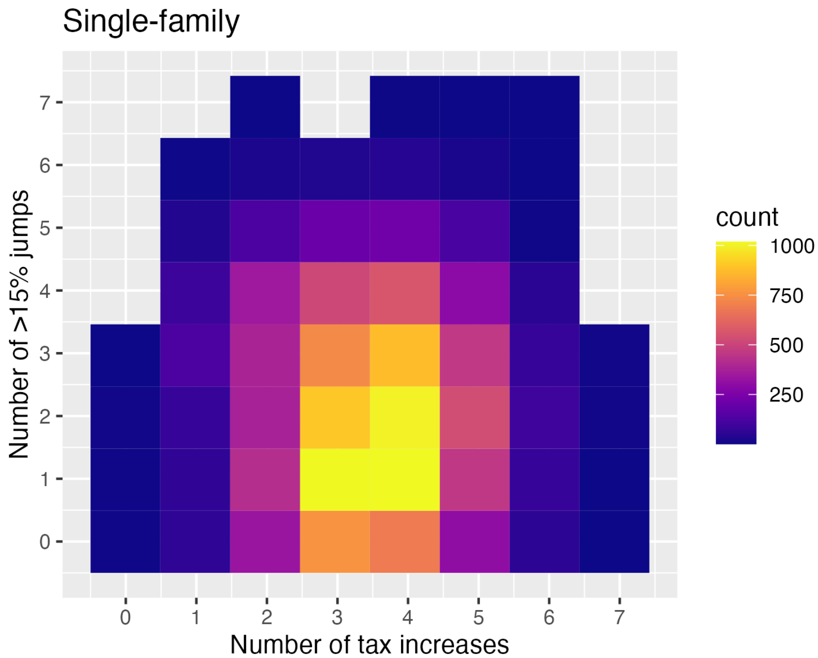

Figure 6: Heat map of assumed tax increases over study period vs jumps in assumed taxes of more than 15% for single-family properties.

- Within the context of the assessment data used in this study, there seem to be no compelling correlates to the scale of jumps in assumed tax bills that appear with any claim to consistency, with the occasional exception of price. Neither the rate of change in mean values nor the heterogeneity of assessments seems related in a persuasive way to the size and frequency of big jumps in assumed tax bill.

- Though there is often a correlation between big jumps in assumed tax bills and low property values, it is inconsistent from one revaluation to the next, implying an occasional, not a fundamental, relationship.

- The prevalence of big jumps in a property's assumed tax bill seems to be nearly identical for residential properties of all three classes, despite significant differences in their market segments over time.

A seemingly random and inconsistent relationship that seems to have effects of similar frequency across different classes of property is broadly consistent with an explanation that points to the analysis mathematics rather than the real-world circumstances of a collection of properties as the source of these jumps. If large swings in tax bills were due to overfitting, one would expect to see those swings defined by their property's distance from actual sales data in N-dimensional space, where N is the number of assessment parameters. These swings will appear essentially random in nature to any observer who finds it challenging to visualize spaces of high dimensionality: that is, most of us. Furthermore, since the choice and number of dimensions varies from one revaluation

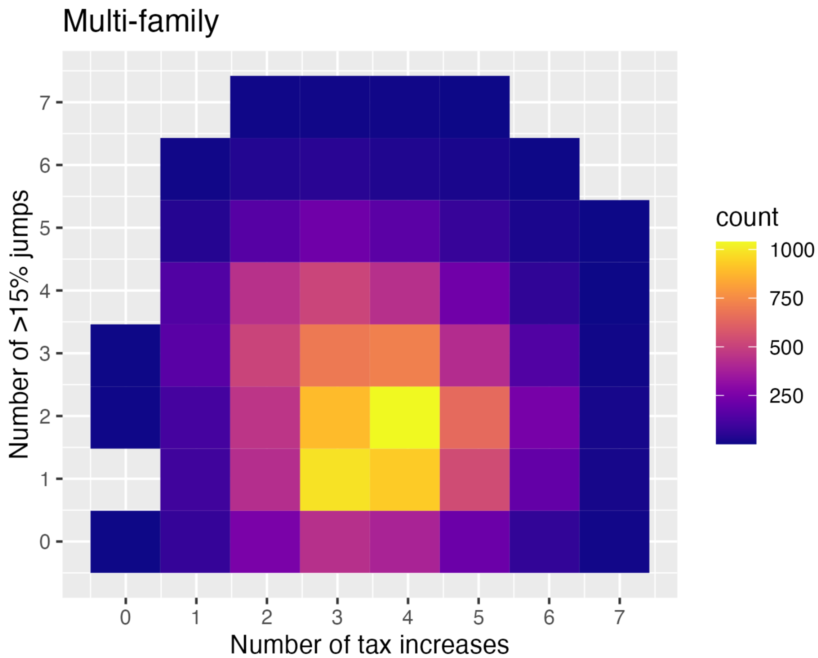

Figure 7: Heat map of assumed tax increases over study period vs jumps in assumed taxes of more than 15% for multi-family properties.

to the next, one would also expect little consistency from one episode to the next, and would not expect the swings to be related to the time since the previous revaluation. In other words, one would expect something very like the circumstances we observe.

Though the subjectivity of overfitting may preclude a conclusive statement, some other observations can be made more positively. Recall that the 1997 reform that created the three-year assessment cycle in Rhode Island was supposed to reduce the uncertainty and disruption for taxpayers of the ten-year cycle. Since that time, a substantial majority of properties saw large jumps twice or more in 21 years, which seems comparable to the previous state of affairs where there was an opportunity for such a jump every ten years. In fact, large numbers of properties saw more jumps than that in the study period. At best it would appear that the 1997 reform did not alleviate the problem, and more likely seems to have exacerbated it.

Another statement that can be made with some confidence is that renters feel the brunt of any randomness in assessment as much or more than owners will. If we assume that property taxes are a cost that is largely passed on to renters [Dusansky et al., 1981, Oates and Fischel, 2016], and that rents are "sticky", tending to come down more slowly than they rise [Verbrugge and Gallin, 2017], then randomness in taxes will create a ratchet effect, where fluctuations up are incorporated into rent, but the fluctuations down are not refunded to the tenant. A savvy landlord might even incorporate the risk of random fluctuations into their rents. The effect of volatility in property taxes will therefore be to increase rents.

The issue of overfitting and temporal equity in assessment is more than a matter of statistical pedantry, though obviously it is also that. Sudden and large increases in taxes create real hardships

Figure 8: Heat map of assumed tax increases over study period vs jumps in assumed taxes of more than 15% for apartment buildings.

for families. Research has noted that a poor family's vulnerability to an involuntary move is a direct function of the proportion of their income spent on property taxes, that a 15% increase in a tax makes a poor family 15% more likely to be forced to move [Martin and Beck, 2018]. That is, it is not unknown for people to lose their houses to foreclosure or eviction over cost increases of this size. Perhaps less evocative, but still important for the health of a community, unpredictable and large fluctuations in property tax bills create a difficult, perhaps even impossible, environment for investors who may want to build housing. How does one arrange financing for costs that may fluctuate randomly 15% at a time?

3.1 Fairness

During the study period 2003–2021, property owners in Providence saw an unusually large number of large jumps in assumed taxes as a result of the 2009–2010 revaluation, as is evident in the distributions shown in Figure 1. Focusing only on properties whose assessments went up less than 150%, over 53% saw a swing in their assumed taxes of more than 15%, and almost 20% saw swings of 30% or more. The anomalous nature of that year is easily explained by the tumult of the real estate markets in the preceding three years, when the sales on which that revaluation was based occurred. What is less easily explained is exactly why that unusual—and transitory—tumult should impact tax bills so heavily.

The reply is often to defer to "market forces". But it would be a peculiar definition of fairness indeed that required all tax bills follow every gyration of the real estate market, no matter how transitory. In fact, the sales record used to generate the 2009–2010 revaluation in Providence included both sales from 2007, when the pressure in the real estate market had not yet collapsed, and from 2009, when it had. Those who cleave to the view that market forces are the sole metric of fairness might suggest that the appropriate reform would be better curation of the sales data, to prevent contradictory data from being included in the same analysis. Perhaps such a reform would be effective, but in doing so would only underscore the subjectivity of the whole enterprise. "The market" as we think of it is an abstraction given its form by subjective choices of which sales and years of sales to analyze, subjective choices of which variables are to be measured, and subjective choices of the weights to applied to those variables. It is not a rejection of objective reality to suggest that considerable shape is given to our understanding of the market by the choices we make of how to depict it.

It is exactly this subjectivity that allows IAAO standards to call for maximizing both horizontal and vertical equity [IAAO, 2017]. . Enumerating multiple such equity goals would be nonsensical if there were no discretion in the estimation of assessments. The same discretion allows governments to insist on temporal equity as well.

The property tax was established in an age where the amount of property one owned was a good proxy for income [Carlson, 2004]. In a real estate market of rapidly changing values, it is not nearly as good a proxy any more even if it retains some of that value. The question is whether any imaginable definition of fairness would require such slavish devotion to market gyrations. Perhaps there are definitions that do not.

3.2 Regressive nature of assessments

Many authors have remarked on the regressive nature of mass appraisal results. Amornsiripanitch [2020] cites invisible factors in sales prices, primarily location-related, as the principal culprit, a finding more or less seconded by Avenancio-Leon and Howard [2019]. Berry [2021] provided a systematic national perspective on the issue, citing these issues, and also limitations of the assessment models, including the implicit assumptions of hedonic pricing noted above. Indeed, though there is little in the way of consistency, the findings here do show that over most of the revaluation episodes in the study data, low property values are associated with a higher range of assumed tax bill jumps, as shown in Figure 4.

Like the other associations considered here, the association between low property values and high frequency of large assumed tax changes is frequent but not consistent. The relationship varies substantially from one revaluation to the next. This effect might be more reflective of changing market forces than the others under consideration here. After all, an inexpensive property might be so because of its structure, its condition, or its location, while an expensive one will likely be good in all three of those categories. Still, the questions of how to define fairness in the context of a dynamic real estate market arise.

Many treatments of assessment practice describe the problem facing assessors as coming up with a "true" market value despite the noisy transaction price data [Amornsiripanitch, 2020, e.g.]. But is that indeed the goal? The point of assessment is to find a way to allocate the burden of supporting municipal services in as equitable way as possible. Estimating market values is a means to that end, not the end in itself. The value of any property sought in an assessment is merely one that is plausible and leads to fair taxation outcomes. To call any assessment "true" seems impossible to demonstrate with any claim to rigor, making that a standard of uncertain utility.

3.3 Possible solutions

It is not constructive criticism to find fault where there can be no remedy, so let this article end by indicating potential solutions to the problem described here. The primary one, of course, is to accord temporal equity the same status as horizontal and vertical equity and optimize assessments for all three. Obviously any individual revaluation episode will fall short of perfection among the three dimensions of equity, but the neglect of temporal equity has had dire ramifications for many cities.

One way to seek this compromise is simply to insist on decent reproducibility via cross-validation of the model. Repeated cross-validation, perhaps five- or six-fold will require relaxation of the goodness of fit requirements, but is more likely to have a temporally equitable outcome. Other possible approaches include:

- Using fewer parameters to fit, and testing individual parameters for predictive value before including them in a regression analysis:

- Explicit smoothing of assessment values from one revaluation cycle to the next, either by a simple rolling average, as in New York City [NYCIBO, 2011], or a weighted method, like a Kalman filter;

- Explicit limits on the assessment or tax bill changes allowed, such as exist in many states [Winters, 2008];

- Separating land value (which tends to vary little across a neighborhood) from building value (with much more variation from one house to the next) in the regression analysis, in effect running two separate analyses on the same property and adding the result.

Further research is needed to determine which of these would be the most effective compromise among the three dimensions of equity, but they all have potential as ways to ease the burden of sudden tax jumps.

It is obviously true that too much smoothing can leave a property's assessment lagging behind its "true" price, and thus undermine horizontal or vertical equity. This has famously been the case in California, whose strict property tax limits have created tremendous horizontal inequities [Wasi and White, 2005]. But this is the very nature of a compromise. Just as no rights are universal in nature, no definitions of equity can be without compromise. The flaw in California's method is that it privileges temporal equity over every other consideration, ignoring horizontal and vertical equity entirely, and makes no consideration for changes in the broad market averages. Other approaches, such as in New York City also see assessments lag values, but not to the same degree because they incorporate the other dimensions of equity [NYCIBO, 2011].

Furthermore, some such weaknesses in equity may have policy solutions. For example, one might address the lag between assessment and prices at the time of sale by taxing a seller on the difference between the assessment and sales price, either at the time of sale, or integrated over previous years. Such a tax might also have some value in tamping down the levels of speculation in local real estate markets. Similar proposals have been made to address the inequities in the California markets [Phillips, 2015].

Recall again that the point of a mass appraisal is to use market values to find a way to fairly allocate the burden of funding a government among its citizens. Market values are a tool we use to find an equitable allocation. Allowing a subjective interpretation of recent property sales to become the sole definition of fairness itself is a category mistake, akin to imagining that test scores are the sole definition of a good education, or economic statistics define a job market. "The map is not the territory," said semanticist Alfred Korzybski; we must always distinguish between reality and our portrayal of it, not least in cases like this, where a failure to do so can lead to inequitable and onerous outcomes.

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