Property Tax Limitations, Covariance Risk, and Mortgage Distress*

Sébastien Bradley† Da Huang‡ Nathan Seegert§

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Abstract

We study how property tax limitations affect mortgage distress through the covariance risk of property taxes, the tendency for tax increases to coincide with economic downturns. Using a tax simulation with policy levers including assessment, rate, and levy limitations, we isolate the effect of tax limitations and show that they increase covariance risk. Using parcel-level data in a state-border discontinuity design, we show that holding tax level fixed, a one-standard-deviation increase in limitation-policy-induced covariance risk raises distress probability by 30%, with stronger effects for financially vulnerable and minority households. These results highlight unintended consequences of tax limitations and motivate policy solutions.

Keywords: Property Taxation, Tax Limitations, Risk, Distress, Mortgage Default, Foreclosure.

JEL Classification: H31, H71, G59, K34, R20

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†School of Economics, LeBow College of Business, Drexel University. 1023 Gerri C. LeBow Hall, 3220 Market Street, Philadelphia, PA 19104. Office phone: (215) 571-4193. E-mail: sbradley@drexel.edu

‡Department of Finance, Northeastern University, 413B Hayden Hall, 360 Huntington Ave, Boston, MA 02115, US. E-mail: da.huang@northeastern.edu

§Department of Finance, Northeastern University, 413D Hayden Hall, 360 Huntington Ave, Boston, MA 02115, US. E-mail: n.seegert@northeastern.edu

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Abstract

We study how property tax limitations affect mortgage distress through the covariance risk of property taxes, the tendency for tax increases to coincide with economic downturns. Using a tax simulation with policy levers including assessment, rate, and levy limitations, we isolate the effect of tax limitations and show that they increase covariance risk. Using parcel-level data in a state-border discontinuity design, we show that holding tax level fixed, a one-standard-deviation increase in limitation-policy-induced covariance risk raises distress probability by 30%, with stronger effects for financially vulnerable and minority households. These results highlight unintended consequences of tax limitations and motivate policy solutions.

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1 Introduction

Homeownership is a defining element of household economic behavior, affecting wealth accumulation, labor supply, portfolio choice, borrowing, and consumption.[1] Correspondingly, a large literature studies policies that encourage homeownership and alleviate mortgage distress (Mian, Sufi and Trebbi, 2010; Piskorski and Tchistyi, 2010; Ghent and Kudlyak, 2011; Mian, Sufi and Trebbi, 2015; Adelino, Schoar and Severino, 2016; O'Malley, 2021; Guren, Krishnamurthy and McQuade, 2021). Yet this focus largely overlooks property taxes, which represent a major, ongoing cost of homeownership and expose households to fiscal risk distinct from mortgage payments. On average, property taxes amount to more than 1% of housing values annually in perpetuity, corresponding to over 20% of housing values under a 5% discount rate. The heavy property tax burden has led nearly all U.S. states to implement property tax limitations to curb the growth of property tax liabilities. In this paper, we show that while these limitations are intended to restrain the tax burdens, they distort the timing of tax liabilities in ways that ultimately raise the effective burden on households. Specifically, they shift tax increases towards economic downturns, precisely when housing values fall and household finances are most constrained. We further demonstrate that this unintended effect of property tax limitations exacerbates mortgage distress, the very outcome these policies were meant to alleviate.

Property tax liabilities are determined by multiplying the taxable value of a property by the applicable tax rate. Property tax limitations restrict the growth of the taxable value (assessment limit), the tax rate (rate limit), or the growth of the total tax liability (levy limit). In practice, tax authorities often combine these limits, each with its own detailed, jurisdiction-specific configuration. A simple example is as follows. A new homeowner purchases a property for \$1 million, which is initially assessed at the same value. During a prolonged economic boom, the market value doubles to \$2 million, but the taxable value rises only to \$1.5 million due to the assessment limit. When a recession hits the following year, the market value falls to \$1.8 million. Because the taxable value remains below the market value, it continues to rise within the allowable limit even as the market value declines. As a result, property tax liabilities increase during downturns, precisely when housing values fall, and household finances are under pressure. Compared to a pure market-value-based tax regime, in which tax liabilities move in tandem with market values,

[1] See Venti and Wise (1998); Kuhn, Schularick and Steins (2020) on homeownership and wealth accumulation; Blanchflower and Oswald (2013); Gerardi, Herkenhoff, Ohanian and Willen (2017) on labor market participation; Flavin and Yamashita (2002); Yao and Zhang (2005); Cocco (2005); Chetty, Sándor and Szeidl (2017); Melzer (2017) on investment risk-taking; Mian and Sufi (2011); Adelino, Schoar and Severino (2015); Chen, Michaux and Roussanov (2020); Adelino, Schoar and Severino (2025) on borrowing; and Mian, Rao and Sufi (2013); Berger, Guerrieri, Lorenzoni and Vavra (2018); Agarwal, Amromin, Chomsisengphet, Landvoigt, Piskorski, Seru and Yao (2023) on consumption.

the assessment limit shifts tax increases from economic booms to recessions.

To formalize this idea, we introduce a measure, *covariance risk*, that captures the extent to which property tax increases coincide with economic downturns. We decompose a property tax liability stream into two components: a tax level term and a covariance risk term. The tax level term represents the average tax liability over time. The covariance risk term captures the covariance between tax liabilities and the state of the economy. A positive covariance risk indicates that tax liabilities are countercyclical, imposing higher taxes during recessions and thus being more burdensome than a constant liability stream. This decomposition allows us to study the timing dimension of property taxation separately from its overall level.

Next, we examine how property tax limitations affect *covariance risk*. The key identification challenge is that tax limitations are typically adopted for endogenous reasons. To isolate the causal effect of property tax limitations on covariance risk, we develop a property tax simulator that holds the economic environment constant while varying specific tax system features. These features include property tax limitations, effective tax rate, and reassessment frequencies. Using this simulator, we compute the *covariance risk* of property taxes for the same property under the same economic conditions, both with and without any form of tax limitations. The difference in covariance risk between the no-limitation regime and any given policy configuration represents the *policy-induced covariance risk*. This measure captures the additional risk in tax timing generated solely by the tax limitation policy itself, independent of changes in the average tax level, which we also compute separately and refer to as the "policy-induced tax level".

We find that property tax limitations increase covariance risk along both the extensive and intensive margins. On the extensive margin, we regress policy-induced covariance risk across all continental U.S. states and years on indicator variables capturing the presence of assessment, rate, and levy limits. We find that adopting assessment, rate, and levy limits raises policy-induced covariance risk by 0.80, 0.74, and 0.33 standard deviations, respectively. On the intensive margin, the tax simulator allows us to hold all other factors constant while varying the stringency of each type of tax limitation. We show that more stringent limits (i.e., lower caps on assessed value growth, tax rates, or tax levy growth) lead to higher policy-induced covariance risk.

It remains an open empirical question whether property tax limitations reduce overall tax levels and whether any such reductions are sufficient to offset the adverse effects of policy-induced covariance risk. Existing evidence is mixed, with prior work documenting limited success in constraining property taxation and local government growth (Dye and McGuire, 1997; Cutler, Elmendorf and Zeckhauser, 1999; Eliason and Lutz, 2018). Consistent with this evidence, we find that the effect of property tax limitations on tax levels is ambiguous. We estimate this relationship by regressing policy-induced changes in tax levels at the state-year level on indicators for assessment, rate, and levy limits. On average, imposing rate and levy limits reduces the policy-induced tax level, while imposing assessment limits slightly increases it. Hence, it remains empirically ambiguous whether tax limitations consistently reduce overall tax levels. Regarding the second question, even if property tax levels decline, it is not clear that households experience meaningful relief. As documented in a large literature, property taxes are capitalized into housing prices (Oates, 1969; Palmon and Smith, 1998; Gindelsky, Moulton, Wentland and Wentland, 2023; Gárate and Pennington-Cross, 2023). Lower property tax levels can raise housing values and, consequently, increase mortgage payments, offsetting any direct benefit from reduced taxes. Given these empirical and theoretical ambiguities, we remain agnostic as to whether policy-induced tax level (changes) mitigate the negative effects of policy-induced covariance risk. Accordingly, in all subsequent analyses, we control for the policy-induced tax level when estimating the impact of policy-induced covariance risk on mortgage distress. Our policy discussion likewise proceeds under the premise that the overall level of property taxation remains unchanged.

We empirically estimate the effect of policy-induced covariance risk on mortgage distress using nationwide parcel-level data from ATTOM Data Solutions and Zillow (ZTRAX). The parcel-level data allows us to avoid measurement issues (at the zip-code level) in Mian and Sufi (2009), as pointed out by Adelino et al. (2016). The data also allow us to control for a comprehensive set of property-specific characteristics that are central to understanding mortgage distress and foreclosure, including loan-to-value ratios, ownership tenure, and home values. A central empirical challenge, however, is that the adoption and implementation of property tax limitations are not exogenous and often reflect underlying dynamics in state taxation and mortgage markets. To address unobserved confounders that may jointly influence tax limitation policy and mortgage distress, it is crucial to identify variation in limitation policies that is plausibly uncorrelated with local economic conditions. The rich parcel-level data allows us to implement a border discontinuity design similar to that in Mian et al. (2015) and Aiello, Bernstein, Kargar, Lewis and Schwert (2025), which mitigates concerns about omitted-variable bias. Under this design, we compare properties located near state borders that face different property tax regimes but are exposed to similar local economic and housing market conditions. This approach necessarily excludes interior regions of states where isolating clean identifying variation is difficult. Nevertheless, the border sample remains broadly representative, encompassing a diverse mix of urban and rural areas as well as affluent and lower-income neighborhoods.

We find that a one-standard-deviation increase in policy-induced covariance risk raises the likelihood of mortgage distress by 0.433 percentage points, equivalent to roughly 30% of the sample mean. For context, this effect is about 70% larger than the effect of owning a home in disrepair and roughly one-quarter as large as the effect of a homeowner becoming underwater on their mortgage. The effect remains comparable when we focus specifically on foreclosure rather than all forms of mortgage distress. Our analysis further shows that these adverse impacts are concentrated among homeowners in predominantly Black neighborhoods, as well as among those who are over-assessed, have higher loan-to-value ratios, or have longer ownership tenure. Together, these patterns suggest that increases in policy-induced covariance risk exacerbate pre-existing financial vulnerabilities.

Crucially, the large effect of policy-induced covariance risk on mortgage distress is estimated while holding the policy-induced tax level constant. In other words, even when the overall level of taxation remains unchanged, the additional risk arising from the unfavorable timing of property taxes under limitation policies significantly increases mortgage distress. In practice, however, the level of property taxation often changes when tax limitations are implemented. As described earlier, assessment limits tend to increase overall tax levels, whereas rate and levy limits tend to reduce them.

Our results have direct implications for policy. The central lesson is that policy design must account for timing risk, not only the level of taxation. In the context of property tax limitations, this lesson implies that policymakers should consider how these rules shift tax liabilities into economic downturns, thereby increasing mortgage distress through elevated covariance risk. These unintended consequences can be mitigated through complementary policies. In particular, expanding property tax deferral programs may reduce covariance risk by allowing vulnerable homeowners to smooth tax payments over time, making effective tax liabilities more procyclical. Importantly, deferral programs preserve the present value of property tax revenues, enabling households to benefit from improved timing without altering the overall level of taxation. While most existing programs target low-income seniors, broader eligibility could provide meaningful relief to financially constrained households without undermining local government revenue stability or the structure of property taxation.

This paper contributes to the household and housing finance literature by identifying property taxation—particularly property tax limitations—as a distinct and previously unstudied source of mortgage distress. A literature explains default and foreclosure through mortgage contract design, borrower leverage, house price dynamics, income risk, and legal enforcement institutions (e.g., Ambrose, Capone and Deng, 2001; Piskorski and Tchistyi, 2010; Ghent and Kudlyak, 2011; Mian et al., 2015; Adelino et al., 2016; O'Malley, 2021; Guren et al., 2021). These studies primarily explain why households default following declines in housing values or adverse income shocks. We complement this literature by showing that mortgage distress can also arise from shocks to *non-mortgage housing obligations*. Even holding fixed mortgage terms, leverage, and local economic conditions, institutional features of property taxation can increase default risk by shifting tax increases toward periods when household balance sheets and liquidity are most strained. This mechanism is particularly important because a substantial share of mortgage distress during downturns occurs among middle-income and prime borrowers (Adelino et al., 2016; Adelino, Schoar and Severino, 2018). These prime borrowers' negative equity and housing leverage from refinancing and home equity loans are further exacerbated by increasing property tax liabilities in the downturn.

More broadly, our analysis contributes to the household finance and macro-finance literature on the transmission of aggregate shocks to households. Macroeconomic shocks can affect household credit availability and consumption (Mian et al., 2013; Benetton, Bracke, Cocco and Garbarino, 2022). These shocks can be mitigated by fiscal and taxation policies (Blundell, Pistaferri and Preston, 2008; Kaplan and Violante, 2014; Dauchy, Navarro-Sanchez and Seegert, 2021) and absorbed by refinancing and home equity extraction (Keys, Pope and Pope, 2016; DeFusco, 2018; Chen et al., 2020; He and le Maire, 2023). We show that poor design in property tax limitations can operate in the opposite direction. By increasing housing-related obligations (e.g., property taxes) precisely when refinancing opportunities become limited and liquidity constraints tighten, unfavorable tax timing amplifies household exposure to downturns. Consistent with evidence that poorly timed tax payments increase mortgage default risk (e.g., Hayashi, 2020; Wong, 2023), our results identify a new channel through which housing market institutions intensify the macroeconomic consequences of recessions.

This paper also contributes to the literature on property taxation and property tax limitation policies. Such limitations exist in nearly all U.S. states and are commonly justified as protections against rapid growth in property tax liabilities. A large body of work studies whether limitation policies constrain property tax growth, local government spending, and housing prices (Poterba and Rueben, 1995; Cutler et al., 1999; Dye, McGuire and McMillen, 2005; Brooks, Halberstam and Phillips, 2016; Eliason and Lutz, 2018), with mixed and often modest or heterogeneous effects. While this literature provides important insights into the level effects of property taxation, it is largely silent on the timing of tax liabilities over the business cycle. This distinction is central in a household finance context, as identical tax levels can impose very different burdens depending on when payments occur. We contribute to this literature by showing that property tax limitations reallocate tax payments across economic states, thereby increasing households' effective tax burden.

2 Property Tax Limitations

2.1 Property Tax Basics

Property tax obligations are calculated at the parcel level as the product of parcel i's *taxable value*, TV_i, and the statutory *millage rate* in jurisdiction j, τ_{ij}. The applicable τ_{ij} may combine rates from multiple overlapping taxing jurisdictions (e.g., counties, municipalities, and school districts) and may differ by property class or according to owners' residency status. In principle, local governments have two levers of adjustment (taxable value and millage rate) to achieve their desired aggregate *tax levy*, $Levy_j = \sum_{i=1}^{N_j} TV_i \cdot \tau_{ij}$. In practice, taxable values are anchored to assessed (market) values, which are themselves intended to reflect the local assessor's best estimate of fair market value. Under market-value-based assessments with annual reassessments and a 100 percent assessment ratio, taxable values and assessed values coincide. In this case, property tax obligations are solely determined by market values and the choice of millage rate.

All but three U.S. states (Hawaii, New Hampshire, and Vermont) have implemented some form of statewide property tax limitations since 1978. These tax limitations are motivated by a mix of concerns over the impact of rising home prices and property tax burdens, the growth of state and local governments' budgets, and the desire for predictable changes in property tax obligations and revenues (O'Sullivan, Sexton and Sheffrin, 1995). These limitations differ in whether they restrict the evolution of the tax base (TV_i), tax rates (τ_{ij}), or their product ($Levy_j$) and are referred to as assessment, rate, and levy limits, respectively. Overall revenue/expenditure limits may also apply and extend beyond property taxes by encompassing other sources of state and local tax revenue. As shown in Table 1, all but nine states employ multiple types of property tax limitations, including three states (Arizona, Michigan, and New Mexico) that use some version of all four.

Insert **Table 1** About Here

Each of these types of limitations implies deviations from the market-value-based property tax regime described above. Along with infrequent reassessments of property values, these limitations can interfere with the relative procyclicality of property tax obligations and thereby lead to potentially negative outcomes. A leading example is that taxable values under assessment limitations can still grow during housing market downturns, thereby increasing the risk of mortgage distress. Similar situations can arise through other forms of tax limitations or combinations thereof. We discuss these situations in the next subsections while highlighting the substantial heterogeneity in policy implementation details across states.

2.2 Assessment Limits

Assessment limits generally restrict the growth rate of taxable values over time, regardless of the true evolution of housing prices. However, states differ in their choices of capped growth rates and applicable property classes, as well as in their treatment of properties after a change of ownership. California's Proposition 13—which marked the first implementation of assessment limitations—mandates a maximum annual growth rate equal to the lesser of 2 percent or the rate of statewide inflation for all classes of property, with resetting (i.e., "uncapping") of taxable values to current market value occurring immediately following an arm's length transaction. Other states apply a range of maximum capped growth rates, apply to only a small subset of homeowners (e.g., Arkansas) or exclusively to primary residences (e.g., the District of Columbia, Maryland), do not trigger taxable value uncapping as a result of changes of ownership (e.g., Arizona, Oregon), apply only to certain localities as a local option (e.g., Georgia, Illinois, New York), apply only to aggregate taxable values (e.g., Colorado, Iowa), or merely stipulate phasing in of property reassessments (e.g., Connecticut, Montana). For purposes of our analysis, we distinguish the "traditional" acquisition-value-based assessment limitations that more closely resemble California's Proposition 13 from other forms of assessment limits. Figure 1a depicts the geographic distribution of these different types of assessment limitation regimes.

Insert **Figure 1** About Here

During housing market downturns, taxable values subject to assessment limitations need not necessarily decline. Indeed, taxable values may continue to rise at the capped growth rate even as property values are falling so long as taxable values remain below the current assessed market value (as might occur after a period of sustained housing price growth in excess of the state's capped growth rate). Once both values converge, further reductions in assessed market values must bring about equivalent reductions in taxable value. States differ on whether there is a subsequent provision for "catching up" to an alternative base year value once house prices begin to rise again, as in, for example, California's Proposition 8.

Insert **Figure 2** About Here

Figure 2a illustrates a hypothetical version of this scenario. The red line depicts the evolution of tax liabilities when taxable values are subject to assessment limitations, while the solid blue line represents tax liabilities under market-value assessments. The dashed orange line mirrors the red line, albeit assuming a higher effective tax rate to maintain revenue neutrality between the market-value and assessment-limitation regimes. This neutrality adjustment isolates how assessment limitation changes tax timing from how it changes tax level. As shown, tax obligations increase more slowly under assessment limitations during a housing market boom, yet they can continue to increase during a bust so long as taxable values remain below market values. Thus, despite limiting tax liabilities when property values are rising, assessment limitations may result in smaller reductions (or even ongoing increases) in tax liabilities during market downturns – precisely when households may already be at greater risk of financial distress. This risk may exacerbate the negative consequences of housing market downturns and act as a trigger event for mortgage foreclosures (Tian, Quercia and Riley, 2016; Gerardi et al., 2017; Low, 2022).

In Figure 2b, we show that the hypothetical situation presented in Figure 2a happens frequently in reality. This panel plots the proportion of parcel-year observations in our sample that saw their tax liability decrease, remain unchanged, or increase while their property value decreased or increased. The most common scenario is that tax payments increase as market values increase. However, the second most common scenario is for tax payments to increase while market values decrease, occurring roughly 35% of the time.

We next show this pattern in aggregate time series. Figure 2c shows the average year-over-year change in housing prices and property tax payments by states with and without assessment limitations. Focusing on the red lines, which represent states with assessment limitations, we see that in 2007 the average growth rate of housing prices (solid line) was roughly -1%, whereas the growth rate of property tax payments (dashed line) was roughly 6%. This pattern corresponds to the "tax-up-value-down" scenario we commonly observe in Figure 2b. The positive 7% difference between the growth rates of property tax payments and housing values indicates an exacerbated distress risk. In other words, homeowners face elevated mortgage distress risk during recessions because property taxes grow faster than the economy (proxied by housing prices). We term this difference the "tax-price adjustment gap" and plot it in Figure 2d. The tax-price adjustment gap increases to 15% in 2008 and 2009, suggesting an even higher level of risk induced by property tax liabilities. During periods of economic booms (e.g., 2012 to 2014), this gap becomes negative because assessment limitations restrict how quickly property taxes can grow, even as housing prices grow rapidly. The positive tax-price adjustment gap during recessions and the negative gap during booms reflect a shift in tax liabilities from booms to recessions, thereby increasing mortgage distress risk. In contrast, the blue line in Figure 2d shows that, for states with no assessment limits, the gap is smaller during recessions and close to zero during booms. Taken together, these results indicate that assessment limits reduce the pro-cyclical nature of tax liabilities, which could lead to mortgage distress.

Reassessment frequency can also affect the procyclicality of the tax liabilities. As reported in the sixth column of Table 1, the frequency of legally mandated reassessments varies substantially across states. Reassessment intervals range from as little as one year (e.g., Alabama, Georgia, Idaho) to as long as eight years in North Carolina, while several states have no statutes dictating a specific reassessment frequency (e.g., Delaware, New York, Pennsylvania). It is worth noting that infrequent reassessments—such as the 20+ year intervals between county assessments that are common in Pennsylvania—can serve as a very strict *de facto* assessment limitation regime, with assessment growth capped at 0% for extended periods. The effect of infrequent reassessments on the procyclicality of property taxes depends on the economic condition at the time of reassessment. The frequency of reassessments is not the focus of this paper, but we incorporate this feature in our property tax simulation and the calculation of *covariance risk* for each state throughout the paper.

2.3 Rate Limits

Rate limits restrict the rate at which property may be taxed by the tax authorities. These are most often expressed in terms of absolute millage rates and commonly involve different caps for different levels of government. For purposes of our analysis, we aggregate these limits across taxing jurisdictions to obtain a single state-level maximum millage rate. For example, Kentucky's statute states that "[t]he tax rate shall not exceed for counties 5 mills, for municipalities 7.5-15 mills on a sliding scale based on population, and for school districts 15 mills." In this case, we treat Kentucky as if it had a statewide rate limit of 35 mills (= 5 + 15 + 15). Rate limits can also be set on a statewide basis as a percentage of fair market value, without specifying each taxing jurisdiction's allowed rate. In rare cases, rate limits can restrict the millage rate *growth*. For example, Colorado caps municipal rates at the prior year's level, thereby effectively imposing a zero-growth rate limit; South Carolina limits the millage rate growth to a function of inflation plus population growth. Figure 1b depicts the geographic distribution of statutory millage rate limitations (expressed as percentages of fair market value for comparability across states). Outside of the Northeast, rate limits are commonplace.

Rate limits frequently exclude certain jurisdictions, exempt debt-service millage, or permit voter overrides, and thus may vary substantially in how binding they are across states. We evaluate whether rate limits are binding in each state using parcel-level data on housing values and property taxes.[2]

[2] In order to gauge whether rate limits are binding for purposes of our tax risk simulations, we compare states' median effective tax rates for newly purchased homes (to avoid the confounding influence of assessment limits) with their statutorily capped rates (standardized to be defined relative to 100 percent of fair market value). If the effective rates observed in the data are significantly higher, we either treat the state as if it does not have a rate limit at all

On the one hand, assuming local governments always try to collect the same amount of property tax revenue, rate limits are more likely to kick in when property values fall. This is because local governments attempt to raise the millage rate to collect the same amount of property tax revenue based on a smaller tax base. In this case, for individual taxpayers, rate limits could dampen countercyclical fluctuations in millage rates and may result in more procyclical tax liabilities, contrary to assessment limitations. On the other hand, if the government's tax revenue requirements also adjust to economic conditions and assessed value adjustments exhibit downward stickiness, rate limits are instead less likely to kick in when property values fall. This is because assessed values (i.e., the tax base) are inflated, and the revenue requirement decreases. In this case, rate limits would make tax liabilities less procyclical. The net effect of rate limitations on the overall procyclicality of property tax obligations is thus an empirical question, the answer to which could vary depending on interactions with other tax system characteristics.[3]

2.4 Levy Limits

Levy limits restrict the amount of aggregate property tax revenue (i.e., tax levies) that a local government can collect from property owners within its jurisdiction. Typically, levy limits are expressed as a limit on the percentage growth in aggregate property tax revenues relative to the prior year. The growth rate limit is defined as a fixed percentage, a number anchored to inflation, or a function of the two. Less commonly, some states instead restrict property tax levies as a share of aggregate fair market value. States can also restrict both the growth rate and the total tax levy as a share of aggregate market values.[4] Figure 1c depicts the geographic distribution of levy limits based on percentage growth limits. We also show limits on levy amounts or other revenue/expenditure limits on the map labeled as "Other Levy/Revenue Limits." Levy limits are widely used outside of the Southeast, with broad geographic variation in limit stringency.

(e.g., Alabama, Arkansas, Georgia, etc.) or we look to additional legislative language that might suggest an alternative higher limit. (For example, Michigan's basic rate limitation is set at 15 mills, excluding debt service; however, this rate can be increased by voter override up to a rate of 50 mills. Given a 50 percent assessment ratio, this translates to a 2.5% rate as a percent of market value. In the data, we observe a median effective rate ranging from 1.6 to 3.1% over our sample period, with most years falling within ± 0.3 percentage points of 2.5%, and we thus treat Michigan as having a binding rate limit of 2.5%.)

[3] Brosy and Ferrero (2021) present evidence for the period around the Great Recession that is broadly consistent with the former characterization of rate limits as inducing more procyclical tax obligations. Rate adjustments to changes in housing prices are attenuated in states with rate limits (of any type), while aggregate assessed values appear to adjust symmetrically to both increases and decreases in housing prices. These tests do not, however, account for the potential confounding influence of correlated tax regime characteristics nor variation in the stringency of these limitations.

[4] For instance, Massachusetts' Proposition $2\frac{1}{2}$ restricts local property tax levies to grow no faster than 2.5 percent per year and to collect tax revenue not to exceed 2.5 percent of assessed market value. The latter is comparable to a 2.5% rate limit. However, this limit applies only in aggregate, so individual properties in MA may still face a tax rate over this amount (e.g., commercial properties).

Levy limits are more likely to bind when property values are rising as a result of property tax revenues exceeding the allowed amount. In this case, local governments must reduce their millage rates to comply with the levy limit. Therefore, levy limits make property taxes less procyclical for individual taxpayers in a way similar to assessment limits. In rare cases, combining levy limits and restrictive rate limits defined in terms of percentage growth (e.g., Colorado) can result in a "ratcheting down" phenomenon. Specifically, rate reductions that occur during booms can never be relaxed thereafter, thereby limiting states' flexibility to raise rates during housing market downturns. Even with the "ratcheting down" dynamic, which is a form of protection to individual taxpayers in recessions, levy limits still decrease the overall procyclicality of property taxes.

We provide a detailed description of property tax limitations in each state in 2016 beyond the high-level information shown in Table 1 and Figure 1. We provide a detailed description of each state's tax limitations and the legislative sources in Internet Appendix A. For even more details, we refer readers to Haveman and Sexton (2008) and Lincoln Institute of Land Policy and George Washington Institute of Public Policy (2023).

3 Property Tax Limitations and Covariance Risk

In this section, we first define the main variable of interest of the paper, *covariance risk*. In short, *covariance risk* captures the (lack of) procyclicality of property taxes relative to macroeconomic conditions. If property taxes are less procyclical, tax increases are more likely to coincide with economic downturns and covariance risk is high, and vice versa. Then, we examine the relation between property tax limitation and covariance risk. To isolate the causal effect of property tax limitations on covariance risk, we build a tax simulation that turns property tax limitations on and off while holding all other parameters of the economy fixed. We calculate the difference in covariance risk between the property tax limitation regime in each state and the no-limitation counterfactual, and refer to this difference as *policy-induced covariance risk*. We show that all property tax limitations increase policy-induced covariance risk at both the intensive margin (the stringency of the limitation) and the extensive margin (whether the limitation exists).

3.1 Covariance Risk

Taxpayers care not only about how much they must pay in ongoing property taxes but also about the timing of those payments relative to their marginal utility. Let x_t be a stream of property tax liabilities, and let m_t be the marginal rate of substitution. Therefore, m_t is high (low) when consumption is low (high) in bad (good) times. The total disutility from this stream of liability is

$\sum_t m_t x_t$, in which m_t up-weights (down-weights) x_t in bad (good) times. The *covariance risk* is

$$Covariance\ Risk = Cov(m_t, x_t) = \sum_t m_t x_t - \sum_t m_t \bar{x}_t. \tag{1}$$

The first term, $\sum_t m_t x_t$, represents how burdensome the tax stream is after the "timing adjustment" through the reweighting by m_t. The second term, $\sum_t m_t \bar{x}_t$, is how burdensome the tax stream would be if it were constant (at $\bar{x}_t$) throughout time. Therefore, *covariance risk* is the additional burden of the tax stream induced by timing (mis)alignment.

Covariance risk is positive when tax liabilities are countercyclical and tax timing is unfavorable. To see this relation, slightly rewrite Covariance Risk in Equation 1 as $\sum_t m_t(x_t - \bar{x}_t)$. That is, when tax liabilities are countercyclical, high taxes (i.e., positive $x_t - \bar{x}_t$) are up-weighted because they occur in bad states of the economy. An increase in covariance risk occurs when tax liability becomes less procyclical and tax timing becomes less favorable. A positive (negative) covariance risk also represents the dollar amount that a taxpayer would be willing to pay (receive) to eliminate the cyclicality in the tax stream and pay a constant tax stream instead.

This covariance risk measure has two key advantages. First, it distinguishes true risk from pure volatility, which is commonly used by policymakers. For example, the State of Utah requires the Governor's office to produce a report every three years on the volatility of its tax revenues. Our measure emphasizes the importance of timing alignment compared to pure variability in assessing tax burden. A constant tax stream is less volatile than a stream of taxes that are high (low) during good (bad) times, but constant taxes are more burdensome, which is captured by our covariance risk measure.

Second, the covariance risk measure captures the burden of taxation independent of the level of taxation. That is, we decompose the $\sum_t m_t x_t$ term, i.e., the total burden of taxation, in Equation 1 into a level component and a timing component. The level component is $\sum_t m_t \bar{x}_t$, and the timing component is the Covariance Risk. This decomposition allows us to separately quantify the timing and level effects of tax limitation policies on property taxes in subsequent analyses. In addition, it also allows us to examine how *covariance risk* affects mortgage distress while holding the tax level constant. In summary, this decomposition reveals the economic mechanism underlying our main results: tax limitations induce unfavorable timing of property taxes, thereby triggering mortgage distress.

3.2 Isolating Effects of Property Tax Limitations on Covariance Risk

Next, we examine how property tax limitations affect covariance risk. The obvious identification challenge for the inference is that property tax limitations are not randomly designed and adopted. Many economic variables can simultaneously affect the cyclicality of the taxes and the adoption of limitation policies. The cyclicality of taxes may also affect the policy choice. The ideal experiment would be to exogenously turn a limitation policy configuration $\mathbb{P}$ on and off and compare the *covariance risk* with and without it.

We approximate this ideal experiment by combining data on limitation policies $\mathbb{P}$ and a tax simulation. Specifically, we calibrate a model that produces dynamic property values and household consumption, which, in turn, lead to property tax collections under limitation policies $\mathbb{P}$ and government revenue goals. Then, we calculate *covariance risk* for the property tax collections under a limitation policy regime $\mathbb{P}$ and without any tax limitation at all. The difference between the two covariance risk measures is the *policy-induced covariance risk*:

$$\Delta\text{Risk} = \text{Covariance Risk}_{\mathbb{P}} - \text{Covariance Risk}_{\text{NoLimit}}. \tag{2}$$

The policy-induced covariance risk incorporates all policy-relevant data: tax rates, assessment limits, rate limits, levy limits, and reassessment schedules, as reported in Table 1. This measure separates the effects of property tax limitations from economic conditions by holding these economic conditions fixed across policy regimes. The policy-induced covariance risk captures all interaction effects among property tax limitations that would otherwise be difficult to identify. For example, in Internet Appendix B, we obtain qualitatively similar results by using assessment limitation variables directly; however, interpreting the estimates becomes more challenging as we include additional policy variables and interaction effects. In subsection 3.2.2, we show that policy-induced covariance risk accurately captures the dynamics of real-world property tax policy and has a high correlation with covariance risk within each state. As a result, policy-induced covariance can be interpreted as the causal effect of a state's policy regime $\mathbb{P}$ on covariance risk. The tax simulation also allows us to run policy counterfactual analyses and demonstrate how each policy affects policy-induced covariance risk and how these effects potentially interact.

3.2.1 Property Tax Simulation

In this section, we describe important aspects of the tax simulation. Details on calibration and parameterization procedure can be found in Appendix A.

We begin by simulating the economic conditions that determine the evolution of property values and household consumption. Specifically, we model the aggregate consumption growth and inflation as AR(1) processes with a stochastic residual term plus a separate Poisson term accounting for recessions. Both series are calibrated to match the empirical data for mean, standard deviation, and correlation. Aggregate consumption growth is calibrated using personal consumption growth in the National Income and Product Accounts (NIPA) from the Bureau of Economic Analysis (BEA). Inflation is calibrated using headline CPI from the Bureau of Labor Statistics (BLS). Then, we obtain 500 simulated property price paths using the Case-Shiller U.S. National Home Price Index (with a stochastic term for individual properties) and calibrate the correlation with consumption growth and inflation. For household consumption growth, we amplify the aggregate consumption growth with a stochastic term to match the parameter documented in Pischke (1995). Lastly, we simulate the transaction status of properties to match the empirically observed turnover rate in our data. We simulate this economy for 50 years, long enough to capture the effects of tax limitations but not so long as to reach a point where the AR(1) process would generate extreme outliers. We repeat this process 1,000 times so that the final outcomes are not affected by the randomness of individual economic processes.

This simulation determines the property taxes (x_t in Equation 1) and the weighting scheme (m_t in Equation 1). The insight of covariance risk is captured by any weighting scheme that upweights tax liabilities in bad times and downweights them in good times. We focus on a classic weighting scheme, in which m_t is a power function of the reciprocal of the household consumption growth, i.e., $(c_{t-1}/c_t)^\gamma$. That is, during bad times, $c_{t-1} > c_t$, $m_t > 1$, and therefore the property tax during bad time t is up-weighted by m_t, and vice versa.[5] Our results are qualitatively similar when using alternative weighting schemes that upweight liabilities in recessions and downweight them in booms.

We obtain the property tax x_t in the following steps. We first calculate the property tax stream under a no-limitation regime, denoted $x_{t,\text{NoLimit}}$. Subscript for individual properties is suppressed for brevity.

1. In the first year, all properties are taxed at the empirically observed effective tax rate, with taxable value being the property value.
2. In subsequent years, the tax authority aims to collect tax revenues at a growth rate that tracks aggregate consumption growth.
3. The tax authority assesses and observes the taxable value of the properties, which is the

[5] More concretely, assuming a CRRA utility: $u(c) = c^{1-\gamma}/(1-\gamma)$, the marginal rate of substitution is

$$m_t = \frac{u'(c_t)}{u'(c_{t-1})} = \left(\frac{c_{t-1}}{c_t}\right)^\gamma,$$

where γ is the coefficient of constant relative risk aversion.

property value under the no-limitation regime.

4. The tax authority sets a tax rate given the tax base to meet the revenue target.
5. Individual household's property tax $x_{t,\text{NoLimit}}$ can be calculated given the taxable value of the property and the tax rate.[6]

This procedure forms the counterfactual baseline with no tax limitations. Following Equation 1, we calculate the counterfactual Covariance $\text{Risk}_{\text{NoLimit}}$.

Next, we calculate the property tax stream, $x_{t,\mathbb{P}}$ in year t, under tax limitation regime $\mathbb{P}$. $\mathbb{P}$ is in the policy space, which spans the parameterizations and combinations of the assessment limits, rate, and levy limits. If policy $\mathbb{P}$ includes a levy limit, then the "tax revenue tracking" in step 2 of the procedure would be subject to a constraint. If policy $\mathbb{P}$ includes an assessment limit, the year-over-year change in taxable values in step 3 of the procedure would be limited by a cap. And finally, if policy $\mathbb{P}$ includes a rate limit, the tax authority must set the new rate within the rate limit, even if that means it cannot raise the otherwise desired level of tax revenue. After obtaining the property tax stream under the limitation regime $\mathbb{P}$, we can calculate the corresponding *Covariance* $Risk_{\mathbb{P}}$.

We calculate the difference between *covariance* $risk_{NoLimit}$ and *covariance* $risk_{\mathbb{P}}$, and we average the difference across 500 households in each simulation and across 1,000 iterations. The resulting average difference is the *causal effect* of tax limitation regime $\mathbb{P}$ on the covariance risk of property taxes. We refer to this difference as *policy-induced covariance risk* and denote it as $\Delta\text{Risk}_{\mathbb{P}}$. Similarly, we also calculate a policy-induced tax level, i.e., the causal effect of policy $\mathbb{P}$ on the $\sum_t m_t \bar{x}_t$ term in Equation 1, and we denote it as $\Delta\text{Level}_{\mathbb{P}}$.

3.2.2 Policy-Induced Covariance Risk Across the U.S.

Next, we use the simulation to examine the effect of each state's property tax limitation policy on the covariance risk and tax level from 2006 to 2016. We hand-collect the tax limitation policy configuration for each state-year (see Table 1 for a summary of the policies and Internet Appendix A for details). The policy configuration for each state is the input of the simulation, and the corresponding policy-induced covariance risk is the output. To simplify notation, we swap the policy subscript $\mathbb{P}$ with the state-year subscript corresponding to which state implemented policy $\mathbb{P}$ in which year. That is, $\Delta\text{Risk}_{s,t}$ ($\Delta\text{Level}_{s,t}$) represents the policy-induced covariance risk (policy-induced tax level) due to the tax limitation policies in state s in year t.

A natural question is how accurately our simulation captures the dynamics of real-world property tax policy. We conduct a validation exercise to assess the simulation procedure. State by state, we apply the tax policy process in the simulation to the real, observed property values, generate a series

[6] No-limit property taxes can differ across simulations due to different initial property values, initial effective tax rates, and reassessment frequencies observed in real data.

of simulated property taxes (using the real property value data), and compare the simulated and empirically observed property taxes. We perform this validation exercise on states with over 70% observations having non-missing property values and property taxes. The correlation between the two series ranges from 0.73 (PA) to 0.97 (MO). The high correlation suggests that our tax simulation accurately captures the dynamics of property taxes in the real world.

Insert **Table 2** About Here

Table 2 shows the summary statistics of $\Delta \text{Risk}_{s,t}$ and $\Delta \text{Level}_{s,t}$. We see that policy-induced covariance risk is roughly \$350 per annum, whereas policy-induced tax level reduction is over \$9,000 per annum. That is, on average, the empirically observed property tax limitation regime across U.S. states leads to less favorable timing of property taxes. Importantly, policy-induced tax level reductions may not alleviate the household's burden, as the overall level of property taxation can be capitalized into housing prices (Oates, 1969; Palmon and Smith, 1998; Gindelsky et al., 2023; Gárate and Pennington-Cross, 2023). As a result, a lower level of property taxation could be offset by higher mortgage payments from the higher housing price. We do not take a stance on this point, as our focus is on the covariance risk associated with property taxes. In all subsequent analyses of mortgage distress and covariance risk, $\Delta \text{Risk}_{s,t}$, we always control for the policy-induced tax level, $\Delta \text{Level}_{s,t}$.

Insert **Figure 3** About Here

Figures 3a and 3b depict the geographic distribution of $\Delta \text{Risk}_{s,t}$ and $\Delta \text{Level}_{s,t}$ for the continental U.S., averaged over the period 2006-2016. For purposes of interpretation, the numbers on the maps are standardized to have a mean value of 0 and a standard deviation of 1. States that appear darkly shaded in Figure 3a and lightly shaded in Figure 3b are ones whose tax limitations induce a large increase in covariance risk while simultaneously offering a large reduction in the tax level, and vice versa. New York State's unique combination of restrictive rate and levy limits and infrequent reassessments yields the highest level of ΔRisk and the lowest ΔLevel, whereas the reverse holds in states like Georgia. More generally, the degree of negative correlation between ΔRisk and ΔLevel varies widely across states.

3.3 Causal Effects of Property Tax Limitation and Covariance Risk

Next, we examine how individual tax limitations affect the covariance risk of property taxes at both extensive and intensive margins.

For the extensive margin, we estimate the following equation:

$$\Delta \text{Risk}_{s,t} = \alpha + \beta_1 \mathbb{1}(\text{Levy Limit})_{s,t} + \beta_2 \mathbb{1}(\text{Rate Limit})_{s,t} + \beta_3 \mathbb{1}(\text{Assessment Limit})_{s,t} \tag{3}$$
$$+ \boldsymbol{\psi} \boldsymbol{X}_{s,t} + \delta_t + \varepsilon_{s,t}.$$

That is, we regress the policy-induced covariance risk of state s in year t on indicator variables of whether state s has corresponding types of tax limitation in year t. $\boldsymbol{X}_{s,t}$ is a vector of control variables, including reassessment frequency as categorical variables and the median effective tax rate of all properties for the state-year. δ_t is year fixed effects that control for macroeconomic trends that affect all states. We drop all nondisclosure states to be consistent with the sample used in subsequent analyses on mortgage distress. We also treat Cook County, IL and New York City, NY as separate tax jurisdictions due to their well-known unique property tax system.

Insert **Table 3** About Here

Table 3 column 1 shows that implementing any type of tax limitation increases covariance risk. Across the continental U.S., imposing levy, rate, and assessment limitations increases policy-induced covariance risk by 0.33, 0.74, and 0.80 standard deviations, respectively. For completeness, we also estimate the relation between implementing individual limitations and policy-induced tax level, $\Delta \text{Level}_{s,t}$, in column 2. We see that implementing levy and rate limits reduces the overall level of property taxation, whereas implementing assessment limits increases it. Given the ambiguous level effect across individual types of limitations, we always control for the overall $\Delta \text{Level}_{s,t}$ in subsequent analyses of mortgage distress and covariance risk.

We also examine the intensive margin of individual tax limitations and $\Delta \text{Risk}_{s,t}$. That is, how does the stringency of a tax limitation affect the covariance risk? Since empirically observed property tax limitation regimes lack sufficient variation in the stringency of each limitation policy, we turn to tax simulations. Specifically, we calculate ΔRisk by setting policy $\mathbb{P}$ as an assessment, rate, and levy limit at different levels of stringency. Figure 4 shows the results.

Insert **Figure 4** About Here

Figure 4 shows that more stringent limitations result in a higher ΔRisk. The solid red line depicts the relation between ΔRisk and the stringency of the assessment limit. We see that when the assessment limit restricts annual taxable value growth rates to less than 0.5% (with no other rate or levy limits), policy-induced covariance risk is roughly \$200. As the cap on taxable value growth is relaxed, ΔRisk decreases. Beyond 8% cap, assessment limits become effectively non-binding, and ΔRisk is virtually zero. We observe a qualitatively similar pattern for rate and levy limitations. Compared to assessment limitations, their effects on ΔRisk are initially higher (i.e., at low capped ETRs and low percentage growth rates for total levies, respectively), but these effects fall off more quickly as the limits become less restrictive.

4 Policy-Induced Covariance Risk and Mortgage Distress

In the previous section, we established that property tax limitations increase covariance risk by making the property tax timing less favorable. With the tax simulation, we are able to isolate the change in covariance risk attributable to property tax limitations, i.e., the policy-induced covariance risk, $\Delta\text{Risk}_{s,t}$, for each state-year. In this section, we examine how policy-induced covariance risk affects mortgage distress. First, we describe the data and sample construction. Then, we describe our empirical strategies, including a border discontinuity design. The results show that a one-standard-deviation increase in policy-induced covariance risk raises mortgage distress by roughly 30%. We also explore heterogeneity across races, loan-to-value groups, and tenure groups. Finally, we discuss policy implications.

4.1 Data

We combine data from ATTOM Data Solutions and ZTRAX (Zillow, 2018) into a comprehensive panel of parcel-level data for the period 2006-2016 to ensure the broadest possible coverage for our analysis. The data encompass the universe of property tax assessment information and purchase, loan, and foreclosure transaction records spanning the continental U.S. We observe a rich set of variables, including historical sale prices, assessed values, tax liabilities, loan amounts, indicators for distress or foreclosure transactions, and housing characteristics such as square footage, lot size, number of bedrooms, number of bathrooms, garage type and size, etc. To the best of our knowledge, we are the first to combine data from ATTOM and Zillow in this manner by matching parcels based on county-level administrative parcel identification numbers or, if the former are missing, street address and zip code. This procedure allows us to fill gaps in the ATTOM data wherever it is lacking in terms of historical coverage, geographic coverage, or available variables, while overlapping observations serve to validate our matching procedure and data reliability.[7]

[7] In cases where values for the same parcel-year observation disagree between data providers, we first strive to use observations that are adjacent in time to identify possible mistakes in the data; otherwise, we default to the use of data from ATTOM Data Solutions based on their reputation for superior coverage of foreclosure events and practical considerations related to data licensing.

We also collect information on property tax system characteristics and other state-specific policies that influence default probabilities. Policy-induced covariance risk and tax level, $\Delta\text{Risk}_{s,t}$ and $\Delta\text{Level}_{s,t}$, are obtained from the tax simulation described in Section 3.2. Data designating which states allow foreclosures to proceed without judicial review (i.e., nonjudicial review) or allow lenders to pursue defaulting borrowers through deficiency judgments (i.e., lender recourse) are from Ghent and Kudlyak (2011) and Mian et al. (2015).

We augment these data by calculating annual property values and loan balances, which allow us to construct loan-to-value ratios (LTVs) to account for potential strategic default incentives. The ATTOM-ZTRAX data only has historical transaction prices. We calculate annual property values using two complementary techniques: an imputation method and a machine learning hedonic estimation method (see details in Appendix B). Property values are also used to construct effective property tax rates (ETRs) to control for households' relative tax burdens and to measure housing price growth relative to tax liability. We calculate annual loan balances from initial loan amounts by using additional data from the Federal Housing Administration on average national monthly interest rates and average state-level annual rates. Using these data, we construct state-specific monthly interest rate series for the two most popular mortgage types identified in our data — 15- and 30-year fixed-rate mortgages. We use the resulting series to impute annual loan balances for all loan transaction records, assuming full monthly payments.[8] Taking the ratio of imputed loan balances to property values yields our desired time-varying parcel-specific estimates of LTV, which we subsequently classify into discrete intervals.

We geocode all parcels with valid street addresses and zip codes in ArcGIS. Then, we use the resulting latitude and longitude coordinates to calculate the shortest distance, as the crow flies, from each parcel to all neighboring counties in other states. We restrict our estimation sample to parcels within 20 km of the nearest state border to implement the border discontinuity design later. This restriction necessarily loses interior regions of states where it is difficult to isolate clean identifying variations that are uncorrelated with unobserved confounding factors. Nevertheless, the resulting border sample still remains economically representative and significant: it encompasses a healthy mix of urban and rural areas and represents approximately \$1.25 trillion in total property value and \$16.1 billion in property tax liabilities as of 2016.

To implement a grid-based border discontinuity design, we also link parcels based on latitude and longitude to the U.S. National Grid (USNG) coordinate system, which is independent of administrative boundaries. Then, we assign parcels to 10 km^2 grid cells using the USNG system,

[8] Initial interest rate information is infrequently populated in either ATTOM or ZTRAX, and it is typically available only for adjustable-rate mortgages. Term information is more consistently recorded, but it is still imperfect. Absent other information, we assume 30-year fixed-rate mortgage rates for all new mortgage loans and refinancing transactions to calculate monthly payments.

some of which straddle the state borders. These border-straddling grids are the narrowest region (in this paper) in which local economic conditions are held fixed but households are subject to different tax regimes due to being on different sides of the state border. We also link all parcels to the census tract in which they reside, so we can control for local demographics and explore heterogeneity in our analysis.

We exclude from the initial sample all homes that (i) are ever valued over \$5 million or below \$1000 in an arm's-length transaction, (ii) are newly built or substantially remodeled, (iii) have effective property tax rates that fall below the 1st percentile or above the 99th percentile of the relevant state distribution, or (iv) exhibit excessively large changes in annual tax obligations or assessed values that cannot be attributed to (re)construction, changes in owner occupancy, or—as in states with acquisition value assessment limitations—changes of ownership. These criteria are described in greater detail in Appendix C. We apply these filters to capture the experiences of the vast majority of property owners regarding property taxation while mitigating the influence of mis-recorded data and (rare) true outliers. We also exclude data from ten price non-disclosure states due to insufficient transaction information. The lack of consistent data in these states makes it difficult to estimate our hedonic pricing model or to implement the border discontinuity design. These states are Idaho, Kansas, Louisiana, Mississippi, Montana, New Mexico, North Dakota, Texas, Utah, and Wyoming. For Missouri, we exclude all but four political subdivisions due to the statewide non-disclosure laws that restrict transaction price information. The four subdivisions — St. Louis City, St. Louis County, Jackson County, and St. Charles County — each require sale price disclosure under local ordinance, unlike the rest of Missouri. Figure 5 describes the geographic distribution of parcels in our final estimation sample that contributes to identification (i.e., where we have complete information for parcels on opposite sides of a state border within border-straddling regions).

Insert **Figure 5** About Here

The complete ATTOM-ZTRAX dataset consists of approximately 390 million parcel-year observations with non-missing property values distributed throughout the continental U.S., of which over 50 million are located within 20 km of a state border. It encompasses nearly 650,000 foreclosure events over the period 2006-2016, representing roughly half of the total reported by ATTOM in its annual tallies across the entire continental U.S. We capture roughly half of the foreclosure events due to 1) sample restrictions and 2) only counting the first foreclosure event in a sequence of related transactions. Figure 6 plots the trend of foreclosure activity that we capture in the national (not just border) sample. It shows that the sample foreclosure rate closely tracks the national trend and highlights the high quality of our sample coverage. In the main analysis, we use mortgage distress as the outcome variable, regardless of whether it results in a foreclosure. In the robustness check, we show that the effect is stronger when we focus only on foreclosure activities.

Insert **Figure 6** About Here

Table 2 summarizes the set of means, medians, and standard deviations for key variables used in the estimation. Distressed properties are defined as any property that entered foreclosure proceedings in a given year, regardless of whether the borrower cured the loan or whether the property was ultimately repossessed by the lender or sold via foreclosure auction or short sale. ΔRisk and ΔLevel amounts are calculated as described in Section 3.2 and measured in thousands of dollars. Unless otherwise specified, we use *standardized* versions of both throughout our analyses for ease of interpretation. These are rescaled to have in-sample average values of 0 and standard deviations of 1. The loan-to-value ratio (LTV) is imputed as described above and classified into six discrete categories, including four categories based on quartiles of the LTV distribution for LTV < 1.6, a fifth category for LTV ≥ 1.6, and a sixth category for all properties with unknown LTV. The unknown-LTV category includes mostly mortgage-less homeowners. Homeowner tenure, age, and renovation age are similarly categorized into discrete intervals. We also collect demographic characteristics at the census tract level, including income, population, and population composition along the dimensions of age, education, and race.

We report values separately for distressed and non-distressed properties, with differences in means reported in the final column of Table 2. All differences in means between the two groups are statistically significant, with p-values well below 0.001. However, the economic magnitude of the unconditional difference in policy-induced covariance risk, ΔRisk, is trivial. In the meantime, distressed properties experience a smaller policy-induced tax level reduction (less negative ΔLevel) compared to non-distressed properties. Distressed properties are significantly less valuable, face higher effective tax rates (despite lower overall tax bills), and experience larger year-over-year changes in tax liability. Distressed properties also exhibit significantly higher average LTVs, have shorter-tenured homeowners, and are modestly older and less recently renovated.[9] Finally, they are also disproportionately located in lower-income, younger, less educated, and larger-minority-share census tracts. We control for all the above characteristics that are unrelated to policy-induced covariance risk (because ΔRisk is isolated in the simulation that exogenously changes the limitation policy), but may contribute to mortgage distress in subsequent analyses.

[9]The continuous LTVs exhibit large outliers even after we apply all the filters mentioned above to screen out extreme observations. These cases are most likely due to multiple loan transactions in a series being treated as additive rather than sequential in the raw data. We mitigate this issue by using discrete LTV categories.

4.2 Empirical Strategy

We estimate the effect of property taxation on mortgage distress at the parcel level using a linear probability model with a rich set of controls and a state-border discontinuity design. The outcome variable, $\mathbb{1}(\text{Distressed})_{i,t}$, is an indicator variable denoting whether or not property i experiences any form of mortgage distress in year t, regardless of whether the borrower cured the loan or whether the property was ultimately foreclosed. Later on, we also examine only foreclosures as the outcome variable and find qualitatively similar results.[10]

We estimate the following equation:

$$\mathbb{1}(\text{Distressed})_{i,t} = \alpha + \beta_1 \Delta\text{Risk}_{s,t} + \beta_2 \Delta\text{Level}_{s,t} + \boldsymbol{\gamma} \boldsymbol{X}_{i,t} + \boldsymbol{\phi} \boldsymbol{X}_{k,t} + \boldsymbol{\psi} \boldsymbol{X}_{s,t} + \text{FE} + \varepsilon_{i,t}. \quad (4)$$

The dependent variable in all specifications is pre-multiplied by 100, so that point estimates can be interpreted directly as percentage-point effects. The independent variable of interest is the policy-induced covariance risk, ΔRisk, at the state-year level. We include ΔLevel in all specifications to control for potential changes in the overall tax level resulting from tax limitation policies.

We control for a comprehensive set of property-, census-track-, and state-level characteristics. We include property-specific factors related to strategic default incentives and other potential triggers of mortgage distress, denoted as the vector of property-level controls, $\boldsymbol{X}_{i,t}$. Specifically, we control for LTV, homeowner tenure, the age of the home, and the age of renovations, all of which are represented as categorical variables as described in Section 4.1. We also control for the current estimated house price (see details in Appendix B) and the lagged effective tax rate. $\boldsymbol{X}_{k,t}$ is a vector of census-tract-level controls that includes the average adjusted gross income, total population, and population composition along dimensions such as age, education, and race. $\boldsymbol{X}_{s,t}$ accounts for other important state-level policy variables that affect foreclosure rates. Specifically, we control for whether the state provides lender recourse (Ghent and Kudlyak, 2011) and whether the state requires judicial review for foreclosures (Mian et al., 2015).

We use a state-border discontinuity design to isolate the influence of policy-induced covariance risk, ΔRisk, on mortgage distress while holding local economic conditions fixed. We do so by including fixed effects based on small regions that straddle state borders, along with year fixed effects. The border-straddling region fixed effects ensure that we compare properties only within a small region, with part of it belonging to one state and the other to another state. The underlying assumption of this discontinuity design is that unobservable local economic conditions are the same on both sides of the border after controlling for observable covariates. As a result,

[10] Tax delinquency would be another interesting outcome to examine. However, unfortunately, the tax delinquency flag in both ATTOM and CoreLogic has too many missing observations to allow meaningful empirical analyses.

comparing properties across the state border within each region recovers the causal effect of the state-level policy. The border design necessarily excludes from the sample interior regions of states where isolating clean identifying variation is difficult. Nevertheless, the border sample remains representative, encompassing a diverse mix of urban and rural areas as well as affluent and lower-income neighborhoods. Many recent empirical studies use a similar border-discontinuity design (Cornaggia, Hund, Nguyen and Ye, 2022; Cornaggia and Iliev, 2023; Gárate and Pennington-Cross, 2023; Aiello et al., 2025).

Concretely, we define two types of border-straddling regions: adjacent county pairs and 10 km^2 grid cells. First, we use adjacent county pairs on opposite sides of the state border, a common approach in the literature. However, counties may differ substantially in area and population density, thereby potentially undermining the identifying assumption. To standardize land area, we define a second type of border region straddling state borders. Specifically, we use the U.S. National Grid (USNG) coordinate system to construct 10 km^2 grid cells.[11] We obtain a set of $j = 1, ...J$ grid cells and map properties (with latitude and longitude coordinates) to grid cells (with USNG coordinates). These grid cells correspond to the fixed effects we include in the estimation. We illustrate this grid-cell-based border-discontinuity design in Figure 7.

Insert **Figure 7** About Here

Figure 7 depicts the border region along the Michigan-Ohio border. Each dot represents a unique property in the sample, with blue ones on the Michigan side and red ones on the Ohio side. The high-density area on the east side of the border is the city of Toledo, OH. The top three administrative areas in Michigan are Hillsdale County, Lenawee County, and Monroe County, whereas the bottom three in Ohio are Williams County, Fulton County, and Lucas County. We highlight the grid cells that contain properties in both Michigan and Ohio (i.e., the border straddling grid cells) in magenta. These magenta cells contribute to identification: when comparing properties within each magenta cell, all properties are subject to the same local economic conditions. As a result, differences in mortgage distress on either side of the state border capture the discontinuity in tax-limitation-policy-induced covariance risk, ΔRisk, after controlling for a comprehensive set of characteristics on property-, census-track-, and state-levels.

Insert **Figure 8** About Here

[11] The U.S. National Grid coordinate system divides the world into equal-sized "square" grid cells (100 km^2) that are defined independently of jurisdictional boundaries. Distortions to the dimensions of these grid cells due to the Earth's curvature are mitigated by zooming in on relatively small grid squares.

Figure 8 illustrates the unique advantage of the grid-based discontinuity design compared to the county-pair-based one. It plots the median value of key housing market characteristics by Census tract in the six counties along the Michigan-Ohio border. Panels 8a, 8b, 8c, and 8d plot housing prices, effective tax rates, loan-to-value ratios, and foreclosure rates. Within each county, we see substantial heterogeneity in these observable characteristics, suggesting that properties may be subject to different local economic conditions and potentially challenging the identifying assumption for the county-pair-based discontinuity design. However, census tracts in the narrow strip just north and south of the state border exhibit relatively similar housing market characteristics. This observation supports the identifying assumption for the grid-based discontinuity design: local economic conditions are similar within the same 10 km^2 grid. Our grid-based design is similar to the 10-mile-strip design used by Mian et al. (2015).

4.3 Effects of Policy-Induced Covariance Risk on Mortgage Distress

4.3.1 Main Estimates

Table 4 reports our estimates of Equation 4. We isolate the effect of policy-induced covariance risk ΔRisk by controlling for policy-induced tax level ΔLevel along with other property-, census-tract-, and state-level controls. Columns 1 to 3 report results based on the county-pair-based discontinuity design using county pair fixed effects. We begin in Column 1 with county-pair fixed effects only and proceed by incorporating the full set of property-, census-tract, and state-level controls (Column 2) and year fixed effects (Column 3). In Columns 4 to 6, we repeat the same process using the narrower 10 km^2 grid cell fixed effects. The grid-based discontinuity design yields 4,740 unique border-straddling cells (versus 947 county pairs in the county-pair-based design). In Columns 7 and 8, we extend the border fixed effects strategy from Columns 4 and 5 by allowing local market effects to be time-varying. That is, we use 10 km^2 grid cell $\times$ year fixed effects. Column 8 is the most saturated—and thus preferred—specification.

Insert **Table 4** About Here

ΔRisk has a positive, statistically significant effect on mortgage distress across all specifications. The point estimates from the county-pair and 10 km^2 grid-cell fixed effects specifications are similar in magnitude. The preferred, most saturated specification in Column 8 suggests that a one standard deviation increase in ΔRisk raises the probability of mortgage distress by 0.44 percentage points, or approximately 30 percent. This is an economically large effect. For comparison, the effect of a one standard deviation increase in ΔRisk is 1) roughly one-quarter as large as the effect of a homeowner becoming underwater (i.e., moving from the third to the fourth quintile of the LTV distribution) and 2) seventy percent larger than the effect due to owning a home in disrepair (i.e., a home that has not been renovated in at least 60 years and hence at greater risk of unanticipated repair costs).

We estimate the effect of policy-induced covariance risk, ΔRisk, while holding policy-induced tax level fixed. That is, we separately control for ΔLevel in all specifications. We do so for a few reasons. First, the conventional wisdom may suggest that tax limitations, although increasing covariance risk, lower overall tax levels and thereby reduce the tax burden for homeowners. We find that this conventional wisdom is not supported by the empirical data. As shown in Table 3, which uses tax limitation policies adopted by U.S. states from 2006 to 2016, implementing assessment limits increases covariance risk and tax level. Thus, there is no clear pattern of negative correlations between ΔRisk and ΔLevel. Second, there is a substantial literature on the capitalization of property tax changes into housing prices (Oates, 1969; Palmon and Smith, 1998; Gindelsky et al., 2023; Gárate and Pennington-Cross, 2023). Therefore, a lower ΔLevel could be capitalized into higher housing prices and offset by higher mortgage payments. Lastly, our policy recommendation later holds the tax level unchanged but significantly reduces covariance risk in property taxes.

Insert **Table 5** About Here

We conduct a series of robustness checks for the most saturated specifications in Table 5. In Column 1, we use foreclosure rather than mortgage distress as the outcome variable. We see that a one-standard-deviation increase in ΔRisk leads to a 0.38 percentage point increase in the foreclosure rate. Given the unconditional foreclosure rate of 1.09 percentage points in the sample, the point estimate represents a large relative increase of 35% compared to the 30% in the main specification with mortgage distress as the outcome variable. Columns 2 to 6 use different grid sizes that divide 100 km evenly (4, 6.25, 12.5, and 20 km), so that the 100 km^2 USNG grids are evenly split into smaller grid cells. We see that all grid sizes yield qualitatively similar estimates compared to the baseline results using 10 km^2 grids. These estimates are also statistically significant, with 12.5 km^2 and 20 km^2 estimates being borderline below the 5% significance level.[12]

[12] We conduct additional robustness checks in the Internet Appendix. In Internet Appendix C, we replace ΔRisk and ΔLevel with year-over-year percent changes in tax liabilities on the property level, and we obtain estimates that are comparable to the effect documented in the literature (Hayashi, 2020; Wong, 2023). In Internet Appendix B, we also examine the direct relation between mortgage distress and assessment limits (i.e., skipping covariance risk in the middle). We find that adopting assessment limits and making them more stringent increases mortgage distress, consistent with our results. Our results extend this analysis and provide a clear mechanism by which tax limitations affect mortgage distress: tax limitation policies increase policy-induced covariance risk, ΔRisk, thereby increasing mortgage distress.

We also examine whether the detrimental effect of policy-induced covariance risk on distress is tied to a specific type of policy or attributable to all types of tax limitations. Specifically, we drop from the sample states that adopt one type of limitation and repeat the estimate using the main specification in Table 4. If the main effect is tied to a specific type of policy, then dropping states adopting that policy would yield a significantly weaker estimate of the effect. We see the opposite in Figure 9. Dropping different types of assessment, rate, and levy limits consistently yield economically and statistically significant estimates (with a few estimates having borderline significance at the 5% level). These results suggest that the effect of policy-induced covariance risk is not an isolated consequence of a single type of tax limit but a systematic consequence of all types of tax limitations.

We also examine whether the effect of policy-induced covariance risk is tied to a specific reassessment policy or different levels of overall property taxation. We drop from the sample states with annual reassessments, frequent reassessments (every 2 to 4 years), and infrequent reassessments (every 5 to 9 years). The estimates are consistently significant, both economically and statistically. We also drop from the sample states with low, medium, and high property taxation, corresponding to median effective tax rates (ETRs) below 1%, between 1% and 2%, and above 2%. Only the sample without states that levy high property tax (a median ETR above 2%) yields an estimate that is economically weak and statistically insignificant. This evidence supports our mechanism: distress is driven by property taxes, not by other confounding factors.

4.3.2 Heterogeneous Effects

Next, we examine the heterogeneity across households. Prior literature suggests that households of different races and with different assessment ratios, loan-to-value ratios, and lengths of tenure may face different mortgage distress risks. Therefore, we estimate the conditional effect of policy-induced covariance risk on property distress along these dimensions. Specifically, we augment the main specification (in Table 4 column 8) with interaction terms between policy-induced covariance risk and indicator variables representing racial, assessment-ratio, LTV, and tenure categories. Figure 10 shows the heterogeneous effects by plotting the point estimates of these interactions with the confidence interval.

Insert **Figure 10** About Here

Figure 10a reports the heterogeneous effects of ΔRisk by races and shows that policy-induced covariance risk has a larger effect on Black households. Since we do not directly observe the household's race, we adopt the second-best strategy: estimating the effect of policy-induced covariance risk on mortgage distress, conditional on the majority race of the census tract. Specifically, we estimate the effect based on whether the census tract has a majority Black, majority Latino, or majority white (+ Other) population. We see that households in predominantly Black census tracts face significantly larger effects of policy-induced covariance risk on mortgage distress.[13] The larger effect is consistent with an extensive literature documenting that minority households face significantly higher effective tax rates (Avenancio-León and Howard, 2022), mortgage interest rates (Gerardi, Willen and Zhang, 2023), and other mortgage costs (Ambrose, Conklin and Lopez, 2020), and are more "vulnerable to adverse economic shocks" (Bayer, Ferreira and Ross, 2016) and housing distress than white homeowners (Reid, Bocian, Li and Quercia, 2017).

Figure 10b reports the conditional effects for households with different assessment ratios (AR), i.e., the ratio of assessed value to market value, which approximate the relative property tax burdens. The differences across AR categories are economically large. Households whose properties are assessed at two or more times their market value face an effect of policy-induced covariance risk that is 80% greater than households whose properties are assessed at less than half of their market value. The statistical significance of the conditional effect is above 1% for households with an AR above 2, just below 5% for those with an AR between 0.75 and 2, and above 10% for those with an AR between 0.5 and 0.75. The conditional effect is not significant for households with an AR below 0.5. That is, financially vulnerable households with high assessment ratios (i.e., high tax burdens) are more susceptible to policy-induced covariance risk leading to mortgage distress. Lower assessment ratios help households mitigate covariance risk. These results echo Atuahene and Berry (2019), who suggest that over-assessments are responsible for "an epidemic of tax foreclosures" in cities like Detroit. More broadly, our result also adds to the growing literature on the prevalence of errors in property assessments with negative ramifications for the progressivity of the property taxes (McMillen and Singh, 2020; Berry, 2021; Avenancio-León and Howard, 2022).

Figure 10c examines the effect across households with different loan-to-value ratios. We see that households in the third and fourth quartiles of the LTV distribution (below 1.6) have the largest effects of ΔRisk on mortgage distress. These households have a mortgage that is around the threshold for being underwater, thus having the strongest motives for strategic delinquency and default. In contrast, households with low LTVs (the two LTV categories of 0 to 0.25 and 0.25 to 0.6) or without a mortgage (the unknown LTV category) see a much weaker effect. Households with a mortgage that is already underwater (the LTV > 1.6 category) also see a smaller effect,

[13] The majority of white, Black, and Latino Census tracts account for 76.3, 15.9, and 3.1 percent of all observations in our estimation sample, respectively. As a result, the differential ΔRisk effects in the latter group are estimated with less precision.

suggesting that they are likely to strategically default anyway, irrespective of the policy-induced covariance risk. As a result, we interpret the heterogeneity across LTVs as evidence that strategic default motives amplify the policy-induced covariance risk of mortgage distress.

Figure 10d examines the effect across households with different tenures. We see that households that have owned their homes for less than 2 years exhibit a conditional effect of ΔRisk that is economically close to zero. Households with longer tenure see a larger effect. One possible explanation is that assessment limits, for instance, only start causing covariance risks after households have owned their homes long enough to experience a large enough divergence between market values and taxable values. New homeowners have small gaps between market and taxable values and are therefore unlikely to experience an increase in the taxable value if the market value drops. This result also helps rule out that the aforementioned strategic default motive in Figure 10c is a mere artifact of new homeownership (whose LTV is also likely close to 1).

4.4 Policy Discussion

So far, we have established that property tax limitations make tax increases more likely to coincide with economic downturns (i.e., they increase covariance risk), thereby increasing mortgage distress. Rather than evaluating property tax limitations in their entirety, we examine policies that can mitigate the effects of tax timing on mortgage distress.

First, the most direct solution would be offering the option to defer property tax payments. Since mortgage distress stems from misalignment between tax liabilities and household income and consumption, tax-deferral programs that allow households to adjust the timing of taxation would provide relief and reduce mortgage distress. A key advantage of this policy solution is that it does not change the overall level of taxation, which echoes our empirical specification in which we always hold the policy-induced tax level (ΔLevel) fixed while estimating the effect of policy-induced covariance risk (ΔRisk). That is, a tax-deferral program reduces mortgage distress caused by policy-induced covariance risk without imposing trade-offs in the level of taxation.

25 of the 48 continental states plus the District of Columbia have some form of property tax deferral program. But these deferral programs are highly restrictive in practice. Virtually all of them are restricted to low-income residents. Most of them have additional eligibility criteria such as age, disability, and military status. In addition, some states lack statewide tax-deferral programs and instead require local governments to opt in to allow residents to defer their property taxes. Only two states (Washington and Nevada) have statewide property tax deferral programs with income restrictions and no apparent restrictions. For details of property tax relief programs across states, including tax deferral programs, we refer the readers to Lincoln Institute of Land Policy and

George Washington Institute of Public Policy (2023). We construct two indicator variables: one for the 25 states plus D.C. that have any tax deferral programs, and one for Washington and Nevada that have more universal tax deferral programs. In untabulated results, we re-estimate the main specification in Table 4 column 8, including an interaction between policy-induced covariance risk and tax-deferral-program indicators. States with any or more universal tax deferral programs have a smaller point estimate of ΔRisk, but the difference with states without tax deferral programs is not statistically significant. We interpret these results as evidence that tax-deferral programs could be effective in mitigating the effects of covariance risk in mortgage distress, but existing programs are too restrictive to have a positive impact.

Second, we also investigate the role of property tax deductibility from federal income tax liability. Federal income tax deductibility of state and local taxes (unrestricted during our period of analysis) means that the federal government effectively serves as a risk-sharing partner in households' property tax obligations. However, this risk-sharing applies only to taxpayers who itemize their deductions. Therefore, we obtain the zip-code-level itemization rate from the IRS's Statistics of Income tables and re-estimate the main specification with an interaction between policy-induced covariance risk and the above-median itemization rate indicator. We do not find evidence that high-itemization-rate areas have a smaller coefficient for ΔRisk compared to low-itemization-rate areas. This result suggests that federal income tax deductions may not be an effective remedy for covariance risk arising from property tax limitations.

More broadly, our results highlight that the timing of policy-induced obligations matters for household financial stability, not just their level. Covariance risk provides a unifying lens for evaluating how a wide range of policies interact with household liquidity and macroeconomic conditions.

5 Conclusion

This paper highlights an important yet overlooked consequence of tax policy: shifting the timing of tax payments can increase households' financial risk and ultimately lead to negative financial outcomes, such as higher rates of mortgage distress. We introduce a novel measure, *covariance risk*, that quantifies the additional tax burden arising from the unfavorable timing of tax liabilities. Then, we use a tax simulation to isolate the causal effect of property tax limitation on covariance risk, which we term *policy-induced covariance risk*. Next, we estimate the effect of policy-induced covariance risk on mortgage distress in a border-discontinuity design. Taken together, we find that property tax limitations increase covariance risk, thereby increasing mortgage distress.

The concept of *covariance risk* offers several advantages both for this analysis and for future research. First, it allows us to separate the timing effects of tax payments from their overall level — an essential distinction in evaluating tax policy impacts. In the case of property tax limitations, this decomposition reveals a trade-off between attempts to dampen overall tax burdens (their intended effect from the standpoint of voters) and the potential for households to face greater financial risk due to counter-cyclical tax adjustments (an unintended effect). Second, our approach demonstrates how *covariance risk* can be used to isolate policy-driven changes in risk exposure, making it a valuable tool for assessing the broader effects of tax policy with economic fluctuations. Third, despite the conceptual importance of tax risk for both firms and households, empirical research has been constrained by the absence of a widely accepted measure. Our framework provides a flexible and readily implementable solution to address this gap.

At a broad level, this paper demonstrates that tax policy must consider not only the magnitude of tax liabilities but also their timing. More specifically, our results suggest that policymakers can mitigate risk by offering mechanisms that allow taxpayers to smooth their tax payments over time. In the context of property taxes, expanding tax deferral programs beyond low-income seniors to a broader — yet still targeted — set of homeowners could help reduce the financial strain caused by covariance risk while preserving the revenue stability that property tax limitations aim to achieve.

References

Adelino, Manuel, Antoinette Schoar, and Felipe Severino, "House prices, collateral, and self-employment," *Journal of Financial Economics*, 2015, *117* (2), 288–306.

_ , _ , and _ , "Loan originations and defaults in the mortgage crisis: The role of the middle class," *Review of Financial Studies*, 2016, *29* (7), 1635–1670.

_ , _ , and _ , "The role of housing and mortgage markets in the financial crisis," *Annual Review of Financial Economics*, 2018, *10* (1), 25–41.

_ , _ , and _ , "Credit supply and house prices: Evidence from mortgage market segmentation," *Journal of Financial Economics*, 2025, *163*, 103958.

Agarwal, Sumit, Gene Amromin, Souphala Chomsisengphet, Tim Landvoigt, Tomasz Piskorski, Amit Seru, and Vincent Yao, "Mortgage refinancing, consumer spending, and competition: Evidence from the Home Affordable Refinance Program," *Review of Economic Studies*, 2023, *90* (2), 499–537.

Aiello, Darren, Asaf Bernstein, Mahyar Kargar, Ryan Lewis, and Michael Schwert, "The marginal value of public pension wealth: Evidence from norder house prices," *Journal of Financial Economics*, 2025, *forthcoming.*

Ambrose, Brent W., Charles A. Capone, and Yongheng Deng, "Optimal put exercise: An empirical examination of conditions for mortgage foreclosure," *Journal of Real Estate Finance and Economics*, 2001, *23* (2), 213–234.

Ambrose, Brent W, James N Conklin, and Luis A Lopez, "Does borrower and broker race affect the cost of mortgage credit?," *Review of Financial Studies*, 08 2020, *34* (2), 790–826.

Atuahene, Bernadette and Christopher R. Berry, "Taxed out: Illegal property tax assessments and the epidemic of tax foreclosures in detroit," *University of California Irvine Law Review*, 2019, *9* (4), 847–886.

Avenancio-León, Carlos F and Troup Howard, "The assessment gap: Racial inequalities in property taxation," *The Quarterly Journal of Economics*, 2022, *137* (3), 1383–1434.

Bayer, Patrick, Fernando Ferreira, and Stephen L Ross, "The vulnerability of minority homeowners in the housing boom and bust," *American Economic Journal: Economic Policy*, 2016, *8* (1), 1–27.

Benetton, Matteo, Philippe Bracke, João F Cocco, and Nicola Garbarino, "Housing consumption and investment: Evidence from shared equity mortgages," *Review of Financial Studies*, 2022, *35* (8), 3525–3573.

Berger, David, Veronica Guerrieri, Guido Lorenzoni, and Joseph Vavra, "House prices and consumer spending," *Review of Economic Studies*, 2018, *85* (3), 1502–1542.

Berry, Christopher R., "Reassessing the property tax," *Working Paper*, 2021.

Blanchflower, David G and Andrew J Oswald, "Does high home-ownership impair the labor market?," *Working Paper*, 2013.

Blundell, Richard, Luigi Pistaferri, and Ian Preston, "Consumption inequality and partial insurance," *American Economic Review*, 2008, *98* (5), 1887–1921.

Brooks, Leah, Yosh Halberstam, and Justin Phillips, "Spending within limits: Evidence from municipal fiscal restraints," *National Tax Journal*, 2016, *69* (2).

Brosy, Thomas and Chiarra Ferrero, "What happened to property taxes after the Great Recession?," *Working Paper*, 2021.

Chen, Hui, Michael Michaux, and Nikolai Roussanov, "Houses as ATMs: mortgage refinancing and macroeconomic uncertainty," *Journal of Finance*, 2020, *75* (1), 323–375.

Chetty, Raj, László Sándor, and Adam Szeidl, "The effect of housing on portfolio choice," *Journal of Finance*, 2017, *72* (3), 1171–1212.

Cocco, Joao F, "Portfolio choice in the presence of housing," *Review of Financial Studies*, 2005, *18* (2), 535–567.

Cornaggia, Jess and Peter Iliev, "The state and local cost of net zero," *Working Paper*, 2023.

Cornaggia, Kimberly, John Hund, Giang Nguyen, and Zihan Ye, "Opioid crisis effects on municipal finance," *Review of Financial Studies*, 2022, *35* (4), 2019–2066.

Cutler, David, Douglas Elmendorf, and Richard Zeckhauser, "Restraining the leviathan: Property tax limitations in Massachusetts," *Journal of Public Economics*, 1999, *71* (3), 313–334.

Dauchy, Estelle, Francisco Navarro-Sanchez, and Nathan Seegert, "Taxation and inequality: Active and passive channels," *Review of Economic Dynamics*, 2021, *42*, 156–177.

DeFusco, Anthony A, "Homeowner borrowing and housing collateral: New evidence from expiring price controls," *Journal of Finance*, 2018, *73* (2), 523–573.

Dye, Richard F. and Therese J. McGuire, "The effect of property tax limitation measures on local government fiscal behavior," *Journal of Public Economics*, 1997, *66*, 469–487.

_ , _ , and Daniel McMillen, "Evidence on the short and long run effects of tax limitations on taxes and spending," *National Tax Journal*, 2005, *58* (2).

Eliason, Paul and Byron Lutz, "Can fiscal rules constrain the size of government? An analysis of the "crown jewel" of tax and expenditure limitations," *Journal of Public Economics*, 2018, *166*, 115–144.

Flavin, Marjorie and Takashi Yamashita, "Owner-occupied housing and the composition of the household portfolio," *American Economic Review*, 2002, *92* (1), 345–362.

Gárate, Sergio and Anthony Pennington-Cross, "Heterogeneity in property tax capitalization: Evidence from municipalities in Wisconsin," *Real Estate Economics*, 2023, *51* (5), 1285–1314.

Gerardi, Kristopher, Kyle F. Herkenhoff, Lee E. Ohanian, and Paul S. Willen, "Can't pay or won't Pay? Unemployment, negative equity, and strategic default," *Review of Financial Studies*, 10 2017, *31* (3), 1098–1131.

_, Paul S. Willen, and David Hao Zhang, "Mortgage prepayment, race, and monetary policy," *Journal of Financial Economics*, 2023, *147* (3), 498–524.

Ghent, Andra C. and Marianna Kudlyak, "Recourse and residential mortgage default: Evidence from US states," *Review of Financial Studies*, 2011, *24* (9), 3139–3186.

Gindelsky, Marina, Jeremy Moulton, Kelly Wentland, and Scott Wentland, "When do property taxes matter? Tax salience and heterogeneous policy effects," *Journal of Housing Economics*, 2023, *61*, 101951.

Guren, Adam M, Arvind Krishnamurthy, and Timothy J McQuade, "Mortgage design in an equilibrium model of the housing market," *Journal of Finance*, 2021, *76* (1), 113–168.

Haveman, Mark and Terri A Sexton, "Property tax assessment limits: Lessons from thirty years of experience," *Lincoln Institute of Land Policy*, 2008.

Hayashi, Andrew, "Countercyclical property taxes," *Virginia Tax Review*, 2020, *40*, 1–51.

He, Alex Xi and Daniel le Maire, "Household liquidity constraints and labor market outcomes: Evidence from a Danish mortgage reform," *Journal of Finance*, 2023, *78* (6), 3251–3298.

Kaplan, Greg and Giovanni L. Violante, "A model of the consumption response to fiscal stimulus payments," *Econometrica*, 2014, *82* (4), 1199–1239.

Keys, Benjamin J, Devin G Pope, and Jaren C Pope, "Failure to refinance," *Journal of Financial Economics*, 2016, *122* (3), 482–499.

Kuhn, Moritz, Moritz Schularick, and Ulrike I Steins, "Income and wealth inequality in America, 1949–2016," *Journal of Political Economy*, 2020, *128* (9), 3469–3519.

Lincoln Institute of Land Policy and George Washington Institute of Public Policy, "Significant features of the property tax," 2023.

Low, David, "What triggers mortgage default? New evidence from linked administrative and survey data," *CFPB Office of Research Working Paper Series*, 2022, *2022-02.*

McMillen, Daniel S. and Rushi Singh, "Assessment regressivity and property taxation," *Journal of Real Estate Finance and Economics*, 2020, *60*, 155–169.

Melzer, Brian T, "Mortgage debt overhang: Reduced investment by homeowners at risk of default," *Journal of Finance*, 2017, *72* (2), 575–612.

Mian, Atif, Amir Sufi, and Francesco Trebbi, "The political economy of the US mortgage default crisis," *American Economic Review*, 2010, *100* (5), 1967–1998.

—, —, and —, "Foreclosures, house prices, and the real economy," *Journal of Finance*, 2015, *70* (6), 2587–2634.

— and —, "The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis," *Quarterly Journal of Economics*, 2009, *124* (4), 1449–1496.

— and —, "House prices, home equity–based borrowing, and the us household leverage crisis," *American Economic Review*, 2011, *101* (5), 2132–2156.

—, Kamalesh Rao, and Amir Sufi, "Household balance sheets, consumption, and the economic slump," *Quarterly Journal of Economics*, 2013, *128* (4), 1687–1726.

Oates, Wallace E, "The effects of property taxes and local public spending on property values: An empirical study of tax capitalization and the Tiebout hypothesis," *Journal of Political Economy*, 1969, *77* (6), 957–971.

O'Malley, Terry, "The impact of repossession risk on mortgage default," *Journal of Finance*, 2021, *76* (2), 623–650.

O'Sullivan, Arthur, Terri A. Sexton, and Steven M. Sheffrin, *Property taxes and tax revolts: The legacy of Proposition 13*, Cambridge University Press, 1995.

Palmon, Oded and Barton A. Smith, "New evidence on property tax capitalization," *Journal of Political Economy*, 1998, *106* (5), 1099–1111.

Pischke, Jörn-Steffen, "Individual income, incomplete information, and aggregate consumption," *Econometrica*, 1995, pp. 805–840.

Piskorski, Tomasz and Alexei Tchistyi, "Optimal mortgage design," *Review of Financial Studies*, 2010, *23* (8), 3098–3140.

Poterba, James and Kim Rueben, "The effect of property-tax limits on wages and employment in the local public sector," *American Economic Review*, 1995, *85* (2).

Reid, Carolina K., Debbie Bocian, Wei Li, and Roberto G. Quercia, "Revisiting the subprime crisis: The dual mortgage market and mortgage defaults by race and ethnicity," *Journal of Urban Affairs*, 2017, *39* (4), 469–487.

Tian, Chao Yue, Roberto G. Quercia, and Sarah Riley, "Unemployment as an adverse trigger event for mortgage default," *Journal of Real Estate Finance and Economics*, 2016, *52*, 28–49.

Venti, Steven F and David A Wise, "The cause of wealth dispersion at retirement: Choice or chance?," *American Economic Review*, 1998, *88* (2), 185–191.

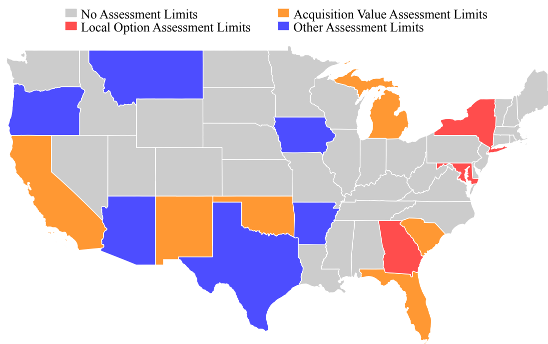
Wong, Francis, "Mad as hell: property taxes and financial distress," *Working Paper*, 2023.

Yao, Rui and Harold H Zhang, "Optimal consumption and portfolio choices with risky housing and borrowing constraints," *Review of Financial Studies*, 2005, *18* (1), 197–239.

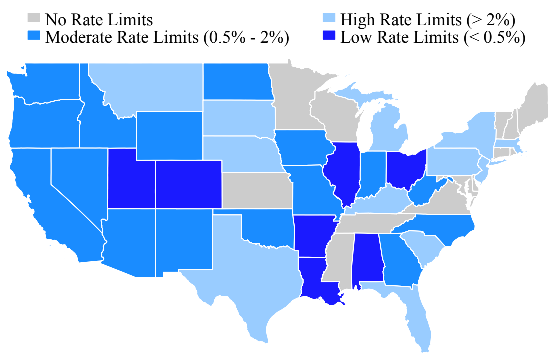
Figure 1: **Property Tax Limitations by State in 2016**

Panels 1a, 1b, and 1c depict different types of assessment, rate, and levy/revenue limitations by state as of 2016.

(a) Assessment Limitations



(b) Rate Limitations



(c) Levy/Revenue Limitations

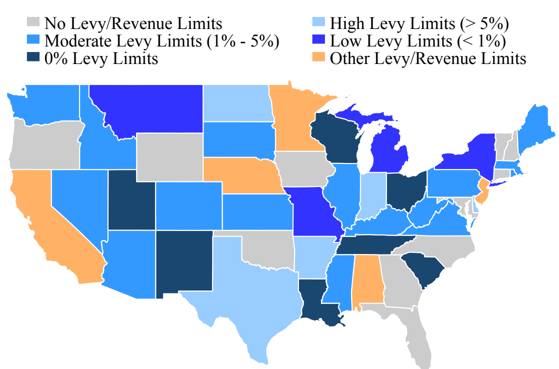
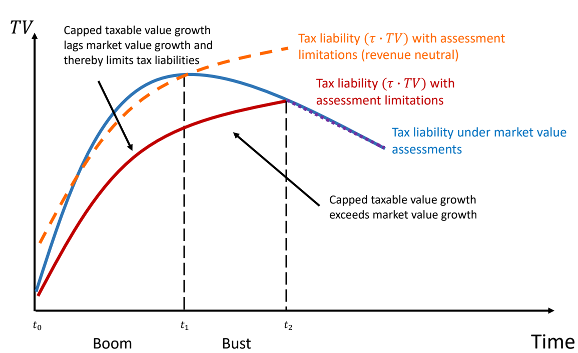


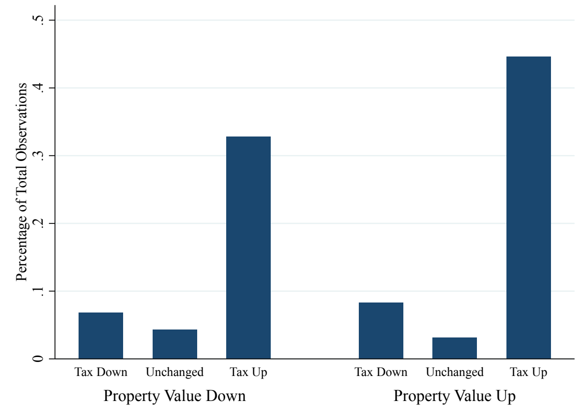
Figure 2: **Housing Prices and Tax Payments**

The figure describes the relation between housing prices and property tax payments. Panel 2a illustrates a hypothetical dynamic wherein tax payments may continue to increase even while market values are declining. Panel 2b shows the proportion of instances in which property tax payments fall, remain unchanged, or rise while the property value is rising or falling in our estimation sample. Panel 2c plots year-over-year changes in housing prices and property tax payments for states with and without assessment limitations. Panel 2d plots the "tax-price adjustment gap", defined as the percentage change in taxes (dashed lines in panel 2c) minus the percentage change in housing price (solid lines in panel 2c).

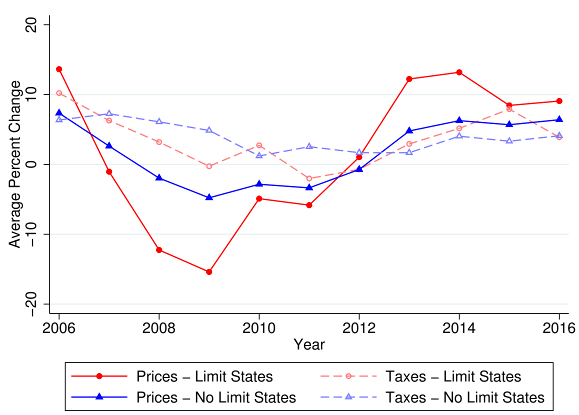
(a) Framework for shifting tax payments



(b) Histogram of tax payments



(c) Prices and Taxes



(d) Tax-Price Adjustment Gap

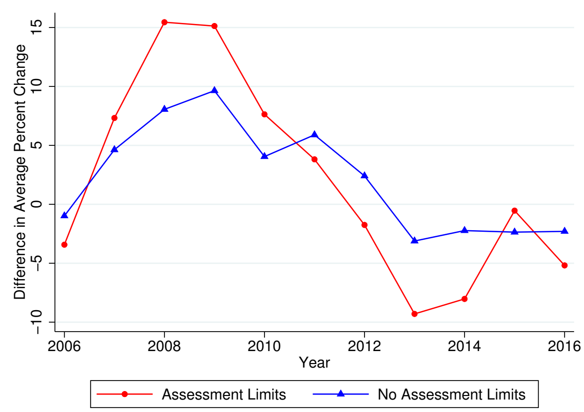
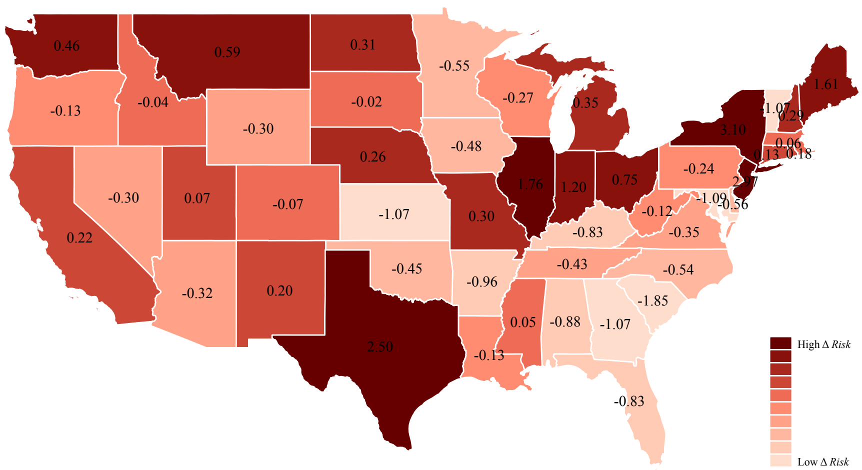


Figure 3: **Policy-Induced Covariance Risk and Tax Level by State**

This figure shows the geographic distribution of the main variables of interest, policy-induced covariance risk and policy-induced tax level. Panel 3a plots policy-induced covariance risk, ΔRisk, by state, averaged across years from 2006 to 2016. Panel 3a plots policy-induced tax level, ΔLevel, by state, averaged across years from 2006 to 2016. ΔRisk and ΔLevel are standardized to have a mean of 0 and standard deviation of 1 for ease of comparison across measures.

(a) Policy-Induced Covariance Risk



(b) Policy-Induced Tax Level

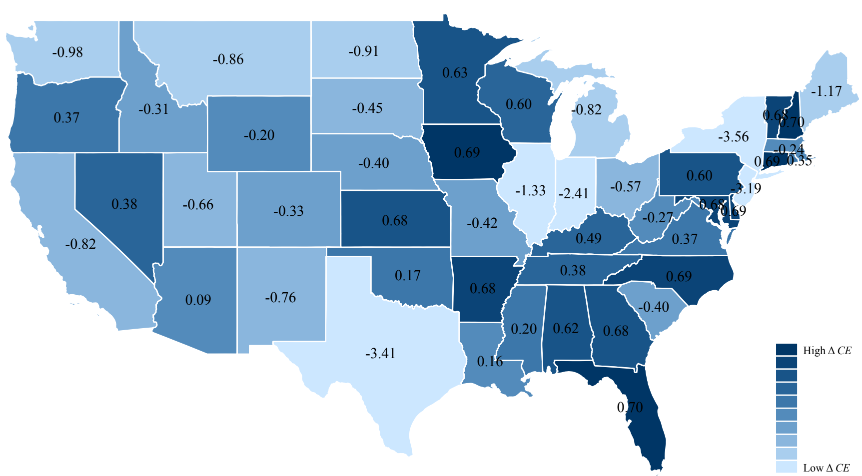


Figure 4: **Policy-Induced Covariance Risk and Individual Property Tax Limitations**

This figure plots the relation between the stringency of individual tax limitations and the policy-induced covariance risk, $\Delta Risk$, based on simulation results. The solid red, dashed blue, and dot-dashed orange lines denote assessment, rate, and levy limitations, respectively. Lower percentage limitations on the horizontal axis indicate more stringent limits.

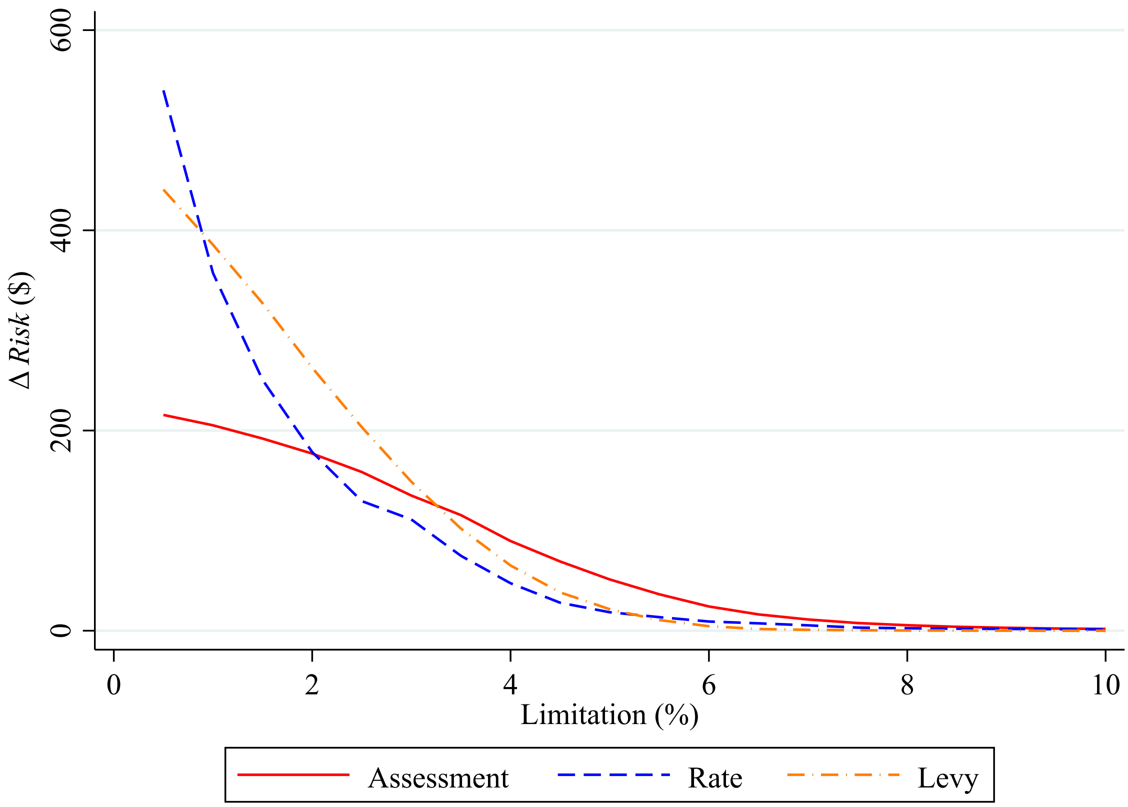


Figure 5: **Geographic Distribution of Unique Parcels in Sample**

This figure depicts the geographic distribution of sample parcels. Each grid in the map is a border county that contains parcels used in the border discontinuity estimates. Darker blue indicates that the county contains more parcels.

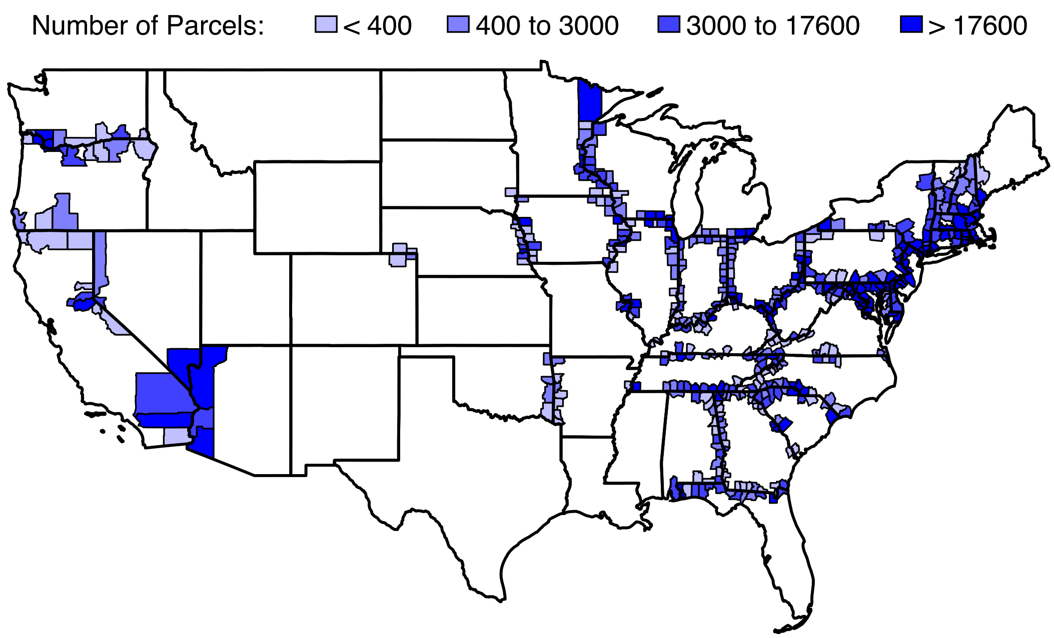


Figure 6: **Foreclosure Activity in Sample by Year**

This figure shows foreclosure activity in the sample by year. Foreclosure activity reflects only the first foreclosure event in a sequence of distressed transactions in the national (not just border) sample of linked property tax assessment, realty transaction, loan, and foreclosure data.

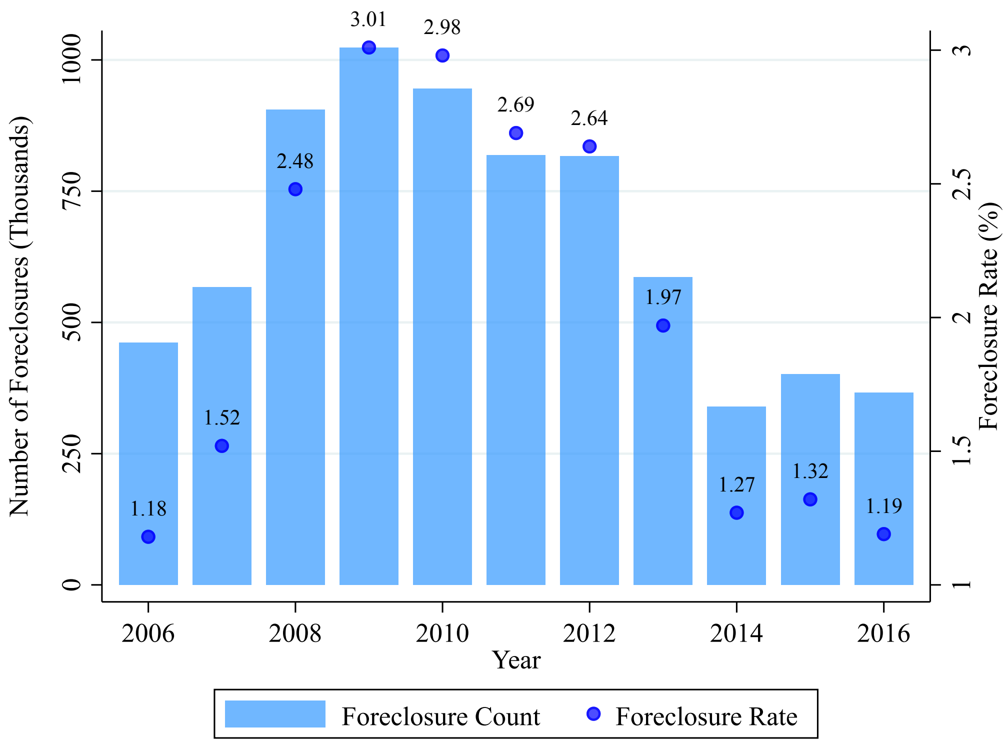


Figure 7: **Border Discontinuity Design with 10-km^2 Grid Cells at Michigan-Ohio Border**

The figure illustrates the grid-based spatial regression discontinuity design with the Michigan-Ohio border as an example. Blue points denote unique properties in the sample in Michigan and red points denote those in the sample in Ohio along the states' shared border. The map is overlaid with 10 km^2 grid cells identified by the United States National Grid (USNG). Border-straddling grid cells that contain parcels in both states are outlined in magenta. Interior cells and border-straddling grid cells that contain parcels from only one state are outlined in gray.

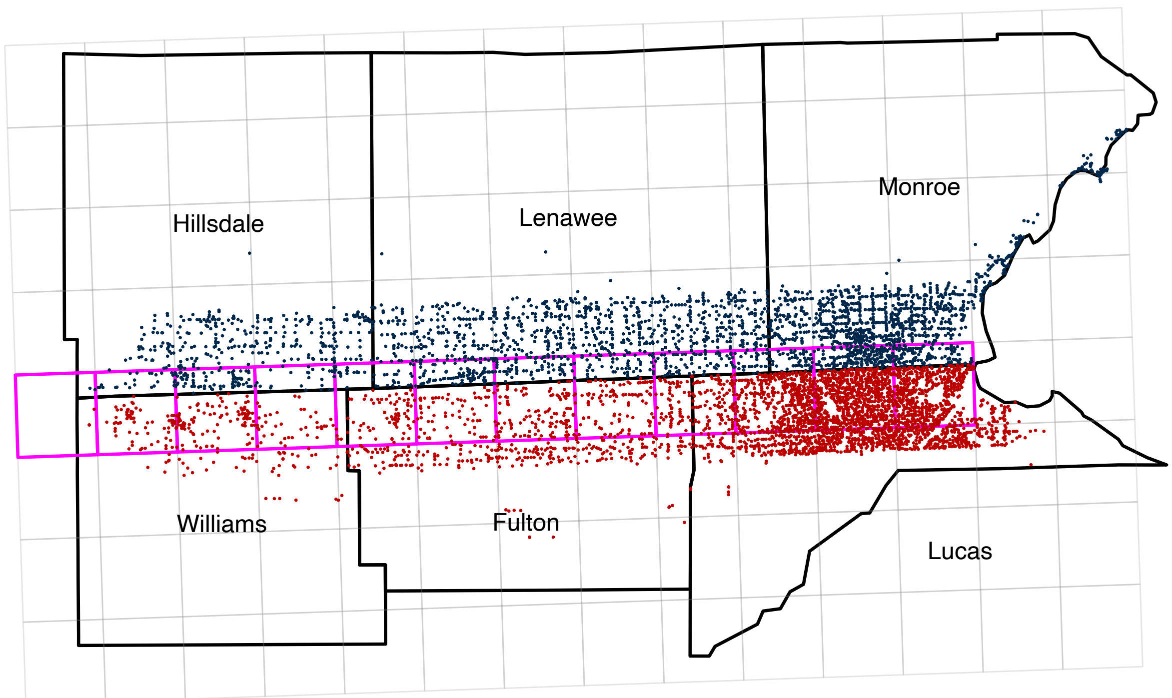
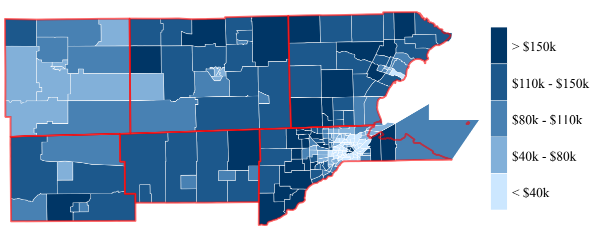


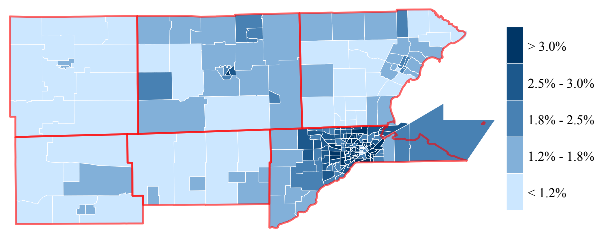
Figure 8: **Local Housing Market Characteristics at Michigan-Ohio Border**

The figure shows median property characteristics in 2015 for all Census tracts located in the six counties along the Michigan-Ohio border. The bold red line represents the (land) border of the counties. The three counties in the top half are Hillsdale, Lenawee, and Monroe counties in Michigan, and the three counties in the bottom half are Williams, Fulton, and Lucas counties in Ohio. The tight cluster of tracts in the southeast corner of the map is Toledo, OH, just south of the state border. Some census tracts in the southeast corner extend beyond the land border of the county to cover islands in Lake Erie, notably the West Sister Island (the eastmost dot on the map).

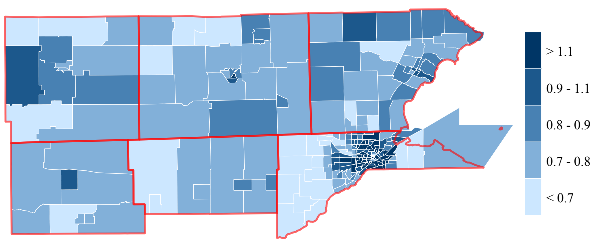
(a) House Price ($)



(b) Effective Tax Rate (%)



(c) Loan-to-Value Ratio



(d) Annual Foreclosure Rate

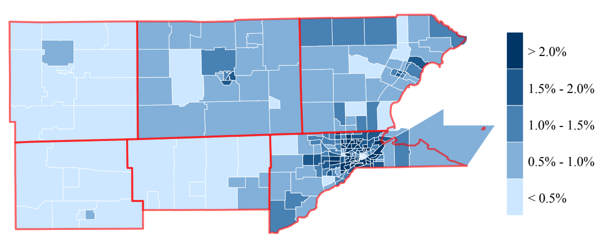


Figure 9: **Stability of the Main Estimate in Absence of Different Policies**

The figure shows the stability of the main estimate in Table 4 column 8 with samples that exclude states that has adopted one policy category at a time. Policy categories include different assessment, rate, and levy limits, categorized following Figure 1. Policy categories also include different reassessment frequencies and different levels of median effective tax rate. Error bands denote 95% confidence intervals.

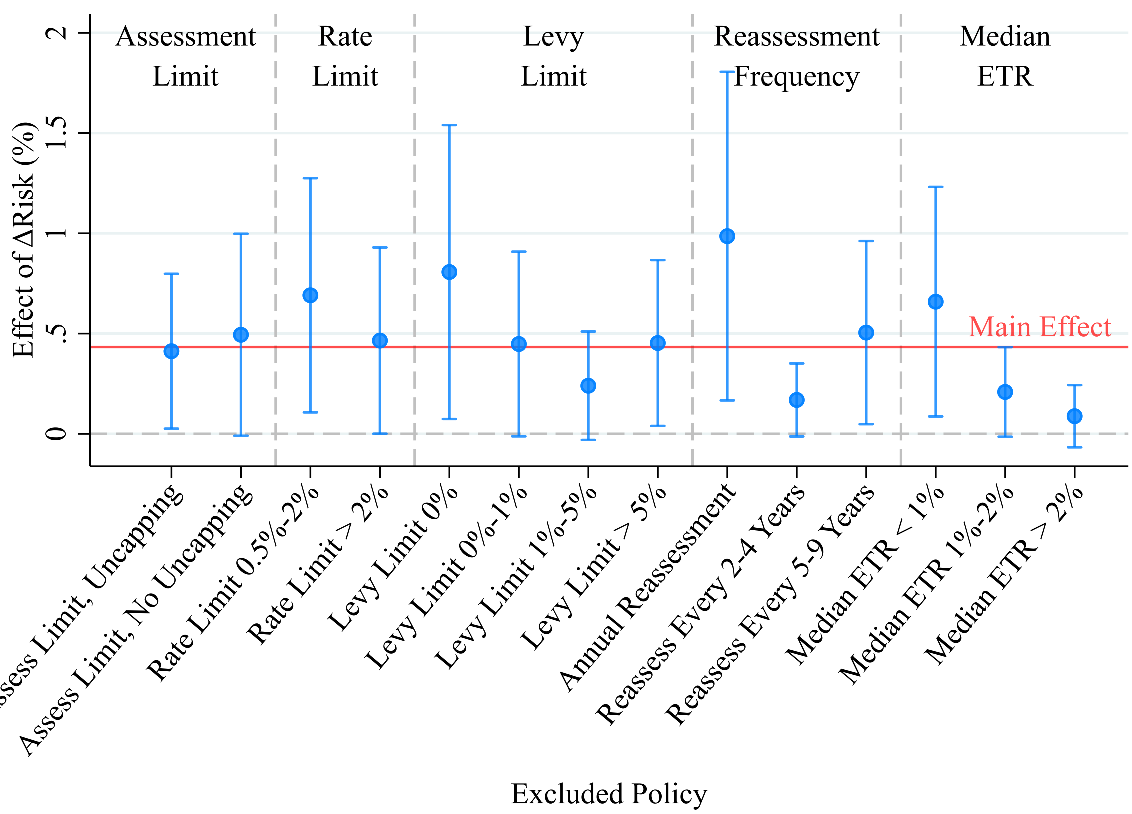


Figure 10: **Heterogeneous Effects of Policy-Induced Covariance Risk on Mortgage Distress**

This figure presents the heterogeneous effects of policy-induced covariance risk (ΔRisk) on mortgage distress by extending Equation 4 to include interactions between main variables of interest (ΔRisk) and indicator variables. Panel 10a reports the coefficients of the interaction with binary indicators denoting majority race by Census tract. Panel 10b reports the coefficients of the interaction with categorical values of assessment ratio multiples. Panel 10c reports the coefficients of the interaction with categorical values corresponding to LTV intervals (plus a sixth category for parcels with unknown LTV, which contains mostly mortgage-less households). Panel 10d reports the coefficients of the interaction with categorical indicators of homeowner tenure duration. Error bands denote 95% confidence intervals. Complete results with the full set of controls and interactions are reported in Table IA.D1.

(a) Race

(b) Assessment Ratio

(c) LTV

(d) Tenure

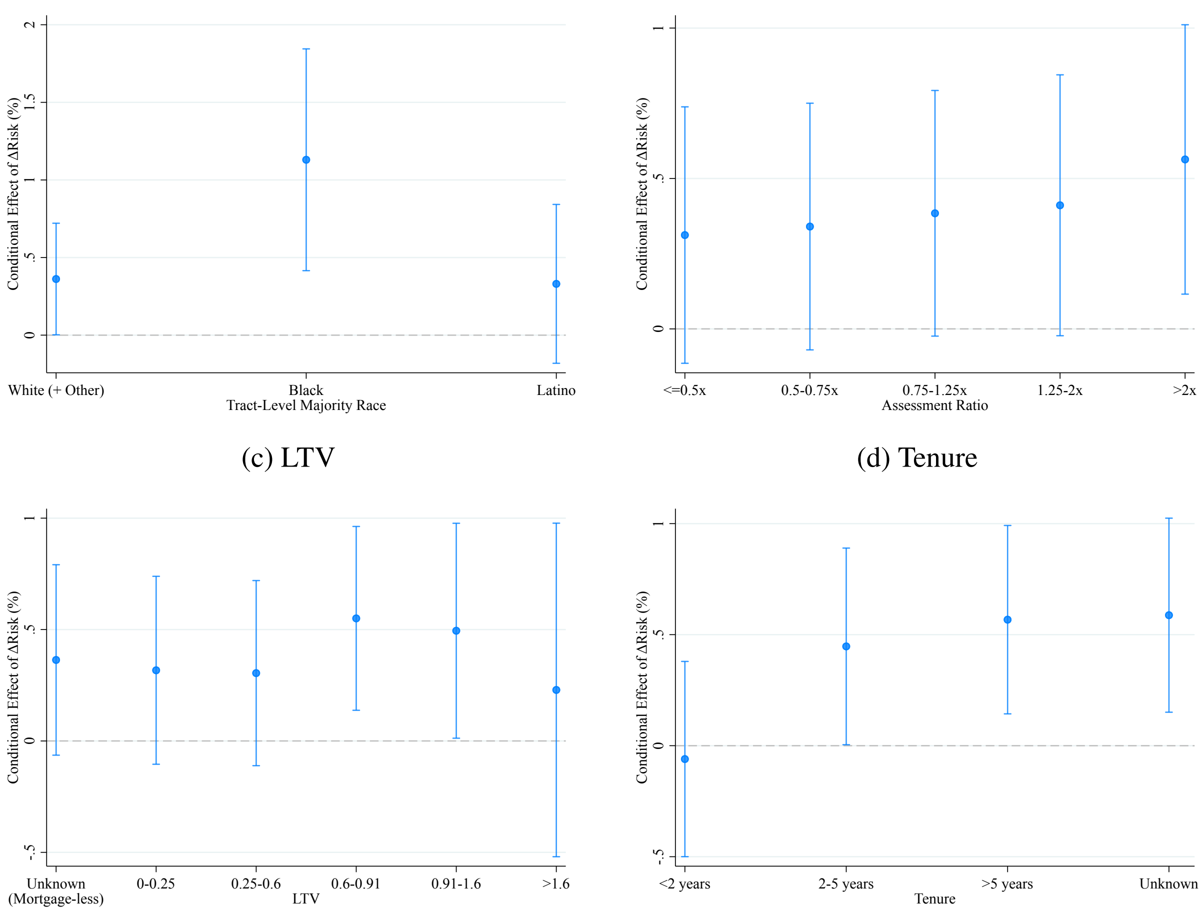


Table 1: **State Policy Characteristics, 2016**

This table describes the tax limitation policy regimes by state as of 2016. See Section 2 and Internet Appendix A for detailed descriptions.

State	Assessment Limits	Rate Limits	Levy Limits	Revenue Limits	Reassessment Interval	Lender Recourse	Non-judicial Review
AL		✓	✓		1	✓	✓
AZ	✓	✓	✓	✓	1		✓
AR	✓	✓	✓		3	✓	✓
CA	✓	✓		✓	[a]		✓
CO		✓	✓	✓	2	✓	✓
CT					5	✓	
DE			✓		Not defined	✓	
DC	✓	✓	✓		1	✓	✓
FL	✓	✓			1	✓	
GA		✓			1	✓	✓
ID		✓	✓		1	✓	✓
IL		✓	✓		4	✓	
IN		✓	✓		1	✓	
IA	✓	✓			2		
KS			✓		1	✓	
KY		✓	✓		1	✓	
LA		✓	✓		4	✓	
ME			✓	✓	Not defined	✓	
MD	✓				3	✓	
MA		✓	✓		1	✓	
MI	✓	✓	✓	✓	1	✓	✓
MN				✓	5		✓
MS			✓		4	✓	✓
MO		✓	✓		2	✓	✓
MT		✓	✓		2		✓
NE		✓		✓	1	✓	✓
NV		✓	✓		5	✓	✓
NH					5	✓	✓
NJ		✓		✓	Not defined	✓	
NM	✓	✓	✓	✓	1	✓	
NY		✓	✓		Not defined	✓	
NC		✓			8		✓
ND		✓	✓		1		
OH		✓	✓		3	✓	
OK	✓	✓			1	✓	✓
OR	✓	✓			1		✓
PA		✓	✓		Not defined	✓	
RI			✓		3	✓	✓
SC	✓	✓	✓		5	✓	
SD		✓	✓		1	✓	
TN			✓		5	✓	✓
TX	✓	✓	✓		3	✓	✓
UT		✓	✓		1	✓	✓
VT					1	✓	
VA			✓		4	✓	✓
WA		✓	✓		1		✓
WV		✓	✓		1	✓	✓
WI			✓	✓	5		
WY		✓			1	✓	✓

[a] California only reassesses properties upon sale. Conditional on sale, however, appraisal frequency is implicitly annual.

Table 2: **Summary Statistics**

This table provides summary statistics for key variables using our main estimation sample. Statistics are presented separately for non-distressed and distressed properties. ΔRisk is policy-induced covariance risk, which can be interpreted as the amount of money an average property owner would be willing to pay per year to eliminate the risk induced by state-specific limitation policies. ΔLevel is the policy-induced tax level, which can be interpreted as the amount of money an average property owner would save (with the negative sign indicating savings) per year due to state-specific limitation policies. See Section 3.2 and Appendix A for detailed descriptions of the construction of these two variables. Price is inferred using a combination of transaction-value interpolations and a machine-learning hedonic estimation procedure detailed in Appendix B. ΔRisk and ΔLevel are at the state-year level. Price, Tax, Lagged ETR (effective tax rate), Δ Tax, %Δ Tax, %Δ Price, Δ Tax Gap (%Δ Tax minus %Δ Price), LTV (loan-to-value ratio), Tenure, Age, Renovation Age are at the property-year level. Demographic characteristics, such as average AGI (adjusted gross income) and population composition by education, age, and race, are at the census-tract-year level.

	I[Distress]=0			I[Distress]=1			
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.
Limitation Policy Outcomes:							
ΔRisk ($000s)	0.355	0.275	0.333	0.351	0.275	0.309	-0.004
ΔLevel ($000s)	-9.539	-3.751	14.058	-9.197	-4.086	12.761	0.342
ΔRisk (Standardized)	0.000	-0.238	1.001	-0.011	-0.238	0.930	-0.012
ΔLevel (Standardized)	0.000	0.412	1.001	0.024	0.388	0.909	0.024
Property-Level Characteristics:							
Price ($000s)	255.048	169.330	298.403	179.093	127.793	195.076	-75.955
Tax ($)	3417.8	1981.4	5391.2	2598.9	1670.0	3350.2	-818.9
Lagged ETR (%)	1.48	1.16	1.36	1.69	1.28	1.53	0.21
Δ Tax ($)	101.2	22.0	880.6	73.3	15.0	603.4	-27.9
%Δ Tax	3.53	1.73	17.26	4.07	1.25	20.23	0.54
%Δ Price	4.76	0.00	162.40	4.26	-1.33	166.99	-0.51
LTV	1.38	0.63	71.95	1.78	0.93	46.47	0.40
Tenure	11.6	9	11.0	8.9	6	9.2	-2.8
Age	55.5	53	33.2	59.1	58	33.6	3.6
Renovation Age	48.8	47	35.5	53.1	54	36.2	4.3
Census-Tract-Level Characteristics:							
Average AGI ($000s)	61.144	48.608	51.301	49.766	43.045	35.836	-11.377
Population	4594.7	4448.0	1723.3	4620.4	4465.0	1745.2	25.6
Pop. Age ∈ [18, 24]	419.2	362.0	344.0	443.9	394.0	305.3	24.7
Pop. Age ≥ 25	3059.9	2980.0	1141.2	2984.1	2911.0	1130.1	-75.8
Pop. Pct. Educ ≤ High School (%)	45.99	47.20	17.81	50.19	51.40	16.50	4.20
Pop. Pct. Educ > Bachelor (%)	27.56	22.60	18.93	22.23	18.00	15.51	-5.33
Pop. Pct. White (%)	70.1	83.8	30.9	55.5	64.4	35.0	-14.5
Pop. Pct. Black (%)	20.1	5.5	29.2	33.7	17.3	35.4	13.6
Pop. Pct. Latino (%)	8.9	4.0	13.5	10.9	4.6	15.6	1.9
Pop. Pct. Asian (%)	3.7	1.5	5.9	3.3	1.2	5.4	-0.4
Observations		30,765,775			449,494		

Table 3: **The Effects of Tax Limitations on Covariance Risk and Certain Equivalent of Property Taxes**

This table presents the results of the following regression:

$$Y_{s,t} = \alpha + \beta_1 \mathbb{1}(\text{Levy Limit})_{s,t} + \beta_2 \mathbb{1}(\text{Rate Limit})_{s,t} + \beta_3 \mathbb{1}(\text{Assessment Limit})_{s,t} \\ + \boldsymbol{X}_{s,t} + \delta_t + \varepsilon_{s,t},$$

where $Y_{s,t}$ is policy-induced covariance risk, ΔRisk, in column 1 and policy-induced tax level, ΔLevel, in column 2 for state s and year t (defined in Section 3.2). Tax limitations are defined in Section 2. $\boldsymbol{X}_{s,t}$ is a vector of state-year level controls that includes reassessment frequency as categorical variables and the median effective tax rate of all properties in the state-year. δ_t is year fixed effects. ΔRisk and ΔLevel are standardized to have an in-sample mean value of 0 and standard deviation of 1. The sample excludes nondisclosure states and includes New York City, NY; Cook County, IL; and Washington, DC as distinct property tax regimes from 2006 to 2016. Standard errors in parentheses are clustered by year. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Dependent variable:	ΔRisk (1)	ΔLevel (2)
𝟙(Levy Limit)	0.330***	-0.626***
	(0.024)	(0.027)
𝟙(Rate Limit)	0.744***	-1.055***
	(0.059)	(0.075)
𝟙(Assessment Limit)	0.802***	0.167***
	(0.039)	(0.049)
Constant	-1.585***	1.785***
	(0.065)	(0.075)
Year fixed effects	Yes	Yes
Controls	Yes	Yes
R-squared	0.740	0.602
Observations	441	441

Table 4: **Mortgage Distress and Policy-Induced Covariance Risk**

This table presents the results of the following regression:

$$\mathbb{1}(\text{Distressed})_{i,t} = \alpha + \beta_1 \Delta\text{Risk}_{s,t} + \beta_2 \Delta\text{Level}_{s,t} + \boldsymbol{\gamma} \boldsymbol{X}_{i,t} + \boldsymbol{\phi} \boldsymbol{X}_{k,t} + \boldsymbol{\psi} \boldsymbol{X}_{s,t} + \text{FE} + \varepsilon_{i,t}.$$

The dependent variable is an indicator variable that equals 100 (so the coefficients can be interpreted as percentage-point effects) if the property experiences any form of mortgage distress. $\Delta\text{Risk}_{s,t}$ and $\Delta\text{Level}_{s,t}$ are policy-induced covariance risk and policy-induced tax level of property taxes, defined in the tax simulation in Section 3.2 (see Appendix A for simulation details). $\boldsymbol{X}_{i,t}$ is a vector of property-level controls that includes the loan-to-value ratio (categorized), price (imputed from a combination of interpolation and hedonic machine learning method, see Appendix B for details), lagged effective tax rate, tenure of homeownership (categorized), age of the property (categorized), and years since last renovation (categorized). $\boldsymbol{X}_{k,t}$ is a vector of census-tract-level controls that includes the average adjusted gross income, total population, and population composition along dimensions such as age, education, and race. $\boldsymbol{X}_{s,t}$ is a vector of state-level policy controls that include whether the state provides lender recourse (Ghent and Kudlyak, 2011) and whether the state requires judicial review for foreclosures (Mian et al., 2015). Columns 1 and 2 include fixed effects based on border county pairs, and column 3 adds year fixed effects. Columns 4 and 5 include fixed effects based on border-straddling 10 km^2 grids (illustrated in Figure 7), and column 6 adds year fixed effects. Columns 7 and 8 include 10-km^2-grid by year fixed effects. ΔRisk and ΔLevel are standardized to have an in-sample mean value of 0 and standard deviation of 1. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Border discontinuity based on	Adjacent County Pairs			10 km^2 Cells			10 km^2 Cells × Year	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\text{Risk}_{s,t}$	0.296**	0.366**	0.315*	0.305**	0.278**	0.240*	0.445***	0.433**
	(0.126)	(0.176)	(0.174)	(0.123)	(0.140)	(0.144)	(0.157)	(0.220)
$\Delta\text{Level}_{s,t}$	0.168*	0.298**	0.201	0.165*	0.212**	0.099	0.297***	0.335*
	(0.090)	(0.137)	(0.137)	(0.092)	(0.107)	(0.111)	(0.115)	(0.172)
Property-level controls:								
LTV								
0.25 - 0.6		-0.069**	-0.078***		-0.077***	-0.085***		-0.085***
		(0.029)	(0.030)		(0.023)	(0.024)		(0.016)
0.6 - 0.91		0.650***	0.666***		0.643***	0.659***		0.649***
		(0.061)	(0.061)		(0.042)	(0.042)		(0.028)
0.91 - 1.6		2.319***	2.312***		2.310***	2.302***		2.251***

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Border discontinuity based on	Adjacent County Pairs			10 km^2 Cells			10 km^2 Cells × Year	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		(0.143)	(0.138)		(0.089)	(0.087)		(0.053)
> 1.6		2.901***	2.887***		2.884***	2.870***		2.843***
		(0.270)	(0.261)		(0.157)	(0.153)		(0.096)
Unknown (Mortgage-less)		-1.509***	-1.549***		-1.541***	-1.583***		-1.619***
		(0.099)	(0.103)		(0.074)	(0.077)		(0.051)
Price		-0.000***	-0.000***		-0.000***	-0.000***		-0.000***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Lagged ETR		0.016	0.034***		0.012	0.031***		0.026***
		(0.013)	(0.012)		(0.009)	(0.008)		(0.007)
Tenure								
< 2 years		-0.943***	-0.979***		-0.958***	-0.993***		-1.016***
		(0.113)	(0.117)		(0.063)	(0.065)		(0.042)
2-5 years		-0.032	-0.089		-0.045	-0.102**		-0.115***
		(0.078)	(0.077)		(0.043)	(0.043)		(0.029)
Unknown		1.425***	1.410***		1.459***	1.447***		1.483***
		(0.107)	(0.105)		(0.065)	(0.063)		(0.066)
Age								
10-19 years		-0.377***	-0.336***		-0.361***	-0.322***		-0.315***
		(0.058)	(0.061)		(0.034)	(0.036)		(0.021)
20-59 years		-0.354***	-0.292***		-0.330***	-0.269***		-0.280***
		(0.065)	(0.069)		(0.038)	(0.041)		(0.023)
60-99 years		-0.286***	-0.177**		-0.245***	-0.136***		-0.103***
		(0.069)	(0.074)		(0.045)	(0.052)		(0.029)
>99 years		-0.119	0.014		-0.106	0.029		0.046
		(0.091)	(0.090)		(0.079)	(0.075)		(0.037)
Unknown		-0.188	-0.016		-0.158	0.009		-0.065
		(0.148)	(0.149)		(0.143)	(0.145)		(0.121)
Renovation Age								
11-32 years		0.017	-0.017		-0.006	-0.033*		-0.004
		(0.029)	(0.027)		(0.019)	(0.019)		(0.011)
33-59 years		0.110***	0.066**		0.107***	0.070***		0.080***
		(0.035)	(0.029)		(0.021)	(0.020)		(0.016)
> 59 years		0.306***	0.237***		0.314***	0.254***		0.255***
		(0.045)	(0.037)		(0.032)	(0.031)		(0.027)
Unknown		-0.513***	-0.579***		-0.532***	-0.589***		-0.457***
		(0.159)	(0.151)		(0.143)	(0.142)		(0.126)
Census-tract-level controls:								
Average AGI		0.000	0.001**		0.000	0.001***		0.001***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Population		0.000***	0.000***		0.000***	0.000***		0.000***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Pop. Age ∈ [18, 24]		-0.000***	-0.000***		-0.000***	-0.000***		-0.000***

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Border discontinuity based on	Adjacent County Pairs			10 km^2 Cells			10 km^2 Cells × Year	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Pop. Age ≥ 25		-0.000***	-0.000***		-0.000***	-0.000***		-0.000***
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)
Pop. Pct. Educ ≤ High School		0.004	0.004		0.004**	0.004**		0.005***
		(0.003)	(0.003)		(0.002)	(0.002)		(0.002)
Pop. Pct. Educ > Bachelor		-0.008***	-0.009***		-0.008***	-0.009***		-0.009***
		(0.003)	(0.002)		(0.002)	(0.002)		(0.001)
Pop. Pct. White		-0.006**	-0.006*		-0.007**	-0.007**		-0.007***
		(0.003)	(0.003)		(0.003)	(0.003)		(0.002)
Pop. Pct. Black		0.008**	0.009**		0.007**	0.007**		0.006***
		(0.004)	(0.004)		(0.003)	(0.003)		(0.002)
Pop. Pct. Latino		0.001	0.001		0.000	0.000		0.000
		(0.003)	(0.003)		(0.002)	(0.002)		(0.001)
Pop. Pct. Asian		-0.007	-0.006		-0.008**	-0.007**		-0.007***
		(0.004)	(0.004)		(0.004)	(0.004)		(0.002)
State-level controls:								
Lender Recourse		0.363	0.333		0.105	0.059		0.208**
		(0.253)	(0.268)		(0.159)	(0.171)		(0.100)
Judicial Review		-0.314	-0.263		-0.345	-0.316		-0.303
		(0.284)	(0.277)		(0.245)	(0.241)		(0.320)
Fixed Effects:								
County pair FE	x	x	x					
10 km^2 grid cell FE				x	x	x		
Year FE			x			x		
10 km^2 grid cell × Year FE							x	x
R-squared	0.004	0.017	0.018	0.005	0.018	0.019	0.010	0.023
Observations		31,215,255			31,215,269		31,215,269	

Table 5: **Robustness of the Effects of Policy-Induced Covariance Risk on Mortgage Distress**

This table reports variations of the most saturated specification of the main effect in Table 4 column 8. Column 1's dependent variable is an indicator variable for foreclosure rather than any form of mortgage distress. Columns 2, 3, 5, and 6 use alternative grid sizes of 4, 6.25, 12.5, and 20 kilometers (which divide 100 kilometers evenly as the 100-km^2 grid is the building block of the USNG system), respectively. Column 4 replicates Table 4 column 8 for ease of comparison. The estimates of controls are untabulated for brevity. All specifications include grid by year fixed effects. ΔRisk and ΔRisk (unreported) are standardized to have an in-sample mean value of 0 and standard deviation of 1. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) that are within 20 km of the nearest state border from 2006 to 2016. Standard errors in parentheses are clustered by grid cell. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

		Alternative Grid Sizes				
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \text{Risk}_{s,t}$	0.379**	0.223**	0.250**	0.433**	0.411*	0.314*
	(0.174)	(0.113)	(0.114)	(0.208)	(0.211)	(0.167)
Outcomes:						
Foreclosure	x					
Distress		x	x	x	x	x
Grid Size (km^2):	10	4	6.25	10	12.5	20
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Grid × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.021	0.026	0.024	0.023	0.022	0.021
Observations	31,215,269	31,215,269[a]				

[a]: Due to singleton/collinear fixed effects, the sample size for the 4 km^2 grid cell × year FE specification is reduced to 31,203,982.

Appendix

Appendix A Simulation Procedure

This section describes the detailed procedure for our tax simulation described in section 3.2. The simulation captures two aspects of property tax ΔRisk – (1) how tax policy affects property tax payments and (2) how such payments interact with household consumption. Therefore, we first simulate the underlying economy, which consists of a panel of aggregate consumption shocks, individual consumption shocks, and property values. Then, we calculate property tax obligations using all applicable tax limitations and compare them with counterfactual tax obligations under a tax regime with no tax limitations. Finally, we calculate the *covariance risk* for property taxes under limitations and under no limitations. The difference between the two is the policy-induced covariance risk, ΔRisk.

• Simulating the Economy Process

We build an underlying economy process that consists of 500 properties (denoted by i) with 50 years of history (denoted by t). We first simulate the aggregate consumption shock series. We collect aggregate consumption data from the National Income and Product Accounts (NIPA) table from the Bureau of Economic Analysis (BEA) for the period 1997-2020. We assume the consumption growth follows an AR(1) process and estimate the following:

$$g_t = \beta_1 + \beta_2 g_{t-1} + \epsilon_t,$$

where g_t is the growth of the personal consumption expenditure (linecode = 1) in year t. In addition, we model a recession process as a Poisson distribution. We assume that recessions occur once every 15 years on average and that aggregate consumption growth declines by 6% during recessions, which is the average across past recessions. Put together, we simulate the aggregate consumption shock as follows:

$$\hat{g}_z = \begin{cases} \bar{g} & \cdots \text{ if } t = 1 \\ \hat{\beta}_1 + \hat{\beta}_2 \hat{g}_{t-1} & \cdots \text{ if } t > 1 \end{cases}$$

$$\tilde{g}_t = \hat{g}_t + \hat{\sigma}_\epsilon \tilde{\chi}_1 - 0.06 \cdot \tilde{\chi}_2,$$

where $\tilde{g}_t$ is the simulated aggregate consumption growth in year t, $\tilde{\chi}_1$ is a random variable that follows a standard normal distribution, and $\tilde{\chi}_2$ is a random variable that follows a Poisson distribution with an arrival rate $\lambda = 1/15$.

We then simulate the individual consumption shock using the aggregate consumption changes. Following Pischke (1995), we make a conservative assumption that individual consumption shocks are on average 10 times as volatile as aggregate consumption shocks. We simulate the individual consumption shock as follows:

$$\tilde{g}_{i,t} = (\tilde{g}_t - \bar{g})\tilde{a}_i + \bar{g},$$

where $\tilde{a}_i$ is a person-specific amplifier that takes the value of a random variable that follows a normal distribution with a mean of 10. That is, on average, the individual consumption shock is 10 times as volatile as the aggregate consumption shock. We also truncate the individual consumption shock at -0.8, assuming that it is unlikely that a person loses more than 80% of her total wealth in one year. This truncation helps avoid occasionally producing extreme values and yields qualitatively similar results without the truncation.

Next, we simulate the inflation process. We collect inflation data (all-item CPI) from 1997 to 2020 from the Bureau of Labor Statistics and estimate the following equation:

$$f_t = \beta_3 + \beta_4 g_{i,t} + \epsilon_t,$$

where f_t is the inflation in year t. We simulate the inflation process as follows:

$$\tilde{f}_t = \hat{\beta}_3 + \hat{\beta}_4 \tilde{g}_t + \hat{\sigma}_\epsilon \tilde{x}_3,$$

where $\tilde{x}_3$ is a random variable that follows a standard normal distribution.

Lastly, we simulate changes in property values. We use the Case-Shiller National Home Price Index to calculate the year-over-year change in property value, h_t, and estimate the following equation:

$$h_t = \beta_5 + \beta_6 g_{s,t} + \beta_7 f_t + \epsilon_t.$$

Importantly, when we simulate taxes across different states, we use the Case-Shiller National Home Price Index rather than more granular housing price indices at the state or even local level (e.g., Zillow and FHFA indices), so we hold housing value (and the entire economy) fixed. As a result, all variation in ΔRisk solely comes from tax policy, which is why we term it “policy-induced covariance risk."

In addition, we assume that, on average, property values decline by 30% during recessions, given that the Case-Shiller Index lost about 30% of its value from the peak to the bottom during the 2008 financial crisis. We simulate the change in property value as follows:

$$h_{i,t} = \hat{\beta}_5 + \hat{\beta}_6 \tilde{g}_t + \hat{\beta}_7 \tilde{f}_t + \hat{\sigma}_\epsilon \tilde{x}_4 - 0.3 \cdot \tilde{x}_2,$$

where$\tilde{x}_2$ is a Poisson process with an arrival rate of 1/15, which approximates the recession. $\tilde{x}_4$ is a random variable that follows a standard normal distribution, which gives cross-sectional variation in the property value growth.

We simulate the initial values of the 500 properties to follow a normal distribution with a mean of 300,000 and a standard deviation of 50,000, with a minimum of 1,000. Using initial values and year-over-year changes in property values, we obtain a full panel of property values.

We also simulate the transaction status of properties. We assume that each property has a 7% probability of being sold in any given year, following the average turnover rate in the data.

• Calculating Property Tax Payments

We next calculate two different property tax payments for each property i in (simulation) year t in the simulated economy – one based on all applicable property tax policies in state-year s (e.g., the tax limitation policy in California in 2016) and one without any tax limitations imposed. Before applying any tax limits, we make three adjustments to account for heterogeneous property values across states, downward stickiness, and infrequent reassessment. First, we re-scale property values by the median transaction value of properties in the border counties of state-year s. Second, we empirically observe downward stickiness in the assessed value of properties. We capture this feature in the following way: if the change in property value, $h_{i,t}$, is positive, the assessed value in the next year changes (grows) by $h_{i,t}$; but if the change is negative, there is a 30% chance that the assessed value in the next year stays the same and a 70% chance that the assessed value changes (declines) by $h_{i,t}$. Lastly, for states that do not have assessment limits and do not reassess properties annually, we process assessed values in one of the two following ways. First, if the state mandates reassessment at specific intervals, we only update assessed values at the corresponding frequency and leave assessed values unchanged in non-reassessment years. Second, if the state does not mandate a specific reassessment frequency, we assume that properties are reassessed to current market value with a 10% mass-reassessment probability (i.e., akin to a 10-year interval between reassessments), consistent with the average practice in DE, ME, NJ, NY, and PA.

In the absence of assessment limits, we set taxable values equal to assessed (market) values in every period. Otherwise, if assessed value growth for a given property exceeds the allowed taxable value growth rate, the taxable value is set such that it grows at exactly the assessment limit. In most assessment limit states, the maximum permissible growth rate for taxable values is anchored to inflation, usually the lesser of statewide CPI inflation and some fixed number. We model these limitations accordingly, based on our model-simulated CPI, f_t. For *acquisition value*-based assessment limitation regimes (e.g., CA, FL, MI), we reset taxable values to market value whenever the property is transacted and resume applying assessment limitations to the property throughout the tenure of the new owner.

To apply levy limits, we start by using the simulated distribution of taxable values and the median effective tax rate (ETR) observed in our data in state-year s to calculate property tax liability for each property i in simulation year t. Then, we assume that states aim to grow their tax revenue by 80% of the aggregate consumption growth, g_t. That is, the state imperfectly tracks the aggregate consumption growth. We compare the implied growth in aggregate tax revenues to the revenue target and any applicable levy limits. If the state has a levy limit and simulated aggregate consumption growth exceeds it, the revenue target is set at the maximum permissible under the levy limit. The mill rate is then adjusted such that next year's aggregate tax revenue meets the revenue target. This process implies that when the housing market is too hot, the state must reduce the mill rate so that total tax revenue grows in line with the lesser of aggregate consumption growth and the levy limit. In contrast, when the housing market is in decline, the state may increase the mill rate to compensate for the smaller tax base (subject to any applicable rate limitations) to maintain its revenue target.

Finally, we apply any relevant rate limits. These have the practical effect of restricting states' ability to achieve their revenue targets during periods of declining taxable values. Rate limits and levy limits together yield a dynamically determined millage rate, which feeds into our final property tax payment calculation. Formally, we multiply the taxable value and millage rate, both subject to various tax limitations, to obtain the final property tax, $x_{i,t}^{\mathbb{P}}$, for property i in simulation year t, subject to the tax limitation policy regime $\mathbb{P}$. We also calculate a counterfactual property tax amount, $x_{i,t}^{\text{NoLimit}}$, assuming no tax limitations and annual reassessments with the same consumption-tracking logic.

• Pricing Property Taxes and Isolating Policy Risk

For each property i in simulation year t, we calculate the Arrow-Debreu price of the stream of property tax payments owed over the entire tenure of the property. We assume a CRRA utility function with a risk aversion of 3.5. Different values yield qualitatively similar results in the empirical analysis because the main independent variable of interest is always standardized. The pricing kernel for property i in simulation year t is:

$$m_{i,t} = 1/g_{i,t}^{3.5}.$$

We denote the tenure of property i in year t as T (i.e., property i was last transacted in year

$t-T$. Throughout homeowners' tenure, the covariance risk of taxes for property i in simulation year t under the policy $\mathbb{P}$ is:

$$Covariance\ Risk_{i,t,\mathbb{P}} = \sum_{j=t-T}^{t} m_{i,j}(x_{i,j,\mathbb{P}} - \bar{x}_{i,j,\mathbb{P}}).$$

That is, we apply Equation **??** to all property tax liabilities over the homeownership tenure. Similarly, we can obtain the covariance risk with no tax limitations:

$$Covariance\ Risk_{i,t,\text{NoLimit}} = \sum_{j=t-T}^{t} m_{i,j}(x_{i,j,\text{NoLimit}} - \bar{x}_{i,j,\text{NoLimit}}).$$

The covariance risk induced by states' property tax limitations, or *policy-induced covariance risk*, for property i in simulation year t is then:

$$\Delta\text{Risk}_{i,t,\mathbb{P}} = Covariance\ Risk_{i,t,\mathbb{P}} - Covariance\ Risk_{i,t,\text{NoLimit}},$$

We drop two types of observations from the simulated panel of properties that could introduce inaccuracies into the simulation. We first drop the first 20 years of the simulation (i.e., $t < 20$) because all properties are hard-coded to be transacted in year 1, which may cause unintended results. By simulation year 20, most properties have been "naturally" transacted at least once, which mitigates the possibility for unintended interactions. Second, we also drop observations for which the property's tenure is greater than 15 years (i.e., $T_{i,t} > 15$) to avoid potential outliers driving the simulation results. The results are qualitatively similar with or without these two filters.

Lastly, we average $\Delta\text{Risk}_{i,t}^{\mathbb{P}}$ across properties (indexed by i) and simulation years (indexed by t) among the remaining observations in the simulated property panel to obtain one value, $\Delta\text{Risk}^{\mathbb{P}}$. We repeat the process 1,000 times and take the average across iterations to avoid effects from any particular realization of the simulated economy. This final value at the policy ($\mathbb{P}$) level is the main independent variable of interest for our empirical analysis. To simplify notation, we swap the policy superscript $\mathbb{P}$ with the state-year subscript corresponding to which state implemented policy $\mathbb{P}$ in which year. That is, $\Delta\text{Risk}_{s,t}$ represents the policy-induced covariance risk due to the tax limitation policies in state s in year t.

Appendix B Machine Learning Hedonic Estimation

We use two methods to calculate annual property values — an imputation method and a hedonic estimation method. Each provides different coverage — and we use whichever method yields the longer parcel-specific history for each property in our analysis.[1] For the imputation method, we link arm's-length real estate transaction records to Zillow's monthly zip-level housing price indices and the Federal Housing Finance Agency's (FHFA) annual zip-level indices. We use both indices individually to extrapolate housing values forward and backward based on local pricing trends. Where feasible, we average the resulting imputed annual values. This procedure has the advantage of being straightforward to implement. However, it only works for properties for which we observe at least one arm's-length transaction during the period for which the Zillow or FHFA housing price indices are available.

Our hedonic estimation method circumvents the lack of own-price transaction information by using transaction prices for nearby properties and applying machine learning methods to estimate annual house prices as a function of available property characteristics. Concretely, we use machine learning techniques in two steps. First, we use machine learning methods to select the set of property characteristics to include in the hedonic model, allowing them to differ by Census tract based on data availability and predictive fit. The model selected for each tract is the one that performs best at predicting house prices out of sample. Second, we use machine learning methods to select the size of the training set — specifically, the number of neighboring Census tracts to include for each focal tract. The number of neighboring Census tracts we use is allowed to differ for each Census tract and is determined by the set that performs best out of sample.

We use machine learning to infer a property's market value based on its characteristics and location. The machine learning procedure can impute a market value for the property without prior arm's-length transactions, using only observable property characteristics. We predict property values, Census tract by Census tract, using the following procedure.

For each (focal) Census tract, we start with all properties in the focal tract and append all properties in the next adjacent Census tract. 10% of the sample is reserved for validation, and 90% is used for training. Given all the information available on transaction price (prediction target) and property characteristics (prediction inputs, including number of rooms, lot size, zip code, presence of a fireplace, etc.), we use an ensemble method with a gradient boosting regression tree. The method can select information to achieve the best fit, accounting for non-linear relations and interactions. We specifically use the histogram-based gradient boosting regression tree method to natively handle missing values and categorical values to improve the efficiency of the process.[2]

After obtaining the prediction output from the gradient boosting regression tree, we regulate potential outliers with a simple censoring procedure. We apply this censoring procedure as a

[1] Zillow's housing price indices are available back to January 1996 for approximately half of all zip codes, with gradually increasing coverage over time, whereas the FHFA's indices are available back to 1975.

[2] For more details, see the documentation of the histogram-based gradient boosting method at: https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.HistGradientBoostingRegressor.html.

preemptive measure because our context is potentially more prone to producing outlier predictions, given that certain input fields are poorly populated. The censoring procedure is as follows: for each property, we run a simple regression, but only using observations with the prediction output within the 25th and 75th percentile range:

$$\text{Y} = \beta_0 + \beta_1 \times \text{Year}$$

where Y is the prediction from the gradient boosting regression tree. We calculate $\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 \times$ Year for *all* observations. We then censor the predicted value at $\hat{Y} * (1 \pm 10\%)$ if the predicted value is outside of the [90%, 110%] range surrounding $\hat{Y}$. Very rarely does the prediction get censored. Lastly, we record the mean squared error with the preferred model.

We then add the next adjacent Census tract to the sample and repeat the process. The iterative process is carried out with the following trade-off in mind. The more Census tracts we include in the sample to predict housing prices in the focal tract, the more information we are using, which improves prediction quality. However, the more Census tracts we include in the sample, the more distant the properties we use to predict prices in the focal tract. That is, the relevance of location-specific information goes down, and the prediction quality could decrease. For each focal Census tract, we expand the sample by adding adjacent tracts until it includes at least 20,000 transactions. We then pick the iteration that yields the lowest mean squared error, which usually bottoms between 5,000 and 10,000 transactions.

The predictions we obtain using this process are therefore parameter-optimized and sample-optimized. We apply this process to all Census tracts in our sample to obtain a machine-learning prediction of market value (hedonic price) for the largest possible sample of properties using minimal available property characteristic information.

Appendix C Sample Construction

Our core dataset starts from the universe of parcel-level administrative assessor data on tax and property characteristics obtained from ATTOM Data Solutions for the continental U.S. for the period 2006-2016, and we match these data based on ATTOM's unique property identifiers to all available data on housing and loan transactions from ATTOM's recorder datafiles, along with indicators of all foreclosure-related events over the corresponding period. These latter data were formerly assembled by RealtyTrac, the then-leading provider of foreclosure information in the U.S.

We group sale and loan transactions falling within 60 days of each other and treat the latest date within each such series as the relevant transaction date. Accordingly, we alternately sum relevant loan amounts (e.g., as appropriate for "piggyback" mortgages) or record only the latest loan transaction in a series, depending on the characteristics of the parties to a given sequence of loan transactions. In the case of multiple distinct transactions or transaction series (i.e., separated by more than 60 days) occurring within the same calendar year, we preserve only the latest arm's length transaction of the year while flagging any distressed transactions that might have occurred earlier in the year.

We apply a parallel set of procedures to format the universe of parcel-level data from ZTRAX (Zillow, 2018) over the same 2006-2016 period and similarly link all available assessment and transaction data (sales, loans, and foreclosures) on the basis of Zillow's unique property identifiers. Constructing a concordance of ATTOM and Zillow's proprietary identifiers in order to validate and complement the ATTOM data using ZTRAX proceeds in three steps. We prioritize merging property records using a combination of legal parcel numbers (i.e., those assigned by local tax assessors) and zip code. Due to frequent inconsistencies in parcel number formatting, we implement an extensive list of county-specific pre-processing to improve the ATTOM-ZTRAX match rate; nevertheless, this leaves a large number of unmatched parcels, either due to inaccurate or missing parcel numbering or missing zip code information. We consequently repeat the procedure by parcel number plus street address (i.e., to catch failed matches due to missing zip codes) and again by street address plus zip code.

Due to the importance of our state-border identification strategy, we drop all observations from the merged ATTOM-ZTRAX concordance of property identifiers which do not include sufficient information for geocoding (i.e., due to missing latitude/longitude coordinates or–where unavailable–missing or incomplete street address or zip code information). We geocode all other addresses using ArcMap 10.7.1/10.8.1 using a U.S. address dual ranges locator to obtain latitude, longitude, and U.S. National Grid coordinates and to calculate parcel distances to state borders.

Where property characteristic data are missing from ATTOM at the parcel-year level, we first attempt to interpolate these from previous and subsequent years of (unchanged) non-missing data. Where this approach is infeasible (e.g. because earlier or later years of data are unavailable), we attempt to use matched data from ZTRAX provided that these imply unchanged property characteristics. Where ATTOM and ZTRAX data conflict, we defer exclusively to ATTOM. Unless otherwise explicitly identified in the assessor data, we infer home remodelings from discrete changes in key property characteristics (i.e., square footage, number of rooms, bedrooms, or bathrooms) provided that lot size remains unchanged.

Prior to imputing annual house prices or loan balances in the merged data, we exclude all transactions featuring purchase prices of less than \$1000 or more than \$5 million, and we exclude short-term loans (i.e. loans with due dates less than 12 months from origination). We also ignore re-recorded deeds or loan transfers between lenders. We apply the same restrictions to sale prices for our machine learning hedonic estimation procedure. To the extent that the imputation or hedonic estimation procedures yield prices outside of these bounds, we exclude such parcels from the analysis for the entire sample period (regardless of the number of years for which this happens).

We apply multiple layers of additional restrictions to our final estimation sample based on extreme or implausible ETRs, changes in annual tax liability or changes in assessed values. These proceed in steps and are designed to avoid applying blanket exclusions that would risk affecting parcels in certain states and/or certain types of homeowners more strongly than others due to state-specific property tax and assessment practices. Thus, we start by excluding observations with ETRs in excess of 100% or inferior to 0.01% using ETRs constructed from either imputed or estimated house prices, which represent approximately 0.5% of all observations with non-missing ETR information. Such extreme values are implausible regardless of state property tax practices. Next, we drop all observations whose ETRs fall below the 1st percentile or above the 99th percentile of each state's respective ETR distribution, based on ETRs constructed from imputed prices, estimated prices, or assessed values (grossed up to full market value according to state assessment ratios). With respect to changes in annual tax liabilities, we drop all parcels for which the percent change in liability fell outside the 5th through 95th percentile within state-year-tenure-homestead status *provided that* the change also exceeded 10% in absolute value *and* either assessment ratios, ETRs, or assessed values also exhibited extreme changes from the prior year (i.e., in the top or bottom 5% of their respective distributions). Alternatively, we drop all parcels for which the percent change in tax liability fell outside the 1st through 99th percentiles within state-year-tenure-homestead status if the change in tax amount exceeded either 100% on the upside or -50% on the downside. Lastly, we drop any remaining parcels that saw their assessed values rise by more than 345% or fall by more than -65% year-over-year, which correspond to less than 1% of values at either end of the distribution for state border counties.

We further exclude from our analysis all parcels in price non-disclosure jurisdictions (i.e., ID, KS, LA, MS, MT, NM, ND, TX, UT, WY, and all but four counties in MO) due to insufficient price information for reliable imputation or hedonic estimation, and we omit new construction and newly-renovated properties (i.e., built or remodeled within the last two years) on account of the difficulty in interpreting changes in assessed value and tax liability over the course of (re)construction.

Figure 5 (in main paper) characterizes the geographic distribution of unique parcels in the latter final estimation sample. Darker shaded border counties denote areas with a higher density of observations. As shown, the highest concentration of observations arises among states east of the Mississippi River and along the U.S. west coast and southwest. Sparsely populated border areas coupled with price non-disclosure imply that our analysis necessarily omits large parts of the U.S. mountain west.

INTERNET APPENDIX

Internet Appendix

Internet Appendix A State-Level Property Tax Limits as of 2016

This Appendix provides a detailed description of state-level property tax limitations as of 2016. Each state can and often does have multiple types of limitations. We list the limit's name, description, type (assessment, rate, or levy), and the legislative origin that defines it. Limits with unconventional specifications (such as the Gallagher Amendment in CO) and limits only applicable to part of the state (such as the Kent County Property Tax Rate Cap in DE) are not coded in the simulation, and hence not shown in Table 1. This appendix heavily sources from Lincoln Institute of Land Policy and George Washington Institute of Public Policy (2023), to which we refer the readers for more details.

Alabama

Overall Tax Lid: For individual properties total property taxes shall not exceed for Class I, utilities, 2% of market value; for Class II, property not other wise classified, 1.5%; for Class III property, including agricultural, forest, historic buildings and sites, and single-family owner-occupied property, 1.0%; for Class IV, all private automobiles and trucks, 1.25%. Levy limit. Ala. Code § 40-8-1.

Property Tax Rate Cap: The tax rate shall not exceed for the state the sum of 6.5 mills; for counties, 5 mills for general purpose; for counties, 2.5 mills for debt service; for municipalities, 10 mills for debt service; for municipalities excepting debt service, 5 mills. School districts are required to levy a minimum of 10 mills. This may be increased not to exceed 3 mills, with voter approval. A 3 mill tax increase election requires the approval of a court judge in order for an election held. Rate limit. Ala. Code § 17-9-5.

Arizona

Local Expenditure Cap: Expenditure growth of counties, cities, and towns is limited to the annual increase in the cost of living and population growth. School districts shall limit their expenditures to adjust for changes in the student population and the cost of living, and multiply the adjusted result by 1.10. Revenue limit (coded as levy limit in the simulation). A.R.S. Const. Art. IX, § 20 § 21.

Assessment Limitation: Assessment growth for primary property taxation purposes is the limited property value in the preceding valuation year plus 5% of that value. Assessment limit. Ariz. Rev. Stat. § 42-13301; Ariz. Rev. Stat. § 42-13304.

Limit on Annual Levy Growth: A county, city, or town may not increase its property tax levy by more than 15% over the previous year's levy, not to exceed the maximum permissible limit. Levy limit. Ariz. Rev. Stat. § 42-17107 (A-4).
Property Tax Levy Cap (Maximum Allowance Levy Limit): The maximum amount of primary property taxes that can be levied shall not increase by more than 2% of the prior year's maximum permissible limit, whether or not the taxing unit levied to the maximum amount. This applies to cities, counties, towns and community college districts. Debt service, special district levy, and county support for school districts are excluded. New construction is exempt from levy limit calculation. Levy limit. Ariz. Rev. Stat. § 42-17051.
Overall Residential Property Tax Rate Cap: The maximum amount of primary property taxes collected from residential property in any tax year shall not exceed 1% (10 mills) of the property's full cash value or the limited property value (LPV), whichever is less. The limit does not apply to debt service and special district levy. Rate limit. Ariz. Rev. Stat. § 42-17152.

Arkansas

Assessment Cap - Amendment 79: The increase in taxable assessed value of a homestead resulting from a reappraisal is limited to 5% each year until the property reaches the full assessed value, but shall not exceed the full assessed value determined by the recent reappraisal. The increase in taxable assessed value of non-homestead real property is limited to 10% each year, but shall not exceed the full assessed value determined by the recent reappraisal. When a property is sold the county assessor shall assess the real property at 20% of the appraised value at the next assessment date. Assessment limit. Ark. Const. Amendment 79.
Property Tax Rate Cap: The tax rate shall not exceed for counties 5 mills for general purposes and for municipalities 5 mills for general purposes. Rate limit. Ark. Code § 26-25-101, § 26-25-102; Ark. Const. Art. 16, § 8 and § 9.
Property Tax Levy Cap: After a countywide reappraisal or reassessment that results in an increase in taxable property of 10% or more, taxes levied shall be adjusted or rolled back. The adjustment or rollback of tax rates shall be designed to assure that each taxing unit will receive an amount of tax revenues no greater than 10% above the revenue received the previous year. Levy limit. Ark. Code § 26-26-402; Ark. Const. Art. 16, § 14.

California

Government Spending Limitation (Gann Initiative): The growth in annual appropriation of tax revenues for the state and each local government is limited to the change in the cost of living and

the change in population. For schools the cost of living is measured by the change in California per capita personal income and for local governments, except schools, the limit is adjusted by either the change in California per capita personal income or the change in the local property tax roll due to the addition of new nonresidential construction. Each year's limit is computed based on the prior year's limit, not the prior year's appropriation. Revenue received by any local government in excess of the amount appropriated must be refunded by a revision of tax rates or fee schedules within the next 2 subsequent fiscal years. Revenue limit (coded as levy limit in the simulation). Ca. Government Code §§ 7900-7914; Cal Const, art. XIIIB; Harris, T., GANN LIMIT.
Proposition 13 Rate Cap: The property tax rate cannot exceed 10 mills, or 1% of assessed value, excluding voter-approved debt service. Rate limit. Cal. Revenue and Taxation Code § 51; Cal. Revenue and Taxation Code § 93; Cal Const, Art. XIII A, § 1.
Proposition 13 Assessment Limitation: The annual increase in assessed value of real property is limited to 2% or the rate of inflation (as shown in the consumer price index or in comparable data for the area under taxing jurisdiction), whichever is less. Assessment limit. Cal. Revenue and Taxation Code § 51; Cal. Revenue and Taxation Code § 170 171; Cal. Const. art. XIII A, § 2 (b).

Colorado

The Taxpayer's Bill of Rights (TABOR) Mill Levy: The tax rate, or mill levy, for local governments is capped at the prior year's rate. For school districts the rate limit is limited to the lesser of the prior year's rate, the rate adjusted to take into consideration state aid, or 27 mills. Rate limit. Colo. Rev. Stat. § 22-54-106(2)(a)(I)-(V); Colo. Const. Art. X, Section 20, cl. 4.
Gallagher Amendment: The Gallagher Amendment requires that the residential assessment rate be adjusted whenever property is revalued. In general, the rate must decline to keep the residential share at 45% of the statewide assessed value. The adjustment ensures that the rate of change to the state's total assessed value of residential property remains essentially the same as it is for nonresidential property. Assessment limit (not coded in the simulation). Colo. Rev. Stat. § 39-1-104.2; Colo. Const. Art. X, Section 3.
The Taxpayer's Bill of Rights (TABOR) and 5.5% Levy Limits: The more restrictive of the TABOR and the 5.5% statutory limit shall take effect. TABOR revenue limit allows for an annual change in property tax revenue based on the percentage change the Boulder/Denver CPI and the local growth. The 5.5% levy limit allows for a 5.5% increase from the prior year plus additional revenue from growth attributed to new construction. The CPI increase for 2016 was 2.772%. Levy limit. Colo. Rev. Stat. § 29-1-301; Colo. Const. Art. X, Section 20, cl. 7.
The Taxpayer's Bill of Rights (TABOR) Fiscal Year Spending: The maximum percentage increase

allowed for all expenditures is inflation in the prior calendar year plus annual growth. This limitation applies to all revenues, adjusted for revenue changes approved by voters. Revenue limit (coded as levy limit in the simulation). Colo. Const. Art. X, Section 20, cl. 7 & 8.

Connecticut

Levy Limit with Override: Because Hartford was the only municipality that adopted the "Tax Cap" under Conn. Gen. Stat §12-62d, repealed in 2006, this levy limit only applies to Hartford. When a budget adopted no later than June 15 exceeds the prior year's levy, adjusted for inflation by more than 2.6%, 1% of the electors may petition for a voter referendum. Unless approved by a majority of voters, the increase in the budget is limited to 2.6% or less. Levy limit (not coded in the simulation). Conn. Gen. Stat. §12-62r(g).

Delaware

Kent County Property Tax Rate Cap: The tax rate for Kent County shall not exceed the sum of 50¢ on each $100 of assessed evaluation. This limit applies only to the county property tax rate, and not other property tax rates in use within the county, such as those of school districts, library districts, or municipalities. Rate limit (not coded in the simulation). Del. Code tit. 9, § 8002(b).
County Property Tax Levy Cap: After a county reassessment is effective, county property tax revenues cannot exceed 15% of the total property taxes imposed for the preceding fiscal year. Any initial assessment made on new construction shall not be taken into account in determining such limitation. Levy limit. Del. Code tit. 9, § 8002(c).

District of Columbia

Assessment Cap Credit: If owner-occupied residential property's assessed value increases by more than 10% in any year, the owner will received a non refundable credit to offset the corresponding increase in tax bill. Assessment limit. DC ST §47-864.
Levy Limit for Class 1 Residential Property: The real property tax rate for residential property identified as Class 1, shall be calculated to yield the same amount of taxes estimated to be collected during the preceding tax year, plus the lesser of (1) 7% or (2) the percentage increase in the total aggregate assessment of taxable real property for residential property. Levy limit. D.C. Code Ann. § 47-812.
Rate Limit for Class 3 and Class 4: The sum of both real and special property tax rates are fixed on Class 3 vacant property at $5 per $100 or 50 mills. For Class 4 blighted property the rate is fixed at $10 per $100 or 100 mills. Rate limit. D.C. Code Ann. § 47-812 (b-10)(1) and (2).

Florida

Maximum Millage Rates: The maximum millage rate that a taxing jurisdiction may levy is a rolled-back rate based on the amount of taxes which would have been levied in the prior year if the maximum millage rate had been applied, adjusted for change in per capita Florida personal income, unless a higher rate is adopted, in which case the maximum is the adopted rate. Rate limit. Fla. Stat. §200.065(5).
Save Our Homes Assessment Limits: For properties receiving the homestead exemption, the annual increase in assessed values is limited to the lower of the following: either 3% of the assessed value of the property for the prior year; or the percentage change in the Consumer Price Index. In 2016 the increase was 0.7%. This limitation only applies to homestead real property. After any change of ownership, homestead property shall be assessed at just value. However, the benefit under Save Our Homes is portable to the new property. Assessment limit. Fla. Stat. § 193.155; Fla. Const. Art. VII §4 (d).
County, Municipality, and School District Millage Limitation: Counties, municipalities, and school districts are each limited to 10 mills, excluding debt service. All special districts other than water management districts are limited to a millage authorized by the vote of the electors within the district. Any county that provides a municipal service may levy an additional 10 mills in unincorporated areas only. Consolidated cities and counties providing both municipal and county services may levy a millage up to 20 mills, but, for each county millage increase above 10 mills, there must be a corresponding decrease in municipal millage. Rate limit. Fla. Stat. §200.065 §200.181; Fla. Const. Art. VII, § 9.
Non-homestead Property Assessment Limit: For all levies other than school district levies, re-assessments for non-homestead properties may not exceed 10 percent of the assessed value of the property for the prior year. If the assessed value of the property exceeds the just value, the assessed value of the property shall be lowered to the just value of the property. Assessment limit. Fla. Stat. § 193.1554; Fla. Stat. § 193.1555; Fla. Stat. § 193.092; Fla. Const. Art. VII §4(h).

Georgia

School District Rate Cap: School districts are limited to 20 mills, excluding debt service. Rate limit. Ga. Const. Art. VIII, § VI.

Idaho

Property Tax Rate Caps: County rates for general purposes within the Current Expense Fund are limited to the greater of 2.6 mills or a rate sufficient to raise $250,000. Cities are limited to 9 mills for general purposes. Additional limits apply to specific county and city funds. If a county establishes a justice fund, the rate is limited to the greater of 2 mills or a rate sufficient to raise $250,000. The limit for city capital improvement funds is .4 mills, with an overall limit of fund not to exceed .4% of market value. Other limits apply to a variety of city and county funds and other taxing authorities. Limits for school districts are set by the State Department of Education including provisions for a budget stabilization fund to replace state revenues. Rate limit. Idaho Code Ann. § 33-802; Idaho Code Ann. § 50-235 § 50-236; Idaho Code Ann. § 63-801; Idaho Code Ann. § 63-805.

Illinois

Property Tax Extension Limitation Law (PTELL): For non-home rule taxing districts, the increase in total levy or extension, for all funds is limited to the lower of 5% or the rate of inflation during the previous year, measured by the urban consumer price index. Levy limit. 35 Ill. Comp. Stat. § 200/18-185;35 Ill. Comp. Stat. § 200/18-190; 35 Ill. Comp. Stat. § 200/18-205; 35 Ill. Comp. Stat. § 200/18-212.
Property Tax Cap Law: The maximum rate allowed by law depends on the type of government unit and the type of fund within each unit. Most tax rates are limited to less than 10 mills. Whenever any taxing district establishes a maximum tax rate lower than that otherwise applicable, it shall publish the ordinance or resolution in one or more newspapers in the district within 10 days after the maximum tax rate is established. The ordinance or resolution shall include a notice of (a) the specific number of voters required to sign a petition requesting that the question of the adoption of the maximum tax rate limit be submitted to the voters of the district; (b) the time within which the petition must be filed; and (c) the date of the prospective referendum. The district clerk or secretary shall provide a petition form to any individual requesting one. Any county which has a chief executive officer elected by the electors of the county and any municipality with a population of more than 25,000 is a home rule unit unless it elects by referendum not be home rule. Rate limit. 35 Ill. Comp. Stat. § 200/18-120, § 200/18-125, §200/18-190(a)(4); 55 Ill. Comp. Stat §5/5-1024; 65 Ill. Comp. Stat. §5/8-3-1; 105 Ill. Comp. Stat §5/17-2; Illinois Const., Art. VII, § 6; Art. VII, § 11, cl. b.

Indiana

Maximum Permissible Ad Valorem Tax Levy: Property tax revenue increases of each taxing unit, except school districts, are limited to the lesser of 6% or the average annual growth rate of Indiana non-farm personal income in the previous 6 years, whichever is lesser. Levy limit. Ind. Code §

6-1.1-18.5-2.

Overall Tax Cap (Circuit Breaker): Overall tax bills of individual parcels are limited to, or capped at, a certain percentage of gross assessed value, depending on type of property. For Homestead properties tax liability is limited to 1% of assessed value. The cap is 2% for non-homestead residential properties, agricultural land, and long term care property; and 3% for all other properties. Although called circuit breaker, there is no income factor associated with this cap, therefore, it is not considered a true circuit breaker for our purposes. Rate limit. Ind. Code § 6-1.1-20.6-1.6; 6-1.1-20.6-3; § 6-1.1-20.6-7.5; Ind. Const. Art. 10 §1.

Iowa

Assessment Limitation: The annual growth in assessed values of residential and agricultural properties is limited to 3% and 8% for utilities. Increases in the assessment of residential and agricultural property are tied to each other. If either class of property increases at less than 3%, then the other class of property is also limited to that percentage increase. Assessment limit. Iowa Code § 441.21(4) § 441.21(5).

Property Tax Rate Cap: For general county services, the rate limit is 3.5 mills of the assessed value of all taxable property in the county; for rural county services, the rate limit is 3.95 mills of the assessed value of taxable property in the county outside of incorporated city areas; municipalities are limited to 8.1 mills for the general fund and 3.38 mills for agricultural or horticultural property. The rates exclude debt service. Other limits apply for specific purposes. Rate limit. Iowa Code § 331.423 - § 331.426; Iowa Code § 384.1; Iowa Code § 384.12; Iowa Code § 257.3.

Kansas

“Truth in Taxation" Lid: Budgets funded from property taxes cannot exceed the amount from the next preceding year, adjusted for inflation except for that from new construction or improvements. Levy limit. Kan. Stat. Ann. § 79-2925b.

Kentucky

Property Tax Rate Cap: The tax rate shall not exceed for counties 5 mills, for municipalities 7.5-15 mills on a sliding scale based on population, and for school districts 15 mills. Rate limit. Ky. Rev. Stat. Ann. § 65.125; Ky. Rev. Stat. Ann. §68.090; Ky. Rev. Stat. Ann. § 160.475; Ky. Const. § 157 § 157A.

"House Bill 44" Property Tax Levy Limit: Levy rates for local governments, including school districts, cannot exceed rates that produce 4% increase in revenue generated using the compensating rate. The levy in excess of the 4% may be subject to a recall petition. Levy limit. Ky. Rev. Stat. Ann. § 132.017; Ky. Rev. Stat. Ann. §132.020; Ky. Rev. Stat. Ann. §132.023; Ky. Rev. Stat. Ann. § 132.027; Ky. Rev. Stat. Ann. § 160.470.

Louisiana

Municipal Millage Limit: The governing authority of a municipality may levy annually an ad valorem tax for general purposes not to exceed 7 mills on the dollar of assessed valuation. The municipality millage limit is 10 mills, if the municipality, by its charter or law, is exempt from payment of parish taxes, or if it maintains its own public schools. Rate limit. La. Rev. Stat. Ann. § 33:2801; La. Const. Art. VI, § 27; La. Const. Art. VII, § 19.
Maximum Authorized Levy: After reassessment, revenues cannot exceed the amount collected in prior year. Millage rates are adjusted to reflect the new property values. The adjusted maximum millage is the prior year's maximum millage rate adjusted to keep property tax revenues from increasing. Levy limit. La. Rev. Stat. Ann. § 47:1705; La. Const. Art. VII, § 18; La. Const. Art. VII, § 23.

Maine

Municipal Property Tax Levy Cap (LD1): Municipal property tax levy increases are limited to a formula based on inflation, assessment growth, and income. The growth limitation factor is the average personal income growth plus the property growth factor. Levy limit. Me. Rev. Stat. Ann. tit. 30A, § 5721-A.
County Assessment (appropriation) Limit: Increase in county assessment which is the total annual county appropriation is limited to the growth limitation factor. The growth limitation factor is 10 year average real income growth and the percent increase in assessed value. Revenue limit (coded as levy limit in the simulation). Me. Rev. Stat. Ann tit. 30-A §706-A.

Maryland

Homestead Property Tax Assessment Freeze: For state property taxes, assessment of eligible residential property is capped at 110% of prior year's value. For county and municipal purposes, assessments may not exceed 110% of prior year's value, but may be less than 110% at local option. Assessment limit. Md. Code, Tax-Property § 9-105.

Massachusetts

Proposition 2½ Levy Limit: The municipal property tax levy limit increases by 2½% annually, excluding new growth (construction and improvements). This means that the tax levy could increase by more than 2½%, if the community did not levy up to the limit in the prior year. Levy limit. Mass. Gen. Laws ch. 59, § 21C.
Proposition 2½ Levy Ceiling: For municipalities, the total property tax revenue cannot exceed 2.5% of total assessed value in the municipality. A municipality that exceeds the limit must annually decrease taxes assessed by at least 15% to reach the rate limit. Rate limit. Mass. Gen. Laws ch. 59, § 21C.

Michigan

Headlee Amendment Levy Cap: If assessed values increase more than the increase in the U.S. consumer price index in the prior year, the maximum authorized rate shall be reduced to yield the same revenue adjusted for changes in the CPI. New construction and improvements, and debt service are excluded. Levy limit. Mich. Comp. Laws §211.34d; MCLS. Const. Art. IX, § 25 § 33.
Property Tax Rate Cap: The total amount of general ad valorem taxes imposed upon real and tangible personal property for all purposes in any one year shall not exceed 15 mills on each dollar of the assessed valuation of property as finally equalized, excluding debt service. The city charter rate is limited to 20 mills. Rate limit. Mich. Comp. Laws § 117.3; Mich. Comp. Laws § 211.203; MCLS. Const. Art. IX, § 6.
State Revenue and Expenditures Limits (Headlee Amendment): Revenues collected by the state are limited to no more than the share revenues were of personal income initially in FY1978-79 and recalculated in 1985. Expenses of state government in any fiscal year shall not exceed the sum of the revenue limit, federal aid, and surplus from the prior year. Revenue limit (not coded in the simulation). Mich. Const. Art. IX, § 26; Mich. Const. Art. IX, § 28.
Assessment Limitation: Taxable value cannot increase in any year by more than the lesser of 5% or inflation as measured by consumer price index for the U.S. For tax year 2016, the inflation rate was 0.3%. Assessment limit. Mich. Comp. Laws §211.27a; MCLS. Const. Art. IX, § 3.

Minnesota

School District Levy and Aid Formulas: Each school district's adjusted net tax capacity, as determined by the Minnesota Department of Revenue, shall not increase by more than the greater of 19% of the certified adjusted net tax capacity in the previous year, or 40% of the difference between current year (absent the limit) and the previous year. Revenue limit (coded as levy limit in the simulation). Minn. Stat. § 127A.48.

Property Tax Levy Limit: Levy limits apply for counties with populations above 5,000 or cities above 2,500, but only if the state Legislature imposes them. If the limits are in place, the commissioner of revenue calculates the levy limit for each city, taking into account state aid when calculating the limits. When state aid increases, the levy limit ensures that the increased state aid is used to replace local property taxes. Similarly, when state aid decreases, the levy limit is removed. The limit was last imposed in 2014. Levy limit (not coded in the simulation). Minn. Stat. § 275.70 - § 275.74.

Mississippi

Property Tax Levy Cap: Counties and municipalities are limited to a 10% increase over the total property tax receipts in any of the previous 3 years, excluding new property. School districts are limited to a 7% increase over the total property tax receipts in any of the previous 3 years, excluding new property. Levy limit. Miss. Code Ann. § 27-39-320 § 27-39-321; Miss. Code Ann. § 37-57-107.

Missouri

Property Tax Statutory Rate Cap: The rate limit for school districts formed of cities and towns (including that of the city of St. Louis) is 27.5 mills. For, all other school districts the rate limit is 6.5 mills. The municipal rate limit is 10 mills, up to 13 mills, by voter override. The rate limit for counties of the first class, and with total assessed value over $300 million, is 3.5 mills. The rate limit for all other counties is 5 mills. The limit does not apply to debt service. Rate limit. Mo. Rev. Stat. § 94.250; Mo. Rev. Stat. § 137.065; Mo. Rev. Stat. § 94.010; Mo. Const. Art. X, § 11.

Property Tax Levy Ceiling and Tax Rate Rollback (Hancock Amendment): Current year tax rates must be set to yield the same gross revenue as allowed in the prior year plus revenue permitted for assessment growth. That adjustment is the lowest of (1) the actual growth rate, (2) inflation growth, or (3) 5%. The tax rate ceiling is the maximum rate for operating funds for the current year prior to any reduction due to local sales tax revenues or voluntary rollback of tax rate. Levy limit. Mo. Rev. Stat. § 137.073; Mo. Const. Art X. § 22.

Montana

Property Tax Levy Cap: Local non-school taxing districts shall limit their property tax revenue growth to last year's levy plus inflation, excluding new property. The maximum millage that may be imposed is established by calculating the number of mills required to generate the amount of property tax actually assessed in the prior year based on the current year taxable value, less any new property, plus 1/2 the average rate of inflation for the prior 3 years. Levy limit. Mont. Code Ann. § 15-10-420; Mont. Code Ann. § 15-10-425.

Nebraska

General Revenue and Expenditure Caps: Cities, counties and, political subdivisions must maintain a base limitation rate on the growth of restricted funds to 2.5%. The basic allowable growth rate (BAGR) for school districts for school FY 2016-2017 is 2.5%. Revenue limit (coded as levy limit in the simulation). Neb. Rev. Stat. § 13-518; Neb. Rev. Stat. § 77-3446; Neb. Rev. Stat. § 79-1025; Neb. Rev. Stat. § 79-1029 § 79-1030.
Property Tax Rate Cap: The tax rate shall not exceed for municipal counties, 10 mills; for cities of the first class for all-purpose levy, 8.75 mills; for cities of the second class and villages, 10.5 mills; for incorporated cities and villages within the boundaries of a municipal county, 9 mills; for incorporated cities and villages not within the boundaries of a municipal county, 4.5 mills; and, for school districts and multiple-district school systems, except learning communities, 10.5 mills. Rate limit. Neb. Rev. Stat. § 19-1309; Neb. Rev. Stat. § 77-3442 § 77-3444.

Nevada

Overall Property Tax Rate Cap: The Nevada Constitution limits the property tax rate to $5 per $100 of assessed value. A statutory limit for all public purposes of overlapping districts is $3.64 per $100 of assessed value. Rate limit. Nev. Rev. Stat. § 361.453; Nev. Rev. Stat. § 361.4545; Nev. Rev. Stat. § 354.705; Nev. Rev. Stat. § 450.760; Nev. Const. Art. 10, § 2.
Overall Levy Growth Limit (Partial Property Tax Abatement): The amount of total property taxes levied on a single property is limited. Under the tax cap, increases in total property taxes on single family residences and certain rental properties cannot exceed 3%. For all other properties the level of allowable increases varies by county, based on the greater of (1) the 10 year average growth of all assessed value or (2) twice the change in the consumer price index for the prior year, not to exceed 8%. Taxes in excess of the limit are abated. Levy limit. Nev. Rev. Stat. § 361.4722 § 361.4724; Nev. Rev. Stat. §361.4727 §361.4728.

New Jersey

General Budget Cap (Appropriation Cap): Counties and municipalities are prohibited from increasing their final appropriations of the budget by more than 2.5% over the prior year or cost-of-living adjustment, whichever is less. Certain exceptions apply. Revenue limit (coded as levy limit in the simulation). .J. Rev. Stat. § 40A: 4-45.1 - 45.3.

Property Tax Levy Cap: Increases in levies for county and municipal governments and for the general fund for school districts, are permitted to a 2% increase above the prior year's budget. Increases for school districts also include adjustments for increased enrollment. Levy limit (not coded in the simulation). N.J.S.A 40A: 4-45.1 et seq; N.J.S.A. 40A: 4-45.44 - 45.47; N.J.S.A. 18A:7F-37 - 42.

New Mexico

Property Tax Rate Cap: The state constitution limits property tax rate totals that have not been approved by the voters to 20 mills. Statute distributes the rate totals as 11.85 to counties, 7.65 mills to municipalities, and .5 mills to school districts. Rate limit. N.M. Stat. § 7-37-7; N.M. Const. art. VIII, § 2.

Assessment Limitation: The increase in taxable value for residential property is limited to the greater of: (1) 103% of the value in the tax year that was immediately prior to the tax year in which the property is being valued, or (2) 106.1% of the value in the tax year that was 2 years prior to the tax year in which the property is being valued. Assessment limit. N.M. Stat. § 7-36-21.2.

Growth Control: Annual growth in property tax revenues is limited to an annual increase measured by the "Growth Control Factor". The factor is the annual increase in the implicit price deflator, not to exceed 5% plus the percentage increase in property value attributable to new construction and improvements to existing property. The growth factor for 2016 is 0.00%. Revenue limit. N.M. Stat. § 7-37-7.1(A)(4).

Yield Control: After reassessment, yield control reduces certain property tax rates from the previous tax rates so that the new rates when applied to the new values yields only the increased revenue allowed based on the growth control factor. The new rates are calculated separately for residential and non-residential properties. Levy limit. N.M. Stat. § 7-37-7.1(A).

New York

Limits on Assessed Value Increases: These limitations apply only in New York City and Nassau County. Increases of the assessed values for individual parcel are based on the class of property. For Class 1 properties, mostly 1, 2 and 3 family or unit residential properties, in both New York City and Nassau county, cannot increase by more than 6% per year or 20% over five years, unless the value increases are due to new construction or renovations. In addition, assessed value cannot exceed 6% of the home's market value. For Class 2 property are all residential properties, including

rentals, coop and condominium apartments. New York City divides the For building with 10 units or fewer, the assessed value cannot increase by more than 8% from the year before or 30% over 5 years , which ever is lower and is capped at 45% of market value, For Class 2 property with 11 units or more, as well as Class 4 properties which includes office, retail, loft, factory, and warehouse properties, increases in assessed value are phased in over 5 years. When a new assessment is made each year, any additional change is again spread out over 5 year period. In Nassau County, assessment increases for all classes other than Class 1, residential, and Class 3, utility, are phased in over 5 years. When a new assessment is made each year, any additional change is again spread out over 5 year period. Assessment limit (not coded in the simulation). N.Y. R.P.T Law § 1805.
Constitutional Limits on Real Estate Taxes for Local Purposes: The amount raised by taxes on real estate in any fiscal year shall not exceed an amount equal to the following percentages of the average full valuation of taxable real estate: for counties, 1.5-2%; for cities and villages, 2%; and, for the city of New York and the counties therein, 2.5%. Levy limit. NY CLS Const Art VIII, § 10.
Property Tax Cap: Annual growth of local property tax levy is limited to 2% or the rate of inflation. It is applied to all independent school districts and all local governments outside of New York City and the school districts of Buffalo, Rochester, Syracuse, and Yonkers. The allowable levy growth for local governments with fiscal year ending December 31, 2016 is 0.73%. Exclusions from the levy limit include expenditures for employers contributions to New York State and Local Employees' Retirements System and the Police and Fire Retirement System and the Teachers' Retirement System in excess of 2%, school district capital expenditures and court orders or judgements in excess of 5% of prior year's levy. Levy limit (not coded in the simulation). N.Y. Gen. Mun. Law §3-c(3)(b)(i); N.Y. Education Law §2023-a.

North Carolina

Property Tax Rate Cap: Counties and municipalities may levy taxes for general administration and public services up to a combined rate of 15 mills. Rate limit. N.C. Gen. Stat. § 153A-149.

North Carolina

Schedule of Levy Limitations (Levy Limit): Unless authorized by the electors of the school district, a school district may not impose levies greater than the amount for the prior school year plus 12% up to a general fund levy of 70 mills, excluding debt service. For taxable years after 2013, the school board may levy no more than 12 mills for miscellaneous purposes and expenses. The school board may levy no more than 3 mills for deposit into a special reserve fund. Levy limit. N.D. Cent. Code § 57-15-14; 57-15-14.2.

Schedule of Levy Limitations (Rate Limit): For counties, the rate for general fund is limited to 60 mills, increasing from 23 by combining 16 previously separate levies. Levies for 17 other specific funds remain. For cities, rates for general fund is limited to 105 mills increasing from 38 by combining 26 previously separate levies. Levies for 16 other specific funds remain. Townships may levy up to 18 mills. The limitations do not apply to levies for principal and interest on bonded debt. School districts may levy up to 70 mills. In addition to the rate limit, school district levies are limited to 12% increase over prior year. (See Levy Limit) If, for taxable year 2015, a county levied more than 60 mills for general fund purposes plus other levies consolidated into the general fund, it may levy the same number of mills for taxable year 2016. The number of mills in excess of 60 mills must be reduced by 25 percent each year beginning with taxable year 2017 so that by taxable year 2020, the county is levying no more than 60 mills for general fund purposes. Similar provisions apply to cities if levies are in excess of the 105 mills. School district levies approved by voters before 2009 must be reduced by 115 mills to receive state aid; levies that were approved after 2009 must be lowered by 40 mills to receive state aid; and levies placed on the ballot after 30 June 2013 must state that specific number of mills proposed and include a statement that the statutory general fund levy limitation is 70 mills. Rate limit. N.D. Cent. Code § 57-15-06; N.D. Cent. Code § 57-15-08; N.D. Cent. Code § 57-15-14; N.D. Cent. Code § 57-15-20.

Ohio

Overall 10 Mill Limitation: The aggregate property tax rates from all overlapping political jurisdictions cannot exceed 10 mills. This rate is applied to taxable value. Rate limit. Ohio Rev. Code § 5705.02; Ohio Rev. Code § 5705.07; Oh. Const. Art. XII, § 2.
Tax Reduction Factors: After revaluation, tax rates for the voter approved levies, those outside the 10 mill limit, are recalculated so that the approved rates generate the same amount of revenue after revaluation as before. Reduction factors are calculated separately for residential and agricultural properties (Class 1) and commercial and industrial (Class II) so that the property taxes remain in the same proportion after revaluation. Levy limit. Ohio Rev. Code § 319.301; Ohio Rev. Code § 5705.211; Ohio Rev. Code § 5713.041.

Oklahoma

Assessment Limitation: The increase in taxable value of real property is limited to 3% for homestead and agricultural properties. Values of all other real properties are limited to 5% per year. The limit does not apply if property is transferred, changed, or conveyed to another person or if improvements have been made to the property. Assessment limit. Okla. Stat. tit. 68, § 2817.1; Okl. Const. Art.

X, § 8B.
Property Tax Rate Cap: There is an aggregate rate limit to 15 mills, with a minimum of 5 mills for school districts. Counties shall levy an additional 4 mills for schools. School districts may levy up to 15 mills in addition with certification of the Board of Education. Rate limit. Okl. Const. Art. X, § 9.

Oregon

Measure 5 Overall Rate Limit: All general government operating taxes per property are limited to 10 mills of real market value and school operating taxes are limited to 5 mills. These limits are based on the real market value of the property, not maximum assessed value. Rate limit. Or. Rev. Stat. § 310.150; Ore. Const. Art. XI, § 11.
Measure 50 Permanent Tax Rate: Measure 50 established a permanent operating tax rate limit. This rate was established by a formula set out by the constitutional amendment based on tax levies and rates in place in 1997 and the tax cuts required by Measure 50. Rate limit. Or. Rev. Stat. §310.200 310.242; Or. Rev. Stat. §280.060; Ore Const. Art. XI §11.
Measure 50 Maximum Assessed Value: The annual increase in maximum assessed value of property is limited to 3% of the prior year's assessed value. Also, property is NOT reassessed when it changes ownership. Assessment limit. Or. Rev. Stat. § 308.146; Ore. Const. Art. XI, § 11.

Pennsylvania

Property Tax Levy Cap: For school districts, annual property tax revenue increases are limited to the the percentage increase in the statewide average weekly wage for the preceding year and the federal employment cost index for elementary and secondary schools. For other jurisdictions, following county reassessment or change in the established predetermined ratio, political subdivisions in counties of second A and third class must reduce the rate so that the amount levied does not exceed 110% of the prior year levy, excluding growth from new construction and improvements. For counties of the fourth through eighth class, levies cannot exceed 105% of the prior year levy. The limit may be exceeded with court approval. Levy limit. 53 P.S. § 6926.327; 53 P.S. § 6926.333; 72 P.S. § 5020-402(b).
Property Tax Rate Cap: Tax rates of political subdivisions cannot exceed 12 mills of market value. Maximum rates per $1 of assessed value include: for counties, second class (Allegheny), 25 mills; for counties, second class A (Bucks, Delaware, and Montgomery), 30 mills; for counties, third class through eighth class, 25 mills; for cities, third class, 25 mills; for cities, third class, under certain circumstances, 30 mills; for boroughs, 30 mills; for institution districts, 10 mills; for townships, first

class, 30 mills; for townships, second class, 14 mills; for school districts, first class A (Pittsburgh), 32.25 mills; for school districts, second, third, and fourth class, 25 mills. School districts can levy additional millage to pay salaries and debt service. Rate limit. 53 P.S. § 6924.320; Pa. Const. Art VIII, § 1.

Rhode Island

Municipal Property Tax Levy Cap: A city or town may levy a tax in an amount not more than 4.00% in excess of the amount levied and certified by that city or town for the prior year. Levy limit. R.I. Gen. Laws § 44-5-2; R.I. Gen. Laws § 44-5-2.1.

South Carolina

Maximum Millage Cap: Increases in the local millage rate for general operating purposes from the prior year's rate are limited to the increase in the consumer price index plus the local entity's percentage population increase in the previous year. In the year in which a reassessment program is implemented, the rollback millage must be used in lieu of the previous year's millage rate. Rate limit. S.C. Code Ann. § 6-1-320; S.C. Code Ann. § 12-37-251(E).
Real Property Valuation Reform Act: Any increase in the fair market value of real property attributable to the periodic countywide appraisal and equalization program is limited to 15% within a 5-year period.

South Dakota

Property Tax Levy Cap: Non-school taxing districts shall limit their property tax revenue growth to the lesser of 3% or the rate of inflation, excluding new property and debt service. Any new taxing district is exempt from this limitation for a period of 2 years immediately following its creation. Levy limit. S.D. Codified Laws § 10-13-35; S.D. Codified Laws § 10-13-36.
School District Property Tax Rate Cap: For taxes payable in 2016, the maximum rates for general fund purposes that a school district may impose are 1.568 mills on agricultural property, 4.75 mills on owner-occupied single-family dwellings, and 8.727 mills on all other property. These maximum rates are set annually by the legislature. Rate limit. S.D. Codified Laws § 10-12-42 - § 10-12-43.

Texas

Property Tax Levy Cap with Truth in Taxation Override: Before setting its tax rate, a county, city, or special district must calculate two rates: the "effective tax rate" and the "rollback rate." The "effective tax rate" is the tax rate that, if applied to the current tax base exclusive of new property, would generate the same amount of revenue as the prior year. The "rollback rate" is the tax rate that, if applied to the current tax base exclusive of new property, would increase revenue for maintenance and operations by 8%. Levy limit. Tex. Tax Code § 26.04; Tex. Tax Code § 26.07 - § 26.08; Tex. Const. Art. VIII, §21.

Property Tax Rate Cap: For counties and municipalities, the tax rate may not exceed 8 mills for general fund, permanent improvement fund, road and bridge fund, and jury fund purposes. For school districts, the maintenance and operations tax rate may not exceed 10 mills, or up to 10.4 mills by choice of the school district's governing body. Rate limit. Tex. Educ. Code § 45.003; Tex. Const. Art. VIII, § 9.

Homestead Cap Value: The annual increases in the appraised value of a residence homestead for a tax year may not exceed the lesser of: (1) the market value of the property; or (2) the sum of: (a) 10% of the appraised value of the property for the preceding tax year, (b) the appraised value of the property for the last year, and (c) the market value of all new improvements to the property. Assessment limit. Tex. Tax Code § 23.23; Tex. Const. Art. VIII §1.

Utah

Levy Limit with Truth in Taxation Override: A taxing entity is required to calculate the certified tax rate which will provide the same amount of property tax revenue as was charged in the previous year. The governing body of each taxing entity must adopt a rate that does not exceed the certified rate. Levy limit. Utah Code Ann. § 59-2-909; Utah Code Ann. § 59-2-919; Utah Code Ann. §59-2-924(3)(a).

Property Tax Rate Cap: The tax rate shall not exceed 3.2 mills for counties with a total taxable value of more than $100 million; otherwise, for counties, 3.6 mills and for municipalities including charter cities, 7 mills combined levies. Each school district's minimum basic tax rate may not exceed the certified revenue levy set by the State Tax Commission and the State Office of Education. Rate limit. Utah Code § 10-5-112; Utah Code § 10-6-133; Utah Code § 53A-17a-103; Utah Code § 53A-17a-135; Utah Code § 53A-17a-143; Utah Code § 59-2-908; Utah Code § 59-2-914.

Virginia

Levy Limit with Truth in Taxation Override: When an annual appraisal, biennial appraisal, or general valuation of property would increase total property taxes by 1% or more, using current regular levy rates, the rate shall be reduced to produce no more than 101% of the previous year's tax levy. This rate is called the reduced or lowered tax rate. Levy limit. Va. Code Ann. § 58.1-3321.

Washington

101 Percent Limit (Initiative 747): Without special ordinance of governing board, taxing districts are allowed to levy only as much as in the prior year, plus new construction. Passage of an ordinance allows the district with population of 10,000 or more to increase the the levy by the lessor of 1% or the rate of inflation, measured by the implicit price deflator. For smaller districts, the increase is 1%. In both cases, the increase is calculated on the highest lawful levy of the district since 1985. Levy limit. Wash. Rev. Code § 84.55.010; Wash. Rev. Code § 84.55.050; Wash. Rev. Code § 84.55.005; Wash. Rev. Code § 84.55.0101.
1% Constitutional Limit: Aggregate of all regular tax rate for all levies including state and local taxing districts, is limited to 1% of full and fair value, or 10 mills or $10.00 per $1,000 of full value. Rate limit. Wash. Rev. Code § 84.52.050; Wash Rev. Code § 84.52.043; Wash. Rev. Code § 84.55.010; Wash. Const. Art. VII, § 2.
Statutory Dollar Rate Limit: The maximum regular levy rates for both senior and junior taxing districts is 5.90per1000 of assessed value or 5.9 mills. Specific maximum rates for senior taxing districts are, for the state, for education purposes only, 3.6 mills; for counties, 1.8 mills; for road districts, 2.25 mills, which may be increased to 2.475 mills, if the total of county and road districts in the county does not exceed 4.05 mills; and, for municipalities, 3.375 mills. Levies for debt service of voter approved bonds and levies approved in excess of the 1% limit are not included under the 5.9 mill limit. Rate limit. Wash. Rev. Code §84.52.043; Wash. Rev. Code §84.52.054.

West Virginia

Overall Property Tax Rate Cap: Overall taxes by all taxing jurisdictions shall not exceed for for class II property, 10 mills; for class III property, 15 mills; and, for class IV property, 20 mills. Rate limit. W. Va. Code § 11-8-6; W. Va. Code § 11-8-16; W. Va. Code § 11-8-17; W. Va. Code § 11-3-9.
Levy Limit with Truth in Taxation Override: If an annual appraisal, triennial appraisal, or general valuation of property would increase the total property tax revenue by 1% or more using the current property tax rates, the rate must be proportionally reduced between the county and municipalities for all classes of property so that the revenue generated by property taxes will be the same as the prior year. Increases in valuation due to new construction, improvements, newly acquired personal property, or the start of recovery of natural resources are not included in this limit. Levy limit. W. Va. Code § 11-8-6e.

Wisconsin

School District Levy Cap: The maximum revenue limit is arrived at by adding the amount of state aid received from the state's general school aid programs and the district's property tax (excluding taxes levied for community support programs), dividing this sum by the average number of pupils enrolled in the 3 previous school years, and multiplying this total by the average number of pupils enrolled in the current school year and the previous 2 school years. Revenue limit (coded as levy limit in the simulation). Wis. Stat. § 121.91.

Property Tax Levy Limit: The property tax levy increase is limited to the valuation factor of any county or municipality (city, village, or town). The valuation factor is defined as a percentage equal to the percentage change in the jurisdiction's equalized value due to net new construction less improvements removed between the previous year and the current year. The permitted increase is 0% or the percentage change due to new construction less improvements removed. Levy limit. Wis. Stat. § 66.0602.

Wyoming

Property Tax Rate Cap: The tax rate shall not exceed, for the state, 4 mills for general fund, 1 mill for charitable organizations, and 12 mills for schools; for counties, 12 mills plus 6 mills for schools; for cities, 8 mills; and for school districts, 25 mills. Debt service limits are up to 1% of assessed value for the state debt; up to 2% for counties, up to 4% for cities and towns, and up to 4% for school districts. Rate limit. Wyo. Stat. § 21-13-303; Wyo. Stat. § 39-13-104; Wyo. Const. Art. XV, § 4 § 6; Wyo. Const. Art. XV §15; Wyo. Const. Art. XV §17; Wyo. Const. Art. XVI, § 3; Wyo. Const. Art. XVI, § 4; Wyo. Const. Art. XVI, § 5.

Internet Appendix B Assessment Limits and the Tax-Price Gap

As we show in Section 3.3 and Table 3, assessment limitations contribute more to tax risk than any other type of tax limit. We attribute this large effect of assessment limitations to the dynamic described in Section 2.2: assessment limitations can lead to rising tax obligations during periods of declining home prices following an extended period of economic booms. And this dynamic is reflected in the divergence between tax-price adjustment gaps for assessment-limitation states and non-assessment-limitation states, as depicted in Figure 2d in the main paper.

Given the significant effect of assessment limits, we present additional analyses in this section on how assessment limits affect parcel-level property tax liabilities and how the tax-price adjustment gap affects mortgage distress. The tax-price adjustment gap has a few drawbacks. First, it lacks a clean economic interpretation. In contrast, the policy-induced covariance risk clearly presents the economic mechanism through which property tax limitation affects mortgage distress. Second, we cannot use it to address the effects of interactions among different features of states' property tax regimes, or the stringency of those regimes. Nevertheless, we view this exercise as providing additional reduced-form evidence of the importance of tax limitations for households' financial well-being.

Concretely, our analysis proceeds in three steps. First, we confirm that assessment limitations affect tax liabilities in a predictable manner as a function of homeowner tenure and the state of the economy. Next, we show that assessment limitations are associated with higher probabilities of mortgage distress under certain conditions. Finally, we demonstrate that when tax liabilities grow faster than housing values and the tax-price gap widens (e.g., during a market downturn in assessment limitation states), mortgage distress rises. For each of these tests, we employ methods and data similar to those used in our main analyses.

Our first empirical specification tests how changes in housing prices affect property tax liabilities, conditional on whether properties are subject to assessment limitations and the number of years elapsed since the last change of ownership (i.e., tenure). In particular, we expect the percent change in annual tax liability, $\%\Delta Tax$, to be generally less responsive to changes in market values, $\%\Delta Price$, in states with assessment limits and for new homeowners in assessment limitation states to experience relatively large increases in tax liability due to taxable value uncapping. To test these stylized facts, we use the following estimating equation

$$
\begin{aligned}
\%\Delta\text{Tax}_{i,t} = {} & \beta_0 + \beta_1 \mathbb{1}(\text{AssessmentLimit})_{s,t} + \beta_2 \% \, \Delta \, \text{Price}_{i,t} \\
& + \beta_3 \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \% \, \Delta \, \text{Price}_{i,t} \\
& + \theta^k \mathbb{1}(\text{Tenure})_{i,t} + \gamma^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \\
& + \rho^k \mathbb{1}(\text{Tenure})_{i,t} \times \% \, \Delta \, \text{Price}_{i,t} \\
& + \delta^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \% \, \Delta \, \text{Price}_{i,t} \\
& + \boldsymbol{X}_{i,t} + \boldsymbol{X}_{k,t} + \boldsymbol{X}_{s,t} + \text{FE} + \varepsilon_{i,t},
\end{aligned}
\tag{IA.B1}
$$

where an observation is a property i in year t, and property i is in a state s and grid cell j. Tenure is a categorical variable given by a vector of indicator variables that denote different durations of ownership. Due to the nature of the assessment limits, their effects can differ depending on how long an owner has had the property, which we capture through the interaction terms and the vector of coefficients δ^k. $\boldsymbol{X}_{i,t}$, $\boldsymbol{X}_{k,t}$, and $\boldsymbol{X}_{s,t}$ are control variables on property-, census-track-, and state-levels, respectively, specified in Table 4 in the main table.

Results from this first-stage test are shown in Table IA.B1. As shown in column 1, properties in assessment limitation states experience larger overall changes (roughly 0.5 percentage points) in annual property tax obligations than their counterparts in adjacent no-limit states. However, the rate at which changes in house prices are passed through to tax obligations in all states is considerably less than 1. This pair of results likely indicates that tax assessments tend to adjust slowly and infrequently across all states, including those with notional market-value assessment regimes.[1] As a result, the combination of taxable value uncapping for newly sold properties and regular capped taxable value adjustments evidently results in larger average changes in annual tax obligations in states with acquisition value assessment limits. In column 2, we allow changes in house prices to be passed through to tax liability at different rates in assessment limitation states. We further break down the average rate of property tax increases in these states by homeowner tenure. Relative to homeowners with at least 6 years of tenure (i.e., the omitted category), new homeowners in assessment limitation states experience tax increases that are approximately 5 percentage points greater, on average, consistent with a relatively modest "pop-up tax" due to taxable value uncapping during this time period. Furthermore, changes in house prices are passed through to property taxes at similar rates in states with and without assessment limitations *on average*. However, as shown in column 3, this latter effect masks the fact that longer-tenured

[1] As noted in the last column of Table 1, a large number of states only reappraise property every four years or more, and some, like Pennsylvania, have no fixed schedule for doing so.

homeowners in assessment limitation states experience significantly attenuated (if not reversed) changes in tax liability in relation to housing prices relative to new homeowners, consistent with the discussion in Section 2.2 of asymmetric tax adjustments.

Next, we evaluate the reduced form effect of assessment limitations on the probability of mortgage distress at the property i and year t level, which we estimate as a linear probability model:

$$\begin{aligned}\mathbb{1}(\text{Distressed})_{i,t} = {} & \beta_0 + \beta_1 \mathbb{1}(\text{AssessmentLimit})_{s,t} + \beta_2 \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\ & + \beta_3 \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} + \theta^k \mathbb{1}(\text{Tenure})_{i,t} \\ & + \gamma^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \\ & + \rho^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\ & + \delta^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\ & + \beta_2 \mathbb{1}(\text{NonJudicial Review})_{s,t} + \beta_3 \mathbb{1}(\text{Recourse})_{s,t} \\ & + \boldsymbol{X}_{i,t} + \boldsymbol{X}_{k,t} + \boldsymbol{X}_{s,t} + \text{FE} + \varepsilon_{i,t}. \end{aligned} \tag{IA.B2}$$

We again allow the effect of assessment limitations to differ by homeowner tenure. We further allow these effects to differ depending on whether house prices decreased from the prior period to capture possible asymmetric effects. We also augment our vector of controls to incorporate additional factors related to strategic default incentives and proxies for trigger events, exactly as in Equation 4 in Section 4.2.

As shown in the first column of Table IA.B2, long-tenured homeowners (i.e., the reference category) in assessment limitation states are significantly less likely to experience mortgage distress (conditional on LTV, age, etc.). Though this effect is at least partially offset among short-tenured homeowners or homeowners of unknown tenure. Meanwhile, a reverse pattern with respect to tenure and mortgage distress appears to hold in states without assessment limitations. The contrast between these two results, as a function of tenure, likely reflects the impact of taxable-value uncapping for new homeowners in states with assessment limitations. The results in column 1 also imply that falling house prices increase the probability of distress, without any statistically significant difference between states with and without assessment limits.

We incorporate a complete set of interactions between assessment limit, tenure, and directional price change indicators in column 2. We see that new homeowners are at significantly lower risk of distress in states without assessment limits (and even more so when prices are falling). In contrast, new and short-tenured homeowners are at significantly higher risk of distress in assessment limitation states (especially when house prices are falling). Overall, homeowners with the highest mortgage distress are those in assessment limitation states during market downturns with a homeownership tenure of 2-5 years. This tenure is long enough to have potentially enjoyed a few years of capped taxable growth prior to the downturn, but not long enough to have accumulated a significant tax reduction relative to what market values would dictate.

Finally, in order to investigate the role of asymmetric tax adjustments more directly, we replicate the preceding analysis of mortgage distress, replacing the indicator for falling house prices with a measure of the property-specific tax-price adjustment gap discussed in Section 2.2. Having demonstrated above that assessment limitations affect changes in annual property tax obligations in predictable ways, this is akin to a "second-stage" analysis. The main variable of interest, the tax-price adjustment gap, is defined as the difference between the percent change in annual tax liability and the percent change in house prices. This measure incorporates the primary mechanism through which assessment limits deviate from market-value-based annual assessments. Absent any changes in statutory tax rates, the tax-price adjustment gap should equal zero under market-value-based annual assessments. As a result, non-zero values hence represent the extent to which changes in property tax liabilities deviate from such a regime.

As shown in column 1 of Table IA.B3, larger tax-price gaps are responsible for a higher probability of mortgage distress everywhere, but this effect is significantly more pronounced in assessment limitation states and is virtually twice as large. Furthermore, this effect is again largest for the 25 percent of homeowners who have been in their homes 2-5 years, and more than twice as large for those in assessment limitation states (column 2). Otherwise, assuming a zero tax-price gap, new homeowners are generally at the lowest risk of distress in states without assessment limits, with risk gradually increasing for longer-tenured homeowners thereafter. But this pattern is reversed mainly in assessment limitation states, presumably due to the significant effect of taxable value uncapping and subsequent capped taxable value growth.

As noted in Section 2.2 and documented in Figure 2d, the average tax-price adjustment gap in assessment limitation states peaked at nearly 15 percentage points in 2008 and 2009. Rescaling the overall partial effect of the tax price gap for homeowners in assessment limitation states who have resided in their homes 2-5 years by this average 15 percentage point amount translates to an implied increase in the probability of distress of approximately 0.29 percentage points (i.e., $(0.008 + 0.011) * 15 = 0.285$). For comparison, homes with an LTV of 91 to 160 percent or higher face a 2.2 to 2.9 percentage-point increase in the probability of distress relative to those with an LTV below 25 percent. Living in a heavily outdated home (last renovated 60 or more years ago) increases the probability of distress by roughly 0.15 percentage points, presumably due to a higher risk of unanticipated repairs. As such, during the worst of the Great Recession, the average short-tenured homeowner in assessment limitation states saw an increased likelihood of mortgage distress as a result of asymmetric tax adjustments of a comparable magnitude to nearly twice the effect of owning a home in disrepair, or one tenth as large as the effect of being severely underwater on one's mortgage. These effect sizes are comparable to those obtained in relation to the average increase in covariance risk due to assessment limitations, as discussed in Section 4.3.

Table IA.B1: **The Effects of Assessment Limitations on Changes in Annual Property Taxes**

This table presents the estimates of Equation IA.B1 using the most saturated specification in column 8 of Table 4 in the main paper. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Y = %ΔTax	(1)	(2)	(3)
I[AssessmentLimit=1]	0.510***	0.303	0.303
	(0.195)	(0.217)	(0.217)
Tenure			
< 2 years	1.878***	1.027***	1.027***
	(0.078)	(0.056)	(0.056)
2-5 years	-0.033	0.155***	0.154***
	(0.027)	(0.019)	(0.019)
Unknown	-0.025	-0.037	-0.036
	(0.052)	(0.057)	(0.057)
% Δ Price	0.001***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)
I[AssessmentLimit=1] × % Δ Price		0.000	0.001
		(0.000)	(0.001)
Tenure × I[AssessmentLimit=1]			
< 2 years		4.966***	4.958***
		(0.326)	(0.326)
2-5 years		-1.113***	-1.113***
		(0.106)	(0.106)
Unknown		0.057	0.057
		(0.131)	(0.131)
Price	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
ETR_{t-1}	-0.660***	-0.661***	-0.661***
	(0.019)	(0.019)	(0.019)
Tenure × % Δ Price			

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Y = %ΔTax	(1)	(2)	(3)
> 5 years			0.000
			(0.000)
< 2 years			
2-5 years			0.000
			(0.000)
Unknown			0.000
			(0.000)
Tenure × I[AssessmentLimit=1] × % Δ Price			
> 5 years			-0.002**
			(0.001)
< 2 years			
2-5 years			-0.001
			(0.001)
Unknown			-0.001
			(0.001)
Observations		23,299,480	
R-squared	0.432	0.433	0.433

Table IA.B2: **The Effects of Assessment Limitations on Mortgage Distress**

This table presents the estimates of Equation IA.B2 using the most saturated specification in column 8 of Table 4 in the main paper. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
I[AssessmentLimit=1]	-0.851***	
	(0.055)	
I[Δ Price < 0]	0.119***	
	(0.026)	
I[AssessmentLimit=1] × I[Δ Price < 0]	0.032	
	(0.022)	
Tenure		
< 2 years	-0.907***	-0.791***
	(0.101)	(0.102)
2-5 years	-0.389***	-0.447***
	(0.072)	(0.048)
Unknown	1.553***	1.669***
	(0.152)	(0.139)
Tenure × I[AssessmentLimit=1]		
< 2 years	0.287***	0.030
	(0.059)	(0.060)
2-5 years	0.436***	0.090***
	(0.053)	(0.034)
Unknown	0.196**	0.015
	(0.077)	(0.067)
Tenure × I[Δ Price < 0]		
< 2 years		-0.160**
		(0.077)
2-5 years		0.200**

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
		(0.086)
Unknown		-0.148**
		(0.074)
Tenure × I[AssessmentLimit=1]		
× I[Δ Price < 0]		
< 2 years		0.264***
		(0.057)
2-5 years		0.362***
		(0.070)
Unknown		0.033
		(0.061)
LTV		
0.27 - 0.65	-0.069***	-0.065***
	(0.015)	(0.015)
0.65 - 0.9	0.633***	0.639***
	(0.021)	(0.021)
0.9 - 1.6	2.214***	2.191***
	(0.038)	(0.038)
> 1.6	2.825***	2.809***
	(0.072)	(0.071)
Unknown	-1.602***	-1.589***
	(0.034)	(0.034)
Age		
10-19 years	-0.417***	-0.413***
	(0.032)	(0.032)
20-59 years	-0.395***	-0.390***
	(0.032)	(0.032)
60-99 years	-0.245***	-0.238***
	(0.035)	(0.035)
>99 years	-0.036	-0.027
	(0.042)	(0.042)
Unknown	-0.185	-0.165

Continued on next page

Y = Pr(Distressed$_t$=1), Y $\in$ {0, 100}	(1)	(2)
	(0.133)	(0.133)
Renovation Age		
11-32 years	-0.023*	-0.015
	(0.013)	(0.013)
33-59 years	-0.002	0.009
	(0.015)	(0.015)
> 59 years	0.167***	0.177***
	(0.021)	(0.021)
Unknown	-0.385***	-0.380***
	(0.130)	(0.130)
Price	-0.000***	-0.000***
	(0.000)	(0.000)
Lagged ETR	0.036***	0.038***
	(0.005)	(0.005)
I[Recourse=1]	0.134	
	(0.297)	
I[NonJudicialReview=1]	-0.523***	
	(0.100)	
I[Recourse=1] × I[Δ Price < 0]	-0.015	
	(0.025)	
I[NonJudicialReview=1] × I[Δ Price < 0]	0.047**	
	(0.018)	
Tenure × I[Recourse=1]		
< 2 years	-0.075	-0.146*
	(0.080)	(0.078)
2-5 years	0.153**	-0.021
	(0.068)	(0.043)
Unknown	-0.376**	-0.455***
	(0.157)	(0.140)
Tenure × I[NonJudicialReview=1]		
< 2 years	0.046	-0.026
	(0.076)	(0.077)

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
2-5 years	0.242***	0.055*
	(0.059)	(0.032)
Unknown	1.182***	0.968***
	(0.126)	(0.093)
Tenure × I[Recourse=1]		
× I[Δ Price < 0]		
< 2 years		0.107
		(0.071)
2-5 years		0.282***
		(0.085)
Unknown		0.111
		(0.079)
Tenure × I[NonJudicialReview=1]		
× I[Δ Price < 0]		
< 2 years		0.128**
		(0.056)
2-5 years		0.415***
		(0.083)
Unknown		0.426***
		(0.097)
Observations	23,299,465	
R-squared	0.028	0.028

Table IA.B3: **The Effects of Tax-Price Adjustment Gap on Mortgage Distress**

This table presents the estimates of the effects of the tax-price adjustment gap, Δ Tax Gap (defined in Section 2.2), on mortgage distress using the most saturated specification in column 8 of Table 4 in the main paper. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
Δ Tax Gap	0.006***	0.000
	(0.001)	(0.001)
I[AssessmentLimit=1] ×Δ Tax Gap	0.003***	
	(0.001)	
Tenure		
< 2 years	-0.939***	-0.874***
	(0.036)	(0.105)
2-5 years	-0.082***	-0.325***
	(0.022)	(0.075)
Unknown	1.694***	1.818***
	(0.050)	(0.172)
Tenure × I[AssessmentLimit=1]		
< 2 years		0.125**
		(0.058)
2-5 years		0.326***
		(0.049)
Unknown		0.024
		(0.081)
Tenure ×Δ Tax Gap		
2-5 years		0.008***
		(0.001)
> 5 years		0.005***
		(0.001)

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
Unknown		0.010***
		(0.001)
Tenure × I[AssessmentLimit=1]		
×Δ Tax Gap		
< 2 years		0.002
		(0.001)
2-5 years		0.011***
		(0.002)
> 5 years		0.003***
		(0.001)
Unknown		0.010***
		(0.002)
% Δ Price	-0.000	-0.000
	(0.000)	(0.000)
I[AssessmentLimit=1] × % Δ Price	-0.000	-0.000
	(0.000)	(0.000)
LTV		
0.25 - 0.6	-0.087***	-0.084***
	(0.016)	(0.016)
0.6 - 0.91	0.630***	0.639***
	(0.021)	(0.021)
0.91 - 1.6	2.230***	2.231***
	(0.038)	(0.038)
> 1.6	2.871***	2.882***
	(0.071)	(0.071)
Unknown	-1.647***	-1.641***
	(0.034)	(0.035)
Age		
10-19 years	-0.426***	-0.423***
	(0.033)	(0.033)
20-59 years	-0.396***	-0.402***
	(0.032)	(0.033)

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
60-99 years	-0.248***	-0.253***
	(0.036)	(0.036)
>99 years	-0.021	-0.025
	(0.043)	(0.043)
Unknown	-0.155	-0.151
	(0.133)	(0.133)
Renovation Age		
11-32 years	-0.020	-0.016
	(0.013)	(0.013)
33-59 years	-0.001	0.004
	(0.016)	(0.016)
> 59 years	0.152***	0.154***
	(0.020)	(0.020)
Unknown	-0.262**	-0.262**
	(0.129)	(0.129)
Price	-0.000***	-0.000***
	(0.000)	(0.000)
Lagged ETR	0.051***	0.049***
	(0.005)	(0.005)
I[Recourse=1]	-0.097	-0.147
	(0.339)	(0.431)
I[NonJudicialReview=1]	0.032	-0.277***
	(0.087)	(0.104)
Tenure × I[Recourse=1]		
< 2 years		-0.094
		(0.083)
2-5 years		0.127*
		(0.071)
Unknown		-0.563***
		(0.175)
Tenure × I[NonJudicialReview=1]		
< 2 years		0.007

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Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)
		(0.077)
2-5 years		0.200***
		(0.061)
Unknown		1.129***
		(0.130)
I[Recourse=1] × % Δ Price	0.000	0.000
	(0.000)	(0.000)
I[NonJudicialReview=1] × % Δ Price	0.000	-0.000
	(0.000)	(0.000)
Observations	22,663,442	
R-squared	0.027	0.028

Internet Appendix C Effects of Tax Changes

We benchmark our analysis against previous studies by Hayashi (2020) and Wong (2023), and highlight the advantages of our novel measure, ΔRisk. We repeat the empirical specifications in Table 4 but instead use observed parcel-level year-over-year percent changes as the main independent variable, which we term %ΔTax. We standardized %ΔTax to have an in-sample mean of 0 and a standard deviation of 1 (see the summary statistics in Table 2 in the main table). Table IA.C1 presents the results.

Under the most saturated specification (Column 8), a one standard deviation increase in %ΔTax (i.e., a 17.3 percent increase in tax liability, or $590) implies a 0.06 percentage point increase in the probability of mortgage distress. Equivalently, this implies that a $1,000 increase in annual tax liabilities raises the probability of distress by 7.2 percent. This magnitude is comparable to prior work. For comparison, Hayashi (2020) finds that a $1,000 increase in annual tax payments results in a 0.1 percentage point (5.6 percent) increase in the probability of mortgage default due to property reassessments in Maryland. Wong (2023) extends a similar analysis to nine states and reports that a $1000 increase in annual property tax payments due to countywide reassessment is associated with a 0.67 percentage point (15 percent) increase in the probability of 30-day mortgage delinquency, 11 months after the onset of increased escrow payments.[1] Our estimates of the effect of Tax Growth are thus comparable to Hayashi (2020) and Wong (2023), despite material differences in our research design and geographic coverage.

Examining the effect of changes in tax payments on mortgage distress nevertheless neglects two important considerations. First, tax payments are affected by factors beyond tax policy alone. These include both exogenous and endogenous influences that may affect taxpayers' assessed values or applicable tax rates (e.g., local economic conditions, investments in home renovations, whether a home is used as a primary residence, etc.). Second, this analysis does not distinguish between increases in tax liability that occur during market booms and those that occur during market downturns. This timing difference represents a significant source of risk beyond simple changes in tax levels. It is therefore difficult to evaluate the effects of specific policies on mortgage distress by focusing on changes in tax payments. We address the first issue (the potential endogenous variation in observed liabilities) using our property tax simulation in Section 3.2. We address the second issue and highlight the timing effect with our decomposition of simulated liabilities in Section 3.1. As a result, we prefer and present the main specification in Table 4 in the main paper.

[1] A direct comparison of effect sizes is complicated by the fact that Wong (2023) focuses exclusively on mortgage-holding households with tax escrow accounts. In contrast, our sample consists of all homeowners, including those without mortgages. The unconditional probability of mortgage delinquency reported by Wong (2023) is roughly 2.7 times higher than the distress probability we observe in our sample.

Table IA.C1: **Mortgage Distress and Changes in Annual Tax Liability**

This table replicates the analysis in Table 4 of the main paper, using a different main independent variable of interest, %ΔTax, which is calculated as the percent changes in annual tax liability at the parcel level. The estimation includes the comprehensive set of controls shown in Table 4, which is not tabulated here for brevity. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
%ΔTax	0.036	0.035	0.026	0.038***	0.036***	0.027**	0.062***	0.061***
	(0.025)	(0.021)	(0.020)	(0.014)	(0.013)	(0.012)	(0.017)	(0.018)
FE and Controls:								
County pair FE	x	x	x					
10 km^2 grid FE				x	x	x		
10 km^2 grid × Year FE							x	x
Controls		x	x		x	x		x
Year FE			x			x		
R-squared	0.004	0.017	0.018	0.005	0.018	0.019	0.010	0.023
Observations		31,209,231			31,209,241		31,209,241	

Internet Appendix D Additional Tables

This section presents tables that are not shown in the main paper for brevity.

Table IA.D1: **The Heterogeneous Effects of Policy-Induced Covariance Risk on Mortgage Distress**

This table presents the estimates of the heterogeneous effects of the policy-induced covariance risk, ΔRisk, on mortgage distress using the most saturated specification in column 8 of Table 4 in the main paper. The conditional effects for each subsample are also presented in Figure 10. The sample includes all residential properties in the continental U.S. (excluding nondisclosure states) within 20 km of the nearest state border from 2006 to 2016 (see Appendix C for details on sample construction). Standard errors in parentheses are clustered by county pair in columns 1 to 3 and are clustered by 10 km^2 grid cell in columns 4 to 8. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1.

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
ΔRisk	0.342	0.312	0.229	-0.060
	(0.209)	(0.217)	(0.382)	(0.224)
ΔLevel	0.265	0.273	0.049	-0.267
	(0.172)	(0.175)	(0.306)	(0.188)
I[HighAGI=1]	-0.013			
	(0.075)			
I[HighAGI=1] × $\Delta Risk$	0.030			
	(0.069)			
I[HighAGI=1] × ΔCE	0.033			
	(0.068)			
I[MajorityBlack=1]	0.808*			
	(0.469)			
I[MajorityBlack=1] × $\Delta Risk$	0.782***			
	(0.207)			
I[MajorityBlack=1] × ΔCE	0.584***			
	(0.163)			
I[MajorityLatino=1]	-0.372			
	(0.261)			
I[MajorityLatino=1] × $\Delta Risk$	-0.016			
	(0.181)			
I[MajorityLatino=1] × ΔCE	0.041			
	(0.152)			

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Y = Pr(Distressed$_t$=1), Y $\in \{0, 100\}$	(1)	(2)	(3)	(4)
AR $\times$ $\Delta Risk$				
$\leq 0.5\times$				
$0.5 - 0.75\times$		0.028		
		(0.039)		
$0.75 - 1.25\times$		0.072		
		(0.060)		
$1.25 - 2\times$		0.099		
		(0.076)		
$> 2\times$		0.251***		
		(0.080)		
AR $\times$ ΔCE				
$\leq 0.5\times$				
$0.5 - 0.75\times$		-0.024		
		(0.050)		
$0.75 - 1.25\times$		0.032		
		(0.064)		
$1.25 - 2\times$		0.065		
		(0.076)		
$> 2\times$		0.158**		
		(0.068)		
LTV $\times$ $\Delta Risk$				
0 - 0.25			0.088	
			(0.348)	
0.25 - 0.6			0.076	
			(0.353)	
0.6 - 0.91			0.321	
			(0.333)	
0.91 - 1.6			0.266	
			(0.244)	
> 1.6				

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Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
Unknown			0.135	
			(0.355)	
LTV × ΔCE				
0 - 0.25			0.106	
			(0.288)	
0.25 - 0.6			0.049	
			(0.289)	
0.6 - 0.91			0.310	
			(0.272)	
0.91 - 1.6			0.333	
			(0.204)	
> 1.6				
Unknown			0.298	
			(0.297)	
Tenure × $\Delta Risk$				
< 2 years				
2-5 years				0.507***
				(0.097)
> 5 years				0.628***
				(0.111)
Unknown				0.648***
				(0.156)
Tenure × ΔCE				
< 2 years				
2-5 years				0.560***
				(0.086)
> 5 years				0.674***
				(0.123)

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
Unknown				0.867***
				(0.172)
I[Recourse=1] × I[HighAGI=1]	-0.169**			
	(0.069)			
I[NonJudicialReview=1] × I[HighAGI=1]	0.011			
	(0.070)			
I[Recourse=1] × I[MajorityBlack=1]	-0.638			
	(0.464)			
I[NonJudicialReview=1] × I[MajorityBlack=1]	-0.132			
	(0.120)			
I[Recourse=1] × I[MajorityLatino=1]	0.297			
	(0.250)			
I[NonJudicialReview=1] × I[MajorityLatino=1]	0.497**			
	(0.211)			
I[Recourse=1] × AR				
≤ 0.5×				
0.5 – 0.75×		0.151***		
		(0.058)		
0.75 – 1.25×		0.059		
		(0.062)		
1.25 – 2×		0.112		
		(0.076)		
> 2×		0.366***		
		(0.090)		
I[NonJudicialReview=1] × AR				
≤ 0.5×				
0.5 – 0.75×		0.209***		
		(0.061)		
0.75 – 1.25×		0.134**		
		(0.064)		

Continued on next page

Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
1.25 – 2×		0.166**		
		(0.067)		
> 2×		-0.112		
		(0.070)		
I[Recourse=1] × LTV				
0.25 - 0.6			0.015	
			(0.060)	
0.6 - 0.91			0.040	
			(0.102)	
0.91 - 1.6			-0.075	
			(0.188)	
> 1.6			-0.033	
			(0.261)	
Unknown			-0.254	
			(0.182)	
I[NonJudicialReview=1] × LTV				
0.25 - 0.6			0.117**	
			(0.050)	
0.6 - 0.91			0.141	
			(0.090)	
0.91 - 1.6			0.431**	
			(0.168)	
> 1.6			0.231	
			(0.237)	
Unknown			-0.571***	
			(0.189)	
I[Recourse=1] × Tenure				
< 2 years				-0.245*
				(0.131)
2-5 years				-0.072
				(0.078)
Unknown				-0.363**

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Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
				(0.183)
I[NonJudicialReview=1] × Tenure				
< 2 years				-0.024
				(0.117)
2-5 years				0.027
				(0.089)
Unknown				0.649***
				(0.134)
AR				
≤ 0.5×				
0.5 – 0.75×		-0.192***		
		(0.065)		
0.75 – 1.25×		-0.138**		
		(0.070)		
1.25 – 2×		-0.230***		
		(0.082)		
> 2×		-0.647***		
		(0.099)		
LTV				
0.25 - 0.6	-0.084***	-0.100***	-0.129*	-0.081***
	(0.025)	(0.025)	(0.066)	(0.025)
0.6 - 0.91	0.649***	0.657***	0.562***	0.657***
	(0.042)	(0.042)	(0.108)	(0.042)
0.91 - 1.6	2.249***	2.287***	2.151***	2.264***
	(0.084)	(0.082)	(0.199)	(0.084)
> 1.6	2.838***	2.927***	2.770***	2.862***
	(0.147)	(0.149)	(0.282)	(0.148)
Unknown	-1.622***	-1.716***	-1.214***	-1.608***
	(0.081)	(0.079)	(0.174)	(0.081)
Price	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)

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$Y = Pr(Distressed_t = 1)$, $Y \in \{0, 100\}$	(1)	(2)	(3)	(4)
Lagged ETR	0.024***	0.070***	0.028***	0.024***
	(0.007)	(0.008)	(0.007)	(0.007)
Tenure				
< 2 years	-1.017***	-1.044***	-1.010***	-0.784***
	(0.066)	(0.071)	(0.064)	(0.150)
2-5 years	-0.115***	-0.133***	-0.104***	-0.055
	(0.042)	(0.043)	(0.040)	(0.090)
Unknown	1.487***	1.631***	1.511***	1.634***
	(0.065)	(0.071)	(0.070)	(0.182)
Age				
10-19 years	-0.315***	-0.318***	-0.303***	-0.314***
	(0.032)	(0.032)	(0.032)	(0.032)
20-59 years	-0.284***	-0.290***	-0.269***	-0.293***
	(0.036)	(0.037)	(0.036)	(0.037)
60-99 years	-0.114***	-0.129***	-0.094**	-0.119***
	(0.042)	(0.045)	(0.042)	(0.044)
>99 years	0.036	0.048	0.056	0.028
	(0.059)	(0.058)	(0.062)	(0.061)
Unknown	-0.072	-0.048	-0.039	-0.070
	(0.137)	(0.136)	(0.137)	(0.144)
Renovation Age				
11-32 years	-0.004	-0.004	-0.001	-0.001
	(0.015)	(0.015)	(0.015)	(0.015)
33-59 years	0.079***	0.069***	0.085***	0.082***
	(0.019)	(0.021)	(0.020)	(0.021)
> 59 years	0.247***	0.221***	0.260***	0.258***
	(0.027)	(0.026)	(0.028)	(0.028)
Unknown	-0.466***	-0.255*	-0.460***	-0.459***
	(0.142)	(0.131)	(0.140)	(0.148)
Average AGI	0.001***	0.001***	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Educ ≤ HS Pct	0.004**	0.005***	0.005***	0.005***

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Y = Pr(Distressed$_t$=1), Y ∈ {0, 100}	(1)	(2)	(3)	(4)
	(0.002)	(0.002)	(0.002)	(0.002)
Educ ≥ Bachelor's Pct	-0.010***	-0.009***	-0.009***	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
Population	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Population 18-24 Pct	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Population ≥ 25 Pct	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
White Pct	-0.006**	-0.007***	-0.007***	-0.007**
	(0.003)	(0.003)	(0.003)	(0.003)
Black Pct	0.005	0.006**	0.006**	0.006**
	(0.003)	(0.003)	(0.003)	(0.003)
Latino Pct	0.002	0.000	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
Asian Pct	-0.005	-0.007**	-0.007**	-0.007**
	(0.004)	(0.004)	(0.004)	(0.004)
I[Recourse=1]	0.327*	0.005	0.434**	0.307
	(0.182)	(0.204)	(0.204)	(0.198)
I[NonJudicialReview=1]	-0.274	-0.385	-0.031	-0.472
	(0.265)	(0.318)	(0.295)	(0.302)
Observations	31,209,061	30,721,170	31,209,241	31,209,241
R-squared	0.023	0.023	0.023	0.023