Asymmetric Risk of Housing Distress from Property Tax Limitations*

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Abstract

Homeowners face risk due to variation in annual property tax liabilities, which may result in financial distress and eventual mortgage foreclosure. By reducing the pro-cyclicality of property tax liabilities, we show that property tax limitations can expose households to greater systematic risk despite reducing intertemporal variation in tax amounts overall. We develop an innovative measure of tax policy risk using Arrow-Debreu securities and obtain simulated measures of risk that capture all of the key characteristics of states' property tax regimes. Using a state border discontinuity design and parcel-level data for the universe of U.S. residential properties, we show that a one standard deviation increase in tax policy risk ($\approx$ \$200) increases the probability of mortgage distress by approximately 0.19 percentage points. The magnitude of this unintended effect is comparable to the increase in probability of mortgage distress associated with owning a home in disrepair and is approximately one eighth as large as the effect of moving between the third and fourth quartiles of the loan-to-value distribution (near the threshold for being underwater).

Keywords: Property Taxation, Assessment Limits, Distress, Mortgage Default, Foreclosure.

JEL Classification: G21, G28, E44, K34, R20

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1 Introduction

Concerns over rapidly rising property tax obligations during housing market booms have resulted in the widespread adoption of property tax limitations. Politically, these limitations have proven extremely popular by protecting potentially illiquid homeowners from large increases in their property tax bills while ensuring more stable state and local tax revenues. As such, all but three U.S. states have implemented some type of property tax limitation (Anderson, 2006). These policies reduce intertemporal variation in property tax liabilities by limiting the growth rate of the tax base, tax rates, or their product. However, these policies can also have the perverse effect of increasing homeowners' exposure to systematic risk by allowing property tax liabilities to be higher than they would otherwise be during housing market contractions.

We investigate to what extent this unintended consequence of property tax limitations reallocates risk and leads to costly housing distress. Housing distress can lead to foreclosure and a host of negative externalities related to labor supply (Bernstein, 2021), aggregate demand (Mian et al., 2015), housing investment (Melzer, 2017), and housing prices (Campbell et al., 2011; Hartley, 2014). Indeed, as viewed through the lens of the seminal Domar and Musgrave (1944) risk-sharing result in capital taxation, even without triggering foreclosure, the disproportionate shifting of downside risk onto homeowners under these types of property tax limitations may also dampen housing investment and economic growth.

A priori, the effect of property tax and assessment limitations on mortgage distress is unclear. On the one hand, these limits decrease risk while housing prices are rising because they decrease uncertainty about future tax liabilities. When housing prices are falling, however, assessment limitations may allow liabilities to continue to increase if a parcel's tax assessment remains below its market value. Limits on the growth of aggregate tax revenues may similarly dampen the pro-cyclicality of homeowners' property tax liabilities. As a result, property tax limits have the potential to reduce mortgage distress when housing prices are rising and increase mortgage distress when housing prices are falling—precisely when households are otherwise likely subject to greater illiquidity and possible financial distress. Crucially, this implies that homeowners' property tax burdens from a risk standpoint depend not only on intertemporal variation in tax payments but also on the timing of these payments relative to the state of the economy (i.e., on the *covariance* between tax payments and macroeconomic conditions.)

We construct a measure of tax policy risk that reflects this insight and captures all key features of states' property tax regimes. We estimate the impact of tax policy risk on mortgage distress at the property level to determine whether its magnitude is large enough to warrant consideration in the implementation of state and local property tax systems. This strategy requires parcel-level data, which we obtain from ATTOM Data Solutions and Zillow (ZTRAX) for the universe of residential homes throughout the continental U.S. for the period 2006-2016. These data allow us to observe housing characteristics, property tax assessments and tax liabilities, sales, loan transactions, and foreclosure events. We use imputation and machine learning methods to estimate housing prices for all parcels in years without market transactions to obtain measures of parcel-specific loan-to-value ratios and effective tax rates and thereby isolate their impact on housing distress.

For purposes of identification, we exploit a state border discontinuity design consisting of three different types of border pairs based on county pairs, 10-, and 5 km^2 U.S. National Grid grid cells and focus on properties located within 20 miles of the nearest state border. We use these resulting border pairs and a within estimator to control for time-varying unobservable local market conditions, including labor or housing market shocks. Our estimation strategy thus compares properties within narrowly defined state border regions as a function of their exposure to tax policy risk resulting from states' varied property tax limitations and related tax system characteristics.

We find that a one standard deviation in tax policy risk ($\approx$ \$200, or slightly more than half the average increase in risk associated with the adoption of assessment limitations) increases the probability of mortgage distress by 0.19 percentage points. This constitutes a significant trigger event for mortgage distress and is of a comparable order of magnitude as the increase in risk of mortgage distress for homes in disrepair, or approximately one eighth as large as the increase in probability of distress associated with moving between the third and fourth quintiles of the loan-to-value distribution (i.e., from an LTV of 0.6-0.91 vs. 0.91-1.6). Furthermore, the effects of tax policy risk are amplified during periods of higher unemployment and are felt most strongly among severely underwater homeowners (LTV $>$ 1.6), while cumulative housing price appreciation serves to partially insulate homeowners from risk.

Our paper combines insights from two important literatures on household finance and property taxation. Previous literature on household finance has shown that differences in government policy can create different incentives and pressures that lead to mortgage distress. Earlier work has considered default rates across areas depending on repossession risk (O'Malley, 2021), deficiency judgements (Clauretie, 1987; Jones, 1993; Ambrose et al., 2001; Ghent and Kudlyak, 2011), and judicial requirements (Mian et al., 2015). Policies that increase the cost of foreclosure for either borrowers or lenders are associated with fewer delinquencies and default. Thus, for example, state laws that require foreclosures to proceed through the court system (i.e., judicial review) reduce the frequency of foreclosures on delinquent homeowners, and likewise for state laws that grant lenders the ability to pursue defaulting borrowers for deficiency judgments, i.e., lender recourse (Ghent and Kudlyak, 2011).

There is also a large body of literature that discusses the possibility of various "trigger events" for financial distress, such as unemployment, illness, or change in marital status. Empirical evidence of significant trigger events is relatively scant due to the difficulty of linking homeowner characteristics to loan and housing characteristics (Tian et al., 2016). Gerardi et al. (2017) is a rare exception that evaluates the impact of both strategic default incentives and unemployment as a trigger event. More recently, Low (2022) exploits newly linked administrative and survey data to document that a substantial majority of 90-day delinquent mortgagees cite liquidity problems as contributing to their payment difficulties, such that only around 4 percent of 90-day delinquencies can be classified as purely strategic. Unfortunately, the American Survey of Mortgage Borrowers dataset used by Low (2022) does not ask explicitly about property tax payments as a source of liquidity problems, consistent with the limited attention devoted to property taxes as a possible precipitating factor for mortgage distress (Anderson and Dokko, 2009, 2016; Bradley, 2013; Hayashi, 2020; Wong, 2020). We add to this literature by showing how the unintended consequences of particular property tax provisions may lead to mortgage distress, all the while controlling for homeowners' strategic default incentives based on their loan-to-value position.

A large literature on property taxation studies to what extent property taxes are capitalized into housing prices (e.g., Oates (1969); Wales and Wiens (1974); Rosen (1982); Yinger et al. (1988); Palmon and Smith (1998); Koster and Pinchbeck (2022)) while more recent studies examine the saliency of particular features of property tax regimes (Bradley, 2017, 2018; Cabral and Hoxby, 2012). Thus, for example, Bradley (2017) shows how household inattention to property tax rules related to the implementation of assessment limitations can lead to homebuyers mistakenly treating temporary tax savings as permanent and thus substantially overpaying for their homes. Further work has focused on capital misallocation due to lock-in effects resulting from assessment limitation rules that benefit incumbent homeowners (Quigley, 1987; Wasi and White, 2005; Ferreira, 2010; Ihlanfeldt, 2011; O'Sullivan et al., 1995b). We add to this literature by studying how property tax limitations *collectively* affect market outcomes and reallocate risk between homeowners and local governments, with implications for mortgage distress and eventually housing investment, pricing, etc.. In the process, we utilize a novel method for simulating tax policy risk and provide a synthesized approach—unique to the literature—to evaluating multiple interacting features of state property tax systems.

The remainder of the paper is structured as follows. Section 2 describes the basic mechanics of property taxation in the U.S. and explains the essential characteristics of different types of property tax limitations. Section 3 explains our theoretical method for pricing tax liabilities and its decomposition into tax policy risk and level components, and Section 4 elaborates on how we apply this method to simulated property tax liabilities from a model of state property tax systems. Section 5 describes our data and the construction of key regression variables. Section 6 lays out our primary empirical strategy; Section 7 presents our main results, including a discussion of heterogenous effects and mechanisms; and Section 8 concludes.

2 Property Tax Limitations

Since California's adoption of Proposition 13 in 1978, all but three U.S. states (Hawaii, New Hampshire, and Vermont) have implemented some form of property tax limitations to constrain the growth of state and local governments' budgets and reduce the volatility of property tax collections due to housing market fluctuations. These limitations differ in whether they are intended to restrict tax rates (i.e., statutory "millage" rates), the tax base (i.e., taxable values), or their product. These are referred to as rate limits, assessment limits, 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. In practice, as shown in Table 1, all but nine states employ some combination of property tax limitations, including four states (Arizona, Colorado, Michigan, and New

Mexico) that use some version of all four types of limits.[1]

In this section, we describe the general characteristics of each of the three types of tax limitations that apply exclusively to property taxes. Importantly, the exact implementation characteristics of particular property tax limitations (along with interactions among these) can vary widely from state to state. As discussed in Section 3, this variation is integral to our simulation framework and thus our calculation of households' exposure to tax policy risk.

2.1 Property Tax Basics

Property tax obligations are calculated at the parcel level as the product of the parcel's *taxable value* and the applicable statutory *millage rate* (i.e., the tax amount per thousand dollars of taxable value). Millage rates are set—subject to statewide limitations—at the local level via the political process and commonly combine rates from multiple overlapping taxing jurisdictions (e.g., counties, municipalities, and school districts) and often differ by property class or owners' residency status. Taxable values, on the other hand, are determined as a function of assessed (market) values. Assessed values are in turn intended to reflect the local assessor's best estimate of fair market value based on a combination of mass appraisal methods and market studies. In the simplest case, under a system of market-value based assessments with annual reassessments and a 100 percent assessment ratio, taxable values and assessed values coincide, and property tax obligations are solely determined by market values and the local millage rate.

In practice, however, states frequently apply assessment ratios of less than 100 percent, do not reassess or appraise property on an annual basis, or apply assessment limitations—all of which can lead taxable values to differ from assessed market values.[2] As reported in the last column of Table 1, the frequency of legally-mandated reassess-

[1]See O'Sullivan et al. (1995a) for a discussion of the set of factors that precipitated the widespread adoption of property tax limitations in the U.S. Haveman and Sexton (2008) describe the general characteristics of assessment limitation regimes and other types of property tax limits. Numerous papers examine whether state and local tax limitations are in fact effective at constraining local governments (e.g., Poterba and Rueben (1995); Cutler et al. (1999); Dye et al. (2005); Brooks et al. (2016); Eliason and Lutz (2018)). We refer the reader to the Lincoln Institute of Land Policy's "Significant Features of the Property Tax" database for a succinct description of individual state provisions and their evolution over time.

[2]Without pre-existing rate limitations, assessment ratio designations are wholly arbitrary as rates could merely be adjusted accordingly in order to raise the desired level of property tax revenue. Anecdotally, assessment ratios of less than 100 percent are said to arise after major statewide reassessments to preserve revenue neutrality without necessitating statewide rate changes.

ments varies substantially across states. Reassessment intervals range from as little as one year (e.g., Alabama, Georgia, Idaho, etc.) up to as long as eight years in North Carolina, while several states have no statutes dictating a specific reassessment frequency (e.g., Delaware, New Hampshire, Pennsylvania, etc.).[3] We turn next to a discussion of assessment limitations, but we note first that infrequent reassessments—such as the 20+ year intervals between county assessments that commonly occur in Pennsylvania—can act as a very strict de facto assessment limitation regime. This has important implications for the calculation of tax policy risk and the relevant "no policy" counterfactual against which risk is measured, and we return to this point in Section 3.

2.2 Assessment Limits

Assessment limits generally restrict the growth rate of taxable values that can occur over time, regardless of the evolution of housing prices (and therefore assessed values). 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, for instance, 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.[4] Other states apply maximum capped growth rates that are unlikely to bind (e.g., Minnesota's since-eliminated Limited Market Value Law, which had a cap equal to the greater of 15 percent or 25 percent of the change in market value), 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, and as shown in Table 1, we hence distinguish the "traditional" acquisition value based assessment limitations that more closely resemble California's Proposition 13 from other

[3]Not coincidentally, assessment limit states all perform annual "reassessments" either formally or informally.

[4]Ferreira (2010) examines how a carve-out for 55+ year olds moving within county relaxes the lock-in effect that otherwise results from California's restrictive form of acquisition value based assessment limitations.

forms of assessment limits. Figure 1 depicts the geographic distribution of these different types of assessment limitation regimes.

During housing market downturns, California's Proposition 8 amendment—also adopted in 1978—stipulates that properties' taxable values may temporarily fall below their "factored base year value" in cases where this is justified on the basis of reassessed market values, but subsequent reassessments may dictate increases in taxable values that exceed the 2 percent capped rate (until the factored base year value is once again reached).[5] States with otherwise similar assessment limitation systems likewise allow for reductions in taxable values during market downturns, albeit without necessarily employing the same statutory language as in Proposition 8. For instance, in Michigan, where annual reassessments are automatic, 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 commensurate reductions in taxable value, and there is no subsequent provision for "catching up" to some alternative base year value once house prices begin rising again. In either case, the treatment of taxable values for homes whose market values are declining implies that reductions in tax liabilities are prone to occur with a lag (if at all) in states with assessment limitations relative to states where taxable values rise and fall in direct proportion to market values, as in states with market value based assessments (assuming frequent reassessment). Figure 2 illustrates a hypothetical version of this scenario. The risk—as we formalize in the next section—is that despite limiting tax liabilities when property values are rising, assessment limitations may result in smaller reductions (or even ongoing increases) in tax liability during market downturns—precisely when times are bad and households may already be at greater risk of financial distress. Asymmetric adjustments to property tax liabilities in assessment limitation states could thereby exacerbate the negative consequences of housing market downturns and act as a trigger event for mortgage foreclosure.

Figure 3 provides preliminary evidence of the aforementioned effects of assessment limits in the data. As shown, homes in assessment limitation states experienced far more

[5] Factored base year value is defined as a property's market value at the time of purchase (or 1975, whichever is more recent) adjusted by the state's annual growth factor over the set of intervening years of ownership.

pronounced swings in average prices (solid red) than homes in other states (solid blue), both during the initial market downturn and the subsequent run-up. Meanwhile, tax liabilities remained relatively elevated in both groups of states (shown in dashed red and blue) through the initial years of the market downturn–suggesting that taxable values are generally sticky downwards everywhere. However, *relative to the magnitude of the corresponding reductions in prices*, taxes adjusted faster and to a greater degree to declining prices in the set of states without assessment limits. These differences in adjustment rates are depicted directly in Figure 4, where each line corresponds to the percent change in tax liability minus the percent change in price. This "tax-price adjustment gap" peaked at nearly 15 percentage points in 2008 and 2009 for assessment limitation states–nearly double the corresponding amounts for states without assessment limits.

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 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.[6] Elsewhere, rate limits are instead set on statewide basis as a percentage of fair market value, without specifying each taxing jurisdictions' allowed rate, or they restrict millage rate *growth*.[7] Figure 5 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.

In many cases, only a subset of taxing jurisdictions' millage rates are capped (e.g., by excluding school districts, such as in Alabama, Arkansas, Delaware, etc.), rate limits do not apply to rates for debt servicing, or they are subject to voter override (with differing vote thresholds). It is reasonable to expect that different states' rate limits may therefore be more or less effective at constraining overall property tax rates.[8] Insofar

[6]For example, the Lincoln Institute's Significant Features database says the following about Kentucky's property tax rate cap: "[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 has a state-wide rate limit of 35 ($= 5 + 15 + 15$) mills.

[7]Colorado, for example, caps municipal rates at the prior year's level, thereby effectively imposing a growth rate limit of zero. South Carolina instead limits the growth in millage rates in relation to inflation plus population growth.

[8]In order to gauge whether rate limits are binding for purposes of our tax risk simulations, we com-

as rate limits are ever binding, this is more likely to occur when property values are falling as a result of local jurisdictions trying to raise the same amount of property tax revenue off of a smaller tax base. If a jurisdiction previously imposed a tax rate of 1.4% and property values fell by 10 percent, for example, the tax rate would need to rise to 1.56% ($1.4\%/(1-0.1)$) in order to maintain the same level of property tax revenue. A rate limit of 15 mills in this case would interfere with this adjustment, and the tax rate would be restricted to 1.5% despite the jurisdiction wanting to collect a higher amount of revenue from its property tax. From the perspective of individual taxpayers, this implies that rate limits should dampen counter-cyclical fluctuations in millage rates and—absent other property tax limitations—should yield more pro-cyclical tax liabilities, contrary to assessment limitations.

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, these are expressed in terms of limiting the percentage growth in aggregate property tax revenues relative to the prior year and can be defined as a fixed percentage amount, a number anchored to inflation, or some function of the two. Other states instead restrict property tax levies as a share of aggregate fair market value, while some states restrict both the growth rate and total tax levy in relation to aggregate market values.[9] Figure 6 depicts the geographic distribution of levy limits (based on percentage growth limits—limits on levy amounts or other revenue/expenditure limits are included in "Other"). Outside of the Southeast, these are widely used.

pare 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 (e.g., Alabama, Arkansas, Georgia, etc.) or 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%.)

[9] 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 an amount of tax revenue not to exceed 2.5 percent of assessed market value. The latter is comparable to a rate limit of 2.5%, albeit one which only applies to the local tax base in the aggregate, such that individual properties in MA may still face a tax rate over this amount (e.g., commercial property).

Levy limits are more likely to bind when property values are rising as a result of property tax revenues exceeding the allowed amount, in which case local jurisdictions must reduce their millage rates to comply with the levy limit. For example, if a jurisdiction in a state with a 5% growth levy limit expected to raise 110 percent of the prior year's revenue at unchanged tax rates due to housing price appreciation, it would need to reduce its millage rates by 4.8 percent ($0.0476 = 1.1/1.05 - 1$) in order to yield no more than 105 percent of the prior year's levy amount. When combined with restrictive rate limits that are also defined in terms of percentage growth (e.g., Colorado), this can result in a "ratcheting down" phenomenon, whereby rate reductions that occur during boom times can never be relaxed thereafter and thereby limit states' flexibility in raising rates during housing market downturns. More generally, levy limits should dampen pro-cyclical fluctuations in property tax obligations, especially in states that do not otherwise limit taxable value growth.[10] Much like assessment limits, however, this dampening effect ought to predominantly affect tax obligations during periods of rising housing prices. During periods of declining values, levy limits of the percentage growth variety do not preclude rising tax obligations.

3 Pricing Property Tax Risk

In this section, we introduce an Arrow-Debreu framework to price property tax risk. We first use a stylized example to illustrate the intuition for this framework. We then formalize this framework and apply it to property tax payments.

3.1 Arrow-Debreu Framework

A crucial aspect of property tax risk is that it is not just about how uncertain, or variable, tax liabilities can be. Tax risk also depends on the timing of when tax liabilities arise in relation to macroeconomic conditions. Consider the following example with two states of the world, good times and bad times, that occur with equal probability and are defined by the price of Arrow-Debreu (AD) state-contingent securities. Specifically, suppose that the price of the AD security that pays 1 in the good state is 0.2 and the price of the AD

[10] As noted above, some states also limit growth in tax revenues from all sources, not just property taxes. We treat such revenue limitations as having a proportional effect on property taxes (i.e., equivalent to levy limitations).

security that pays 1 in the bad state is 0.6. The price is greater for the AD security that pays out in the bad state of the world because the value of additional consumption is higher (i.e., marginal utility in the bad state is higher for a risk-averse consumer). In this economy, a risk-free bond that pays 1 in both states (by implicitly combining both AD securities) would be priced at 0.8 ($0.8 = 0.2 + 0.6$). The following table describes this hypothetical economy:

	Good Times	Bad Times	Price
Arrow Debreu 1	1	0	0.2
Arrow Debreu 2	0	1	0.6
Risk-free Bond	1	1	0.8

Next consider three property tax regimes—no limits, loose limits, and strict limits. Under the no-limit regime, the property owner pays $5 in property taxes in the good state in which property values are high and pays $1 in property taxes in the bad state when property values are low. Property tax limits restrict how much tax liabilities may rise in good states, but they also restrict how much they may fall in bad states, and indeed—as discussed in the previous section—more restrictive tax limitations can even give rise to increased tax liabilities in bad states of the world. In the good state, suppose therefore that the property owner subject to the loose-limit regime pays $4 instead of the $5 in the no-limit regime. In the bad state, the property owner pays $1 in both the loose-limit and no-limit regimes. Under the strict-limit regime, the property owner pays even less property tax in the good state, specifically, $2, and pays more in the bad state, specifically, $3. One interpretation of the payments in the strict-limit regime is that the government charges more in the bad state to hit its expected revenue targets. The following table describes this stylized example:

	Tax Liability				AD Price		
	Good Times	Bad Times	Expected	Std. Dev.	Total	CE	Risk
No Limit	5	1	3	2	1.6	2.4	-0.8
Loose Limit	4	1	2.5	1.5	1.4	2	-0.6
Strict Limit	2	3	2.5	0.5	1.8	2	0.2

• **Standard deviation-based risk.** The standard deviation provides a statistical measure of the variability in an outcome. In this example, the standard deviation of the tax liability monotonically decreases as the tax limits become more strict. This is consistent with policymakers' prior – stricter tax limits reduce the variability of property taxes for property owners over time. However, we argue that this is an inadequate measure of risk because it fails to consider property owners' consumption and their value of money in each state of the world. We propose an alternative evaluation system as the following.

• **Consumption-based risk.** All else equal, property owners would rather pay higher property taxes in good times (when the marginal utility of money is low) than in bad times (when marginal utility is high). This dynamic is captured by the higher price of the AD security that pays out in the bad state of the world than for the AD security that pays out in the good state. Hence, we calculate the AD price for the tax liability for each regime, which is the sum of the payment in a given state of the world times its AD price,

$$\begin{aligned} 5 \times 0.2 + 1 \times 0.6 &= 1.6 && \text{No-limit} \\ 4 \times 0.2 + 1 \times 0.6 &= 1.4 && \text{Loose-limit} \\ 3 \times 0.2 + 2 \times 0.6 &= 1.8 && \text{Strict-limit} \end{aligned}$$

The higher the AD price of the property tax liability, the more impactful the outflow of wealth is for the property owner given their consumption. Said differently, this property tax owner would be willing to pay \$1.6 to avoid paying the property tax in the no-limit regime, compared to \$1.4 and \$1.8 in the loose-limit and strict-limit regimes, respectively. In this example, the AD price of the property tax liability is highest for the strict-limit regime because the tax payments are negatively correlated with the states of the world. This comparison is in stark contrast to the standard deviation-based measure of risk, where the strict-limit regime has the least variability.

The AD price of the property tax liability captures the risk and level effects. For example, the AD price of the property tax liability is lower for the loose-limit regime than for the no-limit regime because the expected payment is lower: \$2.5 compared to \$3. Because we are interested in the risk aspect of the price, we decompose the AD price into a certainty-equivalent (CE) component and a risk component.

• **Certainty-equivalent price.** The CE price is the amount that the property owners would be willing to pay had the property tax liability not been state-contingent. As such, the CE component is calculated as the expected payment in both states,

$$
\begin{array}{rc}
3 \times (0.2 + 0.6) = 2.4 & \text{No-limit} \\
2.5 \times (0.2 + 0.6) = 2 & \text{Loose-limit} \\
2.5 \times (0.2 + 0.6) = 2 & \text{Strict-limit}
\end{array}
$$

• **Risk price.** The risk price is the amount that the property owner would be willing to pay to avoid the risk associated with their property tax liability. As such, the risk component of the AD price is calculated as the sum over states of the world of the state-contingent payment minus the expected payment multiplied by the AD state-contingent price:

$$
\begin{array}{rc}
(5-3) \times 0.2 + (1-3) \times 0.6 = -0.8 & \text{No-limit} \\
(4-2.5) \times 0.2 + (1-2.5) \times 0.6 = -0.6 & \text{Loose-limit} \\
(2-2.5) \times 0.2 + (3-2.5) \times 0.6 = 0.2 & \text{Strict-limit}
\end{array}
$$

By construction, the AD price is equal to the sum of the CE and risk price components. This example highlights that the risk price can be positive or negative. Negative prices for the no-limit and loose-limit regimes indicate that property owners prefer these tax regimes to paying a certain amount because their payments provide consumption-smoothing insurance—i.e., they get to pay lower taxes in bad times. The positive price for the strict-limit regime indicates that property owners would prefer to pay the CE amount to their actual tax liability. In all cases, a higher price indicates more risk.

In this stylized example, tax policy risk is highest in the strict-limit regime and lowest in the no-limit regime. Said differently, from a risk perspective, property owners prefer the no-limits regime because property taxes in this case are positively correlated with individual consumption. The more limitations policymakers impose on the property tax, the weaker such a positive correlation becomes (i.e., the less pro-cyclical are tax liabilities). Positive (negative) risk prices, therefore, capture the value loss (gain) to homeowners due to the counter-cyclicality (pro-cyclicality) in tax payments, controlling for differences in overall tax levels.

The insight from this stylized example – namely, that tax limits increase risk – is not specific to the chosen numbers. This intuition holds true as long as (1) the AD price of the good state of the world is lower than that of the bad state of the world (i.e., homeowners are risk averse) and (2), tax liabilities are weakly decreasing in limit stringency in the good state of the world and weakly increasing in the bad state of the world.

We next formalize this intuition and apply it to the property tax payments.

3.2 Pricing Property Tax Risk

We price property tax risk by combining property tax payments and a pricing kernel that defines states of the world. We then define the price of the property tax risk as the risk component from the AD price decomposition. The Arrow-Debreu pricing kernel $p_{i,t}$ for person i in year t is the state probability π_t multiplied by the ratio of marginal utilities of consumption $U'(C_{i,t})$ between years t and $t-1$,

$$p_{i,t} = \pi_t \frac{U'(C_{i,t})}{U'(C_{i,t-1})}. \tag{1}$$

We assume that marginal utility is positive and decreasing with consumption $U'(C_{i,t}) > 0$ and $U''(C_{i,t}) < 0$. In a bad year, $C_{i,t} < C_{i,t-1}$ and the ratio of marginal utilities is greater than one; $U'(C_{i,t})/U'(C_{i,t-1}) > 1$. In a good year, $C_{i,t} > C_{i,t-1}$ and the ratio of marginal utilities is less than one; $U'(C_{i,t})/U'(C_{i,t-1}) < 1$. These ratios up-weight payments in bad years and down-weight payments in good years. This captures the effect of covariance between consumption and property tax payments. For concreteness, we assume CRRA utility with a risk aversion parameter of η,[11]

$$U(C_{i,t}) = \frac{C_{i,t}^{1-\eta} - 1}{1-\eta} \quad \eta \geq 0,\ \eta \neq 1. \tag{2}$$

The risk price is given by applying the pricing kernel to the property tax payment $q_{s,i,t}$ for property i under tax limit policy s in year t, net of the average tax payment $\bar{q}_{s,i}$, and summing across years y.

$$\mathbb{R}_{s,i,t} = \sum_y p_{i,y}(q_{s,i,y} - \bar{q}_{s,i}). \tag{3}$$

[11] Barsky et al. (1997) estimate the intertemporal elasticity of substitution (θ) to have an upper bound of 0.36 and a midpoint of 0.18. We therefore use a conservative estimate of $\eta = 1/\theta = 3.5$ for CRRA risk aversion to calculate the pricing kernel. Different assumptions of η yield qualitatively similar results.

To accurately capture the experience of property tax risk from the property owner's perspective, the year range, y, that Equation (3) operates over should be homeowner tenure, i.e., all years since the owner bought the property through year t. This calculation of the risk price can be applied to property tax payments in the data or to simulated property tax payments.[12]

4 Pricing Tax Policy Risk

4.1 Policy Simulation

As discussed in Section 2, property tax liabilities reflect the effects of both tax policies and economic conditions. To isolate policy effects, we therefore simulate property tax payments as a function of state-level property tax system characteristics while fixing economic conditions to apply uniformly across states.[13] Concretely, we construct a panel of 500 simulated properties indexed by i over 50 years indexed by z. Economic conditions are captured by the property's market value, whether it transacts that year or not, and the property owner's consumption (consisting of both aggregate and idiosyncratic shock components), calibrated using the Case-Shiller U.S. National Home Price Index, Consumer Price Index, and personal consumption expenditures from the Consumer Expenditure Survey. We repeat the simulation 1,000 times with different underlying economic processes to average out the effect from any particular economy.

We calculate two series of property taxes within each simulation for the policy in state s in year t: $q_{s,t,i,z}$, which stands for the amount of property taxes owed by property i in simulation year z subject to set of tax limit policies in place in state s and year t, and $q'_{s,t,i,z}$, which represents the counterfactual level of tax liability assuming no tax limitations. First, we set the statutory millage rate in the first year of the simulation to be the median effective tax rate for newly-purchased homes that we observe in the data and allow tax rates thereafter to evolve according to any applicable rate or levy

[12]Note that the identity holds here the same way it does in the stylized example: the property tax risk is the difference between the AD price ($\mathbb{P}_{s,i,t} = \sum_y p_{i,y} q_{s,i,y}$) and the certainty equivalent component ($\mathbb{C}_{s,i,t} = \sum_y p_{i,y} \bar{q}_{s,i}$); $\mathbb{R}_{s,i,t} = \mathbb{P}_{s,i,t} - \mathbb{C}_{s,i,t} = \sum_y p_{i,y} q_{s,i,t} - \sum_y p_{i,y} \bar{q}_{s,i}$.

[13]We do not model local option tax limitations, as the details of these regimes are poorly tracked, especially on a historical basis. Thus, for example, we treat Georgia as having no assessment limitations outside of the years 2009-2010, despite the state allowing local assessment freezes in other years, or we assume a 10 percent capped taxable value growth rate for Maryland's assessment limitation regime, despite the state allowing for lower caps at the county and municipal levels.

limitations and revenue needs, where revenue needs are assumed to grow at the same rate as aggregate consumption. Similarly, we assume in the first year of the simulation that taxable values and (assessed) market values coincide at $300,000. In subsequent years, we allow taxable values to evolve in relation to market values subject to any assessment limits, with taxable value uncapping occurring upon sale.[14] In states without assessment limits, taxable values are reset to equal market values according to each states' reassessment frequency.[15]

Next, we model the effects of levy limits by calculating the percentage growth in property tax revenues that would result from applying the previous year's tax rates to current taxable values in the state and comparing these to the state's revenue growth target and capped levy growth amount. Tax rates are then adjusted to yield revenues that match the lesser of the state's permissible levy limit or growth target, subject to any further rate limits. In cases where the state would want to raise the millage rate to a level that would exceed their rate limit in order to meet their revenue target, the tax rate will be set *at* the limit and the revenue target will not be met without further increases in taxable values.

Finally, we calculate the property tax, $q_{s,t,i,z}$, as the product of taxable value and the applicable millage rate, subject to all relevant assessment, rate, and levy limits; reassessment frequency; and starting revenue requirements. We also calculate a counterfactual property tax, $q'_{s,t,i,z}$, that equals the product of current market value (i.e., assuming annual reassessment) and the unrestricted millage rate anchored to the same initial revenue requirements and revenue growth targets. The difference between $q_{s,t,i,z}$ and $q'_{s,t,i,z}$ measures the collective impact of all state-year property tax limitations on property tax liabilities.

As an illustration of this technique, Figure 7 plots the property tax amount ($q_{s,t,i,z}$) over the simulation horizon for the same property. Differences between tax amounts across series are due only to differences in states' combined property tax policies. The

[14]In Arizona and Oregon, changes of ownership do not trigger taxable value uncapping. As such, we model taxable values in these states as being subject to perpetual limits on taxable value growth.

[15]For those states where reassessment frequency is not statutorily mandated, we assume a 10 percent idiosyncratic reassessment probability (i.e., akin to a 10-year interval between reassessments). In practice, states like Delaware and Pennsylvania tend to go much longer between county reassessments, whereas states like Maine and New Hampshire reassess more frequently. The results of our empirical analysis are qualitatively unchanged by instead assuming reassessment frequencies that are more closely aligned to actual practices in these states (i.e., 5 percent annual reassessment probability for Delaware and Pennsylvania and 33.33 percent for Kansas, Maine, New Hampshire, and New Jersey).

two highlighted series are Oregon and California. Compared to the rest of the states (displayed in gray), Oregon and California's property tax systems yield relatively low property tax liabilities due to their stringent assessment limits (3% for OR and the lower of 2% or CPI inflation for CA). While both states have otherwise comparable tax limitations, a key distinction is that Oregon's assessment limitation regime does not trigger taxable value uncapping upon sale. Hence, the spike in property tax liability that occurs in California around year 27—at the time of the first recession year, as indicated by red vertical lines—is largely the result of the property coincidentally transacting in the prior year.

For additional details about this simulation procedure, see Appendix A.

4.2 Tax Policy Risk

In order to produce the measure of tax policy risk that we use in our empirical analysis, we first calculate the risk price for the simulated tax payments $q_{s,t,i,z}$ and counterfactual tax payments $q'_{s,t,i,z}$ using the formula in Equation (3), $\mathbb{R}_{s,t,i,z}$ and $\mathbb{R}'_{s,t,i,z}$, respectively. We then take the difference between risk prices with and without limits and average across all 1,000 replicates of our panel of 500 simulated properties:

$$\textit{Tax Policy Risk}_{s,t} = \frac{1}{N}\sum_i \Delta\mathbb{R}_{s,i,t} = \mathbb{R}_{s,i,t} - \mathbb{R}'_{s,i,t}. \tag{4}$$

Figure 8 shows how *Tax Policy Risk* differs across states. The dollar amounts shown on the map represent the amount of money (averaged across policy years 2006-2016) that the owner of a \$300,000 home would be willing to pay in different states to eliminate all risk associated with property tax limits.[16] As shown, there is considerable variation across states, from a high of \$1279 in New York state to a low of -\$270 in South Carolina. Broadly, these differences reflect the effects of all of the interactions among states' multiple property tax system characteristics. Insofar as a \$300,000 home represents a different segment of the housing market in different states, however, it may be inappropriate to

[16]Note that this is distinct from the amount that homeowners would be willing to pay to avoid the overall difference in property tax obligations that is attributable to property tax limits, which reflects both the certainty equivalent (*Tax Policy Level Diff*) and risk components (*Tax Policy Risk*) of the tax price. Abstracting from level differences can be justified on the grounds that such differences should be fully capitalized into prices; that property taxes are a pure benefits tax; or that states raise similar amounts of revenue across all tax instruments at their disposal, such that lower property taxes are offset by higher taxes on household consumption elsewhere.

base states' revenue requirements on non-representative housing values. (For example, Michigan might not levy as high of effective property tax rates if median house prices were $300,000 instead of between $75,000 and $125,000, as in the data.) This issue is a moot point for our empirical analysis as we control explicitly for parcel-level housing prices and effective tax rates, but for purposes of visualizing the distribution of tax policy risk, we replicate Figure 8 in Figure 9 with risk prices rescaled to match states' median house prices. This implies a substantially lower level of risk for the median property owner in lower property value states like Michigan, whereas this has less impact on tax policy risk in states with higher property values.

5 Data

We combine data from ATTOM Data Solutions and Zillow (ZTRAX) into a comprehensive panel of parcel-level data spanning the continental U.S. for the period 2006-2016 to ensure the broadest possible coverage of property tax assessment, realty transaction, loan, and foreclosure records for our analysis. To the best of our knowledge, we are the first to combine both data sources in this manner, which consists of matching parcels based on county-level administrative parcel identification numbers or street address and zip code. This has the virtue of allowing 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 general data reliability.[17]

These data include variables on sale prices and dates, assessed values, tax payments, 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.. In order to account for potential strategic default incentives, we augment these data by calculating annual property values and loan balances that allow us to construct loan-to-value ratios (LTV). Property values are also used in the construction of effective property tax rates (ETRs) to control for households' relative tax burdens, as well as in the measurement of housing price growth relative to tax liability.

[17]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 use two different methods to calculate annual property values—an imputation method and a hedonic estimation method—and we use whichever method produces the longer parcel-specific history for each property in our analysis. 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, and we extrapolate housing values forward and backward based on local pricing trends using both indices individually. Each provide different coverage.[18] 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, which we allow to differ by Census tract as a function of data availability and predictive fit. The model selected for properties in each tract is the one that performs the best in 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. How many neighboring Census tracts we use is allowed to differ for each Census tract and is determined by the set that performs the best out of sample.

To calculate annual loan amounts, we combine data from the Federal Housing Administration on average national monthly interest rates and average state-level annual rates to 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.[19] Taking the ratio of imputed loan balances to property values

[18]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.

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

yields our desired time-varying parcel-specific estimates of LTV, which we subsequently classify into discrete intervals.

We geocode all parcels with valid street address and zip code information using ArcGIS, and we use the resulting latitude and longitude coordinates to calculate the shortest distance as the crow flies from each parcel to all neighboring counties located in other states, up to 20 miles. We also link parcels based on latitude and longitude to the U.S. National Grid coordinate system, which bears no relationship to administrative boundaries, and we assign parcels to both 5- and 10 km^2 grid cells accordingly.

The resulting dataset consists of approximately 390 million parcel-year observations with non-missing property values distributed throughout the continental U.S., of which roughly 100 million are located in state border counties within 20 miles of the nearest state border. Besides restricting ourselves to parcels within (at most) 20 miles of a state border for purposes of our state-border discontinuity design, we also exclude from our initial sample (i) all homes that are ever valued in excess of $5 million or less than $1000 in an arm's-length transaction, (ii) newly built or substantially remodeled properties, (iii) properties with effective property tax rates that fall below the 1st percentile or above the 99th percentile of the relevant state distribution, and (iv) properties that 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. Broadly speaking, the intent of these sample restrictions is to capture the experiences of the vast majority of property owners with respect to property taxation while mitigating the influence of misrecorded data and (rare) true outliers. The argument for (ii) is somewhat distinct and reflects both practical and theoretical considerations in that it is very difficult to establish what constitutes an "excessive" change in annual tax liability for construction that occurs over multiple years, and the owners of such properties commonly face distinct mortgage financing environments, either as developers, flippers, or buyers of builder-financed homes.

We also exclude data from ten price non-disclosure states due to a lack of sufficient transaction information to estimate our hedonic pricing model or to credibly implement our border pair fixed effects analysis. These states are Idaho, Kansas, Louisiana, Mississippi, Montana, New Mexico, North Dakota, Texas, Utah, and Wyoming. The existence of non-disclosure laws restricting the availability of transaction prices information also dictates the exclusion of all but four political subdivisions of Missouri.[20]

For purposes of our empirical analyses, missing data for certain key variables naturally result in further sample truncation. Nevertheless, our initial border sample represents approximately $2.75 trillion in total property value and $49.6 billion in property tax liabilities as of 2016 and encompasses nearly 1.9 million foreclosure events over the period 2006-2016.[21] After implementing all of the aforementioned sample restrictions, we finally limit our data analysis to a 33 percent random subsample of all parcels for computational tractability.

In order to ensure the success of our border-pair identification strategy—namely, our ability to isolate the impact of property tax limitations at state borders from other sources of coincident variation in mortgage distress—we strive to control for other important state-specific policies that may also influence default probabilities. Thus, we follow Ghent and Kudlyak (2011) and Mian et al. (2015) and utilize their designations of states which 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). Data on time-varying state-level property tax limitations are drawn primarily from the Lincoln Institute of Land Policy's "Significant Features of the Property Tax" database (Lincoln Institute of Land Policy and George Washington Institute of Public Policy, 2023).

Table 2 summarizes the set of means, medians, and standard deviations for our key regression variables, based on our main estimation sample. Distressed properties are defined as any property which entered into foreclosure proceedings in a given year, regardless of whether the borrower was able to cure their loan or whether the property was ultimately repossessed by the lender or sold via foreclosure auction or short sale. *Tax Policy Risk* and *Tax Policy Level Diff* are calculated as described in Section 4 and measured

[20] St. Louis City, St. Louis County, Jackson County, and St. Charles County each require sale price disclosure via local ordinance, unlike the rest of the state of Missouri.

[21] Altogether, we capture 8.1 million foreclosure events in our full sample for the continental U.S., slightly less than half the number reported by ATTOM Data Solutions in their annual tallies. (See e.g., https://www.attomdata.com/news/market-trends/foreclosures/attom-webinar-summary-what-to-expect-in-the-distressed-real-estate-market/.) This discrepancy owes in part to our inability to match foreclosure events to parcels for which we otherwise do not observe any arm's length real estate transactions, along with other sample restrictions. It is also unclear how sequences of foreclosure events (e.g., the issuance of a notice of default followed by a notice of trustee sale and/or other foreclosure auction) are treated for purposes of ATTOM's annual tabulations, whereas we only count the first foreclosure event in a sequence of related transactions. Figure A.1 shows the evolution of foreclosure activity in our complete national sample 2006-2016.

in thousands of dollars. LTV is imputed as described above and ultimately classified into six discrete categories based on quartiles of the LTV distribution for $LTV < 1.6$ along with a fifth category for $LTV \geq 1.6$, and a sixth category for all properties with unknown LTV. Homeowner tenure, age, and renovation age are categorized in a similar manner.[22] 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 groups are statistically significant with p-values uniformly well below 0.001. Distressed properties thus face modestly greater tax policy risk (despite a lower absolute tax price), higher average LTVs[23], and higher effective tax rates. Distressed properties are also significantly less valuable, have short-tenured homeowners, and are modestly older and less recently renovated. All of these characteristics speak to unconditional variation in property- and household-level attributes that may contribute to mortgage distress by affecting either homeowners' incentives for strategic default or their susceptibility to precipitating trigger events.

6 Empirical Strategy

As described above, property tax limitations can have unintended effects on household risk by shifting tax payments from high-consumption states of the world to low-consumption states of the world. By limiting the pro-cyclicality of property tax burdens—and thereby raising property tax liabilities during times of weak macroeconomic conditions relative to what would have occurred in the absence of such limits—there is a potential for tax policy risk to trigger mortgage distress. However, it is an empirical question as to whether these shifts in tax burden are large enough for this risk to have a meaningful effect (and outweigh any possible level effect from these same limitations). Otherwise, households might simply self-insure and use liquidity to smooth out these shifts in the timing of tax burdens. Previous literature suggests that even relatively modest changes in property tax burdens can lead households to financial distress (Anderson and Dokko, 2009; Bradley, 2013; Anderson and Dokko, 2016; Wong, 2020) despite the large costs to households from mortgage distress and foreclosure.

[22] Renovation age differs from age insofar as year remodeled differs from year built in the data. Where year remodeled is missing, we assume that it coincides with year built.

[23] The continuous distribution of imputed LTVs points to the existence of large outliers. This issue is mitigated in our analysis by using discrete LTV categories. Median LTVs are of a plausible magnitude.

We are interested in whether the unintentional risk effects resulting from property tax limitations are large enough to have real impacts on households through increased mortgage distress and foreclosure. The ideal experiment would randomly assign households different bundles of property tax limitations and compare household outcomes over time in terms of mortgage distress. In practice, however, households are not randomly assigned these limitations, thereby creating the potential for a feedback loop between economic conditions that increase the probability of foreclosure and the enactment of property tax limitations. Another practical hurdle in terms of identifying the effects of tax limitations is the high dimensionality of interactions between types of limits and the stringency thereof.

We use a state-border discontinuity design to dampen the feedback loop between economic conditions and property tax limits. The border design allows us to compare properties that face similar local economic conditions except for being subject to different property tax limitations. This is achieved in our empirical specifications by including border pair ($\times$ year) fixed effects. The maintained assumption underpinning this identification strategy is that—conditional on a wide range of property characteristics—homeowners within a narrowly-defined border pair region would face identical distress probabilities on either side of the state boundary if not for differences in property tax system characteristics that give rise to differing exposure to tax risk.

Concretely, we consider three different types of border pairings: county pairs, as well as 10 km² and 5 km² grid cells. County pairs have the virtue of being commonly used in the literature on account of their convenience and their readily understood administrative boundaries; however, counties may differ substantially in size and population density and, in some cases, represent vast areas of land that are less reasonable to treat as uniform markets. To standardize land area, we therefore use the U.S. National Grid coordinate system to construct either 10 or 5 km² grid cells.[24] We refer collectively to each of these types of border pairings as producing a set of $j = 1, ...J$ grid cells, all of which produce distinct mappings of parcels to grid cells and partition parcels differently with respect to all relevant local taxing authority boundaries.[25] In the following results,

[24]The U.S. National Grid coordinate system divides the world into equal-sized "square" grid cells (100 km²) 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. Insofar as certain parcels are attributed to multiple border pair regions, fixed effects are estimated accordingly. This approach is similar to the 10-mile strips used by e.g., Mian et al. (2015).

[25]See Avenancio-León and Howard (2022) for an in-depth discussion of the role of overlapping govern-

we ultimately emphasize those that use the narrowest 5 km² grid cells, but we obtain qualitatively similar results using either county pairs or 10 km² grid cells.

Figure 10 provides an illustration of median property characteristics for the set of all Census tracts located in the six counties along the Michigan-Ohio border as of 2015. The agglomeration of Census tracts in the southeast corner of each subfigure is Toledo, OH, and the state border follows the near-horizontal midsection line of each map. As shown, tracts just north and south of the state border exhibit relatively similar median characteristics, especially in terms of housing prices (10a) and LTV (10c). Outside of the more densely populated areas, foreclosure rates are more heterogeneous (10d), and effective tax rates (10b) unsurprisingly reflect more pronounced county, municipal, and school district influences on statutory millage rates. Nevertheless, we view these illustrations as supporting the general concept of the existence of border-straddling local housing markets. Figure 11 depicts the location of each parcel in our estimation sample for the same six counties at the Michigan-Ohio border along with the approximate latitude-longitude coordinates of the 5 km² grid cells that form the basis of our resulting preferred fixed effects estimation strategy. Interior grid cells are outlined in gray, while the set of border-straddling cells which serve as the source of identifying variation for our primary analyses are highlighted in magenta. The western portion of the Michigan-Ohio border which exhibits relatively greater cross-border differences in tract-level housing market characteristics (Figure 10) is also quite sparsely-populated, as shown in Figure 11, and thereby contributes little to identification.

We use our measure of tax risk described in Section 3 to parsimoniously capture the high dimensionality of interactions among property tax limits. The model produces a single measure of the tax price that encompasses all features of the property tax regime in a given state, which we decompose into tax policy *risk* and level components. Intuitively, *Tax Policy Risk* represents the price that households would be willing to pay to avoid the risk effects resulting from the set of property tax limits in their state. A higher value of tax policy risk is therefore predicted to increase the probability of mortgage distress and foreclosure, regardless of whether this risk is primarily attributable to any specific form of assessment limitations, rate limits, or levy/revenue limits (or any combination thereof).[26]

ments for property tax purposes.

[26]We consider an alternative reduced-form model in Appendix E which focuses specifically on the consequences of assessment limitations. This alternative model provides qualitatively similar results but

In order to test this core prediction, we estimate the effect of *Tax Policy Risk* on mortgage distress at the property i year t level using a linear probability model where the outcome variable, $\mathbb{1}(\text{Distressed})_{i,t}$, is an indicator that equals one if property i experiences any form of mortgage distress in year t and zero otherwise:

$$\begin{aligned}\mathbb{1}(\text{Distressed})_{i,t} = \beta_0 + \beta_1 \text{Tax Policy Risk}_{s,t} + \beta_2 \text{Tax Policy Level Diff}_{s,t} \\ + X_{i,t}\beta + Z_{s,t}\beta + \lambda_{j,t} + \varepsilon_{i,t}\end{aligned} \tag{5}$$

The regressor of interest, Tax Policy $\text{Risk}_{s,t}$, varies at the state s year t level, as does Tax Policy Level $\text{Diff}_{s,t}$, which we include only to absorb the effects of residual differences in average property tax *amounts* that may result from the application of tax limitations.[27] Our state-border discontinuity design dictates the use of either year and grid cell fixed effects λ_t and λ_j, or grid cell by year pair fixed effects $\lambda_{j,t}$, as denoted above. We augment this design with a vector of property level control variables $X_{i,t}$ to incorporate additional parcel-specific factors related to strategic default incentives and other triggers of mortgage distress. These include controls for LTV, homeowner tenure, the age of the home, and the age of renovations (all represented as categorical variables), along with controls for the current estimated house price and the lagged ETR. $Z_{s,t}$ accounts for other important state policy variables that have been shown elsewhere to affect foreclosure rates (Ghent and Kudlyak, 2011; Mian et al., 2015)—namely, whether states permit lender recourse or non-judicial review.

In later tests, we interact Tax Policy $\text{Risk}_{s,t}$ with different time-varying state- and parcel-level characteristics that may affect households' susceptibility to tax risk, and we investigate the contributions of different property tax system features to measured risk.

7 Results

7.1 Main Effects

Table 3 reports our estimates of the effect of property tax risk on the probability of mortgage distress in the current period. The dependent variable is pre-multiplied by 100

has a less direct interpretation and is unable to account explicitly for correlated tax policy choices.

[27] Such differences are not a true source of risk and are primarily attributable to differences across states in the average effective tax rates which anchor our simulations. These differences ought to be reflected in house prices and ETRs, both of which are accounted for separately at the parcel level in our analysis.

such that point estimates from the linear probability model can be interpreted directly as percentage point effects. Column 1 presents the no-controls baseline and encompasses nearly 40 million observations. All other specifications include a full set of controls for LTV, house price, last period's ETR, tenure, and the age of the home and major renovations (if any). We also include policy variables denoting states which allow lender recourse and non-judicial review. Columns 2-4 employ progressively narrower border fixed effects, while columns 5-7 replicate the same sequence of specifications with border by year *pair* fixed effects to account for unobserved time-varying local economic conditions. For brevity, we only report the set of coefficient estimates that relate to property tax risk in Table 3, but the complete set of estimates can be found in Appendix Table A.2.

As shown, greater tax policy risk is associated with a significantly higher probability of mortgage distress across all specifications. According to our most basic (and naïve) specification in column 1, increasing tax policy risk by one thousand dollars—equivalent to moving a parcel from e.g., Maryland to Michigan at the height of the Great Recession—is thus estimated to raise the probability of mortgage distress by 0.362 percentage points from a baseline probability of 1.125 percent. Naturally, this unconditional estimate is susceptible to numerous potential biases. Incorporating controls for LTV, tenure, age, etc., along with different sets of fixed effects yields even larger estimated effects of tax policy risk (columns 2-7). In general, whereas the point estimates are decreasing in the size of the regions spanned by our time-invariant border pair fixed effects (columns 2-4), the reverse largely holds where we allow for time-varying border pair fixed effects (columns 5-7). We consequently emphasize the more conservative—and most narrowly-identified—estimates presented in column 7, and we use 5 km^2 grid cell $\times$ year fixed effects in all subsequent tests.[28] The coefficient on tax policy risk in column 7 of 0.908 constitutes an economically significant impact of risk from property tax limitations on mortgage distress. By way of comparison, the full results for the same specification in Appendix Table A.2 imply that moving from the lowest quintile of the LTV distribution to the highest quintile raises the probability of distress by approxi-

[28]Narrowing our estimation sample to only include parcels within 10 or 5 miles of state borders (*N* equals approximately 15 million and 8.5 million observations, respectively) produces virtually unchanged estimates of the effect of tax policy risk for the specifications involving either 10 km^2 or 5 km^2 grid cell $\times$ year fixed effects. More generally, all of the point estimates corresponding to specifications 2-7 in Table 3 are tightly clustered between 1 and 1.5. This is unsurprising given our identification strategy, which leverages within variation in border-straddling regions. Results are available from the authors upon request.

mately 2.8 percentage points. Thus, the effect of a thousand dollar increase in tax risk is roughly one third as large as the effect of being severely underwater. More modestly, a one standard deviation increase in tax risk ($\approx$ \$200) has a roughly equivalent effect on the probability of distress as owning a home in disrepair (i.e., homes that have not been renovated in at least 59 years).

7.2 Heterogeneity

Table 4 extends our preferred specification from column 7 of Table 3 to test whether certain time-varying market- or parcel-level characteristics affect homeowners' susceptibility to property tax risk. Accordingly, we present the main effects of tax policy risk along with interactions with state-by-year average unemployment rates (column 1), parcel-specific LTV (column 2), or homeowners' cumulative housing price growth since purchase (column 3). Complete results including uninteracted covariates and a full set of interactions with the other state policy control variables are provided in Appendix Table A.3. As shown in column 1, the effect of tax policy risk is increasing in the unemployment rate, consistent with the idea that the consequences of risk are amplified during periods of weaker macroeconomic performance and dampened during good times. At the average in-sample unemployment rate of 6.5 percent, a thousand dollar increase in tax policy risk thus raises the probability of mortgage distress by approximately 0.7 percentage points, and this effect is raised by a further 0.35 percentage points for every additional percentage point increase in the unemployment rate.[29] At the parcel level, the results in column 2 reveal that households in the top quintile of the LTV distribution incur the largest effects of tax risk on mortgage distress, while those with unknown LTV amounts—which presumably includes a substantial proportion of homeowners without mortgages—face the smallest such effects. Strategic motives for mortgage delinquency and default are thus amplified in states whose combined property tax system characteristics result in greater tax risk. Conversely—albeit limited to a relatively small subsample of observations—the effects of tax risk are partially mitigated

[29]The unemployment rate rarely dipped below 5 percent outside of the years 2006-2007 and 2015-2016 in our estimation sample. Taken literally, our estimates imply a negative overall partial effect of tax risk during these periods of low unemployment. Allowing further non-linearity in the relationship between tax risk and unemployment by interacting risk with a quadratic function of the unemployment rate reveals a similar pattern; however, the marginal effects of tax risk on mortgage distress are not significantly different from zero for either very low or very high unemployment rates. See Appendix Figure A.2.

among homeowners who have experienced substantial housing price appreciation since buying their homes (column 3), and vice versa for homeowners who have experienced housing price declines.

7.3 Mechanisms

We now drill down on *Tax Policy Risk* to understand what mechanisms (i.e., property tax system characteristics) have the largest effects on risk. To do so, we estimate the effect of different types of property tax limitations on *Tax Policy Risk* (measured in dollars) and report these estimates in Table 5. The fullest specification (column 8) includes indicator variables denoting the application of particular tax limits in a given state-year—$\mathbb{1}(\text{Levy Limit})_{s,t}$, $\mathbb{1}(\text{Rate Limit})_{s,t}$, and $\mathbb{1}(\text{Assessment Limit})_{s,t}$,—along with continuous measures of limit stringency, and controls for reassessment frequency. This specification is given by

$$\begin{aligned}\textit{Tax Policy Risk}_{s,t} = \beta_0 + \beta_1 \mathbb{1}(\text{Levy Limit})_{s,t} + \beta_2 \mathbb{1}(\text{Rate Limit})_{s,t} + \beta_3 \mathbb{1}(\text{Assessment Limit})_{s,t} \\ + \beta_4 \text{Levy Limit}_{s,t} + \beta_5 \text{Rate Limit}_{s,t} + \beta_6 \text{Assessment Limit}_{s,t} + X_{s,t}\beta + \varepsilon_{s,t}. \qquad (6)\end{aligned}$$

We first report the extensive margin effects of levy, rate, and assessment limits on *Tax Policy Risk* estimated separately. These appear in columns 1-3 of Table 5, respectively. Relative to an unconditional average value of \$245, *Tax Policy Risk* is on average \$181 higher in states with levy limits, \$103 higher in states with rate limits, and \$338 higher in states with assessment limits. These numbers are similar when we include all types of property tax limitations in the same specification (column 4), albeit somewhat smaller for levy limits (\$168) and larger for both rate limits (\$149) and assessment limits (\$363).

In columns 5-7, we introduce additional measures of limit stringency and report estimates of the corresponding intensive margin effects of different tax limitations, where larger values of these continuous measures imply less restrictive limits. As expected, policy risk decreases for every percentage point increase in allowed levy growth, statutory effective tax rates, or capped taxable value growth. With all variables included (column 8), we find that *Tax Policy Risk* decreases by \$27 for every percentage point increase in allowed levy growth, by \$18 for every percentage point increase in the maximum effective property tax rate, and by \$17 for every percentage point increase in allowed taxable value growth. Overall, these results imply that households would be willing to pay between approximately \$150 and \$350 annually—*on average*—to avoid the risk consequences associated with these different types of property tax limitations. For the set of households that are more susceptible to liquidity shocks, such that this risk leads to mortgage distress, the costs are certainly much higher.

8 Conclusion

Using parcel-level panel data for the near universe of residential properties located within 20 miles of all U.S. state borders and a comprehensive measure of property tax risk that reflects states' full complement of property tax system characteristics, we confirm that tax policy risk has a pronounced effect on mortgage distress. Thus, despite reducing intertemporal variation in property tax liabilities, property tax limitations have the perverse effect of increasing risk for homeowners during market downturns, and we show that this increase in risk constitutes a significant trigger event for mortgage distress. Moreover, these effects are reinforced among homeowners facing otherwise stronger strategic incentives for default due to being underwater on their mortgage loans, and vice versa.

Tax policy risk is hence a fundamental aspect of property tax systems throughout the U.S., even in regimes that were ostensibly devised to protect homeowners from rising tax obligations. Missing from consideration is the role that counter-cyclical tax adjustments may play in amplifying household financial distress during periods of weak macroeconomic performance and whether targeted measures to protect vulnerable homeowners during market downturns may be warranted.

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Figure 1: State Assessment Limitation Regimes (2016)

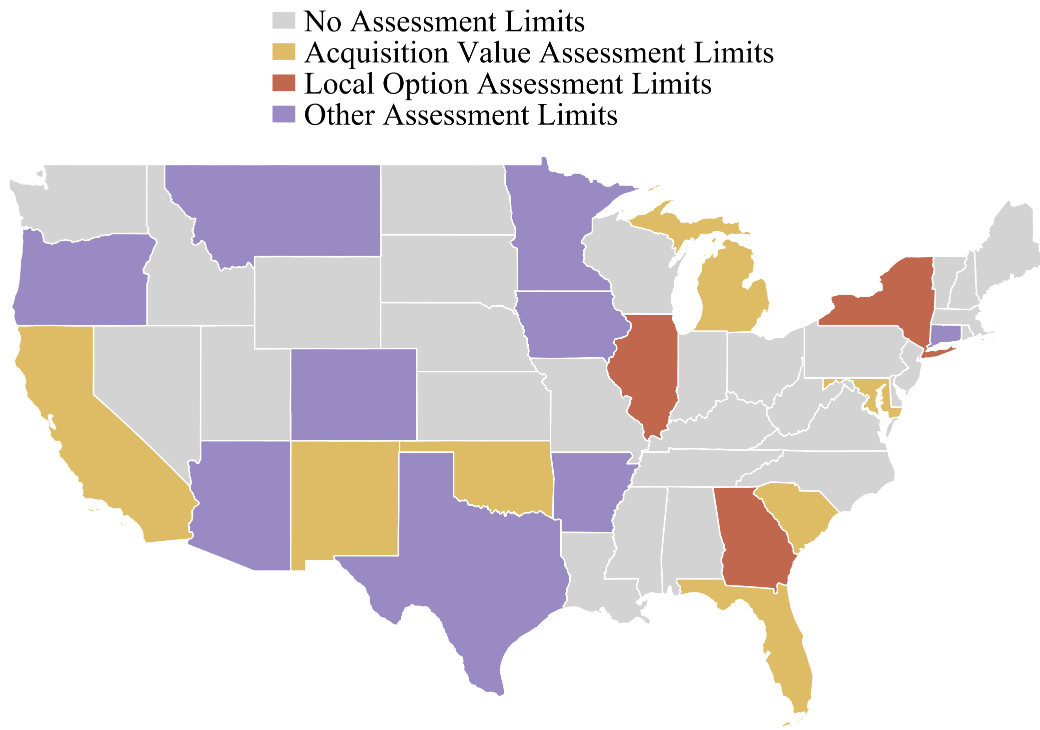


Figure 2: Taxable Values versus Assessed Market Values

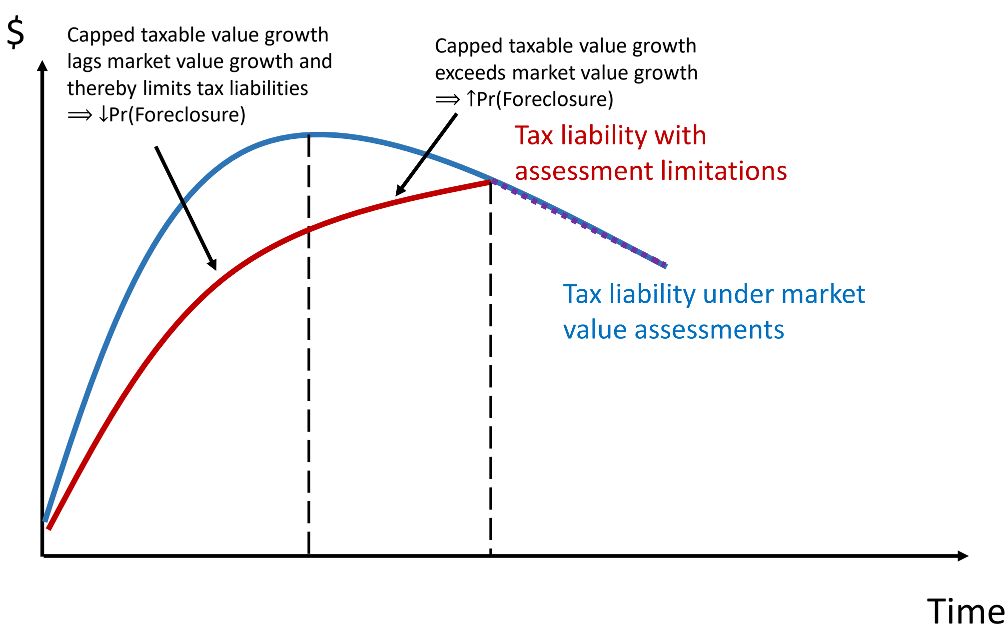


Figure 3

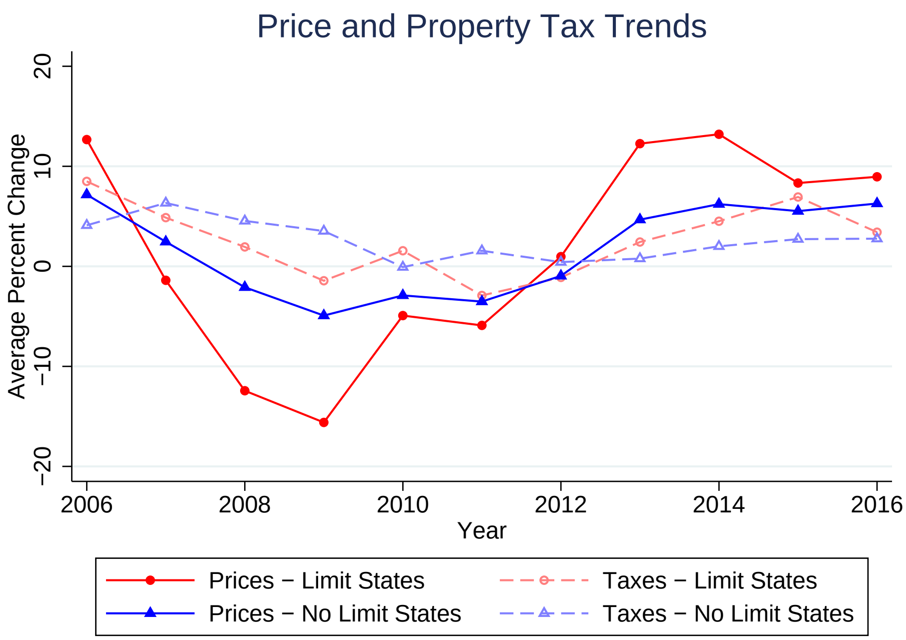


Figure 4

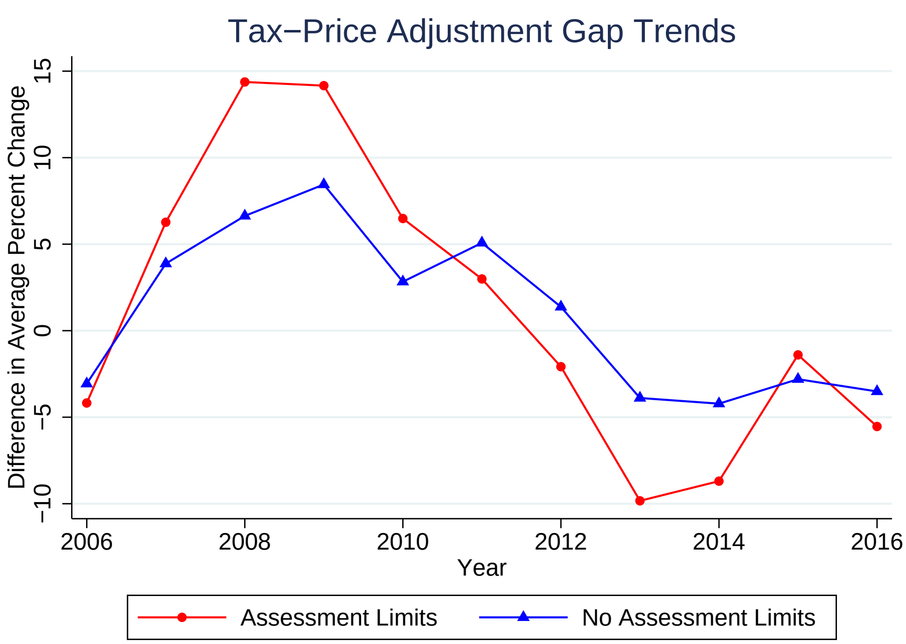
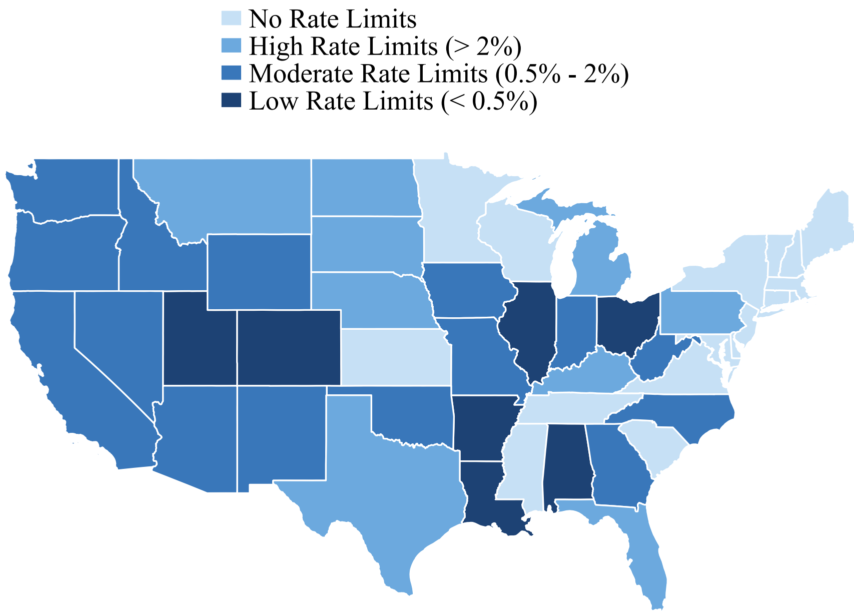


Figure 5: State Rate Limitation Regimes (2016)



To ensure comparability across states, statutory millage rate caps are translated into percentages of fair market value using applicable assessment ratios.

Figure 6: State Levy/Revenue Limitation Regimes (2016)

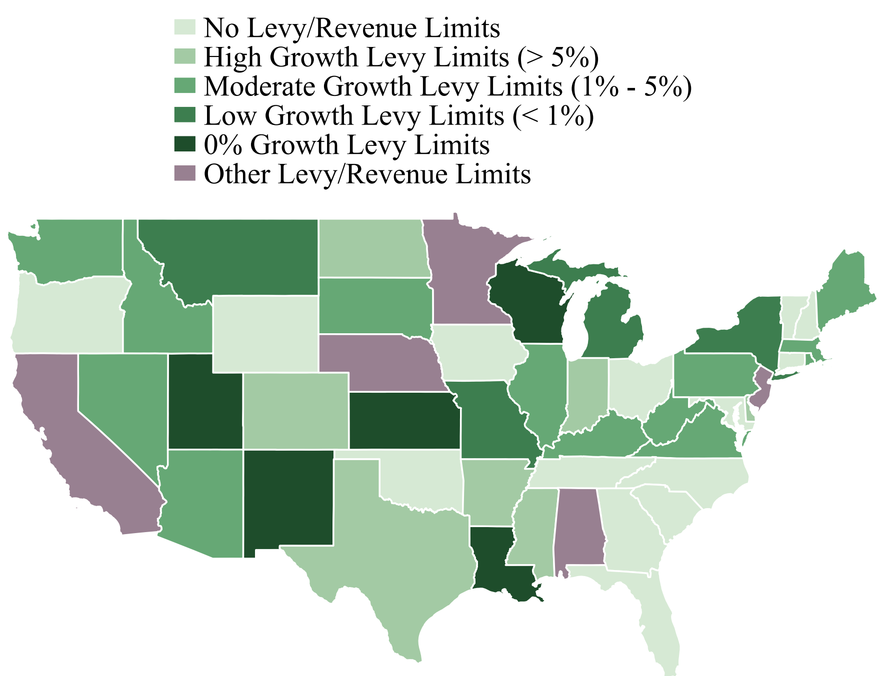
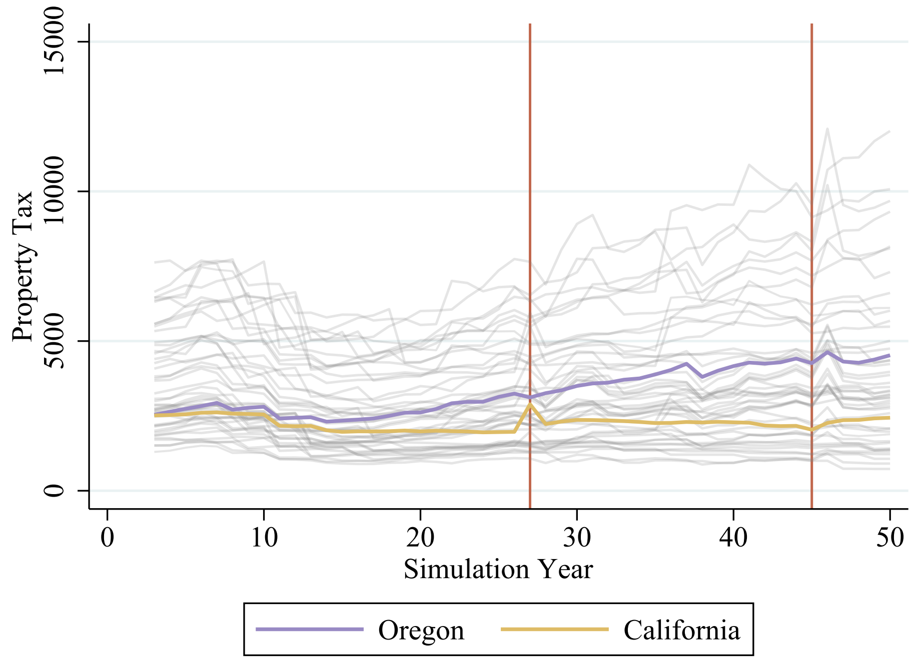


Figure 7: **Simulated Property Tax Bills**



Different lines depict the evolution of states' simulated property tax bills of the same property as a function of state-specific policies for the same economy and transaction process. Red vertical lines denote recession years in the simulation.

Figure 8: **Policy Risk by States**

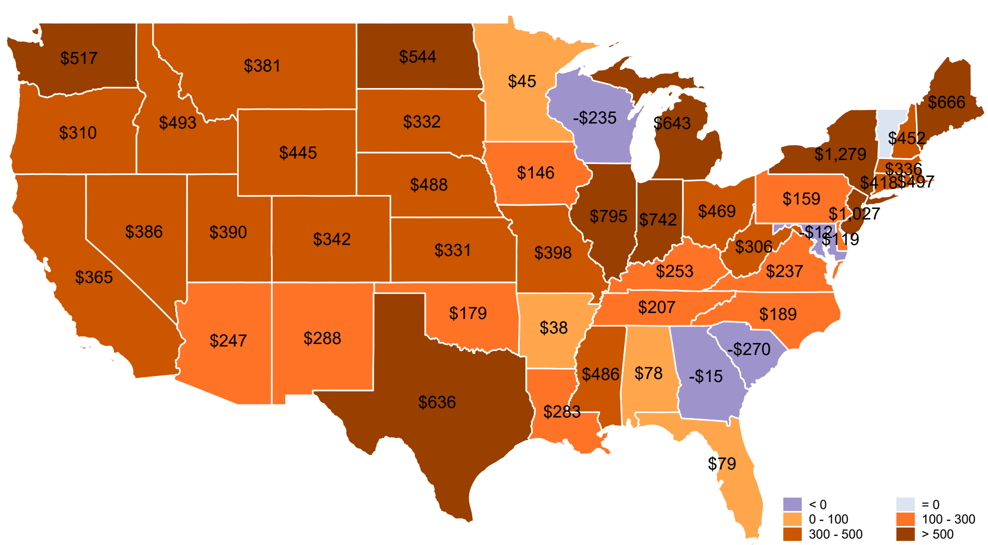


Figure 9: **Policy Risk by States – Rescaled**

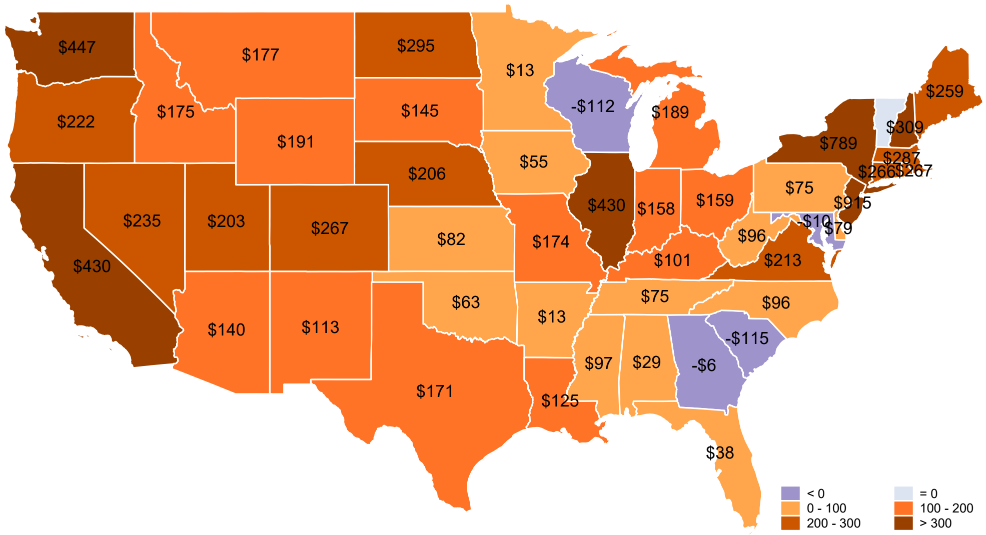
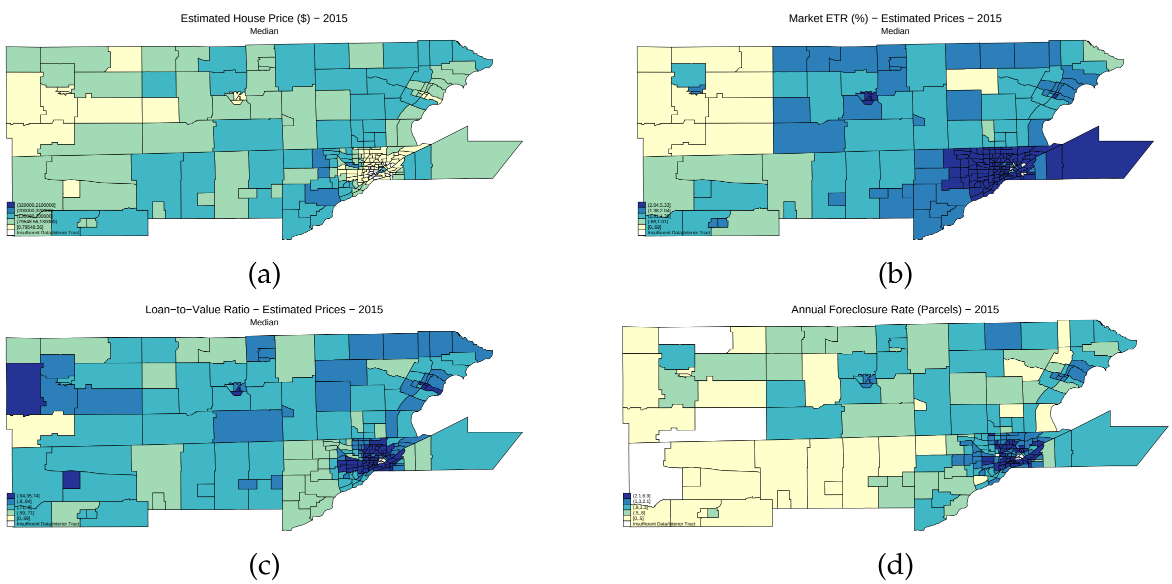
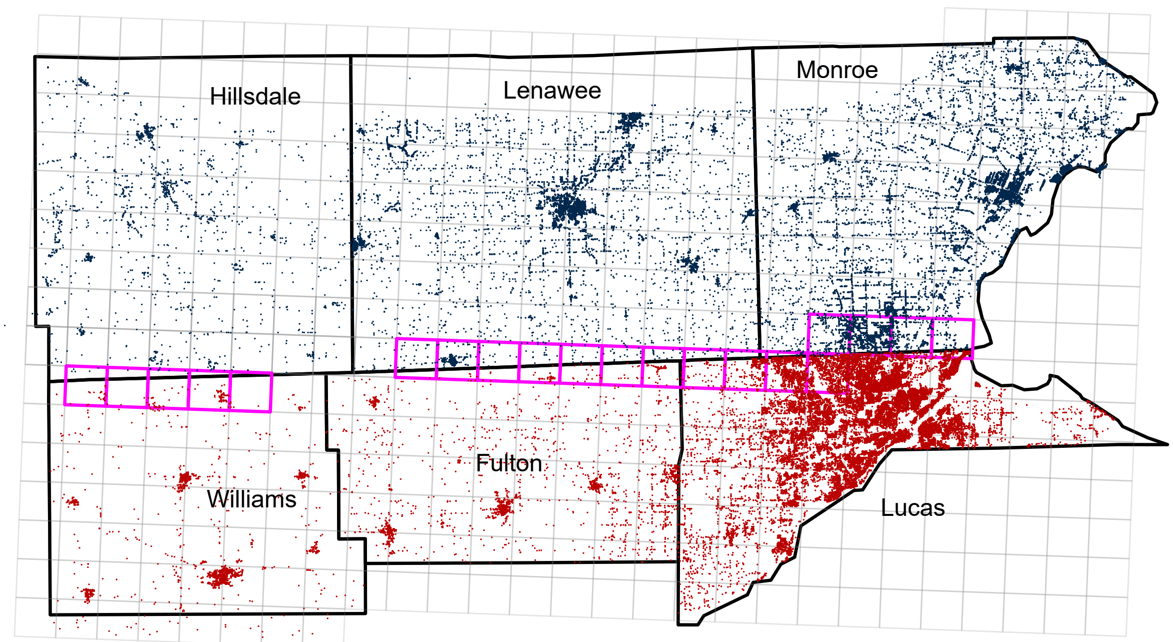


Figure 10: Local Housing Market Characteristics Across State Borders: MI-OH



Maps each show median property characteristics for the set of all Census tracts located in the six counties at the Michigan-Ohio border. The state border follows the near-horizontal midsection line. The tight cluster of tracts in the southeast corner of the map is Toledo, OH, just south of the state border.

Figure 11: Parcels and 5 km² Grid Cells: MI-OH



Blue (red) points denote all unique parcel locations in our estimation sample for Michigan (Ohio) along the states' shared border. Border-straddling 5 km² grid cells that contain parcels in both states are outlined in magenta based on the latitude-longitude coordinates of included parcels, while interior cells and border-straddling cells that contain parcels from only one state appear outlined in gray.

Table 1: State Policy Variables (2016)

State	Assessment Limitations	Other Assess Limits	Levy Limits	Rate Limits	Revenue/Spend Limits	Truth in Taxation	Lender Recourse	Non-Judicial Review	Appraisal Frequency
AL			x	x			x	x	1
AR		x	x	x			x	x	5
AZ		x	x	x	x	x		x	1
CA	x			x	x			x	-[a]
CO		x	x	x	x		x	x	2
CT		x	x				x		5
DC		x	x	x			x	x	1
DE			x	x		x	x		-
FL	x			x		x	x		1
GA		x		x		x	x	x	1
IA		x		x					2
ID				x			x	x	1
IL			x	x			x		4
IN			x	x			x		4
KS			x				x		-
KY			x	x		x	x		4
LA			x	x			x		4
MA			x	x			x		5
MD	x					x	x		3
ME			x		x		x		-
MI	x		x	x	x		x	x	1
MN			x		x			x	1
MO			x	x		x	x	x	2
MS			x				x	x	4
MT			x	x				x	2
NC				x				x	8
ND			x	x		x			1
NE			x	x	x		x	x	1
NH							x	x	-
NJ			x		x		x		-
NM	x		x	x	x		x		1
NV			x	x			x	x	5
NY		x	x				x		4
OH			x	x			x		6
OK	x			x			x	x	1
OR		x		x				x	1
PA			x	x			x		-
RI			x				x	x	9
SC	x			x			x		5
SD			x	x			x		1
TN			x				x	x	6
TX		x	x	x		x	x	x	3
UT			x	x		x	x	x	5
VA			x			x	x	x	4
VT							x		1
WA			x	x	x			x	6
WI			x		x				1
WV			x	x			x	x	1
WY				x			x	x	6

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

Table 2: Summary Statistics

	I[Distress]=0			I[Distress]=1			
Variable	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Diff.
Tax Policy Risk ($000s)	0.253	0.277	0.210	0.265	0.277	0.213	0.012
Tax Policy Level Diff ($000s)	-4.507	0.030	8.199	-4.627	0.017	7.985	-0.120
LTV	1.57	0.63	77.41	2.06	0.92	51.66	0.50
Price ($)	251188	177433	276850	185844	140078	184123	-65344
Lagged ETR (%)	1.48	1.17	1.35	1.64	1.25	1.47	0.16
Tenure	11.2	9	10.3	8.3	6	8.1	-2.9
Age	48.4	44	32.7	48.7	45	33.7	0.3
Renovation Age	42.6	37	33.9	43.7	38	34.8	1.2
Observations	22,966,629			332,836			

Table 3: Mortgage Distress and Tax Policy Risk

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tax Policy Risk	0.362*	1.735**	2.752***	3.135***	1.361**	1.455**	0.908***
	(0.215)	(0.706)	(0.675)	(0.470)	(0.557)	(0.688)	(0.279)
Tax Policy Level Diff		0.012	0.031***	0.040***	0.011*	0.003	0.005
		(0.008)	(0.010)	(0.008)	(0.006)	(0.006)	(0.006)
	$\ddots$	$\ddots$	$\ddots$	$\ddots$	$\ddots$	$\ddots$	$\ddots$
Constant	1.125***						
	(0.063)						
Fixed Effects:							
County pair		x					
10 km² grid			x				
5 km² grid				x			
Year		x	x	x			
County pair × Year					x		
10 km² grid × Year						x	
5 km² grid × Year							x
Observations	38,980,885	23,323,135	23,322,881	23,321,903	23,322,560	23,317,620	23,299,465
R-squared	0.000	0.017	0.018	0.019	0.020	0.023	0.027

Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses) are clustered by 5 km² grid cell. For brevity, only main effects are shown. Specifications (2)-(7) include controls for LTV, house price, lagged ETR, tenure, age, and renovation age, as well as indicators for recourse and non-judicial review states. Complete results for the set of specifications involving grid cell FE are reported in Appendix Table A.2.

Table 4: Mortgage Distress and Tax Policy Risk - Heterogenous Effects

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(1)	(2)	(3)
Tax Policy Risk	-1.554**		2.590***
	(0.750)		(0.892)
Tax Policy Level Diff	0.002	0.002	-0.015
	(0.006)	(0.006)	(0.013)
Tax Policy Risk × Unemployment Rate	0.349***		
	(0.124)		
Tax Policy Risk × LTV			
0 - 0.25		1.132***	
		(0.291)	
0.25 - 0.6		1.074***	
		(0.289)	
0.6 - 0.91		0.996***	
		(0.293)	
0.91 - 1.6		0.646**	
		(0.308)	
> 1.6		1.720***	
		(0.397)	
Unknown		0.603**	
		(0.286)	
Tax Policy Risk × % Δ_{T-0} Price			-0.0004***
			(0.000)
	$\ddots$	$\ddots$	$\ddots$
Fixed Effects:			
5 km² grid × Year	x	x	x
Observations	23,299,465	23,299,465	4,755,156
R-squared	0.027	0.028	0.061

Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses) are clustered by 5 km² grid cell. For brevity, only main and differential effects are shown. All specifications include controls for LTV, house price, lagged ETR, tenure, age, and renovation age, as well as indicators for recourse and non-judicial review states and all applicable interactions. Complete results are reported in Appendix Table A.3.

Table 5: Mechanisms

$Y = \textit{Tax Policy Risk}_{s,t}$	Extensive margin (1)	(2)	(3)	(4)	Intensive margin (5)	(6)	(7)	(8)
$\mathbb{1}(\text{Levy Limit})_{s,t}$	181.175***			167.828***	252.619***			281.624***
	(25.987)			(24.147)	(29.410)			(27.445)
$\mathbb{1}(\text{Rate Limit})_{s,t}$		103.163***		148.691***		104.635***		152.608***
		(26.266)		(23.916)		(28.667)		(26.421)
$\mathbb{1}(\text{Assessment limit })_{s,t}$			338.072***	363.452***			346.668***	417.073***
			(53.811)	(48.926)			(53.232)	(46.539)
$\text{Levy Limit}_{s,t}$					-21.955***			-26.679***
					(4.593)			(4.183)
$\text{Rate Limit}_{s,t}$						-0.828		-18.457***
						(6.415)		(5.406)
$\text{Assess. limit}_{s,t}$							-20.244***	-16.987***
							(6.094)	(5.710)
			$\ddots$	$\ddots$			$\ddots$	$\ddots$
F-statistic	48.607	15.426	18.772	31.778	0.197	7.703	17.180	30.138
Adj. R-Square	0.103	0.034	0.114	0.270	-0.002	0.031	0.135	0.359
Observations	417	417	417	417	417	417	417	417

The dependent variable is our measure of *Tax Policy Risk* (see Section 4) which varies at the state-year level. Levy, rate, and assessment limits are defined in Section 2. The first four columns report extensive margin estimates using indicator variables for whether a state-year has a given limit. The last four columns report intensive margin estimates using indicator variables and continuous variables (a higher limit makes it less binding). In columns (3), (4), (7), and (8), we include an indicator variable for whether assessment frequency is equal to 1 year to isolate the effect of assessment limits, see Appendix **??** for more details on the simulation and assessment frequency. This table excludes nondisclosure states, such that there are 38 state observations per year from 2007 to 2016 and 2006 has 37 state observations (missing South Dakota) for a total of 417 observations. Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses).

Appendix A Simulation Procedure

This section describes the detailed procedure for our simulation. The simulation captures two aspects of property tax policy risk – (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 shock, individual consumption shock, and property value. We then calculate the tax payments with and without the tax limits policy. Finally, we price the risk of tax payment and isolate the risk price of the tax limits policy.

• **Simulate the Economy Process**

We build an underlying economy process that consists of 500 properties (denoted by i) with 50 years of history (denoted by z). We first simulate the aggregate consumption shock series. We collect the aggregate consumption data from 1997 to 2020 from the Bureau of Labor Statistics. We assume the consumption growth follows an AR(1) process and estimate the following:

$$g_{s,t} = \beta_1 + \beta_2 g_{s,t-1} + \epsilon_{s,t},$$

where $g_{s,t}$ is the growth of the personal consumption expenditure (linecode = 1) for state s in year t. In addition, we separately model a recession process that follows Poisson distribution. We assume that recessions happen once every 15 years on average and that the aggregate consumption growth decline by 6% during recessions. Put together, we simulate the aggregate consumption shock as the following:

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

$$\tilde{g}_z = \hat{g}_z + \hat{\sigma}_\epsilon \tilde{x}_1 - 0.06 \cdot \tilde{x}_2$$

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

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

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

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, i.e., 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 with the assumption that it is unlikely that a person loses more than 80% of her total wealth in one year. This helps avoid extreme values and produces qualitatively similar results compared to not having this truncation.

We next simulate the inflation process. We collect inflation data 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 the following:

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

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

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

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

In addition, we assume that on average property value declines by 0% during recessions. We simulate the change in property value as the following:

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

where $\tilde{x}_4$ is a random variable that follows a standard normal distribution.

We then 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 but not lower than

1,000. With initial values and the changes in value of properties, we obtain a full panel of property values.

Finally, we also simulate the transaction status of the property. We assume that each property has a 7% probability of being sold in any given year, consistent with the average turnover rate in our data for the period 2006-2016.

• **Calculate the Property Tax**

We next calculate two property tax payments for each property i in (simulation) year z in the simulated economy – one payment with the tax limit policy in state s in (real) year t and one without. Before applying the tax limits, we make three adjustments with respect to heterogeneous property value across states, downward stickiness, and infrequent reassessment. First, we re-scale the property value by the median transaction value of properties in the border counties of state s in year t. We use the border counties for re-scaling to be consistent with our empirical design. Second, we empirically observe downward stickiness in the assessed value of properties. We capture this feature in the assessment value in the following way: if the change in property value, $h_{i,z}$, is positive, the value in the next year changes (grows) by $h_{i,z}$; but if the change is negative, there is a 30% chance that the value in the next year stays the same and a 70% chance that the value in the next changes (declines) by $h_{i,z}$. Lastly, for states that do not have assessment limit and do not reassess the property value every year, we process the assessment value in one of the two ways: (1) if the state has a fixed reassessment frequency greater than 1, we code the assessment value such that it updates once every fixed number of years, i.e., in non-assessment years the value is the last assessed value; (2) if the state does not mandate a fixed reassessment frequency, we assume each property has a 10% chance of being reassessed and updated to current market value.

We apply assessment limit on the taxable value. If the assessment value next grows too fast and would exceed the assessment limit, the taxable value is set such that it grows at exactly the assessment limit. Most states have a fixed assessment limit but some states (FL, CA, and MI) have a dynamic assessment limit, usually the lower of the CPI (simulated as f_z) and a fixed number. For states that have the pop-up feature, we reset the taxable value to market value every time the property is transacted and apply the assessment limit rule to the property throughout the tenure of the new owner.

We apply levy limit in the following way. We use the taxable value and the effective tax rate (ETR) we empirically observed in state s year t to calculate a property tax for each property i in simulation year z. We then assume that the state has a complementary taxation policy – the state has a revenue growth target of g_z, the aggregate consumption growth. However, if the state has a levy limit and the aggregate consumption growth exceeds the limit, the revenue target is set at the levy limit. The state then adjusts the mill rate such that the tax revenue next year meets the revenue target. When the property market is too hot, the state reduces the mill rate such that the total tax revenue grows in line with the aggregate consumption growth. When the property market crashes, the state increases the mill rate to compensate for the smaller tax base.

We then apply mill rate limit. When the state wants to raise the mill rate during recessions, it has to comply with the mill rate limit. If the state would like to raise the mill rate that exceeds the limit, it is allowed to raise the mill rate at the mill rate and the revenue target will not be met. This process yields a dynamically determined mill rate taking into consideration of levy limit and mill rate limit.

We then calculate the final property tax, $q_{s,t,i,z}$, for property i in simulation year z with the tax limit policy of state s in year t to be the product of the taxable value and the dynamic mill rate. We also calculate a counterfactual property tax without any tax limit policy, $q'_{s,t,i,z}$, to simply be the market value times the ETR observed empirically.

• **Price Property Tax and Isolate Policy Risk**

For each property i in year z, we calculate the Arrow-Debreu price of the property tax during the entire tenure of the property. We assume a CRRA utility with a risk aversion of 3.5. The pricing kernel for property i in year z is:

$$p_{i,z} = 1/g_{i,z}^{3.5}$$

Note that the pricing kernel is not state-policy specific (i.e., it has no s and t subscript).

Denote the tenure of property i in year z as $T_{i,z}$. Throughout the tenure, the AD price of the property tax for property i in simulation year z under the policy in state s and year t:

$$\mathbb{P}_{s,t,i,z} = \sum_{y=z-T_{i,z}}^{z} p_{i,y} q_{s,t,i,y}$$

We further decompose the AD price of the property tax into a certain-equivalent component:

$$\mathbb{C}_{s,t,i,z} = \sum_{y=z-T_{i,z}}^{z} p_{i,y} \bar{q}_{s,t,i,y}$$

where $\bar{q}_{s,t,i,y}$ is the average property tax payment throughout the tenure, and a risk component:

$$\mathbb{R}_{s,t,i,z} = \sum_{y=z-T_{i,z}}^{z} p_{i,y} (q_{s,t,i,y} - \bar{q}_{s,t,i,y})$$

Note that by construction, $\mathbb{P}_{s,t,i,z} = \mathbb{C}_{s,t,i,z} + \mathbb{R}_{s,t,i,z}$. We also apply the same pricing kernel to the counterfactual property tax without policy, $q_{s,t,i,z}$, and obtain the counterfactual version of $\mathbb{P}'_{s,t,i,z}$, $\mathbb{C}'_{s,t,i,z}$, and $\mathbb{R}'_{s,t,i,z}$. The property tax risk induced by tax limits policy, or policy risk, is then:

$$\varDelta\mathbb{R}_{s,t,i,z} = \mathbb{R}_{s,t,i,z} - \mathbb{R}'_{s,t,i,z}$$

We then drop two types of observations from the simulated panel of properties that could potentially cause inaccuracies for the simulation. We first drop the first 20 years of the simulation (i.e., $z < 20$) because all properties are hard-coded to be transacted in year 1, which may cause unintended results. By the simulation year 20, most properties have at least "naturally" been transacted once before, which mitigates the potential unintended interactions. Second, we also drop observation with which the tenure of the property is greater than 15 years (i.e., $T_{i,z} > 15$) to avoid potential outliers driving the simulation results.

Finally, we average across the remaining observations in the simulated property panel to obtain one value, $\varDelta\mathbb{R}_{s,t}$, that captures the tax policy risk for state s in year t. 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 is the main independent variable of interest for the empirical analysis.

Appendix B Variable Definitions

Notation	Description
i	An index that denotes property or property owner.
z	An index that denotes year in the simulation.
s	An index that denotes state.
t	An index that denotes year.
$p_{i,z}$	The pricing kernel for property owner i in year z.
π_t	The state probability of the world in year t.
$C_{i,t}$	The consumption of property owner i in year t.
$q_{s,t,i,z}$	The tax payment of property owner i in simulation year z under the policy in state s in year z.
$\mathbb{P}_{s,t,i,z}$	The Arrow-Debreu price of property taxes during the entire tenure of property owner i in simulation year z under the policy in state s in year z.
$\mathbb{C}_{s,t,i,z}$	The certainty equivalent of property taxes during the entire tenure of property owner i in simulation year z under the policy in state s in year z.
$\mathbb{C}'_{s,t,i,z}$	The counterfactual of $\mathbb{C}_{s,t,i,z}$, i.e., the certainty equivalent without any tax limit policy.
$\mathbb{R}_{s,t,i,z}$	The property tax risk during the entire tenure of property owner i in simulation year z under the policy in state s in year z.
$\mathbb{R}'_{s,t,i,z}$	The counterfactual of $\mathbb{R}_{s,t,i,z}$, i.e., the property tax risk without any tax limit policy.
$\Delta\mathbb{R}_{s,t,i,z}$	The difference between $\mathbb{R}_{s,t,i,z}$ and $\mathbb{R}'_{s,t,i,z}$, i.e., the property tax risk during the entire tenure of property owner i in simulation year z under the policy in state s in year z.

Continued on next page

Table A.1 – continued from previous page

Variable Definitions	Description
$\Delta\mathbb{R}_{s,t}$	The simple average of $\Delta\mathbb{R}_{s,t,i,z}$ over i and z, i.e., the tax policy risk of state s in year t.
$\mathbb{1}(\text{Distressed})_{i,t}$	An indicator that equals one if property i experiences any form of mortgage distress in year t and zero otherwise.
Tax Policy Risk$_{s,t}$	The same as $\Delta\mathbb{R}_{s,t}$, i.e., the tax policy risk of state s in year t.
$\mathbb{1}(\text{Levy Limit})_{s,t}$	An indicator that equals one if state s has a levy limit in year t and zero otherwise.
$\mathbb{1}(\text{Rate Limit})_{s,t}$	An indicator that equals one if state s has a millage rate limit in year t and zero otherwise.
$\mathbb{1}(\text{Assessment Limit})_{s,t}$	An indicator that equals one if state s has an assessment limit in year t and zero otherwise.
Levy Limit$_{s,t}$	The level of levy limit in state s in year t.
Rate Limit$_{s,t}$	The level of millage rate limit in state s in year t.
Assessment Limit$_{s,t}$	The level of assessment limit in state s in year t.

Appendix C Machine Learning Hedonic Estimation

TBA

Appendix D Sample Construction

TBA

Appendix E Assessment Limits and the Tax-Price Gap

As we show in Section 7.3, assessment limitations contribute more to tax risk than any other type of tax limit. This is not entirely surprising given the discussion in Section 2.2 about how assessment limitations can give rise to rising tax obligations during periods of declining home prices, and this is reflected in the divergence between tax-price adjustment gaps for assessment limitation states versus other states, as depicted in Figure 4.

In this section, we investigate to what extent assessment limits affect property tax liabilities at the parcel level and how the resulting spread between the growth in tax payments and home values ultimately affects mortgage distress. In contrast to the measure of tax policy risk used for our primary analyses, the tax-price adjustment gap lacks a clean economic interpretation, and we cannot use it to readily address the effect of interactions among different features of states' property tax regimes, or the stringency thereof. 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 at a faster rate than housing values and the tax-price gap is growing (e.g., during a market downturn in assessment limitations states), this contributes to an increased probability of distress. For each of these tests, we employ similar methods and data as used in our main analyses.

Our first empirical specification consists of testing how changes in housing prices affect property tax liabilities as a function of whether those 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

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

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 which denote different durations of ownership. Due to the nature of assessment limits, the effect of the limits can differ based on how long an owner has had the property, which we capture with the interaction terms and vector of coefficients δ^k. $X_{i,t}$ is a vector of property-specific control variables, which consists of the lagged ETR and estimated house price. All specifications include grid cell by year pair fixed effects $\lambda_{j,t}$ to implement our border discontinuity design.

Results from this first-stage test are shown in Table A.4. As shown in column 1, properties in assessment limitation states experience larger changes in annual property tax obligations overall—roughly 0.5 percentage points larger—than their counterparts in adjacent no-limit states, while 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 points to the fact that tax assessments tend to adjust slowly or infrequently in all states, including those with notional market value assessment regimes.[30] As a result, the combination of taxable value uncapping for newly sold properties along with regular capped taxable value adjustments–neither of which are closely tied to changes in home prices–evidently translate to larger average changes in annual tax obligations in states with acquisition value assessment limits. In column 2, we allow for changes in house prices to be passed through to tax liability at a different rate in assessment limitation states, and we further break down the average rate of property tax increases in these states as a function of 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 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

[30] 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.

probability model:

$$
\begin{aligned}
\mathbb{1}(\text{Distressed})_{i,t} = & \beta_0 + \beta_1 \mathbb{1}(\text{AssessmentLimit})_{s,t} + \beta_2 \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\
& + \beta_3 \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} + \theta^k \mathbb{1}(\text{Tenure})_{i,t} \\
& + \gamma^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \\
& + \rho^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\
& + \delta^k \mathbb{1}(\text{Tenure})_{i,t} \times \mathbb{1}(\text{AssessmentLimit})_{s,t} \times \mathbb{1}(\Delta \text{ Price} < 0)_{i,t} \\
& + \beta_2 \mathbb{1}(\text{NonJudicial Review})_{s,t} + \beta_3 \mathbb{1}(\text{Recourse})_{s,t} \\
& + X_{i,t}\beta + Z_{i,t}\beta + \lambda_{j,t} + \varepsilon_{i,t},
\end{aligned}
\tag{A.2}
$$

We again allow for the effect of assessment limitations to differ according to homeowner tenure, and we allow these effects to differ further depending on whether house prices decreased from the prior period to capture possible asymmetric effects. We augment our vector of controls $X_{i,t}$ to incorporate additional factors related to strategic default incentives and proxies for trigger events, exactly as in equation **??** in Section 6.

As shown in the first column of Table A.5, 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, and the contrast between these sets of 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 contribute to a higher probability of distress, without any statistically significant difference between states with or without assessment limits. With a full set of interactions between assessment limit, tenure, and directional price change indicators (column 2), we note that whereas new homeowners are at significantly lower risk of distress in states without assessment limits (and even more so when prices are falling), new and short-tenured homeowners are at significantly higher risk of distress in assessment limitation states (especially when house prices are falling). Overall, the set of homeowners who face the greatest increase in risk of mortgage distress are the subset of homeowners in assessment limitation states during market downturns who have been in their homes 2-5 years—long enough to have potentially enjoyed a few years of capped taxable growth prior to the downturn but not so long as 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 sort of "second-stage" analysis. Defined as the difference between the percent change in annual tax liability and the percent change in house price, $\Delta Tax - PriceGap$ incorporates the primary mechanism through which assessment limits may induce property tax liabilities to deviate from what would occur under annual market value based assessments. Absent any changes in statutory tax rates, this variable should equal zero under a system of annual market value based assessments, and non-zero values hence represent the extent to which changes in property tax liabilities deviate from such a regime.

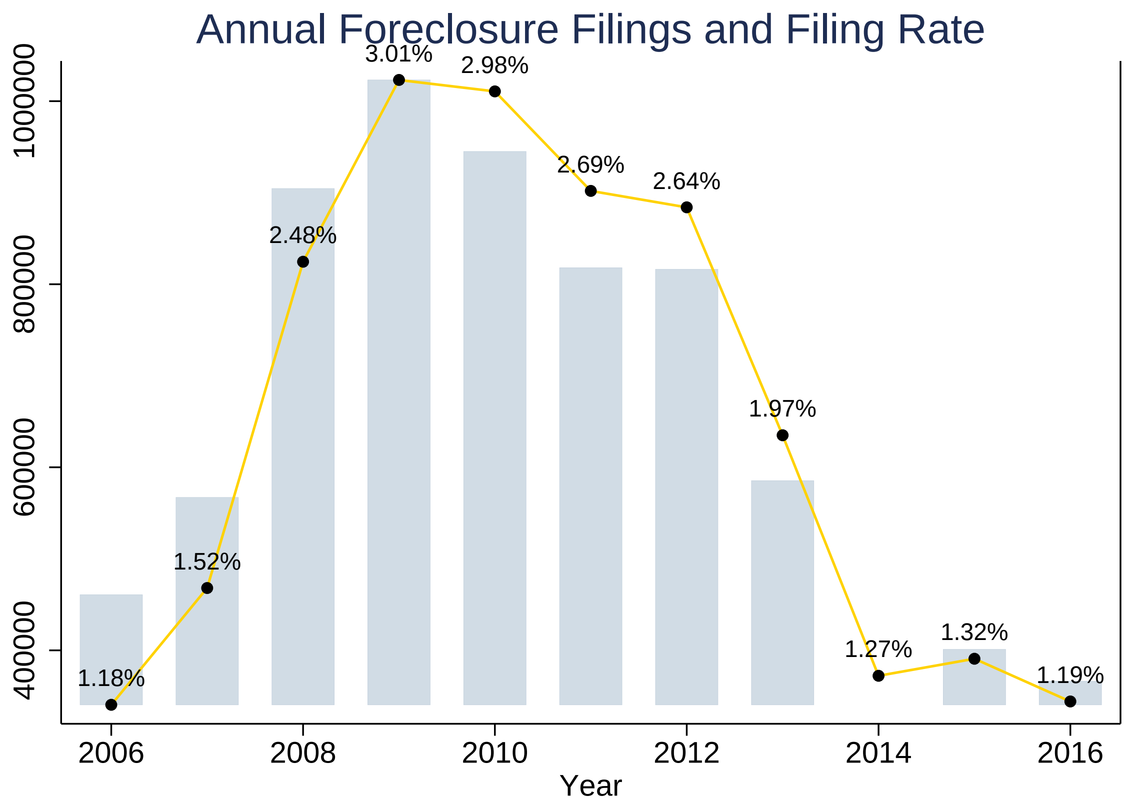
As shown in column 1 of Table A.6, larger tax-price gaps are responsible for a higher probability of mortgage distress everywhere, but this effect is significantly more pronounced in assessment limitation states and virtually twice as large. Furthermore, this effect is again largest for the 25 percent 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 zero tax-price gap, new homeowners are generally at lowest risk of distress in states without assessment limits, with gradually increasing risk for longer-tenured homeowners thereafter, but this pattern is largely reversed in assessment limitation states, presumably due to the outsized role of taxable value uncapping and subsequent capped taxable value growth.

As noted in Section 2.2 and documented in Figure 4, the average Δ Tax-Price 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.[31] For comparison, homes with an LTV of 91 to 160 percent or more are estimated to face a 2.2 to 2.9 percentage point increase in the probability of distress relative to those with an LTV of less than 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 tax policy risk due to assessment limitations, as discussed in Section 7.

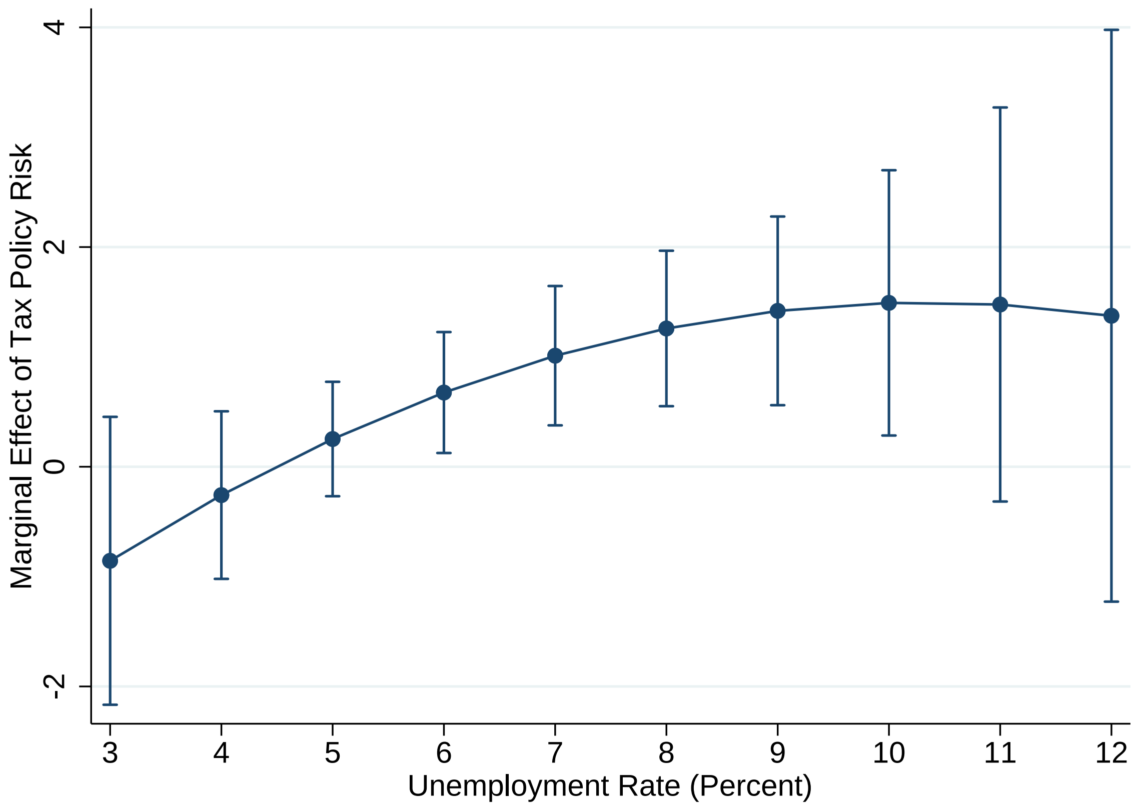
[31] i.e., $(0.008 + 0.011) * 15 = 0.285$

Figure A.1: Trends in National Foreclosure Activity



Foreclosure activity reflects only the first foreclosure event in a sequence of distressed transactions for our initial (national) sample of linked property tax assessment, realty transaction, loan, and foreclosure data.

Figure A.2: Marginal Effects of Tax Risk as a Function of Unemployment



Marginal effects of tax risk are estimated from a model featuring interactions of tax risk with a quadratic function of state-year average unemployment rates.

Table A.2: Mortgage Distress and Tax Policy Risk

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(3)	(4)	(6)	(7)
Tax Policy Risk	2.752***	3.135***	1.455**	0.908***
	(0.675)	(0.470)	(0.688)	(0.279)
Tax Policy Level Diff	0.031***	0.040***	0.003	0.005
	(0.010)	(0.008)	(0.006)	(0.006)
LTV				
0.25 - 0.6	-0.091***	-0.078***	-0.085***	-0.074***
	(0.018)	(0.015)	(0.018)	(0.015)
0.6 - 0.91	0.612***	0.622***	0.616***	0.624***
	(0.028)	(0.021)	(0.028)	(0.021)
0.91 - 1.6	2.270***	2.258***	2.233***	2.213***
	(0.057)	(0.039)	(0.055)	(0.038)
$>$ 1.6	2.896***	2.856***	2.855***	2.822***
	(0.110)	(0.075)	(0.104)	(0.071)
Unknown	-1.531***	-1.558***	-1.569***	-1.597***
	(0.053)	(0.033)	(0.055)	(0.034)
Price	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Lagged ETR	0.048***	0.039***	0.047***	0.037***
	(0.008)	(0.005)	(0.007)	(0.005)
Tenure				
$<$ 2 years	-0.883***	-0.897***	-0.898***	-0.913***
	(0.054)	(0.034)	(0.056)	(0.035)
2-5 years	-0.064**	-0.078***	-0.070**	-0.082***
	(0.032)	(0.021)	(0.035)	(0.022)
Unknown	1.554***	1.582***	1.610***	1.643***
	(0.080)	(0.047)	(0.081)	(0.048)
Age				
10-19 years	-0.469***	-0.439***	-0.457***	-0.426***
	(0.055)	(0.040)	(0.053)	(0.033)
20-59 years	-0.435***	-0.390***	-0.435***	-0.394***
	(0.055)	(0.036)	(0.055)	(0.032)
60-99 years	-0.322***	-0.306***	-0.267***	-0.241***
	(0.063)	(0.040)	(0.060)	(0.035)
>99 years	-0.127*	-0.080*	-0.086	-0.032
	(0.072)	(0.047)	(0.070)	(0.042)
Unknown	-0.085	-0.090	-0.162	-0.178
	(0.137)	(0.131)	(0.141)	(0.133)
Renovation Age				
11-32 years	-0.071***	-0.064***	-0.033*	-0.021
	(0.023)	(0.016)	(0.020)	(0.013)
33-59 years	-0.021	-0.017	-0.004	0.002
	(0.026)	(0.017)	(0.022)	(0.015)
> 59 years	0.241***	0.211***	0.219***	0.174***
	(0.033)	(0.022)	(0.031)	(0.021)
Unknown	-0.573***	-0.580***	-0.399***	-0.387***
	(0.126)	(0.128)	(0.132)	(0.130)
I[Recourse=1]	0.223	0.749***	-0.080	0.146
	(0.154)	(0.220)	(0.189)	(0.274)

Continued on next page

I[NonJudicialReview=1]	-0.518**	-0.277***	-0.445	-0.084
	(0.227)	(0.095)	(0.326)	(0.101)
Fixed Effects:				
10 km² grid	x			
5 km² grid		x		
Year	x	x		
10 km² grid × Year			x	
5 km² grid × Year				x
Observations	23,322,881	23,321,903	23,317,620	23,299,465
R-squared	0.018	0.019	0.023	0.027

Significance levels are designated as *** $p<0.01$, ** $p<0.05$, and * $p<0.1$. Standard errors (in parentheses) are clustered by 5 km² grid cell.

Table A.3: Mortgage Distress and Tax Policy Risk - Heterogenous Effects

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(1)	(2)	(3)
Tax Policy Risk	-1.554**		2.590***
	(0.750)		(0.892)
Tax Policy Level Diff	0.002	0.002	-0.015
	(0.006)	(0.006)	(0.013)
Unemployment Rate	0.060		
	(0.123)		
Tax Policy Risk × Unemployment Rate	0.349***		
	(0.124)		
Tax Policy Risk × LTV			
0 - 0.25		1.132***	
		(0.291)	
0.25 - 0.6		1.074***	
		(0.289)	
0.6 - 0.91		0.996***	
		(0.293)	
0.91 - 1.6		0.646**	
		(0.308)	
> 1.6		1.720***	
		(0.397)	
Unknown		0.603**	
		(0.286)	
% Δ_{T-0} Price			0.001***
			(0.000)
Tax Policy Risk × % Δ_{T-0} Price			-0.0004***
			(0.000)
LTV			
0.25 - 0.6	-0.074***	-0.140***	0.351***
	(0.015)	(0.053)	(0.031)
0.6 - 0.91	0.624***	0.604***	0.165***
	(0.021)	(0.064)	(0.028)
0.91 - 1.6	2.213***	2.153***	1.338***
	(0.038)	(0.108)	(0.034)
> 1.6	2.822***	2.053***	2.562***
	(0.071)	(0.199)	(0.071)
Unknown	-1.597***	-1.161***	-0.724***
	(0.034)	(0.092)	(0.041)
Price	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Lagged ETR	0.037***	0.038***	-0.049***
	(0.005)	(0.004)	(0.011)
Tenure			
< 2 years	-0.913***	-0.911***	-1.984***
	(0.035)	(0.035)	(0.068)
2-5 years	-0.082***	-0.079***	-0.887***
	(0.022)	(0.022)	(0.057)
Unknown	1.644***	1.648***	23.5357***
	(0.048)	(0.049)	(1.950)
Age			

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10-19 years	-0.425***	-0.423***	-0.481***
	(0.033)	(0.033)	(0.049)
20-59 years	-0.393***	-0.391***	-0.193***
	(0.032)	(0.032)	(0.049)
60-99 years	-0.239***	-0.239***	0.007
	(0.035)	(0.035)	(0.065)
>99 years	-0.030	-0.031	0.176**
	(0.042)	(0.042)	(0.071)
Unknown	-0.176	-0.180	-0.177
	(0.133)	(0.133)	(0.352)
Renovation Age			
11-32 years	-0.021	-0.021	-0.092***
	(0.013)	(0.013)	(0.031)
33-59 years	0.001	0.002	-0.039
	(0.015)	(0.015)	(0.035)
> 59 years	0.173***	0.176***	0.369***
	(0.021)	(0.021)	(0.069)
Unknown	-0.388***	-0.382***	-2.144***
	(0.130)	(0.130)	(0.366)
I[Recourse=1]	1.287**	0.262	0.986*
	(0.648)	(0.281)	(0.511)
I[NonJudicialReview=1]	0.217	0.136	-0.670**
	(0.392)	(0.117)	(0.282)
I[Recourse=1] $\times$ Unemployment Rate	-0.155*		
	(0.090)		
I[NonJudicialReview=1] $\times$ Unemployment Rate	-0.044		
	(0.063)		
I[Recourse=1] $\times$ LTV			
0.25 - 0.6		0.045	
		(0.045)	
0.6 - 0.91		0.037	
		(0.055)	
0.91 - 1.6		0.121	
		(0.096)	
$>$ 1.6		0.564***	
		(0.158)	
Unknown		-0.185**	
		(0.086)	
I[NonJudicialReview=1] $\times$ LTV			
0.25 - 0.6		0.109***	
		(0.032)	
0.6 - 0.91		0.036	
		(0.043)	
0.91 - 1.6		0.156**	
		(0.076)	
$>$ 1.6		0.255*	
		(0.140)	
Unknown		-0.413***	
		(0.075)	
I[Recourse=1] $\times$ % Δ_{T-0} Price			-0.0003***

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			(0.000)
I[NonJudicialReview=1] $\times$ % Δ_{T-0} Price			-0.0005***
			(0.000)
Fixed Effects:			
5 km² grid $\times$ Year	x	x	x
Observations	23,299,465	23,299,465	4,755,156
R-squared	0.027	0.028	0.061

Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses) are clustered by 5 km² grid cell.

Table A.4: Property Tax Effects of Assessment Limitations (≈ 1st Stage)

Y = % Δ Tax	(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			
$>$ 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

Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses) are clustered by 5 km² grid cell. All specifications include 5 km² grid cell × year fixed effects.

Table A.5: Distress Probabilities and Assessment Limitations (≈ Reduced Form)

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(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**
		(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***

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	(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
	(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] $\times$ I[Δ Price $<$ 0]	-0.015	
	(0.025)	
I[NonJudicialReview=1] $\times$ I[Δ Price $<$ 0]	0.047**	
	(0.018)	
Tenure $\times$ 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 $\times$ I[NonJudicialReview=1]		
$<$ 2 years	0.046	-0.026
	(0.076)	(0.077)
2-5 years	0.242***	0.055*
	(0.059)	(0.032)
Unknown	1.182***	0.968***
	(0.126)	(0.093)
Tenure $\times$ I[Recourse=1] $\times$ I[Δ Price $<$ 0]		
$<$ 2 years		0.107
		(0.071)
2-5 years		0.282***
		(0.085)

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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

Significance levels are designated as *** p<0.01, ** p<0.05, and * p<0.1. Standard errors (in parentheses) are clustered by 5 km² grid cell. All specifications include 5 km² grid cell × year fixed effects.

Table A.6: Distress Probabilities and Tax-Price Trends (≈ 2nd Stage)

$Y = Pr(Distressed_t = 1), Y \in \{0, 100\}$	(1)	(2)
Δ Tax Gap	0.006***	0.000
	(0.001)	(0.001)
I[AssessmentLimit=1] $\times \Delta$ 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 $\times$ I[AssessmentLimit=1]		
$<$ 2 years		0.125**
		(0.058)
2-5 years		0.326***
		(0.049)
Unknown		0.024
		(0.081)
Tenure $\times \Delta$ Tax Gap		
2-5 years		0.008***
		(0.001)
$>$ 5 years		0.005***
		(0.001)
Unknown		0.010***
		(0.001)
Tenure $\times$ I[AssessmentLimit=1] $\times \Delta$ 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] $\times$ % 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)

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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)
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
		(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

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Significance levels are designated as *** $p<0.01$, ** $p<0.05$, and * $p<0.1$. Standard errors (in parentheses) are clustered by 5 km^2 grid cell. All specifications include 5 km^2 grid cell $\times$ year fixed effects.