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The Impact of Property Tax Appeals on Vertical Equity in Cook County, IL

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Abstract

Cook County has one of the highest rates of property tax appeals in the country. Do appeals make property taxes more fair and accurate? Using administrative property tax data from for 2003-2015, I quantify the level of regressiveness in property taxes. I find property taxes to be highly regressive. I then investigate whether the appeals process mitigates or exacerbates regressiveness. I find that post-appeal assessment ratios are more regressive than pre-appeal ratios, providing evidence that the property tax appeal process decreases vertical equity. I further find that effective tax rates are higher in neighborhoods with a higher percentage of minorities, and lower in wealthier and better educated neighborhoods.

1 Introduction

In his survey of taxation during the first 100 years of American independence, Richard T. Ely wrote:

> The fundamental idea of our tax systems is a democratic one. It is... that men are bound to serve the state in the degree in which they have the ability to serve themselves. The reasons why these earliest methods were abandoned are sufficiently evident... When one acre of land was often worth ten or twenty times, or even fifty times, as much as another situated in the same commonwealth, there could not fail to arise a demand for a system of taxation which would adjust the burdens of the government more accurately and make them bear upon each individual more nearly in proportion to his ability.[1]

Property tax assessment is a politically contentious exercise. As assets have become more complex and less visible, estimating an individual's "capacity to serve herself" has become highly technical and difficult. Modern systems of property tax assessment evolved out of a series of technical and legal innovations to become quasi-judicial apparatus with both administrative and legal levels of review. Local governments nevertheless continue to rely heavily on property taxes, and fairness in taxation is important to the political and economic stability of those governments. However, while economists are generally in favor of property taxes, the public's mind is well set against them; the property tax is regarded as the "least fair" tax by the average American.[2]

The greater the perception that property taxes are unfair, the more likely taxpayers are to appeal their taxes. Indeed, property tax appeals are becoming more numerous nationwide.[3] Cook County, IL (the County), enthusiastically follows this trend. In 2015, about 20 percent of residential taxpayers filed more than 360,000 appeals. Figure 3 shows statistics for appeals between 2003 and 2015. Over that period, the number of appeals increased by about 20% with every reassessment cycle, as has the percentage of appeals resulting in a reduction in taxable value.

The increase in appeals has been actively encouraged by various County officials and offices. County officials actively encourage taxpayers to appeal their property tax assessments, and the County Board of Review (BOR) trains elected officials, including Chicago legislators, to help constituents appeal their taxes. In addition, the County recently instituted a new online property tax appeal system which allows property owners to easily appeal their own taxes without legal representation. These features of the County's property tax system result in a very large number of appeals. Do the large and growing number of property tax appeals encourage fairness and accuracy in Cook County's property tax system?

The focus of this paper is the impact of the property tax assessment system, and property tax appeals in particular, on vertical equity in property taxation. I investigate the *prima facia* case for vertical equity in assessment ratios, property taxes, and tax appeals. The assessment ratio of a property is the ratio of the Cook County Assessors' Office's (CCAO) estimate of that property's market value to the actual sale price of the property, in the year the property sold.[4] The effective tax rate on housing wealth is the ratio of taxes paid in the year a property sold to the sale price of that property, in the year the property sold. If effective tax rates are strongly negatively correlated with home values, I take this as evidence of regressive property taxes.

Using administrative data from the Cook County Assessors' Office (CCAO), I find that property taxes in Cook County became extremely regressive following the collapse of the housing bubble in 2008. Figure 4 shows the depressive effect of the housing bubble on sales volumes and median home prices in the County. Figure 7 displays effective property tax rates by home value for the period following the housing bubble. That figure clearly shows a strong negative relationship between effective tax rates and property values. This is *prima faci* evidence of regressiveness in property taxes.

I also find that appeals make taxes *more* regressive. Figure 1 shows the change in assessment ratios for all properties for the period 2009-2015. Though appeals reduces taxable values, on average, across the range of home values, they tend to decrease them more for more valuable properties. The appeals process as a whole decreases vertical equity by granting proportionately larger reductions in value to more valuable properties.

Property assessment is a complex, constantly evolving field. While the data for this analysis comes from Cook County, IL, I do not believe the County is unique in terms of veritcal equity or property tax appeals. This analysis suggests a number of policy changes to encourage more equity in the property tax system. Lessons learned in the revision and execution of assessment practices in the County can be duplicated by other counties nationwide.

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[1] Ely (1888),[8] p. 131

[2] Gallup (2005)[11]. Also see Chapter 11 of Fisher (1996)[9].

[3] Doerner and Ihlanfeldt (2012)[7].

[4] For simplicity, I calculate the assessment ratio as 10*(assessed value)/(market value), so that an assessment ratio of 1 means that the assessor has perfectly predicted a property's value.

2 The "least bad" tax

The property tax as administered in the United States is a paradox: on the one hand, voters regularly report that they believe they get the "best bang for the buck" from property taxes, [5] local governments rely heavily on property taxes to finance local services,[6] and economists credit the property tax with a number of positive attributes. On the other hand, voters regularly report that the property tax is the "most unfair," "worst" tax according to repeated opinion surveys,[7] there are frequent property tax revolts and other initiatives to limit property taxation, and property tax revenues as a share of GDP are declining in the US even while other tax revenues are increasing. Indeed, the property tax revolts of the late 1970s were defining events in the political economy and local public finance of the United States, and yet there is no consensus to date on the causes of these revolts.[8]

Canonical public finance textbooks take an optimistic view of the property tax with respect to vertical equity. Fisher (2007) sums up a discussion of the economic effects of the property tax writing "these factors combined do not support a conclusion of general property tax regressivity."[9] Rosen (2002) argues that the property tax is broadly hated because it is *perceived* as being regressive. This perception he attributes to the dominance of the "traditional view" of property taxes as excise taxes on a bundle of land and capital, and the disjoint between housing wealth and liquidy assets for some subgroups of taxpayers.[10] He equivocates as to whether the tax is, in fact, regressive.

Other economists have argued as well that the property tax is theoretically progressive.[30] In an environment where the Tiebout Hypothesis holds, property taxes are fully capitalized into home values and behaves like a user fee rather than a tax. In such an environment, Rosen (2002) writes that "the notion of progressiveness is meaningless." It is unclear, however, whether vertically inequitable property taxes might still behave as use taxes; do lower income residents derive greater proportional benefits from local government than wealthier residents? Most recently, Youngman (2016)[29] writes "The easy use of the term regressive to describe the property tax in popular debate is not justified on economic grounds," arguing that the ambiguity of the incidence of the property tax makes it difficult to ascertain its true regressiveness.

Most of the aforementioned work deals with the incidence of a uniform tax on real estate. Recent empirical research, on the other hand, has focused more on the administration of the property tax. In that body of work, there is an emerging consensus that property taxes are administer in such a way as to be regressive on their face. This seems particularly true when conditions for property appraisal are unfavorable, like the period after a major real estate bubble. Suits (1977)[25], Phares (1980)[20], Metcalf (1994)[18], and Plummer (2003)[21] use different approximations of income to compute a suites index and determine whether property taxes are regressive.[11] In these studies, estimated Suites Indices range from .23 (fairly progressive) to -.13 (a bit regressive). More recently, Cornia and Slade (2006)[6] and McMillen and Weber (2008)[17] find that property taxes are regressive in Cook County specifically, although their data are limited in size and cover periods from before the collapse of the housing bubble.

McMillen (2011)[15], Hodge et. al. (2016)[12], and Krupa (2012)[14] find that post-housing bubble assessments became highly regressive in Cook County, Detroit, and Indiana respectively. McMillen (2013)[16] examines the impact of property tax appeals in Chicago in 2006, finding that they decrease vertical equity slightly. Doerner and Ihlandfeldt (2012) [7] examine the effect of appeals on assessment ratios in Miami-Dade County and find that they disproportionately benefit white, rich neighborhoods. This paper most resembles these papers in scope, methods, and focus.

This paper contributes to the literature on local property taxes in a number of ways. First, I document the *prima facia* regressiveness of the property tax system in the second most populous county in the US using a straightforward approach: effective tax rates. This is the only study I am aware of to clearly show how regressive assessments and appeals lead to regressive taxes. I use a very large administrative dataset covering a large period of time to show patterns of assessment and taxation across realized property values and neighborhood demographic attributes. The only other studies I am aware of to use such a large dataset for this purpose is Krupa (2012)[14] and Doerner and Ihlandfeldt (2012)[7]. This paper builds on their analysis by offering novel, and simpler ways of measuring regressiveness, and by examining the period before, during, and after a large housing bubble. This informs our understanding of how the County's property tax performs under conditions which are unfavorable to predicting property real estate values, and whether the appeals process sufficiently corrects for errors in assessed values during a housing bubble. My findings add to a growing body of literature which suggests that the property tax is regressive in practice because assessments are regressive.

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[5] Cabral and Hoxby (2012)[5]

[6] Anderson and Ross (2013)[3]

[7] Gallup (2005)[11]

[8] Anderson and Pape (2011)[2]

[9] Fisher (2007)[10], p. 370

[10] Rosen (2002)[22], p. 494

[11] The Suites Index was proposed by Suites (1977)[25] as a standard measure of verhtical equity in taxation. I calcualte the index in Appendix B. For a good description of the Suites Index, and a bootstrapping method for hypothesis testing, see Anderson (2003)[1]. For a summary of recent empirical work on progressivness in property taxes, see Stanahan et. al. (2014)[26]. The suites index follows the logic of the Gini Coefficient calculated from the Lorenze Curve. To calculate the Suites Index, plot the cumulative tax payments against the cumulative wealth of a population, and calculate one minus the ratio of the area under this curve to the area under a 45 degree line. Like the Gini Coefficient, the resulting index shows the degree to which taxpayers at lower levels of wealth bear larger proportions of the total tax burden.

3 Data and calculations

The data for this analysis comes from administrative records of the CCAO, the Cook County Treasurer's Office, the City of Chicago, and the US Census Bureau, and includes more than 1.5 million residential properties' taxes, assessed values, sales, appeals, and other information used for property tax purposes from 2003-2015. Unique Property Identification Numbers were matched with the Census Tracts which contained them. This allows me to identify correlations between census-tract level characteristics with tract-level property taxes. My final dataset contains 21.4 million observations of residential properties' administrative property tax records from 2003-2015.

I selected properties which sold between 2003-2015. Consistent with standard assessment practices, I take the sale price of a home as the realized value in the year the home sold. My dataset of residential sales contains just less than 600,000 residential home and condominium sales from 2003-2015.[12] Annual sales volumes and median prices are reported in Figure 4.

This study considers three phases in the property tax assessment process. The first step in the assessment process is a "first-pass" made be the CCAO. In this step, the CCAO notifies taxpayers of their preliminary assessed values. These assessed values mostly determine a taxpayers' property taxes for the next three years. After being notified, taxpayers may appeal their assessments through both the CCAO and the BOR, and then in court following these agencies determinations. Following the resolution of all appeals, a final assessed values is assigned to each property. Finally, taxes are calculated based on that final assessed value, exemptions, and the applicable tax rates. This paper focuses on the benchmarks of this process: first-pass assessments, final assessments, and taxes.

To measure regressiveness, I rely on the standard measure used in ratio studies: Price Related Differential (PRD).[13] In Appendix B, I also calculate two other measures of vertical equity. These other statistics are consistent with the patterns shown by the PRD.

The PRD is given as the ratio of un-weighted mean assessment ratios to weighted mean ratios in a given time period:

$$PRD = \frac{\sum_{j=1}^{n} E_{CCAO}[V_j]/V_j/N}{\sum_{j=1}^{N} w_j * E_{CCAO}[V_j]/V_j/N} \tag{1}$$

where property values are used as weights. If the weighted mean is equal to the unweighted mean, assessments are perfectly uniform across home values and the PRD will equal 1. If the weighted mean is relatively smaller than the unweighted mean, higher value properties are assessed at lower rations, and the PRD is greater than 1. PRD is negatively associated with regressiveness. The standard "acceptable" range for PRD is $[0.97, 1.02]$. This range is asymmetric around 1 because there is an upward bias in the denominator which does not effect the numerator.[14] The variance of this statistic is not well defined, so I use bootstrapping to obtain an estimate of the variance.

4 Results and discussion

4.1 Vertical equity in assessments

Table 1 and figure 5 show PRD before and after appeals. Figure 2 plots the change in the PRD by major property type, with bootstrapped margins of error. And figure 1 shows the change in assessment ratios by home value for all County properties 2009-2015.

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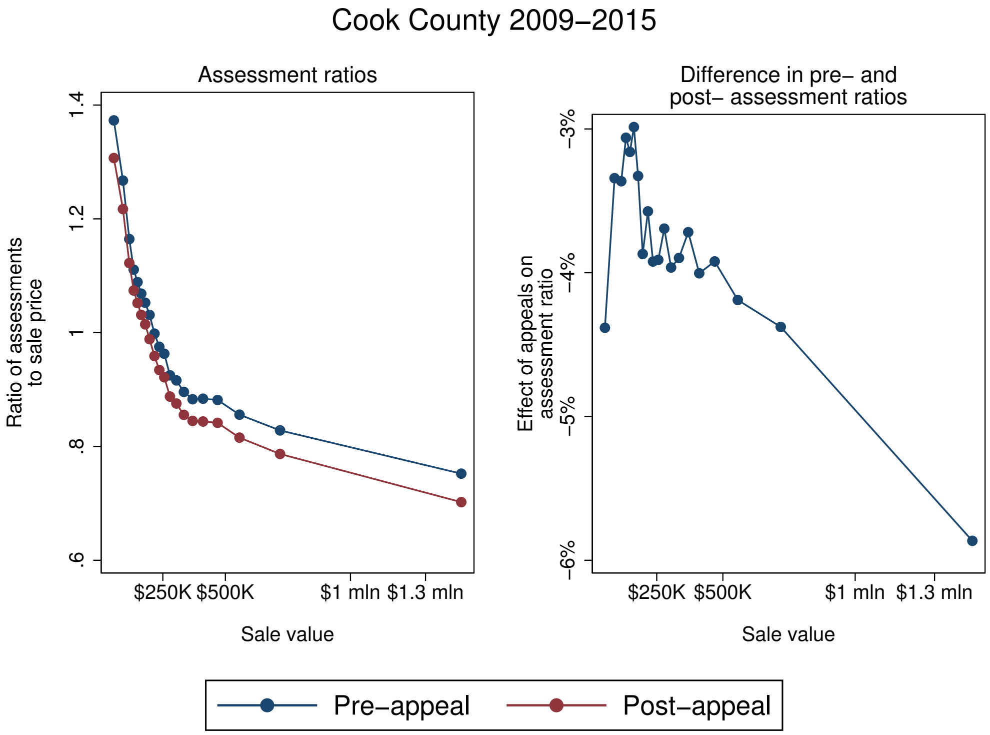
[12] I dropped 68 observations where the appeals process actually increased properties' taxable values. The omission of these observations has no qualitative effect on my results, but their inclusion causes my graphs to display oddly because the amount of increase was extreamly large for these observations.

[13] IIAO Standard for Ratio Studies, 2013, p. 17

[14] IIAO (2013)[13], p. 35

Figure 1: Impact of appeals on assessment ratios by home value



Together, these figures demonstrate that property tax assessments in the County are regressive, and are made more so by appeals. Looking at homes in the 25th and 75th percentiles of sale price 2009-2015, homes in the lower quartile are assessed during the CCAO's first-pass at ratios 23% higher than those in the upper quartile. At the end of the appeals process, homes in the lower quartile are assessed at a rate 24% higher than homes in the higher quartile. That is so because appeals lower taxable value proportionally more at higher home values. Assessment ratios are 3.3% less after appeals for the 25th percentile, and 4.1% less for the 75th percentile. Overall, appeals make property tax assessments more regressive by granting larger reductions at higher market values.

The BOR introduces regressiveness into the property tax system in the way it grants appeals. The BOR often grants reductions in assessed value to properties which are already under-assessed. More than half of under-assessed properties sold 2009-2015 filed an appeal, and the CCAO & BOR granted 22% of those appealing properties some reduction in their assessed values. On average, the CCAO & BOR reduced assessed values for already under-assessed properties which appealed by $5,700, or 23% of the average assessed value for appealing under-assessed properties. By comparison, over-assessed properties saw an average reduction of $8,169, 28% of average assessed values. Simple regressions of the probability of winning an appeal, and the percentage reduction in assessed value on first-pass assessments shows very little correlation between winning appeals and first-pass assessment ratios.

Taxpayers are more likely to appeal their assessments if they are over-assessed, and if their homes are worth more. Even after accounting for these factors, however, neighborhood demographic characteristics are still significantly correlated with assessment ratios, appeals, and effective tax rates. Table **??** shows the results of regressions on outcomes of interest. Areas with higher levels of education, higher property values, and fewer minorities pay significantly lower tax rates. Figure 8 shows selected correlations with demographic characteristics of census tracts and mean effective tax rates. Geographic patterns of tax appeals, assessment ratios, effective tax rates, and home values are shown in 9 - 12. These maps convey a sense of the distribution of property taxes to those familiar with the demographic topography of Chicago.

Some of these correlations may be driven by the fact that taxpayers self-select as to whether they appeal their taxes or not. This self-selection may drive some regressiveness in the appeals process as well. For example, many larger condominiums buildings hire attorneys to file appeals for all of the units in the building, taking advantage of the returns to scale in this type of appeal. Effective tax rates may be consequently lower for larger condominium buildings. Figure 6 shows the strong, positive relationship between condominiums' building size and the probability of any individual unit filing a property tax appeal. The difference in effective tax rates between condominium properties and single-family homes seen in figure 7 may be a product of the different rates of appeal between these types of properties, although assessment methods also differ between these types of properties.

Another factor in tax appeals are attorneys: taxpayers spent an estimated $22 million in lawyers' fees in 2015 appealing their taxes. Tax lawyers in Cook County solicit customers during tax season, and it may be that those lawyers solicit more valuable property more often, since those properties are more likely to yield larger nominal fees. Lawyers may also target English-speaking populations, or areas with more density of sales, where it is easier to find clients and win appeals. There may also be other ways in which lawyers select clients which increase regressiveness in property taxes.

Finally, there may be simple geographic informational spillovers in appeals off all residential properties, making neighbors of taxpayers that appeal more likely to appeal themselves. This may be because neighbors voluntarily share tax information with each other, or because neighbors look at each others' property tax information online. This may result in some neighborhoods having a very high rate of appeal, simply because of the compounding effect.[15]

4.2 Vertical equity in taxes

Regressive property tax assessments lead to regressive property taxes. From 2009-2015, Chicago properties at the 25th percentile of sale value were taxed at a rate 24% higher than properties at the 75th percentile of value.[16] The 25th percentile sale values in Chicago was about $156,000, paying an average tax of about $2,300.

The 75th percentile of sale value was nearly $370,000, paying an average tax of $4,700. The average effective tax rates at these quartiles were about 1.5% and 1.2% respectively. If homes at the 25th percentile paid the same tax rate as those at the 75th percentile, their taxes would be about $465/year lower on average. On the other hand, if Chicago properties in the 75th percentile faced the average effective tax rate that properties in the 25th percentile faced, they would have paid $1,142/year higher taxes on average.

To further contextualize these figures, I randomly selected two representative properties which sold in 2011, the year in which assessments in the County were most regressive. I restricted my selection to owner-occupied, single-family homes in the 25th and 75th percentiles of property value with successful property tax appeals.

The property in the 25th percentile of home values is in the Village of Stickney, IL, a mostly-white suburban community bordering Chicago to the south west. Stickney has a median household income of about $43,000, and about 10% of residents are college educated. The property in the 75th percentile of property values lies in the North Park community of Chicago, where median household income is about $71,000 and about 50% of the residents hold a college degree.

The Stickney property sold in 2011 for $130,000, and the CCAO estimated its market value at $238,660, nearly double its actual market value. In contrast, the North Park property sold in 2011 for $309,000, but the CCAO estimated its market value at $281,100. Both properties filed successful appeals in that year: the Stickney won a reduction of $12,640 of taxable market value, while the North Park won a reduction of $12,300 of taxable market value. The statutory property tax rates in Stickney are nearly twice as high as they are in the City of Chicago, a reflection in part of the lower amount of commercial property value in that community. For a direct comparison of the impact of assessments on taxes, I apply the statutory rate in Chicago to both properties. Under uniform tax rates, the Stickney's property tax bill would have been $4,300, and the North Park property's bill would been $5,100. If both properties had been assessed perfectly, those bills would have been $2,400 and $5,900 under uniform tax rates.

Regressiveness shifts a considerable portion of the total property tax burden onto lower value properties. Consider the 13,539 residential sales in the City of Chicago in 2011. Cumulatively, the total value of those sales was about $5.1 billion. Those properties paid $59.1 million in property taxes in that year. Those revenues are not taken in equal proportion from every property. The County's property taxes were most regressive in 2011; the average effective tax rate on properties in Chicago in the 25th percentile of property value was 30% higher than that on properties in the 75th percentile of property values. The nature of property taxes is such that decreases in taxes for one group is mechanically offset by increases in taxes for another group. Suppose

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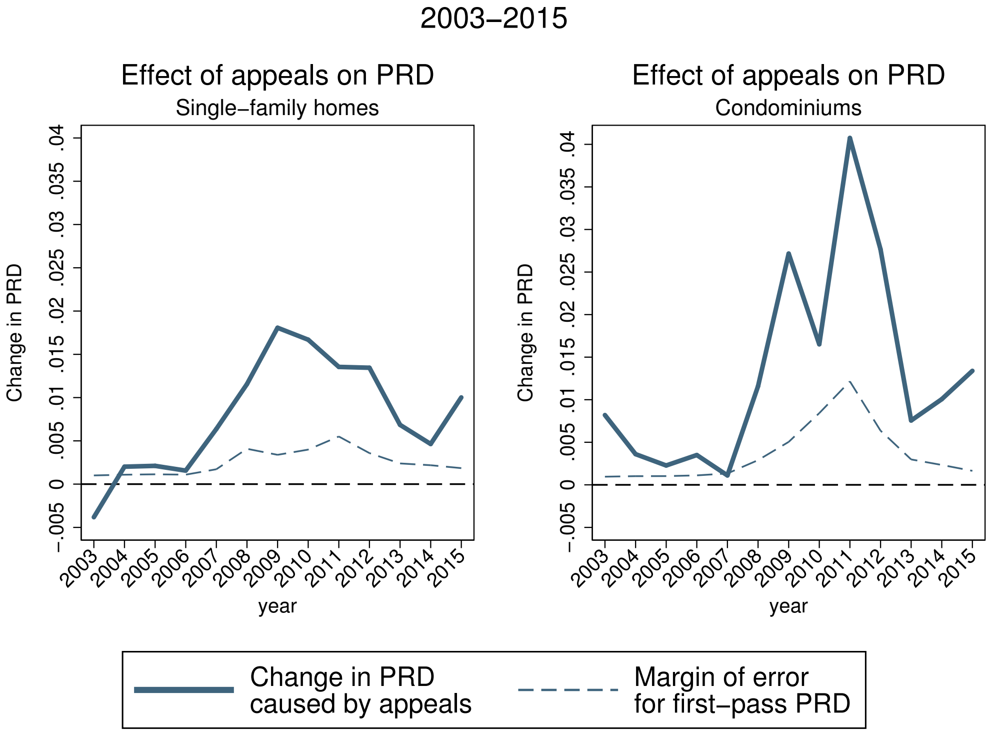
[15] In Cook County, the public may look up property tax records, including taxes paid, exemptions applied, and appeal status, online.

[16] Throughout this analysis, I use Chicago properties to compare effective tax rates, even though I use properties Countywide to compare assessment ratios. This is so because all residential properties in Chicago lie in the same taxing jurisdictions, so comparisons of effective tax rates reflect differences in the assessment process.

Figure 2: Impact of appeals on vertical equity



that the revenues from these properties was collected uniformly according to property value, as is legally stipulated: what impact would this have on tax bills?

Re-calculating each property's tax bill by applying the uniform rate required to raise these funds in equal proportion from all properties, I can quantify the nominal level at which properties are over- and under-taxed. In 2011, nearly 9,500 properties paid taxes higher than that calculated from a uniform rate, while about 4,000 paid lower taxes. [17] Redistributing that tax burden in equal proportion to housing wealth, I find that the average decrease in tax bills for properties paying a higher effective tax rate is about $1,500, while the average increase in tax bills for properties paying lower effective tax rates is about $4,600. There are about 735,000 residential properties in the City of Chicago. If this sample of about 1.8% of all properties is representative of the general pattern of vertical inequity across the City, the magnitude of redistribution of tax burdens from higher to lower value homes could be as much as 50X larger.

Figure 13 graphs the results of this exercise. On the left side of the panel, the average difference between actual taxes paid and taxes paid under a uniform tax rate is plotted against property values. The x-axis is scaled by value percentiles. This graph shows that more than half of the properties in the sample would experience a reduction in their property taxes if a uniform tax rate was applied across home values. The right panel shows the average effective tax rates paid at each percentile of sale value, as well as the uniform effective tax rate required to raise an equivalent amount of revenues from this subsample of properties. To the degree that the bias in assessment ratios exhibited among properties which sold is a good approximation of bias in assessment ratios for all properties, this exercise illustrates the magnitude of the impact of regressiveness in the County.

5 Policy recommendations

Estimating the value of real estate is a difficult and complex task. Concerning California's property tax system, Frederick Stocker wrote

> (The property tax) resembles a structure designed by a mad architect, erected on a shaky foundation by an incompetent builder, and made worse by the well-intentioned repair work of hordes of amateur tinkerers.[18]

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[17] In calculating the uniform rate, I exclude properties in the top and bottom 1% of effective tax rate.

[18] Stocker (1991)[27], p. 1.

To some degree, such can be said of any democratic institution which is the product of negotiated compromise. With advances in computing and statistical sciences, however, it increasingly seems as though the technical aspects of property tax assessments are in want of redesign. Improvements in the County's assessments may translate into large improvements in the administration of the property tax nationwide.

First-pass assessments in the County need to be accurate, and their errors should not be correlated with property values. If traditional methods of estimation do not yield such errors, the CCAO should explore non-traditional methods. For example, the CCAO could conduct a competition with a large cash award for the person or group who designs a significantly better assessment algorithm, similar in spirit to the famous Netfliz Prize. Another example might be to explore survey methods of predicting property value. Are self-reported property values, with some threat of audit, a more reliable way to estimate values? Do neighbors truthfully report their neighbors' property values? The CCAO could investigate these and other approaches to property tax assessment.

Transparency can help improve government services simply by changing the political incentives faced by the county assessor. The CCAO should make the property tax database available, in full, to the public, along with all computer code necessary to replicate the assessors' estimation process. This would not only increase the accountability of the system, but also may encourage an entrepreneurial data scientist to suggest improvements to the predictive models used by the CCAO.

The BOR explicitly evaluates assessments with respect to uniformity, or horizontal equity. This ensures that properties with similar characteristics are assessed at similar levels. This does not address vertical equity at all, as I have shown. Incorporating a systemic review of assessments with respect to vertical equity into BOR considerations might improve the end result of the review process.

Improving the property tax assessment system in the County is not merely a technical exercise. There is are at least two entrenched political classes which benefit from poor-quality assessments. From 2009-2015, tax attorneys made an estimated $133 million in revenues from successful tax appeals. Poor assessments create revenues for tax attorneys, and any attempt to improve assessment quality will likely be met by resistance from these lawyers. In addition, most local politicians assist constituents with tax appeals, in some cases hiring staff members specifically for that purpose. This generates political capital elected officials will be reluctant to trade for better quality assessments.

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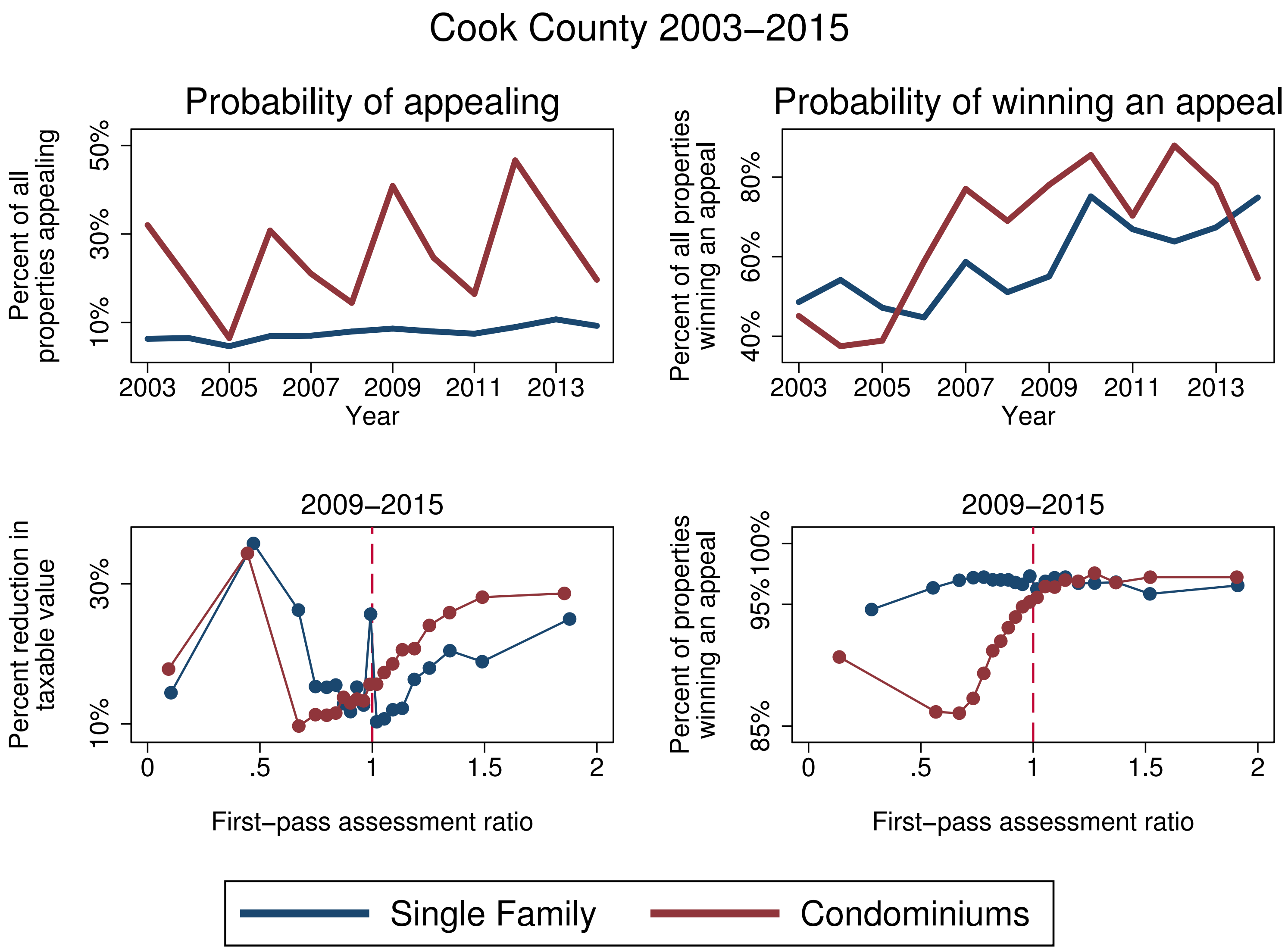
Appendix A: Graphical results and tables

Figure 3: Trends in property tax appeals



Cook County is divided into three assessment areas, each of which is reassessed every three years. The cyclical pattern in the rate of appeal observed in the first graph of this panel reflects the fact that there are many more properties in the City of Chicago, the first assessment traid, than there are in the other two triads.

Figure 4: Impact of the Housing Bubble on volume and prices in Cook County's housing market.

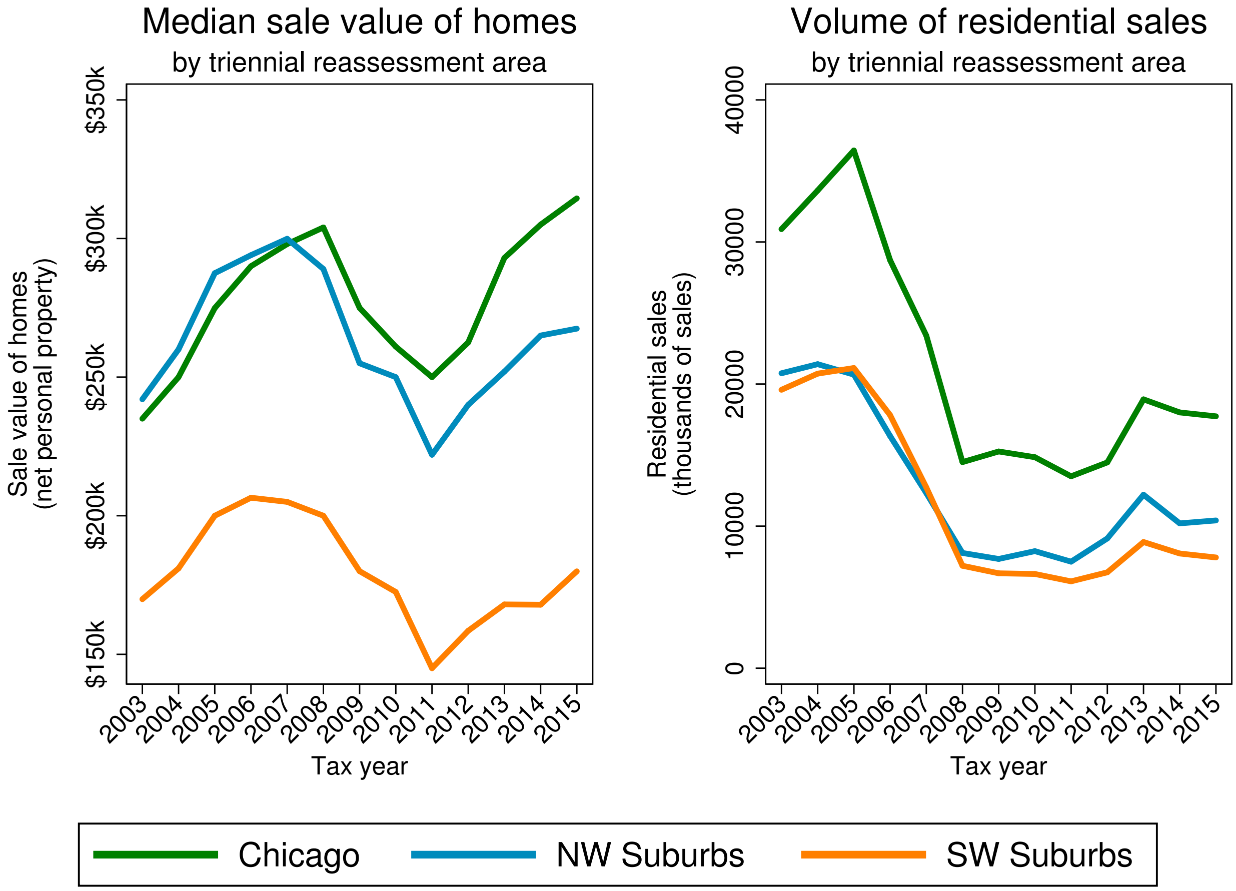


Figure 5: Price-Related Differential

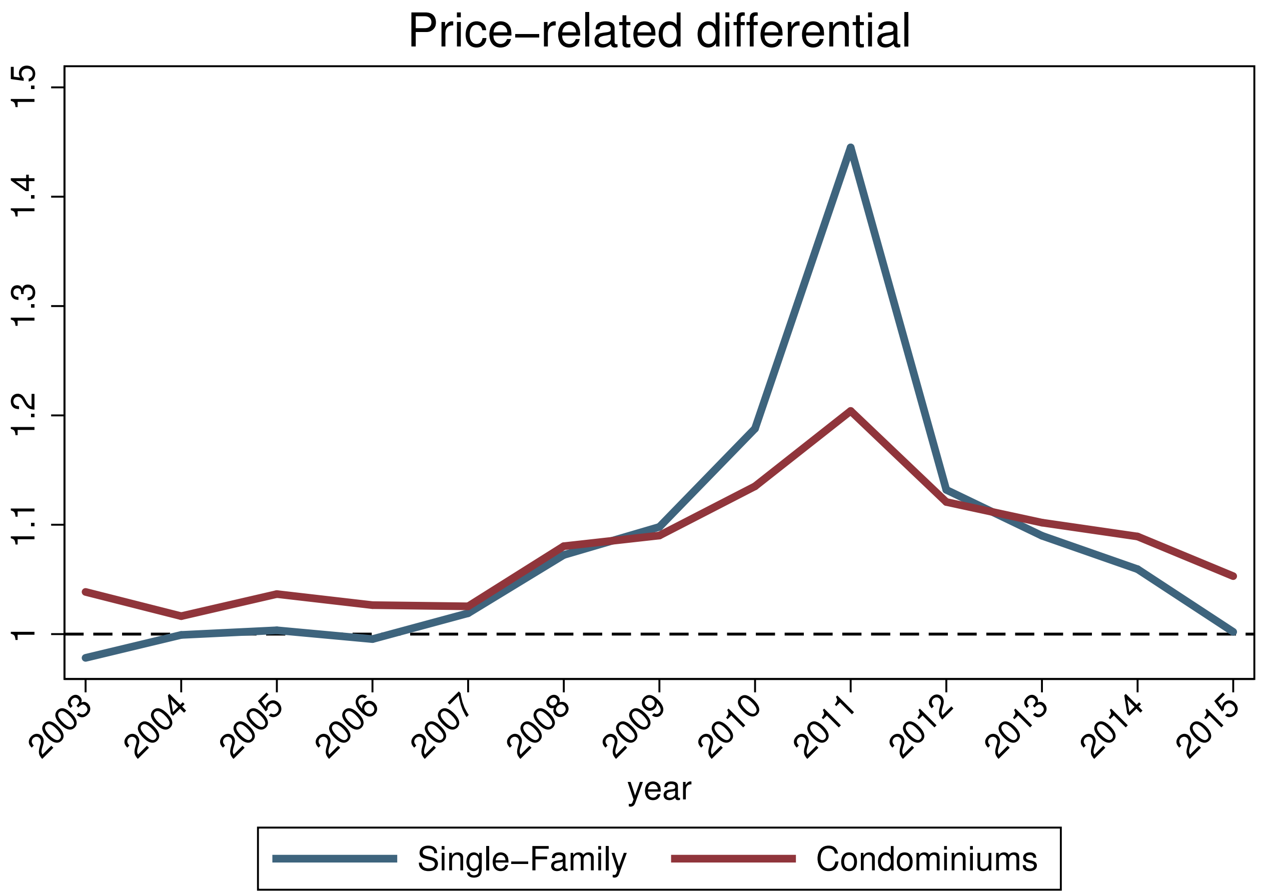


Figure 6: Correlation between condominium building size and probabilty of appeal

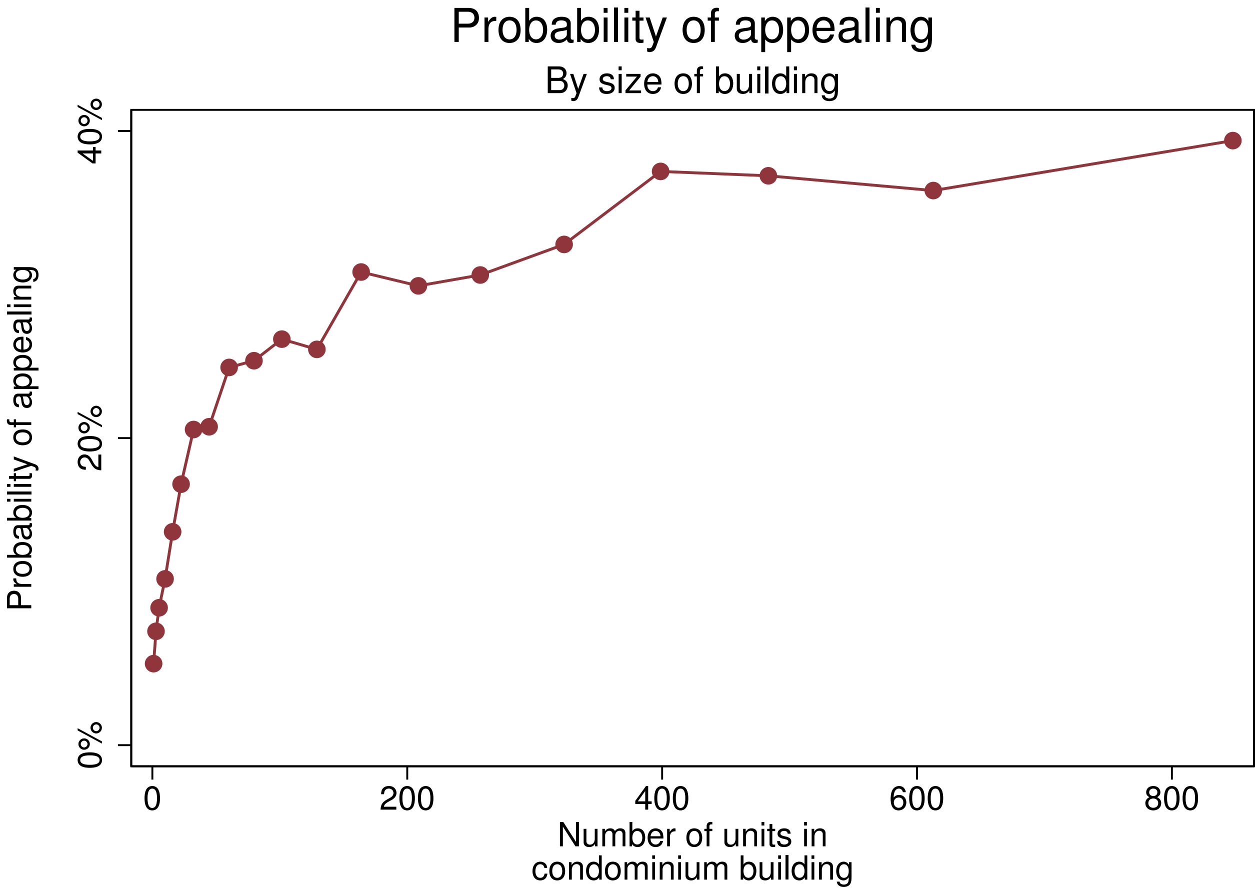
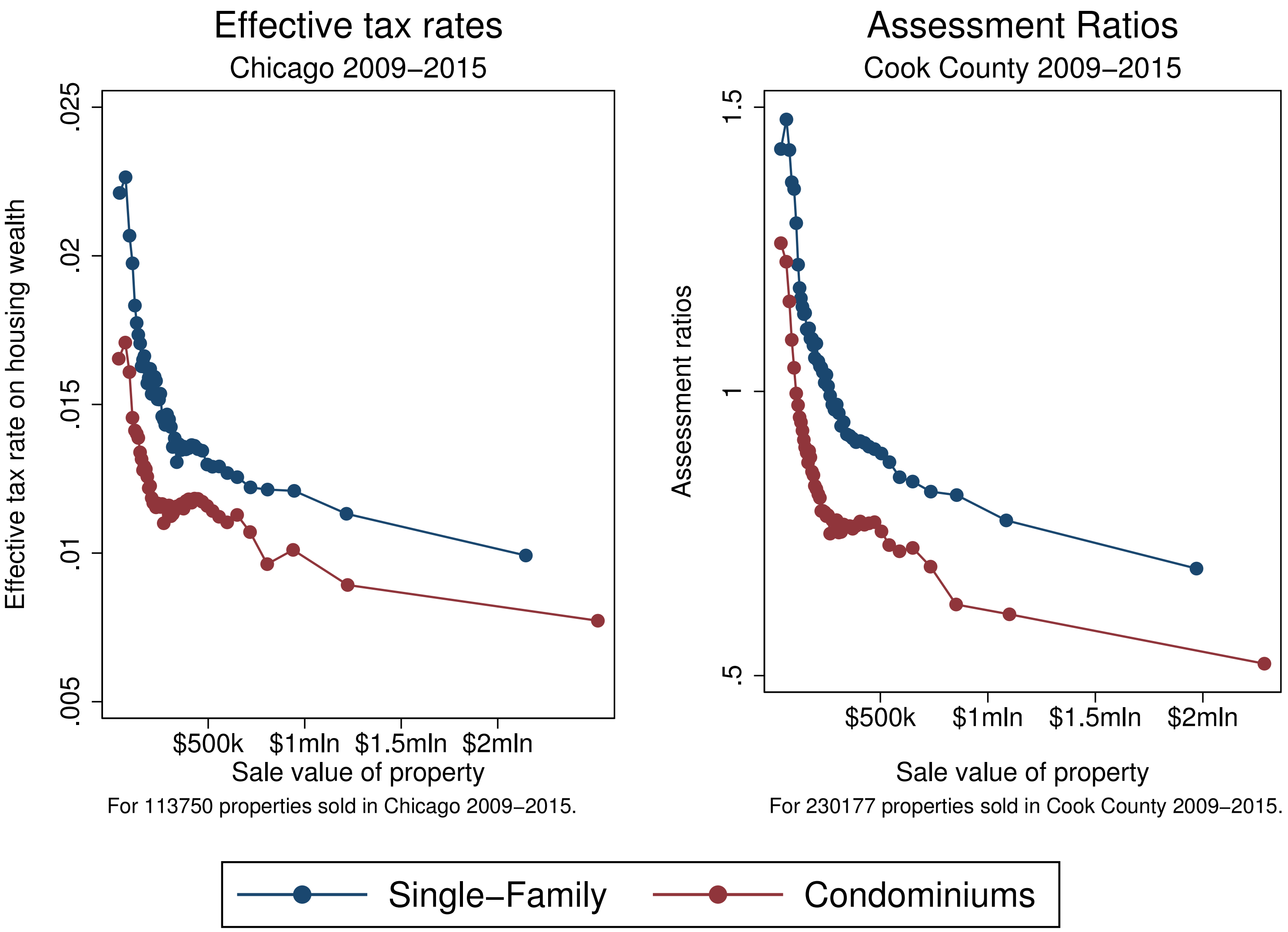


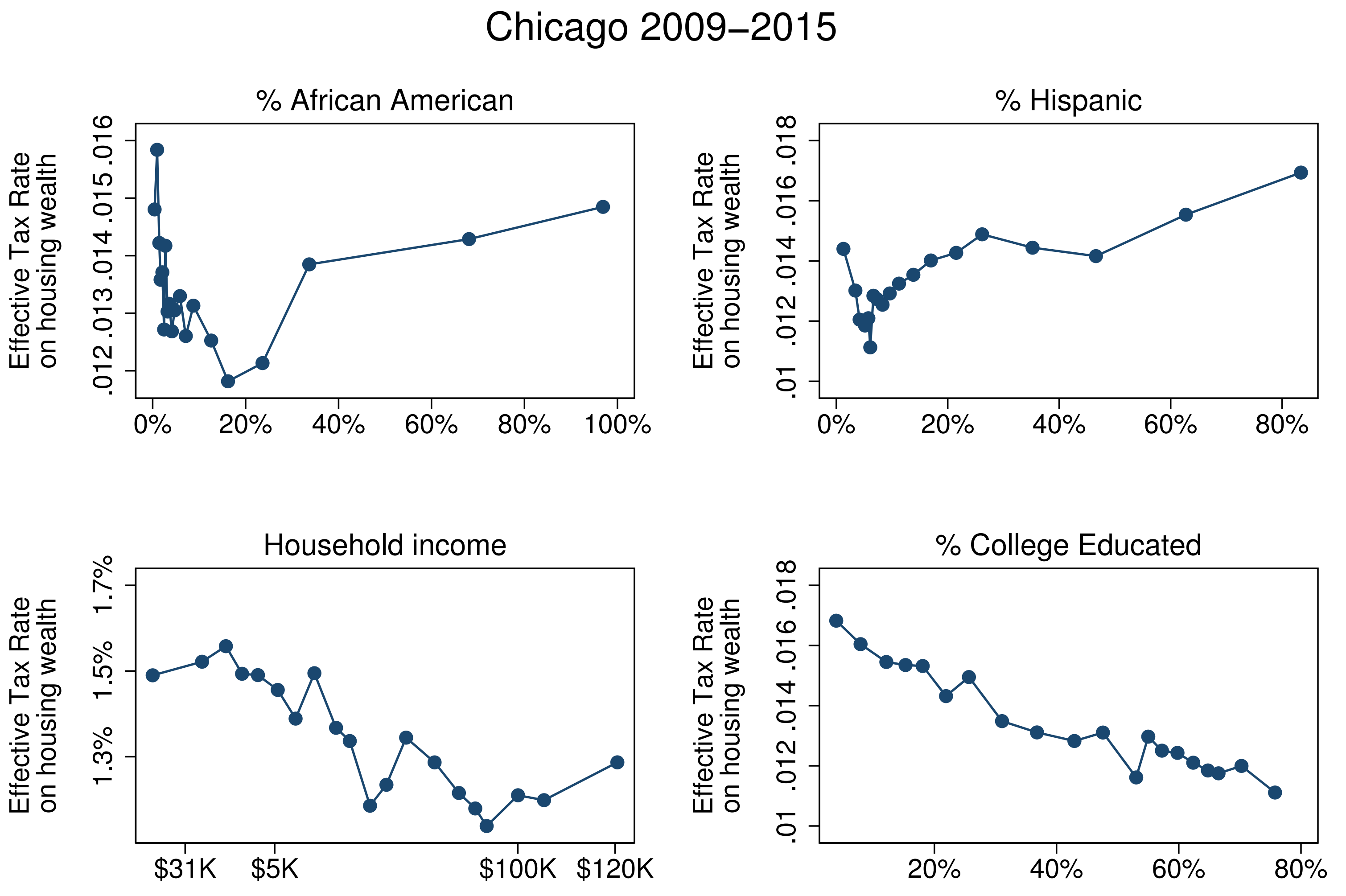
Figure 7: Regressivness in property taxes and assessments



For 113750 properties sold in Chicago 2009–2015.

For 230177 properties sold in Cook County 2009–2015.

Figure 8: Demographic correlates with effective tax rates



For 97918 properties sold between 2009–2015

Figure 9: Map of probability of filing a tax appeal by 2010 Cenusus tract

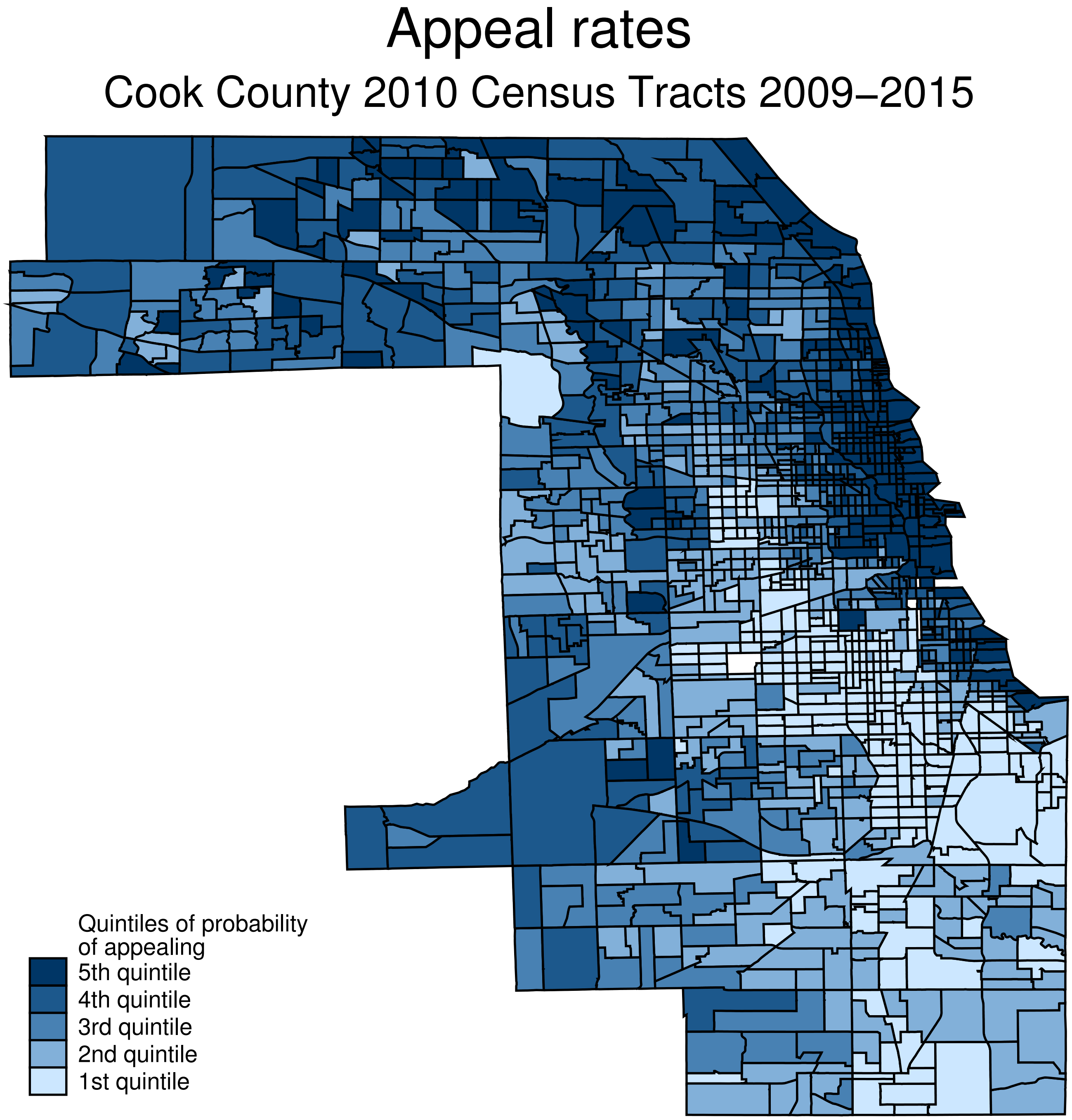

Appeal rates
Cook County 2010 Census Tracts 2009–2015
Quintiles of probability of appealing
5th quintile
4th quintile
3rd quintile
2nd quintile
1st quintile

Figure 10: Map of post-appeal assessment ratios

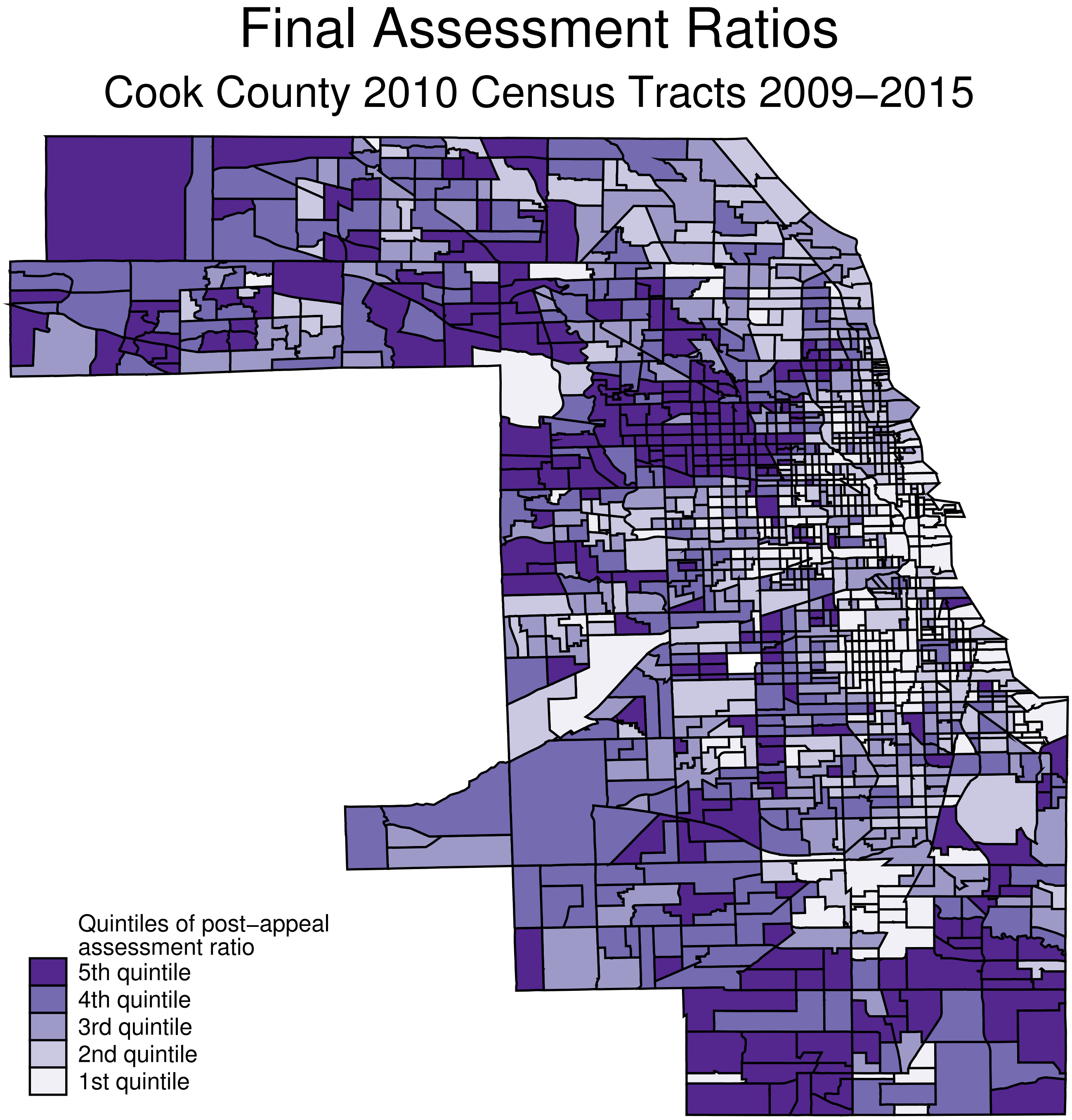

Final Assessment Ratios
Cook County 2010 Census Tracts 2009–2015
Quintiles of post–appeal assessment ratio
5th quintile
4th quintile
3rd quintile
2nd quintile
1st quintile

Figure 11: Map of mean effective tax rate by 2010 Cenusus tract

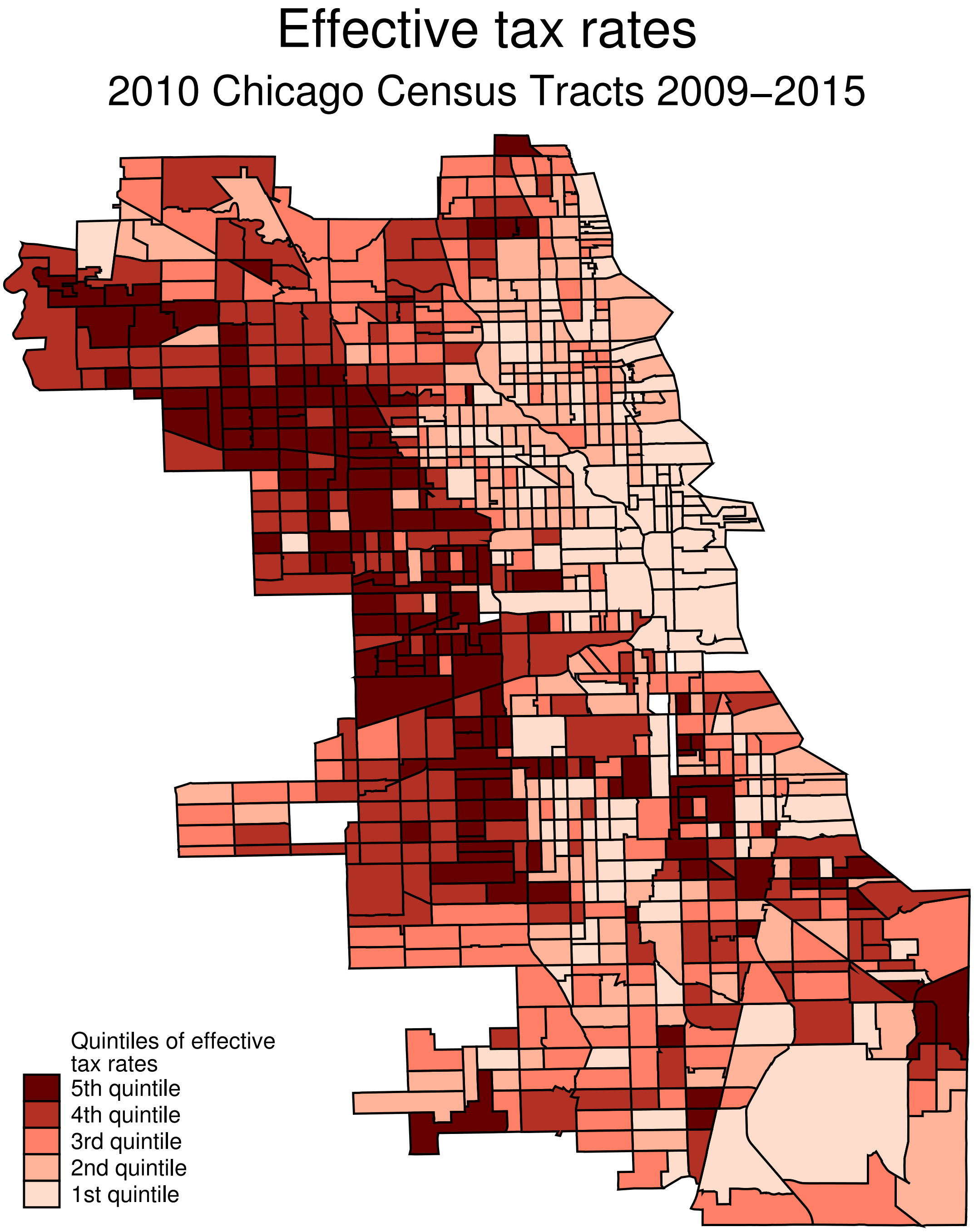

Effective tax rates
2010 Chicago Census Tracts 2009–2015
Quintiles of effective tax rates
5th quintile
4th quintile
3rd quintile
2nd quintile
1st quintile

Figure 12: Map of mean residential sale value by 2010 Cenusus tract

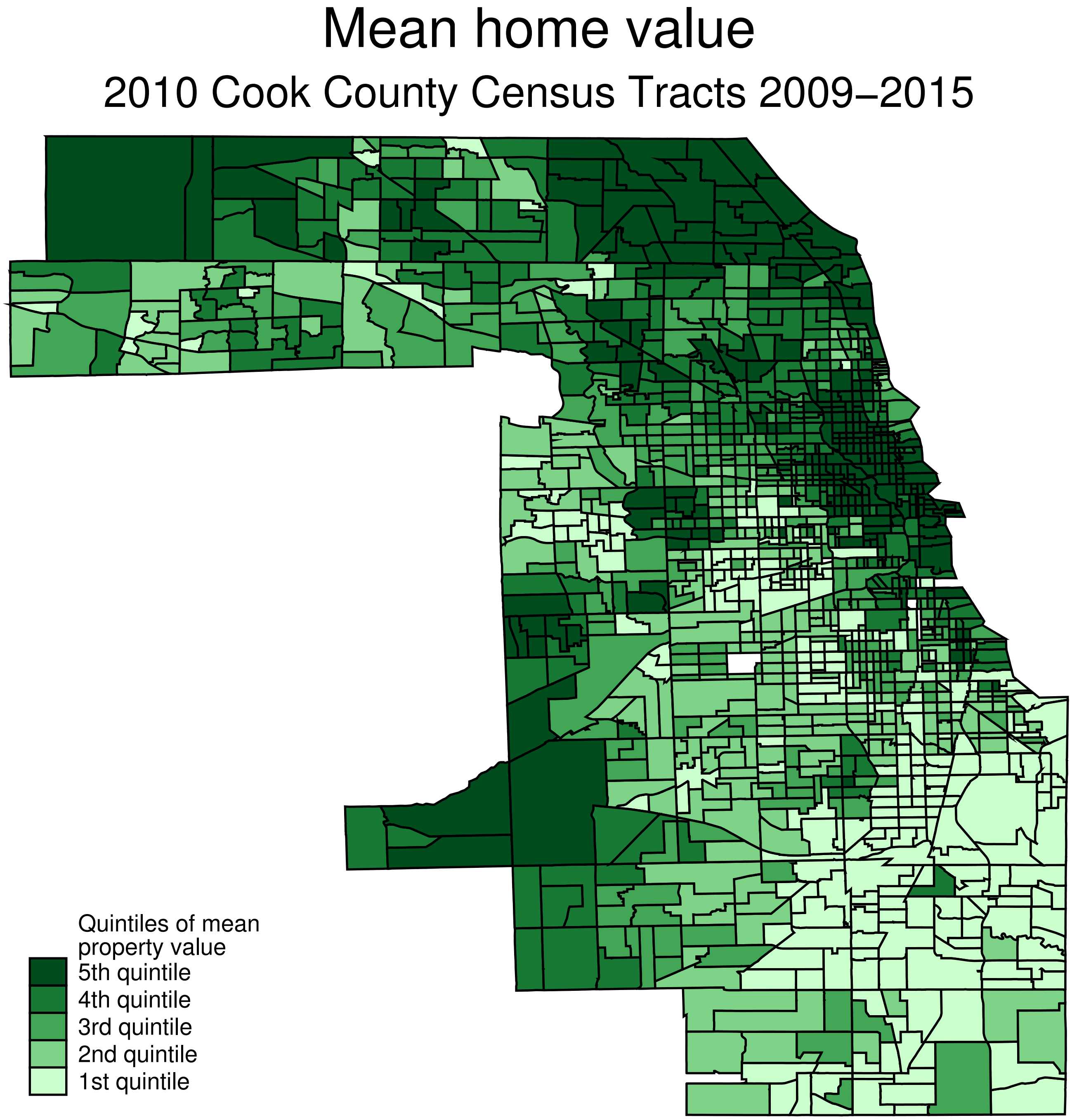
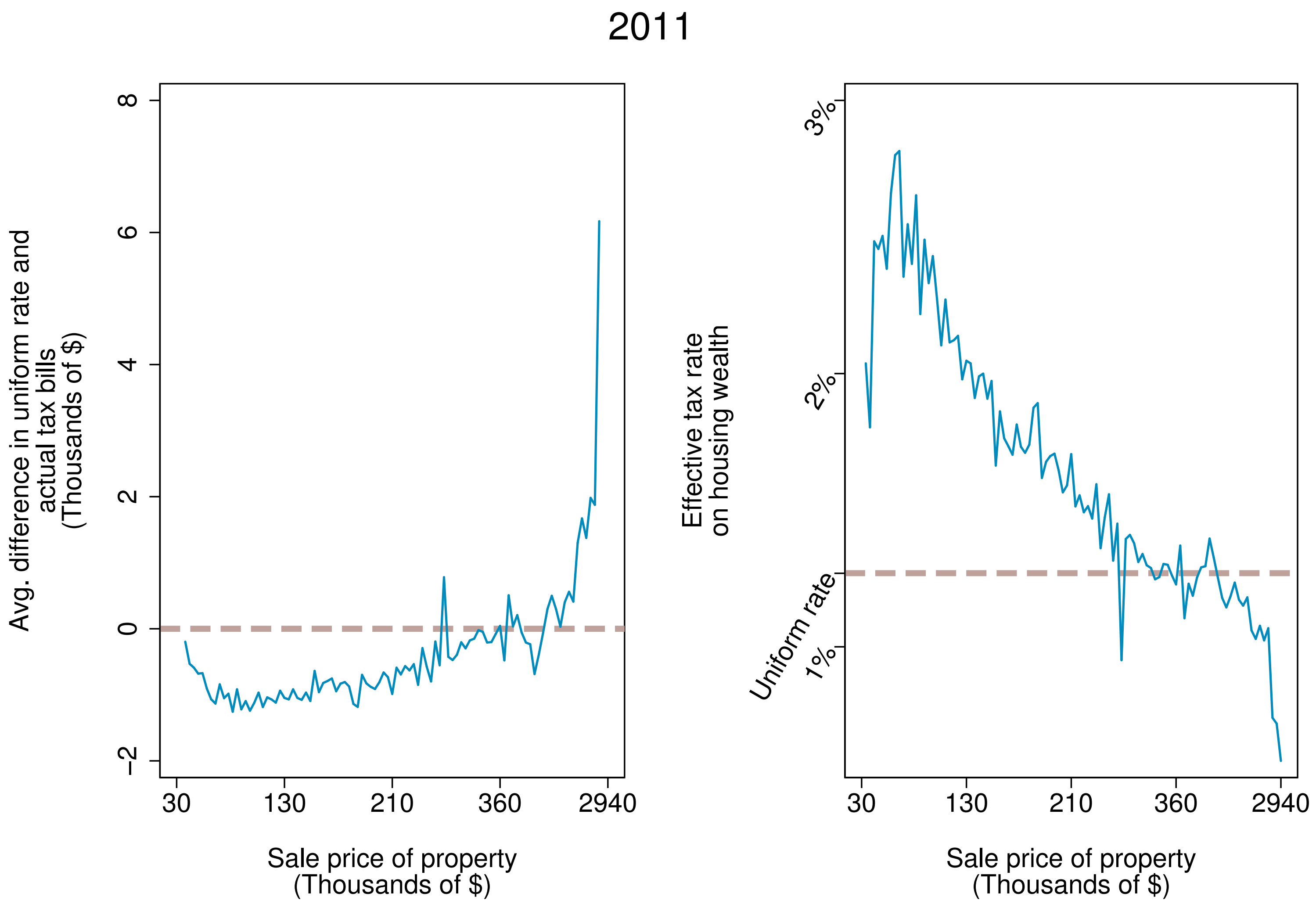

Mean home value
2010 Cook County Census Tracts 2009−2015
Quintiles of mean property value
5th quintile
4th quintile
3rd quintile
2nd quintile
1st quintile

Figure 13: Effect of applying a uniform tax rate to properties sold in 2011



For 13539 properties sold in Chicago in 2011

Table 1: Effect of appeals on PRD by year

Year	Number of sales	First-pass assessments	Margin of error for first-pass PRD	Final assessments	Effect of appeals on PRD
Condominiums					
2003	23647	.9804941	.0009667	.9864979	.0060037
2004	24687	.9992108	.0010699	1.0029	.0036888
2005	26361	1.003314	.001001	1.005927	.0026129
2006	22623	.9929795	.00108	.9989655	.005986
2007	20373	1.020422	.0013968	1.020143	-.0002795
2008	12757	1.079148	.002971	1.086757	.0076089
2009	13497	1.111139	.0048721	1.126737	.0155981
2010	12155	1.214219	.0089586	1.216193	.0019739
2011	10932	1.453566	.0112359	1.487601	.0340348
2012	11989	1.140018	.0063924	1.161866	.0218487
2013	15701	1.099589	.002935	1.09847	-.001119
2014	15059	1.063391	.0022468	1.069806	.0064142
2015	15057	1.002597	.0017878	1.015389	.0127921
Single-family homes					
2003	47848	1.033248	.001004	1.034837	.0015888
2004	51599	1.016408	.0010209	1.018406	.0019974
2005	52785	1.035401	.0011508	1.037576	.0021751
2006	40962	1.025603	.001064	1.028046	.0024426
2007	28624	1.025314	.0015414	1.03179	.0064753
2008	17352	1.082953	.0034686	1.091926	.0089734
2009	16782	1.098144	.0034911	1.112224	.0140803
2010	17776	1.136879	.0037595	1.152979	.0161002
2011	16221	1.208911	.0052592	1.218689	.0097774
2012	18426	1.125253	.0034523	1.135212	.0099592
2013	24365	1.105195	.0024773	1.109264	.0040691
2014	21290	1.0922	.0021832	1.094257	.0020574
2015	20927	1.056025	.0019525	1.063649	.0076243

Table 2: Correlates with appealing, winning appeal

	First-pass assessments	Probability of appealing	Probability of winning an appeal	% reduction in taxable value	Effective tax rate
Property Characteristics					
Sale price	4.87e-13	3.57e-13***	8.69e-13***	4.69e-13***	-1.34e-13*
($100,000)	(1.89)	(3.66)	(4.35)	(3.64)	(-2.39)
Ratio of first-pass estimated		0.0315***	0.236***	0.174***	1.099***
market value to realized market value		(6.61)	(14.67)	(5.45)	(33.68)
Condominium	0.00631	0.0842***	0.139***	0.0201	-0.00741
	(0.37)	(13.51)	(9.34)	(1.18)	(-1.01)
Number of units in	-0.00442**	0.00620***	0.000148	0.00225	-0.00457***
a building	(-3.18)	(10.53)	(0.16)	(1.48)	(-8.70)
Squared number of units	0.0000174	-0.0000246***	-0.000000105	-0.00000381	0.0000239***
in a building	(1.49)	(-4.01)	(-0.01)	(-0.46)	(3.31)
Property Characteristics					
% non-white	0.0100***	-0.000267***	0.00343***	-0.000769	0.00279***
and/or hispanic	(50.22)	(-4.15)	(12.38)	(-0.76)	(8.69)
% Holding a BA or higher	1.452***	0.183***	0.458***	-0.231***	0.471***
	(29.32)	(9.53)	(10.90)	(-4.65)	(10.22)
N	589259	589259	90016	90016	279428
r2	0.782	0.267	0.661	0.00196	0.913

t statistics in parentheses

Errors clustered on 2010 Census Tracts

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B: Alternate measures of vertical equity

In addition to PRD, I also calculate Price Related Bias (PRB), and a version of the Suites Index. Price Related Bias is calculated by regressing the adjusted assessment ratio against the adjusted mean sales price for a given period, and capturing the resulting coefficient β_1. I trim the first and last percentile of assessment ratios from my annual regression samples, which is consistent with standard assessment practices. My regression is:

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i \tag{2}$$

where

$$Y_i = \frac{V_i - Median(E_{CCAO}[V])}{Median(E_{CCAO}[V])} \tag{3}$$

and

$$X_i = \frac{ln(\frac{E_{CCAO}[V_i]}{(Median(E_{CCAO}[V])} + V_i)}{2ln(2)} \tag{4}$$

Where $Med(E_{CCAO}[V])$ is the median CCAO estimated market value.

PRD is positively correlated with regressiveness, while PRB is negatively correlated with regressiveness. The standard "acceptable" bounds for PRB are $0 \pm .03$. The PRB may be interpreted as the effect of doubling a property's value on that property's assessment ratio. In 2015, the post-appeal PRB figure for the County was -.042. The interpretation of this coefficient is that doubling a property's value would be associated with an decrease in its assessment ratio by 4.2%. As with PRD, I calculate PRB from both first and final assessment ratios to measure the impact of appeals on progressiveness, and find qualitatively identical results to PRD.

The Suites Index is given:

$$S = 1 - (1/5000) \int_0^{100} T(Y)dy \tag{5}$$

$$S \approx \sum_{i=0}^{N} [T(Y_i) + T(Y_{i-1})][Y_i - Y_{i-1}] \tag{6}$$

where Y and $T(Y)$ are the cumulative percentage of the total income and the corresponding cumulative percentage of tax burden, respectively. I use property value in lieu of income, since I cannot directly observe individual taxpayers' incomes. I therefore calculate this Suites index using the subsample of properties which sold in each year.

Figure 14 shows the "Suites Curve" plotted with a 45 degree line, representing a proportional distribution of taxes across property values. In the figure, the Suites Curve lies above the proportional line, indicating that lower value properties bear a disproportional larger portion of the property tax burden.

Since the Suites Index can only be calculated using actual taxes paid, I cannot calculate a pre- and post-appeals Index. In order to recalculate taxes for individual taxpayers supposing they had not appealed, I would have to make an assumption about the effect if a larger tax base on the statutory tax rate. Tax levies are set *ex ante* the determination of the tax base, and tax rates are determined simply by the ratio of the tax levy to the base. Changing the base by excluding appeals will increase the statutory rate in a somewhat unpredictable way. Thus, I present indices only for post-appeal taxes.

Figure 14: Price-Related Differential

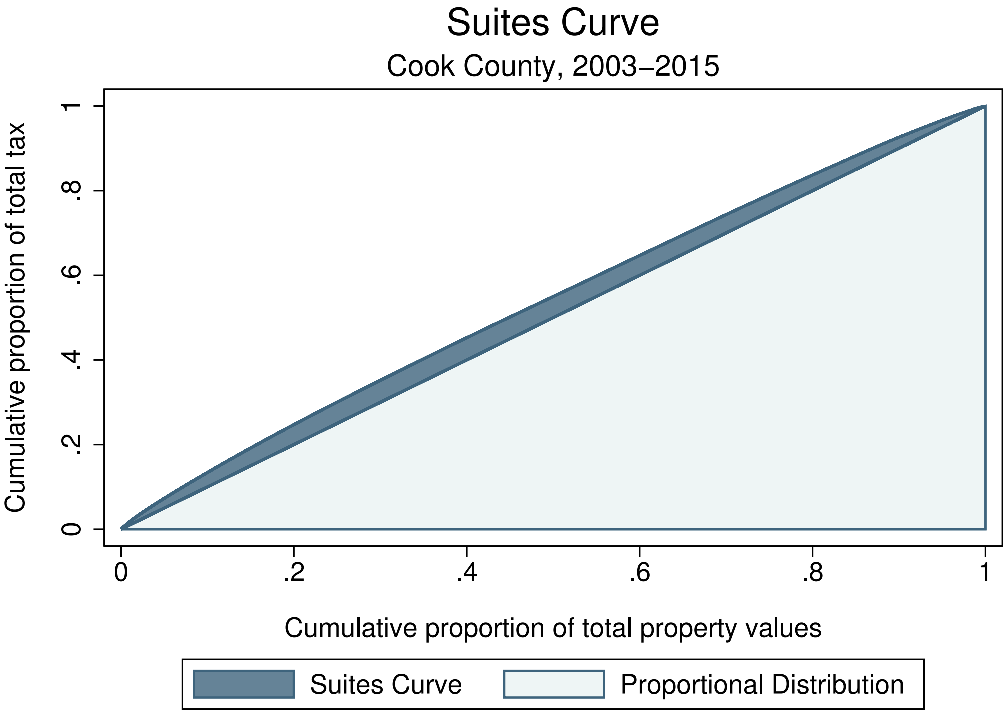


Table 3: Price-related Bias and Suites Indices

Year	Number of sales	First-pass assessments	Final assessments	Margin of error for first-pass PRB	Effect of appeals on PRB	Suites Index	Margin of errror
2003	71495	-.0252729	-.02802	.0008249	-.0027471	.0037802	.0015675
2004	76286	-.0169512	-.0185279	.0008047	-.0015767	-.0048736	.0014858
2005	79146	-.037817	-.0383912	.0008311	-.0005742	-.003165	.0015807
2006	63585	-.0164822	-.0196375	.0008008	-.0031553	.0060896	.001734
2007	48997	-.0205835	-.0219423	.0010023	-.0013588	-.0183435	.0019752
2008	30109	-.0720933	-.0780768	.0014491	-.0059834	-.0779939	.00343
2009	30279	-.118095	-.1312703	.0021423	-.0131753	-.1106438	.0044872
2010	29931	-.146046	-.1514736	.0020353	-.0054276	-.1760897	.0064089
2011	27153	-.1864577	-.1939308	.0020569	-.0074731	-.3616682	.0078987
2012	30415	-.1304321	-.1353229	.0014716	-.0048909	-.1064669	.0042314
2013	40066	-.1122607	-.1064409	.0011106	.0058197	-.0896962	.0029003
2014	36349	-.0866059	-.0853196	.0010966	.0012862	-.079108	.003676
2015	35984	-.0353427	-.0426762	.001061	-.0073335	-.0325671	.0022702