When Prices Begin to Reflect Risk: Evidence From A Reform in Hazard Insurance for U.S. Mortgages

Matthew Carey Ricardo Correa Anil Jain†

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Abstract

Changes in the price of risk can influence credit and investment even when the underlying risk is unchanged. We study this mechanism using a nationwide shift to more granular flood-insurance pricing that raised premiums sharply in some locations and lowered them elsewhere. Linking detailed insurance records to loan-level mortgage data, we compare census tracts experiencing larger premium increases with nearby tracts that did not. Higher-premium areas saw declines in new mortgages, smaller loan sizes, and shifts toward borrowers with weaker credit, alongside reductions in new construction. The results show how re-pricing long-mispriced risks affects household budgets and lender behavior, with broader implications for credit supply and local investment.

Keywords: Hazard Risk, Insurance, Mortgages
JEL Codes: G12, G21, E31

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1 Introduction

Flood risk is a significant U.S. natural hazard, generating roughly $6 billion in annual damages with expected increases as development expands into vulnerable areas.[1] Yet residential flood insurance remains scarce: as of 2019, only about 4 percent of households nationwide, and 48 percent of those in designated high-risk zones, held policies (Bradt et al., 2021). The National Flood Insurance Program (NFIP), which provides nearly all residential coverage, has accumulated $22.5 billion in debt due to repeated catastrophic losses and long-standing premium subsidies. In October 2021, FEMA introduced Risk Rating 2.0 (RR2), the first comprehensive overhaul of NFIP pricing since 1968. RR2 replaced the prior zone-based formula with a property-level system incorporating building characteristics, proximity to water, expected flood frequency, and replacement cost, sharply altering the premium schedule while leaving underlying hazard risk unchanged.

We examine how this repricing affected mortgage and housing markets. Using confidential loan-level data linked to detailed NFIP policy records, we estimate the effect of RR2 on mortgage originations, borrower composition, loan performance, house prices, and new construction. Our primary treatment measure is the census-tract "cap share," defined as the fraction of policies receiving the statutory 18 percent maximum increase at their first renewal under RR2. Cap share captures the extent of pre-reform subsidization and the implied magnitude of premium increases as policies converge toward full-risk rates. We exploit cross-sectional variation in cap share in a difference-in-differences design with state-by-month or county-by-month fixed effects.

A key advantage of RR2 for identification is that it generates a large, plausibly exogenous

[1] This is the average inflation-adjusted cost per year between 2010 and 2024 from NOAA's National Centers for Environmental Information (https://www.ncei.noaa.gov/access/billions/summary-stats/US/2010-2024).

shock to the *price* of flood risk without any concurrent change in the *level* of physical risk. In contrast to flood map revisions, hurricane strikes, or new climate information—events that alter beliefs about underlying hazard exposure—RR2 adjusts only the pricing formula applied to existing risk. This separation enables us to isolate how mortgage and housing markets respond to a pure repricing shock rather than to updated assessments of physical risk, local damage, or regulatory reclassification.

Before RR2, mortgage lenders could offload much of their exposure to flood risk by shifting it to borrowers—especially those in subsidized areas—through mortgage covenants, and to the federal government through subsidized NFIP premiums (Sastry, 2022). RR2 alters this allocation in two ways. First, it shifts financial risk from the federal government to households whose premiums had previously been suppressed. Second, it redistributes risk within the policyholder pool, lowering premiums for lower-risk households and raising them for higher-risk properties. As a consequence, a greater share of flood risk now resides with mortgage borrowers in exposed areas. Borrowers who maintain coverage face higher premium burdens that may strain repayment capacity, while those who reduce coverage face heightened default risk should a flood occur (Fitzmaurice et al., 2025). We test whether lenders respond to this shift by adjusting mortgage supply in more affected tracts.

Recent research suggests that persistent mispricing of flood risk has inflated U.S. housing values by at least $121 billion (Gourevitch et al., 2023; Hino and Burke, 2020; Niu et al., 2025; Doerner et al., 2025), with information frictions, adverse selection, and cross-subsidization creating substantial allocative inefficiencies in both insurance and housing markets.[2] Despite this, evidence on the housing and mortgage market consequences of improved flood risk pricing is limited. Prior research on the 2012 Biggert-Waters Act,

[2]See (Bradt et al., 2021; Zhang, 2023; An et al., 2023) for discussions of realized moral risk in the market for flood insurance, and (Gruber and Solomon, 2025; Wagner, 2022) for predictions of how Risk Rating 2.0 may rebalance these risks.

which attempted to phase out a narrower set of subsidies, found decreases in prices for some properties, especially those exposed to sea level rise and those properties reclassified into flood zones (Indaco et al., 2019; Ge et al., 2025a; Collier et al., 2023). However, Risk Rating 2.0 differs in critical ways: it applies nationwide rather than targeting pre-FIRM (Flood Insurance Rate Map) properties, it incorporates property-specific characteristics rather than zone-level adjustments, and it redistributes subsidies from higher-risk to lower-risk properties within flood zones. These features create novel cross-sectional variation in treatment intensity that enables identification of causal effects on credit access, housing investment, and market liquidity.

To conduct our empirical test, we combine three primary data sources covering 2015 to 2024. First, we use a nonpublic, enhanced version of FEMA's NFIP policy records, which contains reliable native identifiers linking policies across renewals and accurate census tract coding, advantages not available in public OpenFEMA data. Second, we draw on the National Mortgage Database (NMDB), a five percent nationally representative sample maintained by the Federal Housing Finance Agency (FHFA) containing loan- and borrower-level information at origination and throughout loan performance.

Finally, we employ Cotality's building permit data linked to census tracts to measure new construction activity. Our final sample comprises 1.8 million unique policies across 28,781 census tracts, merged with mortgage and housing market outcomes spanning nearly a decade.

Our identification strategy exploits geographic variation in treatment intensity with saturated fixed effects. The difference-in-differences design compares outcomes in census tracts with varying cap shares before and after Risk Rating 2.0, conditional on either state-by-month or county-by-month fixed effects and census tract fixed effects. County-by-month fixed effects represent our preferred specification, absorbing all time-varying county-level shocks including local economic conditions, housing market trends, and disaster events. The key identifying

assumption is that conditional on these controls, census tracts with different pre-reform subsidization patterns would have experienced parallel trends in mortgage and housing outcomes absent the reform. Event study specifications plotting monthly leads and lags around the reform date provide visual evidence supporting parallel pre-trends.

We find that census tracts with higher cap shares experienced significant declines in mortgage market activity following Risk Rating 2.0. In our preferred specification with county-by-month fixed effects, a 10 percentage point increase in tract cap share is associated with a 1 percent decrease in new mortgage originations after the reform. This effect translates to approximately 2 to 3 fewer mortgages per year in a tract at the 75th percentile of cap share (70 percent capped and 67 mortgages per year) compared to a tract at the 25th percentile (25 percent capped and 53 mortgages per year). We observe similar patterns for average transaction values: tracts at the 75th percentile of cap shares saw property values in mortgage transactions decline by approximately 1.8 percent relative to tracts in the 25th percentile of cap shares. Event study estimates reveal that these effects emerged gradually over the first year following reform implementation, consistent with the staggered timing of policy renewals and the time required for information to diffuse through local housing markets.

On the intensive margin, we document compositional shifts in mortgage borrowers and loan characteristics. New mortgages originated in high-cap-share tracts after the reform went to borrowers with credit scores 3 points lower on average, and the likelihood of loans being sold to GSEs decreased. The share of owner-occupied properties rose by 1.2 percentage points patterns consistent with tightening credit access pushing marginal buyers toward properties with lower flood insurance costs or investors exiting high-premium areas. We find limited evidence of effects on existing mortgage performance, with no significant changes in delinquency rates, although we observe modest reductions in credit card debt among borrowers in tracts experiencing premium decreases.

Heterogeneity analysis reveals that effects strengthen in tracts with more flood policies in force, suggesting general equilibrium responses whereby concentrated insurance market disruptions generate larger spillovers to mortgage and housing markets. We also find suggestive evidence that wealthier tracts experienced larger effects, consistent with Risk Rating 2.0's incorporation of replacement cost into pricing formulas. However, these heterogeneous effects lose statistical significance in our most saturated specifications with county-by-month fixed effects, indicating that local economic conditions explain substantial cross-sectional variation.

This paper makes several contributions to the literatures on disaster risk pricing, insurance market reform, and mortgage credit supply. First, we provide comprehensive empirical analysis of Risk Rating 2.0's effects on housing and mortgage markets using realized premium changes rather than projections. Prior work on NFIP reforms has focused on the 2012 Biggert-Waters Act, which targeted a narrower set of properties and was partially reversed; Risk Rating 2.0 represents a permanent, program-wide repricing with different treatment patterns. Recent concurrent work by Ortega and Petkov (2024) examines Risk Rating 2.0's effects on insurance take-up, while Fabian (2024) analyzes construction responses using predicted rather than actual premium changes in two states. We extend this work by documenting mortgage market responses nationwide and by employing realized rather than predicted premium variation.

Second, we contribute novel measurement of insurance reform treatment intensity. The "cap share" variable captures the pervasiveness of pre-existing subsidization within small geographic areas, providing a continuous treatment measure that varies meaningfully across neighboring census tracts. This measurement approach provides additional information compared to binary indicators for FEMA flood zone designation or discrete flood map revision events used in prior studies (Blickle and Santos, 2022; Indaco et al., 2019; Mulder, 2024). Our access to enhanced NFIP data with reliable policy identifiers linked over time

represents an improvement over public OpenFEMA records, which may contain inconsistent census tract coding that may affect measurement.

Third, we document credit market adjustments to improved risk pricing distinct from previous findings on flood map revisions ((Blickle and Santos, 2022; Arseneau and Kara, 2025)) and other information effects.[3] Blickle et al. (2024) show that lenders already respond to flood risk beyond official FEMA maps, reducing approval rates and loan-to-value ratios for properties with high third-party flood risk scores. We demonstrate that when official insurance pricing changes to better reflect that underlying risk, mortgage markets respond on both extensive margins (fewer originations) and intensive margins (compositional shifts toward riskier borrowers), with effects persisting even after controlling for local economic trends. These findings suggest that flood insurance premium increases operate through affordability channels constraining borrower budgets, complementing recent work by Ge et al. (2025b) linking homeowner insurance premium increases to mortgage delinquency.

Fourth, we provide causal evidence on housing investment responses to improved disaster risk pricing. While prior work documents that flood events, sea level rise projections, and belief changes about disaster risk affect property values (Keys and Mulder, 2020; Hino and Burke, 2020; Bakkensen and Barrage, 2022), less is known about how correcting persistent mispricing through insurance reform affects new construction.[4] Our finding of reduced building permit issuance in high-cap-share tracts suggests that improved price signals may partially correct inefficient development patterns in flood-prone areas, though the slow glide path to full-risk rates likely attenuates near-term effects.

[3]For a sampling of the large literature on flood risk information and property prices, see (Skouralis et al., 2024; Gillespie et al., 2025; Fairweather et al., 2024; Billings et al., 2025; Miller and Pinter, 2022; Pollack et al., 2023; Sun et al., 2022; Aiba et al., 2025).

[4](Peralta and Scott, 2024; Ostriker and Russo, 2024) both study the *initial* implementation of FEMA flood maps on construction and household relocation, finding that existing homeowners were more likely to stay in risky, newly mapped and thus locations, but that new construction fell in newly mapped locations.

The remainder of the paper proceeds as follows. Section 2 describes the institutional features of the NFIP and the Risk Rating 2.0 reform. Section 3 presents our data sources, sample construction, and measurement of treatment intensity. Section 4 outlines our empirical strategy, identification assumptions, and results. Section 5 concludes.

2 Institutional Setting

The NFIP was established in 1968 in response to private insurers' retreat from the flood insurance market. Created by Congress and administered through the Federal Emergency Management Agency (FEMA), the NFIP engages in floodplain risk management programs in addition to providing federally backed insurance policies for both commercial and residential properties. Communities must opt into the NFIP for their residents to be eligible to purchase NFIP policies, which requires the implementation of baseline floodplain management protocols. Over 22,000 communities nationwide participate in the program. Policies are concentrated not only within communities but within regions: approximately sixty percent are in the particularly flood-prone states of Florida, Texas, and Louisiana. There are over four million active residential flood insurance policies nationwide, corresponding to a national take-up rate just under four percent. However, because flood insurance is voluntary for most properties, take-up rates are much lower outside of FEMA's mapped danger zones, known as Special Flood Hazard Areas (SFHAs). Bradt et al. (2021) estimate that only 2.2% of homes outside of SFHAs have flood insurance, compared to 48.3% of homes within SFHAs.

While private insurance companies are beginning to re-enter the flood insurance market, the NFIP still accounts for the vast majority of policies in force at the time of writing, especially those for residential properties. Approximately two-thirds of these residential NFIP policies are for single-family homes. Policies written under the NFIP have strict coverage limits of $250,000 for a residential structure ($500,000 for a commercial structure) and $100,000 for the contents of the structure, none of which have been updated since 1994 (GAO (2013)). Despite this, Collier et al. (2022) find widespread suboptimal behavior in household flood insurance selection, where households with flood insurance typically *over*-insure, often choosing the full coverage amount even in relatively low-risk locations. Contrastingly, Amornsiripanitch et al. (2025) estimate that nearly 90% of at-risk households are under-insured for their flood

risk by an average of $7,000 per year, and that over 70% of those households would benefit from purchasing insurance, even after premium increases.

Unlike homeowners' insurance, flood insurance is typically not mandatory in the United States. The exception to this rule is homes in FEMA-designated flood zones with active mortgages from federally backed lenders. However, monitoring falls to lenders, who often fail to strictly enforce continuous coverage. By tracking the percentage of new home purchases within SFHAs from 2014 to 2018 which maintained flood insurance policies in successive years after their insurance origination, GAO (2021) places a lower bound on compliance rates at approximately 90% after the first renewal year and below 80% after the third renewal year. The true compliance rate is likely higher, as within-SFHA properties can lose their NFIP flood insurance for a number of compliant reasons (SFHA boundary change, home foreclosure, switch to private insurance), although homeowners that never purchase NFIP flood insurance in favor of private insurance or noncompliance are not counted in their statistics. The issue of noncompliance is not new; Michel-Kerjan et al. (2012) found that from 2001-2009, the median NFIP policy tenure was 2 to 4 years, significantly less than the median housing tenure of of 5 to 6 years, implying that a substantial number of NFIP policyholders did not maintain coverage for the full duration of their housing tenure. [5]

The NFIP is funded primarily by the premiums it receives from policyholders. Historically, premium revenue has not been sufficient to cover the costs of paying claims and running the program, leading to a $22.5 billion lifetime budget shortfall owed to the US Treasury. The lion's share of this shortfall was accumulated in crisis years, such as Hurricane Katrina in 2005 and Hurricane Sandy in 2012, where the sheer volume of claims from catastrophic events far outweighed premium receipts. Revenue generation has been hampered by extensive subsidization of policies throughout the NFIP's lifetime, both from actuarially warranted

[5] We replicate their analysis using residential NFIP policy data from 2011 to 2024 and find that median policy tenure remained around 3 years throughout the 2010s, even as median housing tenure rose.

discounts and from grandfathering practices. Previous reform attempts which attempted to cut or phase out some subsidization, such as the Biggert-Waters Act of 2012, were later watered down due to affordability concerns.

Until recently, policy premiums were determined by a coarse formula which mainly relied on the location of a structure on FEMA's official flood maps inside or outside of an SFHA. These flood maps are still a primary method by which an existing or prospective owner can assess the flood risk of a property. While each map is meant to be updated every five years, most of the United States is covered by older maps; in 2019, 75% of flood maps were over five years old, and 11% were over thirty-five years old (Eby (2019)). Additionally, communities or property holders can pursue an appeals process which may downgrade the mapped flood risk of their area and which further delays map updates.

In October 2021, the NFIP began implementing Risk Rating 2.0, the first comprehensive update to its insurance pricing models and policies since the program's inception. Spurred by a growing recognition that its budget shortfall would not be sustainable in the long term, the program reworked its pricing formulas to include many more granular building characteristics, de-emphasizing flood map location in determining premium cost. Also, for the first time, premiums now take into account the replacement cost for a covered building.

The new pricing formula was applied to new policies starting on October 1, 2021, and to existing policies upon renewal between April 1, 2022 and March 31, 2023. New policies pay the rate applied by the new formula, referred to as the 'full risk rate' by FEMA, immediately. However, nearly all existing policies are subject to a statutorily mandated 18% cap on premium increases, meaning that if a policy's full risk rate tripled under the new formula, the policyholder would only see an 18% premium increase at their first renewal after Risk Rating 2.0, and subsequent compounding 18% increases along a 'glide path' until reaching their full risk rate.

The extent of NFIP subsidization prior to Risk Rating 2.0 is evident when considering FEMA's own projections of the time horizon after which existing policies will pay actuarially fair rates under the new pricing formula. As of December 2022, only one-third of NFIP policies were at their full risk rate, and by 2027, five years after Risk Rating 2.0's implementation, only half of policies will reach their full risk rate. FEMA further estimates that in 2035, ten percent of policies will still be below their full risk rate, even after a cumulative 914% increase in premiums accrued since Risk Rating 2.0's implementation (GAO (2023)). A policy with $500 premiums in 2021 that remains on the 'glide path' will cost $1,150 in 2026, and $5,070 in 2035. On aggregate, Risk Rating 2.0 lowered premiums for approximately 18% of policyholders at the time of its implementation, but it is projected to at least double premiums for nearly one-third of existing policyholders.

We note an acceleration in the decrease of residential policies in force after the reform's implementation, but with diverging magnitudes based on the percentage of policies in a given census tract with an 18% premium increase in their first renewal under Risk Rating 2.0, which we refer to as 'cap share' (Figure 1). By indexing each group of census tracts (0-30% cap share, 30-70% cap share, and 70-100% cap share) to their policy-in-force counts as of September 2021, we can see that Risk Rating 2.0 caused pre-existing trends to flip. Low cap share census tracts, on aggregate, had the sharpest rate of decline from January 2018 to September 2021, but after the reform, they have experienced the smallest decrease. Additionally, after full implementation of Risk Rating 2.0 for existing policies (the second gray dashed line at April 2023), high cap share tracts have continued to shed policies at a similar clip since the initial implementation, while the rate of decline for low cap share tracts has markedly slowed. These observations are consistent with Ortega and Petkov (2024), who find that renewal rates fell more sharply in the periphery of the flood zone than in the flood zone itself after Risk Rating 2.0. Census tracts in the periphery are most likely to have high cap shares, as their residents were the primary beneficiaries from the reliance of FEMA's

pre-reform pricing formula on location.

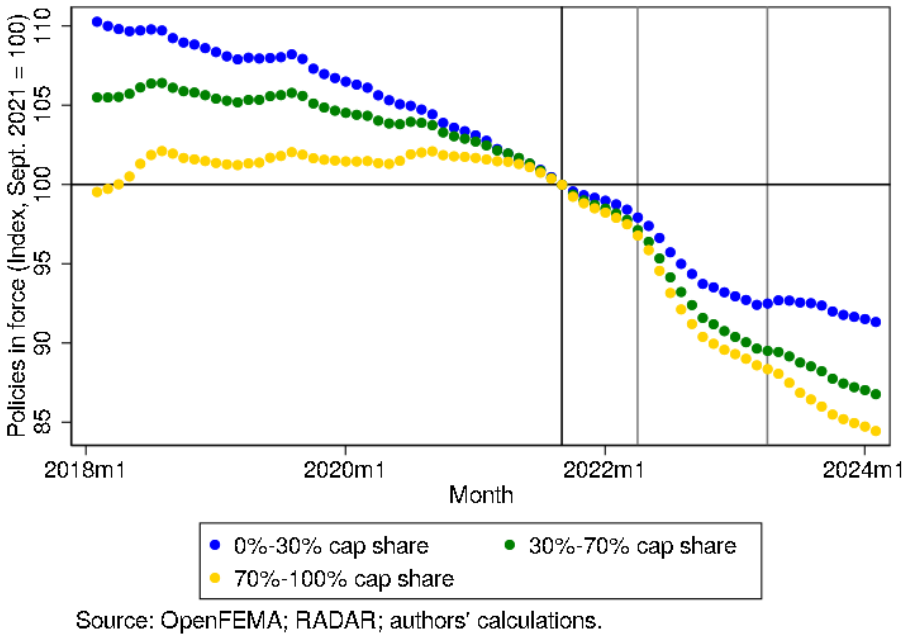
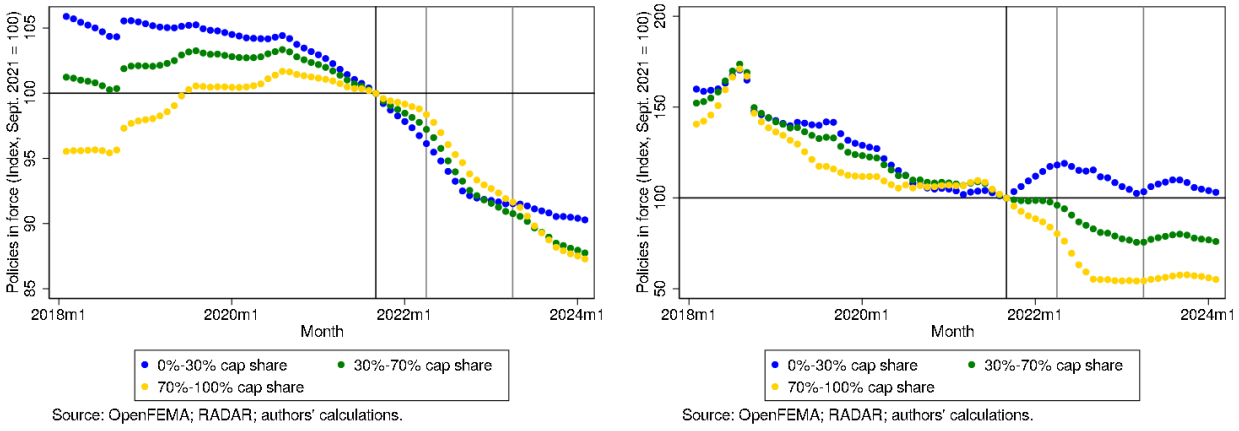


Figure 1: NFIP residential policies in force over time



(a) Existing policies **(b)** New policies

Figure 2: NFIP residential policies in force over time, disaggregated

We divide policy-in-force counts into new policies (those in their first twelve months after origination) and existing policies (those that have been renewed at least once) in Figure 2.

While the decline in existing policies in force relative to pre-reform levels is broadly consistent across cap share terciles within the implementation period for Risk Rating 2.0, since full implementation existing policy counts have stayed relatively stable in low cap share tracts, contrasting with continued declines in medium and high cap share tracts. The divergence seen in 1 during the implementation period is explained by the *increase* in flood policy take-up for low cap share tracts after October 2021, as homeowners were induced into take-up by premium declines. Meanwhile, new policy take-up in high cap share tracts plummeted after Risk Rating 2.0 went into effect for new policies, and has remained depressed since then.

3 Data

We obtain comprehensive information on the universe of NFIP policies from 2009 to 2024 from a nonpublic, enhanced version of the FEMA NFIP redacted policies dataset maintained by the Federal Reserve Bank of Philadelphia. This data includes a host of information on policy coverage and costs, as well as building and policy characteristics such as elevation, community rating, and a mandatory purchase dummy. The key advantage of this vintage is that it contains reliable native identifiers that connect policies over time – since standard flood insurance policies are renewed yearly, a unique policy in effect for n years will have n observations in the data, one for each renewal. These identifiers are not present in the publicly available OpenFEMA vintage, forcing researchers to create their own using nominally time-invariant characteristics such as census block group, base floor elevation, and policy original new business date (see Mulder and Kousky (2023), Ortega and Petkov (2024)). Critically, census tract and block group data is not reliable over time in the public vintage, which has not previously been noted in the literature. As a result, existing algorithms for linking policies over time may substantially mis-identify policy-year observations as distinct

when there are discrepancies in the reporting of census location measures.

Our main analysis sample consists of residential policies on single-family homes with policy origination dates prior to October 1, 2021 and at least one renewal on or after April 1, 2022. This date range only includes policies that were both purchased under FEMA's old pricing regime and renewed at least once under Risk Rating 2.0. We further restrict to policies that did not experience a change in coverage alongside their first renewal under Risk Rating 2.0, and to census tracts with at least eight policies in force in January 2021. Summary statistics for the relevant years of the analysis sample are in Table 1; a broader pre- and post-reform summary snapshot is in Appendix Table A1. The sample includes over 1.8 million unique policies, 87% of which are for primary residences and 42% of which are located in a flood zone. Median coverage for the sample policies is at the $350,000 combined limit for building and contents.

	Pre-reform		Post-reform	
	Mean	Median	Mean	Median
Insurance premium (annual)	653.03	442.00	646.11	522.00
Total coverage	311324.31	350000.00	311324.31	350000.00
Building replacement cost	348690.90	250000.00	348690.90	250000.00
Cost per $1000 coverage	2.50	1.36	2.38	1.49
	Pre-reform		Post-reform	
Located in SFHA	0.424		0.424	
Mandatory purchase	0.163		0.163	
Primary residence	0.866		0.866	
In CRS community	0.729		0.733	
N	1,813,760 (50.00%)		1,813,760 (50.00%)	

Table 1: Descriptive statistics for flood policy sample, specifically the last pre and first post reform years

For each census tract, we generate the distribution of premium changes in the first renewal year under Risk Rating 2.0, obtaining statistics for all policies within a tract, mandatorily purchased policies, and voluntarily purchased policies. These tract-level measures are then

	Policies			Tracts		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
First-year premium change	0.096	0.179	0.192			
Cap dummy	0.626	1	0.484			
Cap share				0.473	0.5	0.282
Observations		1,813,760			28,781	

Table 2: Average first year premium change of +9.6%, 62.6% of policies capped Median census tract had 47.3% cap share

merged with loan-level mortgage data. We use the National Mortgage Database (NMDB), a nationally representative five percent sample of mortgages across the United States maintained by the Federal Housing Finance Agency (FHFA). The NMDB allows us to track loan- and borrower-level data both at the time of origination and across the life of a loan, incorporating additional data on non-mortgage credit outcomes for borrowers which augment our analysis. Importantly, the NMDB includes both conforming and jumbo loans, providing a broad view of the mortgage market at all price points. Descriptive statistics for our analysis sample of NMDB loans are in Table 3. We validate our use of the NMDB by replicating our central results with loan-level confidential Home Mortgage Disclosure Act (HMDA) data, the standard mortgage data set used in the literature.

Further analysis is conducted using the Cotality Home Price Index and Cotality Building Permit data sets. The Home Price Index (HPI) is a weighted repeat-sales index for single-family homes, calculated for regions down to the zip code and county level. Unlike the FHFA's House Price Index, the Cotality HPI is representative of all mortgage loans, including non-conforming/jumbo loans. The Cotality Building Permit data set contains information collected from permit-issuing jurisdictions on the date, status, location, and type of building permits issued in those jurisdictions. National coverage is uneven over time, peaking at approximately 2000 jurisdictions across the United States. We merge building permit data from 2018 to 2024 on shared identifiers with the Cotality Property Basic data set to connect

	(1)			
	Below median	Above median	Diff.	SE
ARM Dummy	0.03	0.02	0.01	(0.01)
GSE Dummy	0.44	0.45	-0.01	(0.02)
Owner Dummy	0.90	0.90	-0.00	(0.01)
Term (months)	331.58	331.48	0.11	(2.52)
First-time Owner	0.41	0.37	0.04*	(0.02)
Credit Score	731.49	735.31	-3.82	(2.23)
Age	42.49	43.47	-0.98*	(0.44)
DTI	35.55	36.21	-0.66*	(0.33)
Interest Rate	4.21	4.21	0.01	(0.03)
Value (Ln)	12.32	12.40	-0.08***	(0.02)
ln_tract_income	11.42	11.44	-0.02	(0.01)
policiesInForceJan21	68.69	141.80	-73.11***	(6.70)
pcount_total	50.75	110.66	-59.91***	(5.42)
pcount_mandatory	8.47	16.26	-7.79***	(1.24)
total_loans_2020	50.78	50.50	0.28	(1.10)

Figure 3: Summary statistics for NMDB loans, split by census tract cap rate being above or below the nationwide median

permits with their census tracts. While this data has some inconsistencies due to its sourcing from municipalities with idiosyncratic reporting conventions, we only utilize fields that have been cleaned or standardized.

4 Results

The statutory 18 percent annual cap on premium increases shapes how Risk Rating 2.0 first appears in the data. Policies that receive premium reductions move immediately to their new, lower full-risk rate, whereas policies requiring large upward adjustments are compressed into the same 18 percent increase at their first renewal–even when their actuarially fair premiums would be 80, 150, or 200 percent higher. This mechanical truncation obscures the true distribution of premium changes. To capture meaningful variation, we therefore construct two tract-level measures: the share of policies experiencing a premium decrease of at least 20 percent, and the share of policies whose first-year increase is capped at 18 percent ("cap share"). Cap share serves as a proxy for the prevalence of pre-reform subsidization within a tract and is our primary measure of treatment intensity.

Our baseline specification is:

$$y_{tract,month} = \beta \times post \times \text{share capped} + \alpha_{geo \times month} + \alpha_{tract} + \varepsilon_{tract,month} \tag{1}$$

where "share capped" denotes the fraction of policies in census tract t whose first renewal under Risk Rating 2.0 was subject to the 18 percent statutory cap, and $y_{t,m}$ is the tract–month outcome of interest (e.g., the number of new mortgage originations). We include either state-by-month or county-by-month fixed effects, along with tract fixed effects, and cluster standard errors at the tract level. These controls absorb all time-varying shocks at the

relevant geographic level and allow identification to come from within-state or within-county comparisons across tracts with different pre-reform subsidization levels. We estimate Poisson models for count outcomes and OLS for all other outcomes.

4.1 Loan-level effects in the extensive margin

We begin by examining how mortgage origination activity responds to the intensity of Risk Rating 2.0 within a census tract. Using a Poisson specification, we estimate whether tracts with a higher share of capped policies experience differential changes in the number of new mortgage loans after the reform. Table 3 reports a consistent negative relationship: tracts with more capped policies see fewer originations relative to other tracts, including those in the same state (column 2) or the same county (column 3). Our preferred specification, which includes county-by-month fixed effects, absorbs local economic conditions and time-invariant tract characteristics, allowing identification to come from within-county differences in pre-reform subsidization. The point estimate in column 3 implies that a tract with a 10 percent cap share experiences roughly 1 percent fewer new mortgages after the reform than a tract in the same county with no capped policies. Figure 4 shows a clear drop in originations beginning immediately after implementation, with no evidence of differential pre-trends apart from seasonality.

4.2 Loan-level effects in the intensive margin

The NMDB also allows us to examine how Risk Rating 2.0 affected the intensive margin of mortgage supply by studying both the characteristics of newly originated loans and the performance of existing ones. After the reform, census tracts with a higher share of capped

	(1) Total Loans	(2) Total Loans	(3) Total Loans
Post x Share Capped	-0.0603***	-0.0966***	-0.0972***
	(0.0197)	(0.0211)	(0.0222)
Observations	3040740	3040216	2713534
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State x Month FE	No	Yes	No
County x Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Risk Rating 2.0 reduced new mortgages in more heavily affected tracts

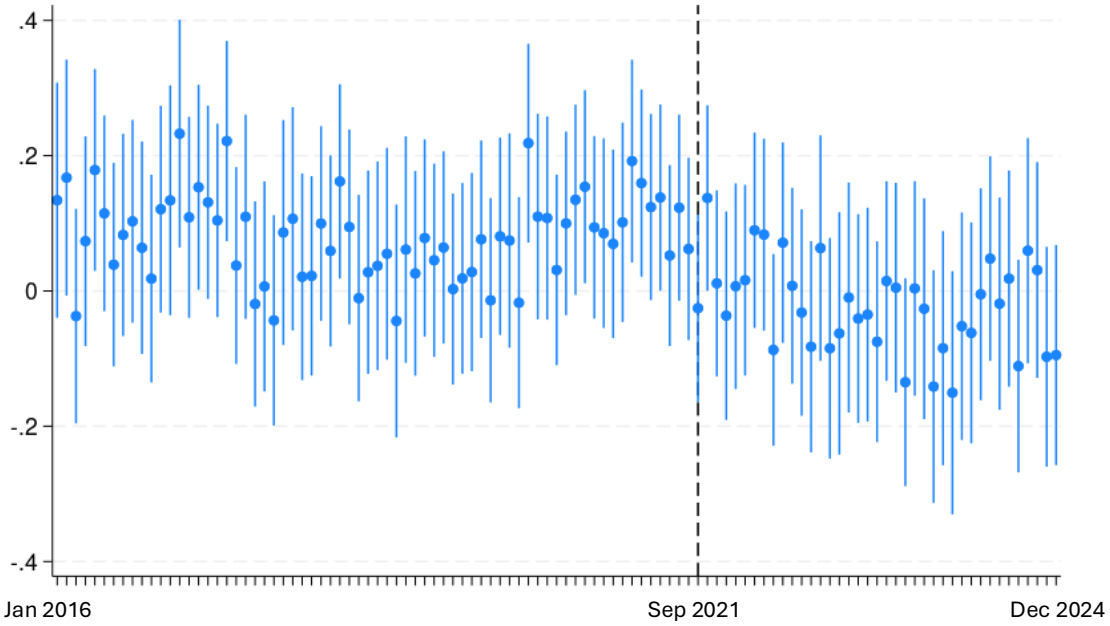


Figure 4: Outcome variable: new mortgage originations. Explanatory variable: cap share of policies interacted with month dummies. The dashed line denotes the last month before the implementation of Risk Rating 2.0 for new mortgages (September 2021).

policies exhibit a noticeable shift in the composition of new borrowers relative to other tracts in the same county, with lower average credit scores and a higher share of first-time owners (Table 4). Quantitatively, a tract with a 100 percent cap share experienced an average credit score decline of just over three points among new borrowers compared with a tract in the same county with no capped policies. Loan sizes also fell: new mortgages in high-cap-share tracts were roughly 4 percent smaller. Taken together with the point estimates for DTI and interest rates, these patterns suggest that lenders may have tightened underwriting standards in more affected areas, requiring larger down payments or offering credit only on smaller loan amounts to borrowers with weaker observable credit profiles.

	(1) Credit Score	(2) Value (Ln)	(3) Owner-Occupied	(4) First-time Owner	(5) GSE Dummy	(6) DTI	(7) Interest Rate
Post x Share Capped	-3.440***	-0.0394***	0.0127***	0.0198***	-0.0286***	-0.0917	0.0131
	(0.858)	(0.00757)	(0.00391)	(0.00666)	(0.00705)	(0.142)	(0.0120)
Constant	740.4***	12.67***	0.912***	0.424***	0.510***	37.41***	4.461***
	(0.136)	(0.00120)	(0.000620)	(0.00106)	(0.00112)	(0.0225)	(0.00190)
Observations	530711	530717	530717	530717	530717	530717	530717
Adjusted R^2	0.143	0.558	0.110	0.108	0.115	0.074	0.721
Tract FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County x Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Tract	Tract	Tract	Tract	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Characteristics of new mortgage loans

However, we find no statistically significant effects on the credit outcomes of existing mortgage borrowers in either high–cap-share tracts or tracts with widespread premium decreases. Although the point estimates in Table 5 suggest modest declines in credit scores and increases in credit card debt for borrowers in high–cap-share tracts—with the opposite pattern in areas experiencing premium reductions—none of these estimates are statistically distinguishable from zero. This absence of detectable effects is consistent with the structure of the reform: because the 18 percent cap attenuates the immediate impact of Risk Rating 2.0 for new flood policies, the credit responses are likely to be much weaker for current borrowers than for new mortgage originations in the short run.

	(1) Credit Score	(2) Overdue Rate	(3) carddebt_tract	(4) Credit Score	(5) Overdue Rate	(6) carddebt_tract
Capped Share x Post	-0.502	-0.00324	101.4			
	(0.955)	(0.00209)	(201.4)			
post_decrease_combined				1.416	0.000756	-355.7*
				(0.993)	(0.00212)	(213.7)
Constant	727.7***	0.0196***	9562.4***	727.4***	0.0187***	9636.8***
	(0.243)	(0.000521)	(51.70)	(0.134)	(0.000281)	(29.10)
Observations	460195	1407635	445189	460195	1407635	445189
Tract FE	Yes	Yes	Yes	Yes	Yes	Yes
County x Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Data Frequency	Quartely	Month	Month	Quartely	Month	Month
Cluster	Tract	Tract	Tract	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Credit outcomes for existing mortgage borrowers

4.3 Flood insurance prevalence and loan originations

We now include the prevalence of flood insurance policies in a given census tract to test whether the reform affected areas differently conditional on this characteristic. Table 6 uses a triple-difference specification of the form

$$y_{tract,month} = \beta_1\big(post_{month} \times \text{share capped}_{tract} \times Z_{tract}\big) + \beta_2\big(post_{month} \times \text{share capped}_{tract}\big) + \beta_3\big(post_{month} \times Z_{tract}\big) + \alpha_{geo\times month} + \alpha_{tract} + \varepsilon_{tract,month}. \tag{2}$$

where Z_t is the share of homes with flood insurance in tract t, and all other terms are defined as in equation (1). This specification allows us to assess whether the effects of Risk Rating 2.0 are amplified in tracts with more extensive insurance coverage. We find that tracts with a higher share of flood-insured homes exhibit somewhat larger declines in new mortgage originations, although these effects diminish in our preferred specification with county-by-month fixed effects.

	(1)	(2)	(3)
	Total Loans	Total Loans	Total Loans
Post x Share Capped x Share Insurance	-0.0111**	-0.00818	-0.00637
	(0.00455)	(0.00519)	(0.00603)
Post x Share Capped	-0.0223	-0.0482**	-0.0592**
	(0.0227)	(0.0243)	(0.0245)
Post x Share Insurance	0.00161	-0.00572	-0.0118**
	(0.00337)	(0.00402)	(0.00482)
Constant	-1.054***	-1.039***	-0.898***
	(0.00366)	(0.00402)	(0.00421)
Observations	3035664	3035230	2706694
Adjusted R^2			
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State x Month FE	No	Yes	No
County x Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Tracts with more flood insurance policies were more affected by the reform

4.4 Spillovers

The dampening effects of Risk Rating 2.0 on the mortgage market are not confined to tracts with high cap shares. We regress new mortgage loan originations on the interaction between month dummies and a dummy variable that takes the value of one if a census tract had *any* flood insurance policies in force as of 2021. Figure 5 shows a gradual decrease in new mortgages after the reform, irrespective of premium changes. Once again, we observe no pre-trends apart from seasonality.

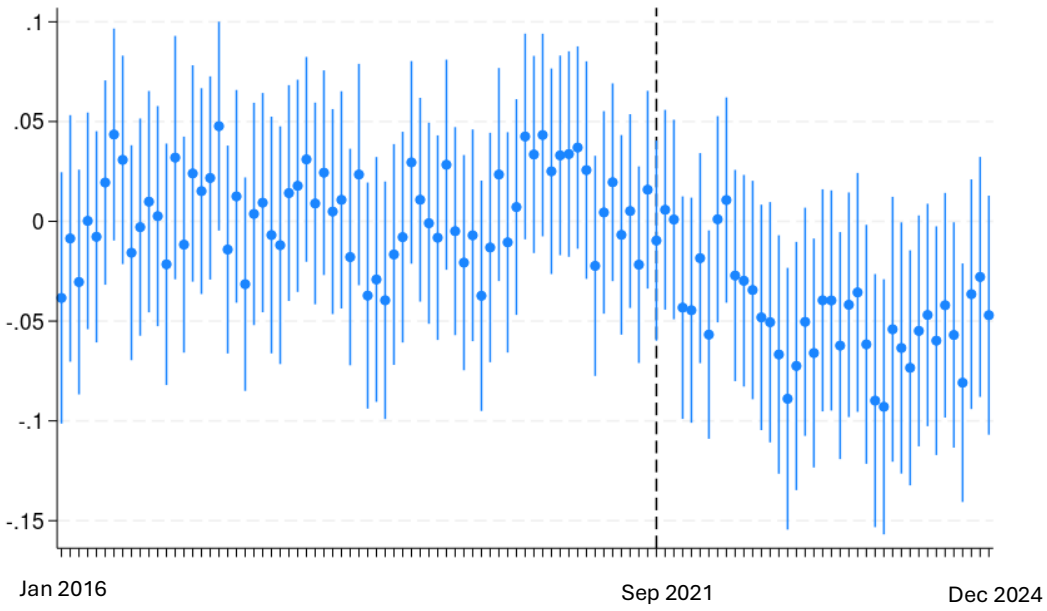


Figure 5: Outcome variable: number of new mortgages
Explanatory variable: any flood policies dummy × month dummies

We also formally test for spillovers on the intensive margin by using the same "any flood

policies" dummy, resulting in a specification of the form

$$y_{tract,month} = \beta_1 \times post \times \text{any policies} + \beta_2 \times post \times \text{any policies} \times \text{share capped} + \alpha_{county \times month} + \alpha_{tract} + \varepsilon_{tract,month} \tag{3}$$

where y is any one of the outcome variables in Table 7; county-month and tract fixed effects are included; and standard errors are clustered at the census tract level. As before, we use Poisson regressions for count variables and OLS for all others.

	(1) Credit Score	(2) Value (Ln)	(3) Owner-Occupied	(4) First-time Owner	(5) GSE Dummy	(6) DTI	(7) Interest Rate
Post × Any policies	-0.858*	-0.0106***	-0.00345*	0.00504	0.00289	-0.00915	0.0106
	(0.452)	(0.00395)	(0.00190)	(0.00354)	(0.00367)	(0.0739)	(0.00690)
Post × Any policies × Share capped	-2.896***	-0.0386***	0.0110***	0.0127**	-0.0236***	-0.0856	0.0165
	(0.759)	(0.00665)	(0.00342)	(0.00588)	(0.00619)	(0.124)	(0.0106)
Constant	737.8***	12.59***	0.922***	0.463***	0.510***	37.18***	4.485***
	(0.0401)	(0.000357)	(0.000172)	(0.000317)	(0.000329)	(0.00667)	(0.000678)
Observations	1376926	1376943	1376943	1376943	1376943	1376943	1376943
Adjusted R^2	0.146	0.582	0.091	0.096	0.116	0.084	0.690
Tract FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County x Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Tract	Tract	Tract	Tract	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Intensive margin spillovers

We find that, regardless of cap share, census tracts with any active flood insurance policies experienced declines in the value of new mortgages and shifts toward borrowers with lower credit scores after the reform, relative to nearby tracts without any flood policies. Consistent with Table 4, when cap share is added to the Post × Any Policies interaction, stronger negative effects are observed on credit score and value, as well as positive and significant increases in the share of first-time owners and owner-occupied homes.

4.5 Investment

Thus far, we have examined the effect of Risk Rating 2.0 on the existing stock of houses. We now ask whether housing investment, measured by the number of new construction building permits issued for single-family homes, was impacted by the policy reform. Developers may be less willing to build new homes in areas with high premium increase cap rates, which indicate the loss of pre-existing subsidization that may have incentivized inefficient capital allocation. However, the lack of changes to FEMA's flood maps may limit prospective purchasers' awareness of flood insurance premium hikes, and could maintain demand in high cap rate areas relative to nearby SFHAs. Additionally, the relatively short time horizon of our analysis may capture developers who had already planned construction in high cap rate areas prior to Risk Rating 2.0's announcement and implementation, although permits are generally required before starting any construction.

We take the universe of new construction building permits for single-family residences that were issued between 2015 and 2024 in jurisdictions collected by Cotality, restricting to only the most recent/complete entry for a given permit, and retaining only permits with a positive approval status. This procedure allows us to drop duplicate observations for a permit that was applied for and later issued, or for a permit that is recorded multiple times due to the participation of multiple contractors, but also fully drops permits that were issued but later revoked or canceled. Permit data is aggregated to the census tract and month level, and then merged with our tract-level flood insurance policy statistics, leaving an unbalanced panel of 658,000 tract-month observations, covering 13,449 census tracts across 49 states.

Our specification is a Poisson regression of the following form:

$$\text{Permits}_{tract,t} = \beta \times post \times \text{cap share} + \alpha_{geo \times t} + \alpha_{tract} + \varepsilon_{tract,t} \tag{4}$$

where "Permits$_{tract,t}$" is the number of new construction building permits for single-family homes that were issued in a given census tract and month; $\alpha_{geo \times t}$ is either state-month or county-month fixed effects; and standard errors are clustered at the census tract level. Of note, the *post* dummy in these regressions switches on starting in October 2021, as Risk Rating 2.0's pricing formula applied for new policies beginning on October 1, 2021. The beta coefficient, when exponentiated, measures the incidence rate ratio for building permit issuance in a census tract with a higher cap share after Risk Rating 2.0's implementation.

	(1) New Permits	(2) New Permits	(3) New Permits
Post × Share capped	-0.182***	-0.135**	-0.151**
	(0.0623)	(0.0653)	(0.0646)
Constant	2.631***	2.647***	2.726***
	(0.00848)	(0.00889)	(0.00876)
Observations	657990	657739	643024
Pseudo R^2	0.540	0.558	0.617
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State × Month FE	No	Yes	No
County × Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Building permits tract level regression results

Results of three specifications with varying saturation of fixed effects are shown in Table 8. In column 3, our preferred specification, we find that census tracts with a higher flood insurance policy cap rate for single-family homes after Risk Rating 2.0 saw a 14% decrease in the issuance of building permits for the new construction of single-family homes, compared to other census tracts in the same county. Alternative model choices, including negative binomial regressions on both the raw data and Poisson starting estimates, yield similar results. When the data is instead aggregated at the county-month level, as in Table 9, the

results lose significance, further bolstering our understanding of Risk Rating 2.0 as primarily addressing cross-subsidization within rather than between counties.

	(1) New Permits	(2) New Permits
Share capped × post	-0.138	-0.383
	(0.220)	(0.246)
Constant	5.938***	6.011***
	(0.0308)	(0.0344)
Observations	82154	81586
Pseudo R^2	0.880	0.907
Month FE	Yes	N/A
County FE	Yes	Yes
State × Month FE	No	Yes
Cluster	County	County

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Building permits county level regression results

4.6 Treatment measure robustness

We validate our use of cap share by constructing two alternate treatment measures: the log differences in the mean and median cost of coverage before and after Risk Rating 2.0. While cap share is constructed by observing the set of policies on single-family homes that persisted *through* the policy change, these alternate measures compare the set of SFR policies that were renewed between October 1, 2020 and September 30, 2021 (the pre-period) and the set of new SFR policies that were originated between October 1, 2021 and June 1, 2024 (the post-period), taking only the first-year price of the latter group. We use a larger post-period

to improve tract coverage, deriving the two alternate treatment measures from pools of 3.4 million pre-period policies and 670,000 post-period policies.

The new premium pricing structure includes a fixed $193 'expense and loss constant' and a variable 'increased cost of compliance premium', both of which are considered separately from the 'full risk' premium construction process by FEMA. However, to obtain the most accurate comparison possible between the two pricing regimes, we retain these fees in our cost of coverage calculations. We align our comparison metrics further by adjusting coverage amounts for deductibles and standardizing costs to [be] per-$1,000 of coverage.

Change in 'full risk' cost of $1000 of coverage	Full Sample	Coastal	Non-Coastal
Average	0.5404	0.6098	0.4678
Median	0.5220	0.5596	0.4849

Table 10: Alternate treatment measure correlations with cap share

[result tables and figures; include headline regression table and maybe either correlation figures or histograms of alt measure distributions]

4.7 Mortgage data robustness: cHMDA

The Home Mortgage Disclosure Act (HMDA) provides researchers with a rich set of conforming mortgage loan data, incorporating records on both successful and unsuccessful mortgage applications, as well as purchase records for originated loans. To validate our choice of the NMDB as our primary analysis data set, we replicate our central results with HMDA data. We utilize a confidential vintage of HMDA (hereafter referred to as cHMDA), which includes more precise information on loan and applicant characteristics, and certain fields such as borrower credit score which are removed from the public vintage. Our cHMDA headline analysis sample includes over 25 million successful conforming loan originations

between 2018 and 2024. As with the NMDB, we retain only cHMDA loans in census tracts with at least eight NFIP policies in force during January 2021. cHMDA data prior to 2022 uses the 2010 Census definitions for reporting census tracts; we use a Census-provided land area crosswalk from 2010 to 2020 tract definitions to accurately match derived NFIP policy statistics over time. We further discard loans in 2020-definition census tracts which did not have a majority 'feeder' 2010 tract (e.g. if the land area of 2020 tract 005 was split equally between 2010 tracts 002, 003, and 004).

Replication of our headline specifications with cHMDA data (Figure 6, Table 11) produces qualitatively and quantitatively similar results to those obtained with the NMDB. Census tracts with a higher cap share experience fewer new home purchase loans than other tracts with relatively lower cap shares, persisting through the incorporation of state-month and county-month fixed effects. We also take advantage of the inclusion of mortgage denials in cHMDA to investigate whether Risk Rating 2.0 affected denial counts and rates. After the reform, we find that mortgage denials *decreased* in high cap share tracts compared to neighboring low cap share tracts, although this effect is not significant across all fixed effect granularities (Table 12). Effects are stronger when including denials for refinancing in addition to those for home purchase loans (Table 13).

5 Conclusion

Risk Rating 2.0 has made progress in realigning the housing market's assessment of and response to flood risk, although spillovers have negatively impacted the mortgage market in areas which nominally benefited from the new pricing formulas. The reform is encouraging homeowners and investors to shift out of areas with unmapped, previously subsidized flood risk, but it is also resulting in more vulnerable populations making up a larger share of

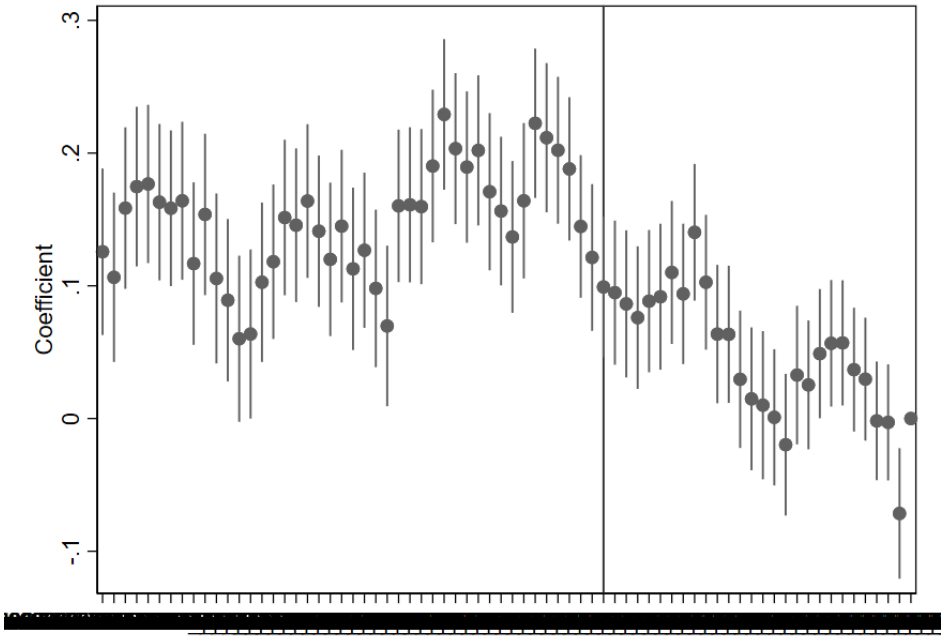


Figure 6: Outcome variable: number of new mortgages
Explanatory variable: cap share of policies interacted with month dummies
Analysis period: 2018-2023

	(1) Total Loans	(2) Total Loans	(3) Total Loans
Share Capped × Post	-0.0907***	-0.120***	-0.103***
	(0.0112)	(0.0121)	(0.0125)
Constant	1.984***	1.993***	2.006***
	(0.00221)	(0.00239)	(0.00249)
Observations	1515834	1515805	1478928
Pseudo R^2	0.381	0.385	0.401
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State × Month FE	No	Yes	No
County × Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Replication of headline results using cHMDA
Analysis period: 2018-2023

	(1) Total Denials	(2) Total Denials	(3) Total Denials
Share Capped × Post	0.00167	-0.0299**	-0.0195
	(0.0130)	(0.0134)	(0.0149)
Constant	0.664***	0.673***	0.698***
	(0.00289)	(0.00299)	(0.00337)
Observations	680935	680930	639795
Pseudo R^2	0.115	0.117	0.140
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State × Month FE	No	Yes	No
County × Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: cHMDA denial of new mortgage loans

	(1) Total Denials	(2) Total Denials	(3) Total Denials
Share Capped × Post	-0.0486***	-0.0977***	-0.0792***
	(0.00932)	(0.00926)	(0.00975)
Constant	1.091***	1.102***	1.119***
	(0.00165)	(0.00163)	(0.00173)
Observations	1210108	1210102	1171568
Pseudo R^2	0.152	0.155	0.174
Month FE	Yes	N/A	N/A
Tract FE	Yes	Yes	Yes
State × Month FE	No	Yes	No
County × Month FE	No	No	Yes
Cluster	Tract	Tract	Tract

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: cHMDA denial including refi

residents in these peripheral areas. Rickard (2025) suggests that these relatively credit-constrained homeowners are less likely to implement adaptive measures for their individual properties, [and their communities are less likely to have overarching mitigation projects?], which may expose both the residents and the NFIP to higher future cost burdens if flood events occur. Affordability concerns remain at the forefront of discussions around the NFIP, and project to remain relevant in the near and medium terms (Sastry et al. (2024)). As time passes, it will be critical for researchers and policymakers to monitor the persistence of Risk Rating 2.0's effects on the housing market.

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A Additional Tables & Figures

	Pre-reform		Post-reform	
	Mean	Median	Mean	Median
Insurance premium (annual)	587.83	395.00	686.96	562.00
Total coverage	306289.21	350000.00	311934.37	350000.00
Cost per $1000 coverage	2.29	1.26	2.50	1.75
Building replacement cost	335908.60	250000.00	492066.78	250000.00
	Pre-reform		Post-reform	
Located in SFHA	0.44		0.43	
Mandatory purchase	0.12		0.16	
Primary residence	0.86		0.87	
In CRS community	0.72		0.72	
N	10099221.00 (74.11%)		3527223.00 (25.89%)	

Table A1: Descriptive statistics for flood policy sample; unbalanced panel where pre-reform covers April 2015 - March 2022 and post-reform covers April 2022 - March 2025