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The Effects of Flood Damage on the Subsidy Cost of Federally Backed Mortgages

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Abstract

This paper uses data on mortgages and expected flood damage for each residential property in the United States to examine how much flood damage is expected to increase the cost of federally backed mortgages (referred to as the subsidy cost). The Congressional Budget Office uses its estimate of the subsidy cost to determine the budgetary effects of mortgages guaranteed directly by the federal government and through entities such as Fannie Mae and Freddie Mac. The analysis focuses only on costs to the federal mortgage programs and does not consider any costs borne by homeowners, mortgage lenders, insurers, or government disaster-recovery programs. It also does not capture potential effects related to rising hazard insurance premiums, lack of insurance options, or possible large-scale devaluation of houses.

CBO estimates that the subsidy cost from flood damage is $275 million in fiscal year 2024 under current climate conditions, an amount that is equivalent to 2.9 percent of the total subsidy cost of the mortgages originated in that year. The cost is estimated to increase to $395 million under the climate conditions projected for 2053 based on an intermediate climate change scenario, an increase of 44 percent relative to the effect under current climate conditions. The subsidy cost from flood damage is concentrated in coastal areas. The subsidy rate associated with flood damage in the riskiest 25 percent of census tracts is four times larger than the national average. Those tracts account for about 90 percent of the total subsidy cost nationwide.

Mortgages guaranteed by Fannie Mae and Freddie Mac are estimated to incur a larger cost from flood damage than mortgages guaranteed by other federal programs. That is because flood damage to homes with mortgages guaranteed by Fannie Mae and Freddie Mac is more likely to exceed the flood insurance cap and because a larger share of the associated homes are located in flood-prone coastal areas.

Keywords: flood damage, federally backed mortgages, subsidy costs, climate change

JEL Classification: G21, H60, H81, Q54

Notes

Numbers in the text, tables, and figures may not add up to totals because of rounding.

All values are expressed in 2024 dollars.

In this paper, “flood risk” refers to the risk of flood damage.

Contents

Introduction

The frequency and severity of floods in the United States is projected to increase because of climate change. Floods pose risks to homeowners and mortgage lenders because they affect the value of homes. Flood damage tends to lower the market value of affected homes, making it more likely that homeowners will default (especially if that damage is not covered by insurance).[1]

A large share of mortgages are guaranteed by the federal government through Fannie Mae and Freddie Mac (two government-sponsored enterprises, or GSEs), the Federal Housing Administration (FHA), and the Department of Veterans Affairs (VA). When homeowners default on their mortgages, some of the losses may fall on those government programs, raising the federal budget deficit. In a previous analysis, the Congressional Budget Office estimated that homes with federally backed mortgages face $9.4 billion in expected damage annually under current conditions—an amount that is expected to rise to $12.8 billion in 30 years (CBO, 2023b). The losses resulting from flood damage can thus increase the cost of the federal mortgage programs (referred to as the subsidy cost).

This paper estimates how much flood damage is expected to increase the subsidy cost of federally guaranteed mortgages. CBO uses its estimate of the subsidy cost to determine the budgetary effects of mortgages guaranteed directly by the federal government and through entities such as Fannie Mae and Freddie Mac. The analysis uses data on mortgages in combination with information on the likelihood of floods for each residential property in the United States under current conditions and based on median projections from an intermediate climate change scenario. Although flood damage negatively affects various entities in the housing market (such as homeowners, mortgage lenders, insurers, investors in mortgage-related securities, and governments), this paper solely examines the cost to federal mortgage programs. It does not examine any costs borne by others, such as the Federal Emergency Management Agency's (FEMA's) Disaster Relief Fund or other federal programs.[2] It also does not capture potential effects related to rising hazard insurance premiums, lack of insurance options, or possible large-scale devaluation of houses.

In CBO's baseline budget projections for fiscal year 2024, the principal balance of federally backed mortgages originated in that year is estimated to be nearly $1.2 trillion. More than $800 billion of that total amount is guaranteed by the GSEs; the rest is guaranteed by the FHA (more than $200 billion) and the VA (nearly $150 billion). CBO uses its projection models to

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[1] See Contat and others (2023) for a survey about the effects of flooding on house prices. See Kousky and others (2020), Du and Zhao (2020), and Billings, Gallagher, and Ricketts (2022) for the effects of hurricanes on mortgage performance and borrower outcomes.

[2] For details about the Disaster Relief Fund, see CBO (2022).

estimate the subsidy rates (or the present value of predicted future net cash flows of mortgages divided by the amount disbursed) of the federal guarantees on the mortgages originated in that year. The subsidy cost is equal to the subsidy rate multiplied by the principal balance originated in 2024 for each program. See CBO (2023a) for the projected principal balance and subsidy cost of federal credit programs in 2024.

CBO incorporates flood simulations into its projection models to estimate the subsidy cost from flood damage. Those simulations are based on the central climate conditions in multiyear periods centered around 2023 (for current climate conditions) and 2053 (for future climate conditions). Under current climate conditions, the cost of federally backed mortgages stemming from flood damage is $275 million in 2024, in CBO's estimation. That cost is equivalent to 2.9 percent of the total subsidy cost of the federally backed mortgages originated in that year.[3] The cost from flood damage is estimated to increase to $395 million (equivalent to 4.2 percent of the total cost of the mortgage programs in fiscal year 2024) under future climate conditions, which is 44 percent higher than the cost from flood damage under current climate conditions.

Although the subsidy cost varies across regions and states, it is concentrated in certain geographic areas—particularly those near the coasts. The subsidy rate associated with flood damage in the riskiest 25 percent of census tracts is four times larger than the national average. Those tracts account for about 90 percent of the total subsidy cost nationwide.

The flood-related subsidy cost of mortgages guaranteed by the two GSEs is estimated to be larger than the cost of the other mortgage programs, even when conditioned on loan size. That is partly because flood damage is more likely to exceed the flood insurance cap for mortgages guaranteed by the GSEs and partly because a larger share of the associated homes are located in flood-prone areas.

Federal Mortgage Programs and Flood Insurance

The federal government guarantees mortgages through various programs. Some flood-related losses may result in costs for those programs, especially if the losses are not covered by flood insurance. The federal government insures properties against flood damage through FEMA's National Flood Insurance Program (NFIP), but not all properties at risk of flood damage are covered by that flood insurance or by private flood insurance. Although this analysis includes mortgages on homes covered by a flood insurance policy, it does not estimate the net cost to the federal government through the NFIP.

[3] The total subsidy cost of the three federal mortgage programs (GSEs, FHA, and VA) in 2024 is estimated to be $9.5 billion; see Supplemental Table 3 of CBO (2023a).

Federal Mortgage Programs

The federal government guarantees mortgages that are acquired by Fannie Mae or Freddie Mac or that are backed by the Federal Housing Administration or the Department of Veterans Affairs. By guaranteeing mortgages, those agencies insure lenders against the cost of borrowers' defaults in exchange for guarantee fees.

The GSEs guarantee more than half of all federally backed mortgages and generally require a larger down payment—typically 20 percent of the loan amount—than other guarantors.[4] For instance, FHA's mutual mortgage insurance program, which mainly serves low-income people or first-time home buyers, typically requires a down payment of 3.5 percent. And VA's mortgage guarantee program, which generally is available to veterans, does not require any down payment. Mortgages are also backed by other, smaller federal programs, such as the one operated by the Department of Agriculture's Rural Housing Service, but CBO does not include them in this analysis because data for those programs are limited.

To lessen their potential losses, the GSEs transfer some risk to private investors through credit-risk-transfer (CRT) transactions. Those transactions involve bundling mortgages and selling the resulting securities. Investors receive payments of principal and interest if there are no losses in the mortgage pool; if there are losses, investors lose some of the principal to cover them. CRT transactions do not incur subsidy costs because they occur at market prices (see CBO, 2017).[5]

Flood Insurance

Flood insurance reduces the exposure of mortgage guarantors to risk from flood damage. The NFIP is the largest provider of flood insurance in the United States, accounting for over 90 percent of the residential policies issued (see Kousky and others, 2023). NFIP policies cover up to $250,000 of flood damage to the building itself for an insured single-family residential property. (The building's contents would require separate coverage.) Private insurers cover a small but growing share of U.S. properties, and many borrowers who buy private flood insurance do so to cover losses that exceed the NFIP's limit. This paper does not consider private insurance coverage because data are limited.

Any location that has a 1 percent or higher annual chance of a flood is designated by FEMA as a Special Flood Hazard Area, or SFHA. (A 1 percent annual probability is equivalent to having about a one-in-four chance of experiencing at least one flood over a 30-year period.) Properties in SFHAs that have federally backed mortgages must be covered by flood insurance throughout

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[4] Fannie Mae and Freddie Mac are in federal conservatorships and are controlled by the Federal Housing Finance Agency, their conservator, and by the Treasury, which has ownership rights to a majority of their stock. See CBO (2018c).

[5] Gete, Tsouderou, and Wachter (2024) use data on CRTs to study how private investors price hurricane risk in mortgages.

the life of the mortgage. The required coverage is the lowest of the replacement cost of the improvements, the current unpaid principal balance, and the NFIP's maximum coverage ($250,000).[6] Mortgage lenders and servicers are required to make sure that borrowers comply. The GSEs, FHA, and VA can void the guarantee of mortgages that do not meet that requirement, passing the losses back to lenders or servicers. As a result, government mortgage programs are protected from most flood damage in SFHAs. In this analysis, properties inside SFHAs are insured for up to $250,000 against flood damage based on the NFIP's coverage data.[7]

Although government mortgage programs are protected from most losses from flood damage in SFHAs, not all areas at risk of flood damage are located in SFHAs. Those areas do not include locations with an annual chance of flooding of less than 1 percent, for example, nor do they account for floods that result solely from heavy precipitation. The boundaries of SFHAs are supposed to be reviewed and potentially updated every five years, but many are outdated and based on old data and modeling (Kousky and others, 2020). And those boundaries will probably shift as the climate continues to change. (The estimates in this paper use current SFHA boundaries.) Moreover, properties outside SFHAs have low take-up rates of flood insurance. People in those areas may be less aware of flood risk because the risk is not disclosed or because they mistakenly think that only homes in SFHAs are at risk of damage from flooding.[8] As a result, flood damage occurring outside SFHAs is more likely to lead to losses for federal mortgage programs, increasing subsidy costs.

How to Estimate Costs to Federal Mortgage Programs From Flood Damage

This analysis relies on the projection models that CBO uses for its baseline budget estimates. In those models, flood damage lowers the price of houses that serve as collateral for mortgages, increasing the losses incurred by federal mortgage programs. To measure the effects of flood damage on the values of properties with mortgages, this analysis matches data on federally backed mortgages with information on flood risk (the likelihood that a property will experience flood damage of a given level).[9] CBO uses the distribution of flood risk to simulate individual

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[6] See Section B7-3-06 in Fannie Mae (2024), Section 4703 in Freddie Mac (2024), Section II.A.1.iv in Department of Housing and Urban Development (2023), and Chapter 9, Section 11 in Department of Veterans Affairs (2024).

[7] For more details about how flood insurance enters the analysis, see Appendix A.

[8] See Fannie Mae (2023) for the results of a survey that shows homeowners' and renters' awareness of flood risk to their residences.

[9] For a detailed description of the data and flood risk estimates, see Appendix A.

flood-damage events, which are introduced into the projection models as shocks to house prices (and, therefore, to the loan-to-value, or LTV, ratios associated with individual mortgages).

Accrual Budgeting and the Subsidy Cost

This paper reports the subsidy cost of federal mortgage programs on an accrual basis, which means that CBO estimates the present value of the projected future cash flows of mortgages in the year the mortgages are originated. That present value, or subsidy rate, measures the lifetime cost relative to the initial mortgage amount per dollar of loan originated. For example, a 1 percent subsidy rate corresponds to a $2,000 lifetime cost for a mortgage of $200,000. To obtain the subsidy rate, CBO discounts the predicted 30-year net cash flows of mortgages and then divides their sum by the initial mortgage amount. The subsidy cost is equal to the subsidy rate times the total mortgage amount.

Although the federal budget measures the cost of credit programs on an accrual basis, most other federal activities are accounted for on a cash basis, which means that transactions are recorded when payments are made or receipts are collected. (See CBO, 2018a for details.) This analysis uses accrual-based estimates because they provide more complete information about programs that involve long time horizons.

Data

CBO uses two separate datasets for this analysis: one on federally backed mortgages and the other on flood exposure. The mortgage data are provided by government agencies or the GSEs. They contain information that CBO's models use to project cash flows and default rates for mortgages and calculate their subsidy rates. The data on properties' location are arrayed by census tract (in other words, county subdivision). They indicate in general terms (but not exactly) where the property that serves as collateral for the mortgage is located. This analysis examines only mortgages for which single-family homes are designated as collateral.

The measures of flood exposure for each residential property are constructed using information from the First Street Foundation (FSF) and the U.S. Army Corps of Engineers' National Structure Inventory (NSI). To begin with, CBO identifies detached single-family residential properties in the NSI and combines that information with data from FSF that project the probabilities of floods of different depths. CBO then applies depth-damage curves to flood depths expected to occur—with an annual chance of 1-in-2, 1-in-5, 1-in-20, 1-in-100, 1-in-200, and 1-in-500—and constructs a probability distribution of flood damage for each property, known as the property's flood risk. Flood risk is measured for a central climate scenario in multiyear periods centered around 2023 and 2053. The climate conditions are based on median outcomes under an intermediate climate change scenario (what the Intergovernmental Panel on Climate Change refers to as SSP2-4.5).

Models

To estimate subsidy costs from flood damage, CBO uses the same models that it employs to calculate subsidy rates of mortgages guaranteed by the GSEs, FHA, and VA. Each of the three programs' models predicts 30-year cash flows—incorporating defaults, prepayments, recoveries, and fees—for a mortgage or a group of mortgages for each of 100 macroeconomic simulations that are centered on CBO's macroeconomic forecast. Specifically, CBO uses a multinomial logit model to project probabilities of default and prepayment and a linear regression model to project recoveries. Fees consist of two types: one-time fees that are paid up-front and ongoing fees that are tied to the unpaid principal balance of mortgages. Those cash flows depend on characteristics of mortgages and borrowers, such as LTV ratios (or the size of a mortgage as a percentage of the house price) and credit scores, as well as macroeconomic variables, such as the unemployment rate and house price index. The models project the price of a house with a mortgage over time using the sales price and the simulated house price index. The predicted house price is then used to derive the predicted LTV ratio over 30 years. See Castelli and others (2014) for details.[10]

The cash flows are discounted on a fair-value basis (which means market risk is taken into account) to generate a subsidy rate, or the present value of net cash flows divided by the amount disbursed, for each of the 100 macroeconomic simulations. The final output is the average of the subsidy rates from those simulations for an annual cohort of mortgages guaranteed by the GSEs, FHA, or VA. (For mortgages guaranteed by FHA and VA, CBO officially reports subsidy rates using procedures specified in the Federal Credit Reform Act of 1990, which discounts cash flows using rates on Treasury securities. To produce comparable estimates for this analysis, however, the agency calculated subsidy rates on a fair-value basis, which discounts cash flows using market rates for all the programs. See CBO, 2018b.)

The projected LTV ratio, which depends on the projected value of the house that is designated as collateral for the mortgage, is one of the key variables used to predict losses from a mortgage. Default rates are positively related to LTV ratios and thus negatively related to the projected value of the house and the borrower's equity. Flood damage lowers house values and, as a result, increases LTV ratios, leading to higher default rates and subsidy rates. Evans and others (2020) use a similar method to measure the effects of flood damage on mortgage defaults. CBO's projection models were estimated using historical data, so the effects of historical flood damage on losses are already incorporated into the models and the reported subsidy rates.

Flood damage also can lead to mortgage defaults through other channels, such as large repair costs for financially constrained households. CBO's projection models do not have the capacity to incorporate such effects. As a result, this paper considers the effects of flood damage on

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[10] Castelli and others (2014) present the projection model for mortgages backed by the FHA. The projection models for the mortgages guaranteed by the GSEs or backed by VA are similar to the one for the FHA mortgages.

mortgage losses only through the value of the damaged house and the resulting change in the LTV ratio. See Fuster and Willen (2017), Gerardi and others (2018), and Ganong and Noel (2023) for detailed discussions of the reasons for mortgage defaults.

Flood Simulations

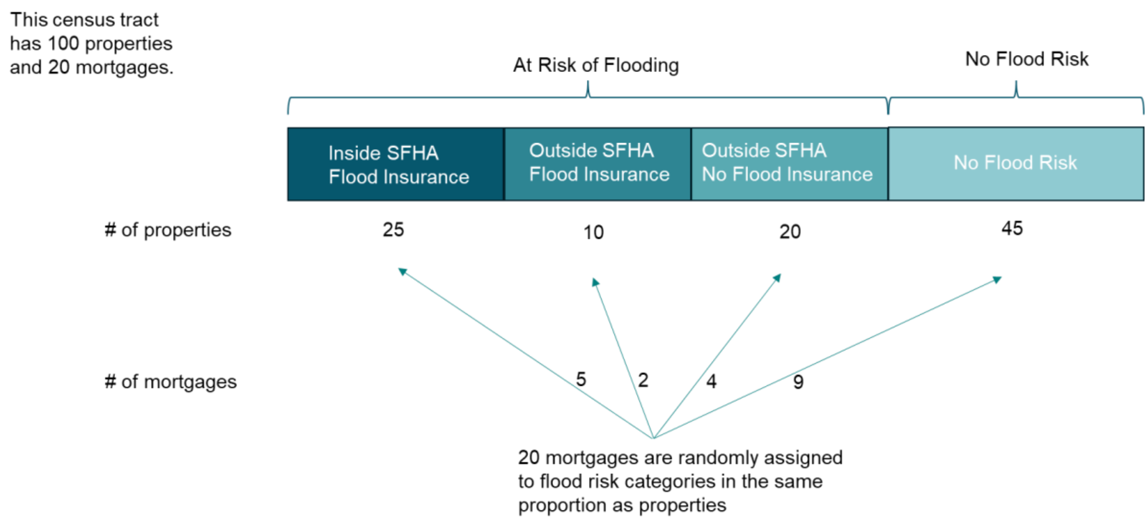
CBO simulates flood events in its projection models to estimate the subsidy costs from flood damage. Each property in the FSF data is categorized as either at risk of flood damage or not at risk of flood damage, and each property at risk of flood damage is categorized as located either inside or outside an SFHA. Properties with federally backed mortgages inside an SFHA are required to have flood insurance, but properties outside an SFHA may or may not have flood insurance. For properties outside an SFHA and at risk of flood damage, CBO estimates the take-up rate for flood insurance using data from FEMA for each census tract. CBO randomly assigns mortgages to properties—each with its own probability distribution of flood damage—in the same census tract in proportion to the total number of properties in each flood risk category. (It is not possible to match properties to mortgages because the mortgage data only provide the census tract in which the mortgaged house is located.)[11]

To illustrate that process, suppose that a census tract has 100 properties and 20 mortgages, and the properties are distributed as follows: 25 with flood risk and located in an SFHA, 30 with flood risk and located outside an SFHA, and 45 with no flood risk (see Figure 1). In addition, suppose that the estimated flood insurance take-up rate of properties outside an SFHA and with flood risk in the census tract is 33 percent. First, 10 properties among 30 properties outside an SFHA and with flood risk are randomly assigned to have flood insurance, and 20 properties are assigned not to have flood insurance based on the take-up rate. Second, the mortgages are then randomly distributed to flood risk categories in the same proportion as the properties: 5 with flood risk and inside an SFHA; 2 with flood risk, outside an SFHA, and with flood insurance; 4 with flood risk, outside an SFHA, and without flood insurance; and 9 with no flood risk. Finally, a property is randomly selected to be matched with a mortgage from the same flood risk category. (The property-mortgage pairing is repeated independently for each macroeconomic simulation.)

[11] Ideally, CBO could perform a fuzzy merge of mortgage data and property deeds to obtain better geographic resolution (see, for example, Sastry, 2022). Doing so on a nationwide basis would require either access to a proprietary dataset (such as those offered by CoreLogic), however, or an enormous effort to compile and standardize publicly available deed and parcel data, which are fragmented across states and counties.

Figure 1.

An Example of How to Assign Flood Risk Information to a Mortgage in a Census Tract



Data source: Congressional Budget Office.

SFHA = Special Flood Hazard Area.

For each year in the 30-year term of a mortgage, a level of flood damage is randomly drawn from the probability distribution of the property assigned to the mortgage. In most cases, that level of damage is zero, meaning that the property is not flooded in the simulation. When the damage is positive (in other words, the property is flooded), the projected price of the house with the mortgage is lowered by the cost of the damage in that year if the mortgage belongs to a category without flood insurance.[12] If the mortgage belongs to either a category inside of an SFHA or a category outside of an SFHA and with flood insurance, the simulated damage—if less than $250,000—is modeled as covered by flood insurance and has no impact on the house price. If the simulated damage exceeds the $250,000 cap, then the house price is lowered only by the cost of additional damage over the cap.

After a simulated flood lowers the house price in that year, the house price grows at the same pace as it would otherwise until the house faces another flood. If flood damage reduces the growth rate of the house price, then the subsidy cost from flood damage would be larger than

[12] In cases when the homeowner repaired some damage using a loan based on the home's equity, the drop in the price of the home would be smaller. Because the repair would lower the homeowner's equity, though, the effect on the default rate would be the same.

what is reported in this paper. If flood damage increases the growth rate of the house price, then the subsidy cost would be smaller. The literature reports mixed results on the effects of flood damage on house price dynamics.[13]

This paper does not incorporate the possible effects of flooding on surrounding areas. For simplicity, flood events lower only the prices of affected houses in the model. The new path of house prices results in different LTV ratios, leading to new expected default rates and cash flows. Those cash flows are discounted to calculate a revised subsidy rate.

Costs to Federal Mortgage Programs From Flood Damage

This section presents the effects of flood damage on the subsidy cost of federally backed mortgages for the following two cases:

- If flood simulations are based on 2023 climate conditions, and
- If flood simulations are based on 2053 climate conditions under a central climate change projection.

To determine those effects, CBO first compares the subsidy rates for each of the cases to a case that has no explicit flood simulations and uses the difference as an estimate of the effect of flood risk in each case. That measure represents the difference between the subsidy rate of the program under current (2023) or projected (2053) climate conditions and a hypothetical scenario in which no flooding takes place. The case without explicit flood simulations incorporates the effect of flood damage that is present in the historical data. Coefficients of the projection models fitted to that data would generate outcomes that were consistent with that historical level of flood risk. (CBO estimates that historical flood risk was lower than that projected for present and future climate conditions.)

CBO then derives the subsidy costs of the two cases and that of the case with no explicit flood simulations by multiplying each subsidy rate by the projected loan amount in fiscal year 2024 in CBO (2023a). Again, the difference in the subsidy cost of the program between each of the two cases and the one with no explicit flood simulations represents the subsidy cost from flood damage for each case. That approach is consistent if the effect of flood damage on subsidy rates has an approximately linear relationship with aggregate flood damage when modeled near

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[13] Ortega and Taspinar (2018) found that after Hurricane Sandy in 2013, house prices in affected areas remained depressed even five years later. Although prices for damaged homes fell even more sharply after the hurricane, though, the authors found that they converged to the level of the surrounding area within five years. Roth Tran and Wilson (2023) looked at a broader set of disasters and found that the most severe disasters have a strong positive effect on area house prices in the short run and negative effects in the long run. They also found that less severe disasters have a slightly positive effect on house prices over time.

current conditions.[14] To provide a sense of the importance of flood insurance, CBO also calculates the subsidy rates without allowing flood damage to be covered by flood insurance.

Total Cost of Federal Mortgage Programs

In CBO's estimation, flood damage raises the overall subsidy rate by 2.3 basis points and 3.4 basis points under 2023 and 2053 climate conditions, respectively. (A basis point is one-hundredth of a percentage point.) The increase in the subsidy rate under current climate conditions implies a subsidy cost of $275 million, which is equivalent to 2.9 percent of the total subsidy cost of the federal mortgage programs in fiscal year 2024.[15] The increase in the subsidy rate under 2053 climate conditions implies a subsidy cost of $395 million, which is 44 percent larger than the effect of flood damage on subsidy rates under current climate conditions (see Table 1).

Those subsidy costs would be roughly doubled if the flood damage was not covered by flood insurance. In that case, flood damage would raise the overall subsidy rates by 5.4 and 7.8 basis points under 2023 and 2053 climate conditions, respectively. Those projections are consistent with the results in CBO (2023b), which shows that about half of expected flood damage would occur inside SFHAs, where flood insurance is required for properties with federally backed mortgages.

[14] That approach is supported by the fact that CBO's estimated effect of flood damage on subsidy rates is about one-third larger under 2053 climate conditions than it is under 2023 climate conditions. The approximate increase in expected annual damage is also one-third.

[15] The total subsidy cost of the three federal mortgage programs in fiscal year 2024 is estimated to be $9.5 billion according to Supplemental Table 3 in CBO (2023a).

Table 1.

Subsidy Costs of Federal Mortgage Guarantees From Flood Damage Under Current and Future Climate Conditions, by Type of Census Tract

		2023 Climate Conditions	2053 Climate Conditions	2023 Climate Conditions	2053 Climate Conditions
		Main estimates		If no flood damage is covered by flood Insurance	
All census tracts	Subsidy rate (basis points)	2.3	3.4	5.4	7.8
	Subsidy cost[a] (millions of dollars)	275	395	621	900
Riskiest 25 percent of census tracts	Subsidy rate (basis points)	9.1	13.5	21.4	31.8
	Subsidy cost[a] (millions of dollars)	240	356	566	839
Coastal census tracts	Subsidy rate (basis points)	5.6	9.8	17.2	27.5
	Subsidy cost[a] (millions of dollars)	136	239	421	671

Data source: Congressional Budget Office.

A basis point is one-hundredth of a percentage point.

a. The loan amounts estimated in CBO's 2023 baseline projections are used to calculate subsidy costs.

Cost by Property Location

The subsidy cost to federally guaranteed mortgages from flood damage is concentrated in census tracts with a large share of flood-prone homes. The effect of flood damage on the subsidy rate for the 25 percent of census tracts with the highest flood risk is estimated to be 9.1 basis points under current climate conditions and 13.5 basis points under 2053 climate conditions. The corresponding subsidy cost from flood damage in that quarter of census tracts accounts for about 90 percent of the cost in all census tracts (see Table 1).

The effect differs for properties in coastal census tracts. The subsidy cost from flood damage in those areas accounts for about 50 percent of the total flood-related cost, but those areas only represent 15 percent of all census tracts.[16] If flood damage to properties in coastal census tracts was not covered by flood insurance, the subsidy cost from flood damage would be tripled (see Table 1). Flood insurance probably has a large effect in those areas because they are often classified as SFHAs: According to the data, the share of homes inside SFHAs in coastal census tracts is 8 percent, whereas the share of such homes in other census tracts is 1 percent.

The subsidy costs from flood damage also vary by state and county. For example, the increase in the subsidy rate from flood damage is more than 5 basis points in Alaska, Florida, Hawaii, Louisiana, South Carolina, and West Virginia. By contrast, that increase is less than 1 percent in Arizona, Kansas, and Nevada (see Figure 2). For California and Florida, the subsidy cost from flood damage is more than $50 million each; for Kansas and North Dakota, it is less than $0.2 million each. The subsidy cost from flood damage is larger in coastal areas, where more of the U.S. population resides. Counties located in those areas or in some inland flood-prone areas (such as parts of Appalachia) face a bigger increase in the subsidy rate (see Figure 3).

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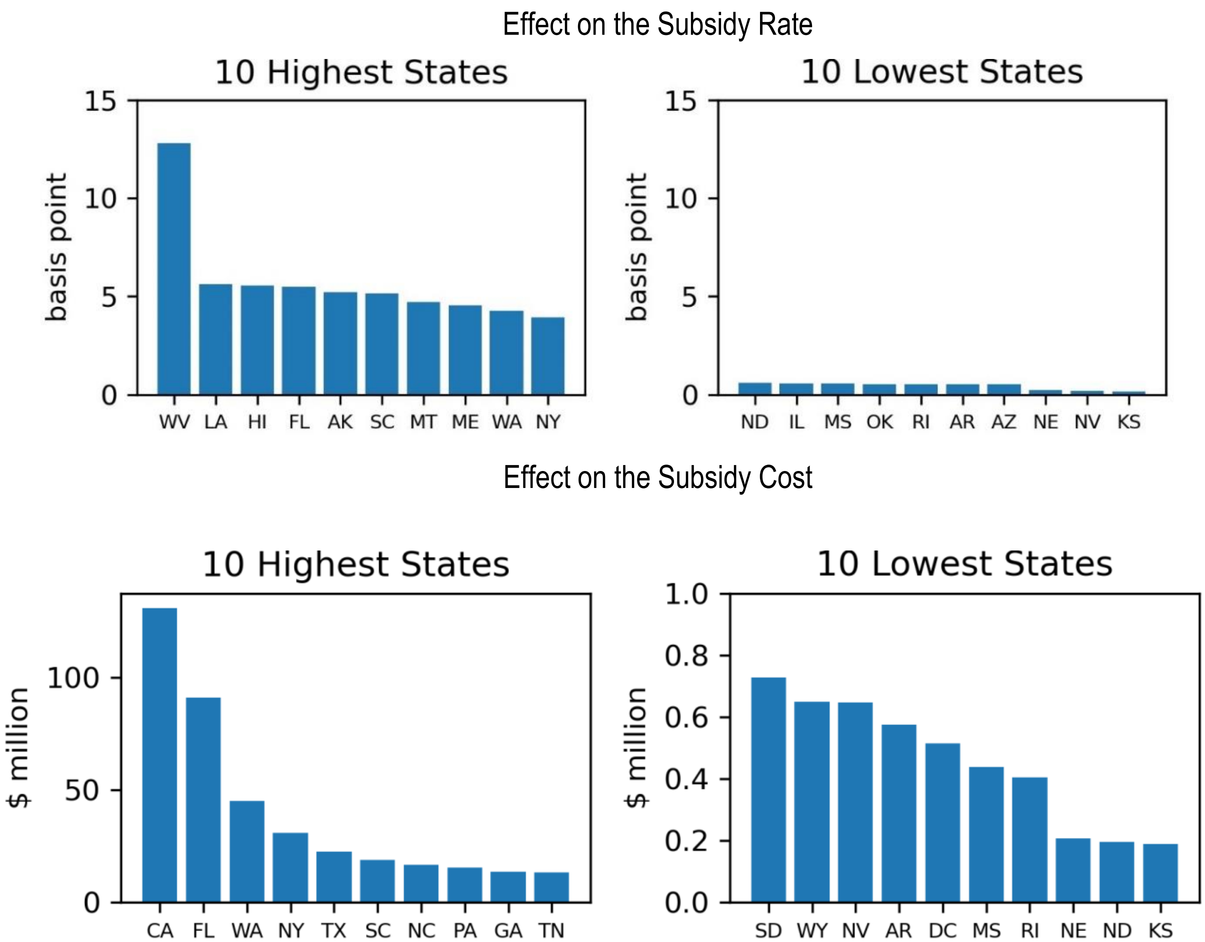
[16] CBO defined coastal tracts as those in a county on the country's saltwater coasts and consisting partly of water. Thus, coastal areas in this analysis either lie on one of the country's saltwater coasts or are in a county on the coast and contain at least part of another body of water, such as a river or lake.

Figure 2.

Effects of Flood Damage on the Subsidy Rate and Subsidy Cost, by State, Under Current Climate Conditions



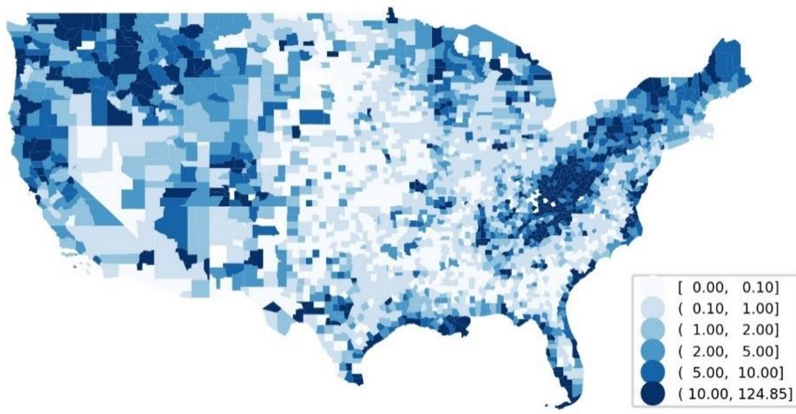
Data source: Congressional Budget Office.

A basis point is one-hundredth of a percentage point.

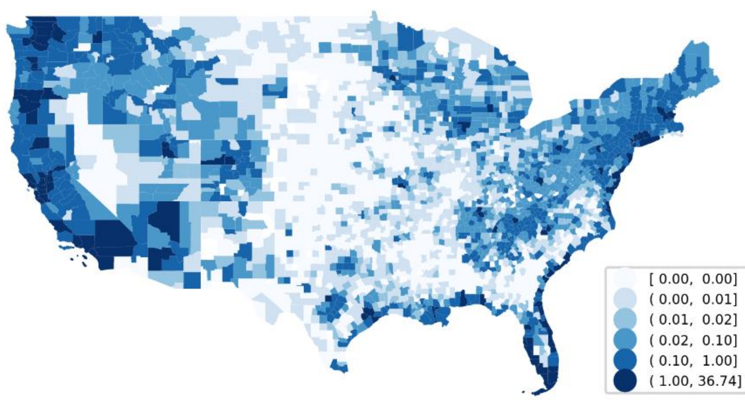
Figure 3.

Effects of Flood Damage on the Subsidy Rate and Subsidy Cost, by County, Under Current Climate Conditions

Effect on the Subsidy Rate (basis points)



Effect on the Subsidy Cost (millions of dollars)



Data source: Congressional Budget Office.

A basis point is one-hundredth of a percentage point.

Cost by Loan Type

The subsidy cost from flood damage to the mortgages guaranteed by the GSEs is estimated to be greater than that to the mortgages guaranteed by the FHA or VA. For GSE mortgages, the effect of flood damage on the subsidy rate is 2.7 basis points under current climate conditions; for FHA and VA mortgages, the subsidy rates are 1.2 basis points and 0.9 basis points, respectively (see

Table 2).[17] GSE mortgages generally have lower LTV ratios and, as a result, lower default rates and subsidy rates, all other things being equal. That does not necessarily lead to lower subsidy costs from flood damage, though, because that effect also depends on other factors, such as a property's location.

Table 2.

Subsidy Costs of Federal Mortgage Guarantees From Flood Damage Under Current and Future Climate Conditions, by Guarantee Program

		2023 Climate Conditions	2053 Climate Conditions	2023 Climate Conditions	2053 Climate Conditions
		Main estimates		If no flood damage is covered by flood Insurance	
GSEs	Subsidy rate (basis points)	2.7	3.9	6.1	8.9
	Subsidy cost (millions of dollars) [a]	215	310	490	714
FHA	Subsidy rate (basis points)	1.2	1.6	2.4	3.5
	Subsidy cost (millions of dollars) [a]	25	34	50	71
VA	Subsidy rate (basis points)	0.9	1.3	1.8	2.3
	Subsidy cost (millions of dollars)[a]	14	19	26	34

Data source: Congressional Budget Office.

FHA = Federal Housing Administration; GSEs = government-sponsored enterprises; VA = Department of Veterans Affairs.

A basis point is one-hundredth of a percentage point.

a. The loan amounts estimated in CBO's 2023 baseline projections are used to calculate subsidy costs, whereas the loan amounts in the mortgage data are used to calculate subsidy rates. That is why the sum of the subsidy costs for the three mortgage programs is not the same as the subsidy cost for all the census tracts in Table 1.

[17] The subsidy costs are derived using the projected mortgage amounts in CBO (2024), whereas the subsidy rates are calculated using the mortgage amounts in the mortgage data. That is why the sum of the subsidy costs for the three mortgage programs in Table 2 is not the same as the total subsidy cost in Table 1.

Under current climate conditions, the effect of flood damage on the subsidy rate of GSE mortgages is 1.6 basis points greater than the combined effect on FHA and VA mortgages, which is 1.1 basis points. That difference of 1.6 basis points can be separated into two components, one related to the difference in subsidy rates across programs but in the same location and one related to location:

$$\Delta SR_{GSE} - \Delta SR_{Other} = \underbrace{\left\{\sum_i w_{GSE,i}\left(\Delta SR_{GSE,i} - \Delta SR_{Other,i}\right)\right\}}_{\{subsidy\ rate\ effect\}} + \underbrace{\left\{\sum_i (w_{GSE,i} - w_{Other,i})\Delta SR_{Other,i}\right\}}_{\{location\ effect\}}$$

where ΔSR_{GSE} (ΔSR_{Other}) is the change in the subsidy rate of GSE mortgages (FHA and VA mortgages) from flood damage, $w_{GSE,i}$ ($w_{Other,i}$) is the ratio of GSE mortgages (FHA and VA mortgages) in census tract *i* relative to those in all census tracts, and $\Delta SR_{GSE,i}$ ($\Delta SR_{Other,i}$) is the change in the subsidy rate of GSE mortgages (the other mortgages) from flood damage in census tract i.

The subsidy rate effect (the first component in the equation) reflects differences in the effect of flood damage on mortgages that are in the same census tract but from different mortgage programs. The location effect (the second component in the equation) reflects any differences in the riskiness of the census tracts in which GSE mortgages and the others tend to be located. For example, if GSE mortgages are more likely than other mortgages to be located in risky census tracts, the effect would be positive.

CBO estimates that the subsidy rate effect accounts for 1.5 basis points of the 1.6 basis-point difference between GSE mortgages and other federally backed mortgages under current climate conditions. Thus, nearly the entire difference across programs is driven by differences in the effect on mortgages within the same census tract rather than differences in the distribution of mortgages across census tracts (the latter of which accounts for the remaining 0.1 basis point). Overall, the results suggest that the interaction of flood risk with CBO's models explains most of the difference and that differences in flood risk across locations play a much smaller role.

There are two reasons that the effect of flood damage on the subsidy rate could be larger for GSE mortgages than for the other mortgages in the same census tract, even though they all face the same flood risk. (In the flood event simulations, mortgages within a given census tract are randomly assigned to flood risk categories.) One reason might be that the $250,000 flood insurance cap is more likely to be exceeded for houses with GSE mortgages, which tend to have higher prices than those with FHA or VA mortgages. The average price of houses with GSE mortgages is about $527,000 in the data, whereas prices of houses with FHA and VA mortgages are about $322,000 and $458,000, respectively.[18]

Another reason that the effect of flood damage on the subsidy rate is larger for GSE mortgages than for FHA or VA mortgages could be GSE mortgages' lower average loan-to-value ratios. In the data, the average LTV ratio of GSE mortgages is 70 percent; for FHA and VA mortgages, the LTV ratios are 93 percent and 91 percent, respectively. A lower LTV ratio is associated with a higher house price for a given loan amount, and a higher house price means more flood damage (in terms of the dollar amount spent) for the same flood event. Because the subsidy rate measures losses relative to the loan amount, the subsidy rate of a mortgage with a lower LTV ratio would increase more for the same flood event when the loan amount is the same. The two reasons overlap because both relate to house prices.

To understand what drives the subsidy effect and the location effect, CBO ran two separate regressions. First, the agency regressed the difference in the average flood effects on the subsidy rates of GSE mortgages and other mortgages in a given census tract on loan and census tract characteristics (see Table 3). That regression showed that half of the subsidy rate effect on GSE mortgages comes from those mortgages' higher likelihood of experiencing flood damage that exceeds the flood insurance cap. The other half of the explained subsidy rate effect is estimated to come from other factors, such as the lower LTV ratios of GSE mortgages. Second, CBO regressed the difference in the share of all GSE mortgages found in a given census tract and the share of all other mortgages found in that census tract on loan and census tract characteristics (see Table 4). More GSE mortgages are in coastal census tracts than the other mortgages, which helps explain why the location effect is positive. Appendix B contains more details about the two regression analyses.

[18] Based on CBO's analysis of NFIP claims over the 2003–2022 period, the cap affected about 13,000 claims, which were 1.4 percent of the total claims paid and represented 8.1 percent of all dollars paid for damage to buildings.

Table 3.

Regression Results on Differences of Changes in Subsidy Rates

Dependent variable: $\Delta SR_{2020,GSE,i} - \Delta SR_{2020,Other,i}$

	Model 1	Model 2	Model 3
constant	1.718**	1.445**	0.545**
$\Delta SR_{nocap,GSE,i} - \Delta SR_{nocap,Other,i}$	1.318**	1.316**	1.264**
$LTV_{GSE,i} - LTV_{Other,i}$		-0.037**	-0.030**
$LoanAmt_{GSE,i} - LoanAmt_{GSE,i}$		0.007**	0.010**
$SR_{base,GSE,i} - SR_{base,Other,i}$			0.004**
$ShareOutsideRisk_i$			24.159**
$adjusted\ R^2$	0.131	0.132	0.232

Data source: Congressional Budget Office.

$\Delta SR_{2020,GSE,i}$ (basis points) is the change in the subsidy rate from of GSE mortgages from flood damage in census tract *i*. $\Delta SR_{2020,Other,i}$ (basis points) is the change in the subsidy rate of FHA and VA mortgages from flood damage in census tract *i*.

$\Delta SR_{nocap,GSE,i}$ (basis points) is the change in the subsidy rate of GSE mortgages in census tract i between the case in which the flood insurance cap applies and the case in which the cap does not apply. $\Delta SR_{nocap,Other,i}$ (basis points) is the change in the subsidy rate of FHA and VA mortgages in census tract *i* between the case in which the flood insurance cap applies and the case in which the cap does not apply.

$LTV_{GSE,i}$ ($LTV_{Other,i}$) is the average loan-to-value ratio of GSE mortgages (FHA and VA mortgages) in census tract *i*. $LoanAmt_{GSE,i}$ ($LoanAmt_{Other,i}$) is the average loan amount of GSE mortgages (FHA and VA mortgages) in census tract *i* (in thousands of dollars).

$SR_{base,GSE,i}$ ($SR_{base,Other,i}$) is the subsidy rate without flood simulation of GSE mortgages (FHA and VA mortgages) in census tract *i*. $ShareOutsideRisk_i$ is the share of properties at risk of flood damage and outside of SFHAs in census tract *i*.

** (*) indicates 1 percent (5 percent) statistical significance based on a heteroskedasticity consistent estimator.

Table 4.

Regression Results on the Share of GSE Mortgages

Dependent variable: $w_{GSE,i} - w_{Other,i}$

	Model 1	Model 2	Model 3
constant	-5.607**	-27.908**	-26.885**
$ShareOutsideRisk_i$	1.401**	1.896**	0.667
$TotalLoanAmount_i$	0.214**	0.206**	0.207**
$Coastal_i$			-1.869**
$ShareOutsideRisk_i * Coastal_i$			5.424**
$State\ Dummies_i$	Not included	Included	Included
$adjusted\ R^2$	0.112	0.159	0.159

Data source: Congressional Budget Office.

$w_{GSE,i}$ is the share of all GSE mortgages in census tract i, $w_{GSE,i}$ is the share of all other federally backed mortgages in census tract i, $ShareOutsideRisk_i$ is the share of properties at risk of flood damage and outside of SFHAs in census tract *i*. $Coastal_i$ is an indicator for whether the census tract is coastal, GSE_i is the share of GSE mortgages in census tract *i* among all census tracts, and $State\ Dummies_i$ are indicator variables for each state.

** (*) indicates 1 percent (5 percent) statistical significance based on a heteroskedasticity consistent estimator.

Limitations of CBO's Estimates

The estimates in this paper are subject to certain limitations. First, mortgage data do not contain information on the exact location of a property designated as collateral for a mortgage. At the same time, flood risk data do not identify whether a property has a mortgage. Therefore, it is not possible to assign flood risk information to an individual mortgage. Instead, CBO assigns that information randomly within a census tract, which leads to uncertainty in its estimates.

The random assignment of flood risk information to mortgages also leads to limitations in the analysis. GSE mortgages could be more exposed to flood damage than other mortgages if they are more likely to be located in flood-prone areas *within* a census tract. In Florida, for example, many GSE mortgages could be associated with high-value properties on the waterfront at high flood risk, but properties with lower replacement values at lower flood risk could be located nearby. In such cases, flood damage could be underestimated because flood risk within that census tract is randomly assigned to the GSE mortgages. CBO could not test that hypothesis, however, because the mortgage data do not have exact location information for the homes that serve as collateral, which means that, in this analysis, a GSE mortgage effectively faces the same distribution of flood risk as any other home in the same census tract.

A second limitation is that CBO considers the effects of flood damage on mortgage losses only through two channels: the price of the flooded house and the LTV ratio. Flood damage can lead to defaults on mortgages through other channels, though, such as large repair costs to financially constrained households. The current projection model does not have the capacity to incorporate such effects. In this analysis, for simplicity, flood damage has a permanent effect on the house price but no effect on its growth rate. In reality, however, some floods could temporarily affect a house's value or could affect the growth rate of house prices (see Roth Tran and Wilson, 2023).

Flood damage also can increase prepayments of mortgages, as pointed out by Kousky, Palim, and Pan (2020) in their analysis of the effects of Hurricane Harvey. Early prepayments decrease fee income to the GSEs, FHA, or VA, leading to higher subsidy costs. The authors speculate that the increase in prepayments could be driven by factors such as sales to investors, increased liquidity from flood insurance claims, and homeowners' desire to leave a flood-prone area after a disaster. Even though CBO's projection model does predict prepayments, it does not capture those dynamics.

This analysis simulates flood events to each mortgage and does not incorporate possible spillover effects on neighboring properties, a third limitation. The value of neighboring houses might decline even though they are not directly damaged by flooding. A large flood could have negative effects on local businesses and their employees, lowering income and raising mortgage defaults in the area (see Indaco, Ortega, and Taspinar, 2021; and Meltzer, Ellen, and Li, 2021).

Two important dynamics in the current housing market are the rapid rise in the cost of hazard insurance and the exit of many insurers from risky areas (see Sastry, Sen, and Tenekedjieva, 2023). House prices in those vulnerable areas could drop as a result, leading potential mortgage borrowers to avoid them. Those dynamics could change the flood risk and subsidy cost of federally backed mortgages in the future.

This paper does not consider state or federal government disaster assistance that could mitigate the effect of flood damage on house prices and on the mortgage programs. The assistance provided by those programs is limited, however, so the effect of the omission is expected to be small. A typical home's claim for flood damage usually greatly exceeds the amount of federal government assistance provided: For example, the average NFIP claim after Hurricane Harvey was about 13 times larger than the average individual assistance payment (Kousky and others, 2020).

Appendix A: Data and Methodology

This appendix describes in detail the mortgage data and flood risk data the Congressional Budget Office used for this analysis. It also discusses how CBO calculated flood damage, determined whether each National Structure Inventory property is in a Special Flood Hazard Area, and estimated flood insurance take-up for properties outside SFHAs. In addition, it includes an auxiliary analysis of the National Flood Insurance Program's coverage maximum of $250,000 per property.

Mortgage Data

Data on mortgages acquired by the government-sponsored enterprises come from the Federal Housing Finance Agency and the GSEs. Data from FHFA have information on the census tract where a mortgaged property is but do not have information on the borrower's credit score. Data from the GSEs, by contrast, contain credit score information but do not have information on the census tract. CBO thus estimates the credit score of a borrower with a mortgage in the FHFA data by taking an average of credit scores of borrowers with mortgages in the GSE data that are similar to the mortgage in the FHFA data (based on location, such as metropolitan statistical area, loan purpose, occupancy purpose, loan-to-value ratio, and other characteristics).

Data on mortgages backed by the Federal Housing Administration and the Department of Veterans Affairs come from the Home Mortgage Disclosure Act (HMDA) database and Ginnie Mae. Data from HMDA have information on the census tract where a mortgaged property is but do not have information on the borrower's credit score. Data from Ginnie Mae, by contrast, contain credit score information but do not have information on the census tract. CBO thus estimates the credit score of a borrower with a mortgage in the HMDA data by taking an average of credit scores of borrowers with mortgages in the Ginnie Mae data that are similar to the mortgage in the HMDA data (based on location, such as state, loan purpose, unit count, LTV ratio, and other characteristics).

Additional information contained in mortgage data include the loan amount, interest rate, borrower's debt-to-income ratio, an indicator whether the mortgage is for purchase or refinance, and an indicator whether the mortgage is for a primary or secondary residence.

CBO uses data on mortgages originated in 2021 (the latest data available when the agency undertook this analysis) to estimate flood-related subsidy costs of mortgages that would originate in fiscal year 2024. The characteristics of the mortgages that would originate in that year could differ from those of mortgages that originated in 2021. CBO estimates that those differences might not affect the estimates much, however, as long as the geographical distributions of those cohorts are similar.

Flood Risk Data

CBO combines data from the NSI and flood risk projections from the First Street Foundation to estimate flood risk for a large set of properties nationwide.[19] The FSF projections contain flood depth information for 144 million properties in the United States based on median outcomes from an intermediate climate change scenario (called SSP2-4.5) generated by the Intergovernmental Panel on Climate Change. CBO uses parcel-level flood risk data from FSF. Each FSF parcel has the flood depths that are exceeded with an annual chance of 1 in 2, 1 in 5, 1 in 20, 1 in 100, 1 in 200, and 1 in 500. The depths represent the average flood depth over the footprint of the building on the parcel.

CBO identifies residential properties (which comprise 1 to 4 housing units as well as manufactured housing) in the NSI data, which was constructed by the U.S. Army Corps of Engineers. The NSI is a publicly available dataset meant to facilitate nationwide analysis of natural hazards, including floods. For each structure, the NSI contains characteristics including latitude and longitude, building use, foundation height, foundation type, estimated replacement value, and estimated value of the building's contents. The NSI does not contain information about flood risk.

The foundation type and height are critical to estimating flood damage. The NSI assigns foundation types directly from parcel data when available (U.S. Army Corps of Engineers, 2024). If that information is unavailable, it is instead based on a previous Army Corps inventory in which the probabilities of a given foundation type vary on the basis of flood zone and the year a structure was built. Foundation height is assigned to each foundation type based on a recent Army Corps survey.

For each residential property in the NSI, CBO uses flood risk information from nearby FSF properties to assign flood risk to that location. To begin with, CBO identifies the closest FSF property. If that property is within 30 meters of the NSI property, then CBO adopts that FSF property's flood risk. That approach reflects two assumptions. First, flood risk can vary significantly over short distances. If there is flood risk information available within 30 meters, then incorporating risk information from more distant FSF properties would not improve CBO's estimates. Second, First Street's parcel locations are based on data from Lightbox, which is the same vendor that provided the parcel information underlying the residential structures in the NSI. As a result, many of the NSI properties are probably represented in the First Street data. In practice, 91 percent of NSI properties have an FSF neighbor within 30 meters.

For the 9 percent of NSI properties without an FSF property within 30 meters, CBO uses a distance-weighted average of up to five FSF properties within 250 meters of the NSI property.

[19] This paper uses version 3.0 of the First Street Foundation's flood risk projections (First Street Foundation, 2023).

That 250-meter criterion avoids putting weight on distant properties that are more likely to differ significantly in their flood risk. The weights are computed using a Gaussian kernel with a mean of zero and a standard deviation of 100 meters. The 0.8 percent of NSI properties that have no FSF properties within 250 meters are dropped from the sample. Because FSF's flood model cannot distinguish very shallow flooding from no flooding, it does not allow for pluvial or coastal flood depths of less than 5 centimeters and fluvial flood depths of less than 20 centimeters (First Street Foundation, 2023). CBO follows that convention as well because its flood depths are interpolated from FSF's flood depths.

Flood Damage

CBO estimates flood damage at each NSI property by applying depth-damage curves to flood depths predicted to occur with an annual chance of 1-in-5, 1-in-20, 1-in-100, 1-in-200, and 1-in-500. For coastal regions, the agency also considers flooding with a 1-in-2 annual chance, which represents high-tide flooding. For each property and flood depth, CBO does the following:

- Subtracts the property's estimated foundation height from the flood depth;
- Assigns an appropriate depth-damage curve (from the Army Corps for fluvial flooding, FEMA for coastal flooding, and FSF for pluvial flooding);[20]
- Computes damage to a structure as a percentage of its replacement value; and
- Multiplies structure damage by the average nonland share of property value in the corresponding census tract to obtain damage as a percentage of property value.

In applying that damage estimate to the projection model, CBO holds the land share of property value constant over time. Larson and others (2020) find that the land share increased from 38 percent to 40 percent nationwide from 2012 to 2019, with significant heterogeneity. If that trend continued, CBO would overestimate flood damage in later years; however, damage is heavily time-discounted, and most mortgages do not last beyond the first few years of the simulation, so the effect on the overall estimate is probably small. Nationwide, 10 percent of the properties in the sample face at least a 1-in-500 annual chance of flood damage under current climate conditions.

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[20] The fluvial and coastal depth-damage curves are those used by the Army Corps' natural hazard consequences model known as "go-consequences" (https://github.com/USACE/go-consequences/wiki/Occupancy-Types). For fluvial flooding, the damage functions come from the Army Corps' Economic Guidance Memorandum 04-01 (https://planning.erdc.dren.mil/toolbox/library/EGMs/egm04-01.pdf) or the Hydrologic Engineering Center's Flood Impact Analysis model (www.hec.usace.army.mil/software/hec-fia). For coastal flooding, the damage functions are from FEMA's Coastal Probabilistic Flood Risk Analysis efforts; see pages D-36 to D-59 of the appendixes of FEMA's *Building Codes Save* study at www.fema.gov/emergency-managers/risk-management/building-science/building-codes-save-study. For 1-in-2 year (high-tide) flooding, this analysis uses coastal depth-damage curves that do not include damage from wave action.

Flood Zones

Using information from FSF and the NSI, CBO decides whether a property is in a Special Flood Hazard Area, which is any place that has a 1 percent or higher annual chance of a flood. When a property is within 30 meters of an FSF property, the agency assigns that FSF's estimated flood zone to the property; otherwise, it retains the NSI's information. CBO prefers to assign the FSF's flood zone classification because the NSI is missing information about flood zones in some areas (Washington, D.C., for example).

To assess that approach, CBO looked at NSI properties that are affirmatively placed in an SFHA to see whether the FSF classified its nearest property as being in an SFHA. For NSI properties that are assigned to an SFHA and have an FSF property within 30 meters, CBO finds that the FSF property is also in an SFHA 81 percent of the time. If the nearest FSF property is more than 30 meters away, the match rate falls to 61 percent, supporting CBO's decision to defer to the NSI's flood zone designation in those cases.

Flood Insurance Take-Up

CBO combines data from FEMA, the NSI, FSF, and the Census Bureau to estimate tract-level take-up rates of flood insurance in a multistep process. For each census tract, the agency does the following:

- Compiles the number of unique NFIP policies inside and outside an SFHA,
- Computes the share of housing units in the NSI located inside and outside an SFHA,
- Multiplies that share by the number of housing units from the 2015–2019 editions of the American Community Survey to estimate the number of housing units inside and outside of SFHAs, and
- Divides the number of NFIP policies by the number of housing units.

If the take-up rate is greater than 100 percent inside the SFHA, CBO then reallocates housing units from outside the SFHA into the SFHA until take-up is 100 percent and recomputes take-up outside the SFHA. If the take-up rate is greater than 100 percent outside the SFHA, CBO then reallocates housing units from inside the SFHA to outside the SFHA until take-up is 100 percent and recomputes take-up inside the SFHA. If there are more total policies than total housing units in the census tract, then CBO sets take-up rates to 100 percent inside and outside the SFHA.

That procedure is based on one used by Bradt, Kousky, and Wing (2021). It results in similar summary statistics, both inside and outside the SFHA.

	Takeup Outside of SFHA						
Tract Count	Mean	SD	Min	25%	50%	75%	Max
71808	0.02	0.07	0	0	0	0.01	1.00

The take-up rate of properties at risk of flood damage and outside an SFHA is derived by dividing the take-up rate outside the SFHA by the share of properties at risk of flood damage among those outside the SFHA.

Flood Insurance Coverage Cap

In CBO's flood simulations, households with flood insurance have coverage up to the lesser of the value of their structure or $250,000, in accordance with the building coverage limit for residential NFIP policies. However, federally backed mortgage holders in an SFHA are only required to obtain coverage for the unpaid balance of their loan if it is less than both the replacement value of the structure and $250,000.

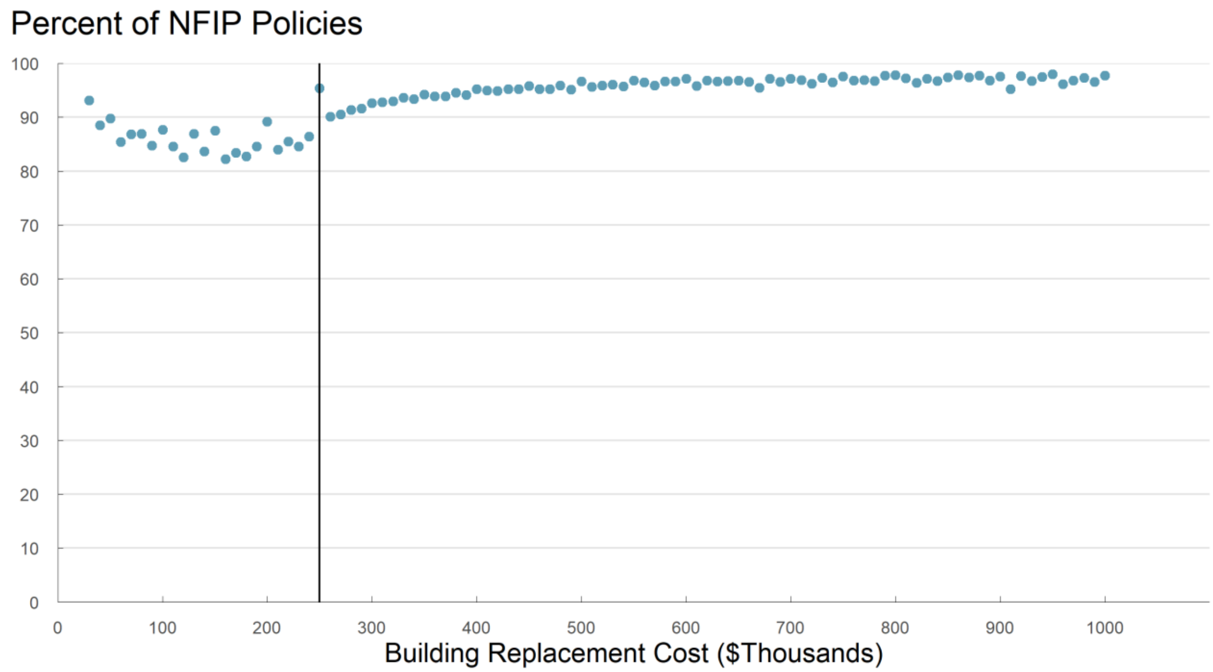
Even though that is the formal coverage requirement, CBO wants its model to reflect the actual behavior of those purchasing flood insurance. To that end, CBO analyzed FEMA's deidentified NFIP policy data. To make sure the $250,000 cap applied to all policies in the sample, CBO restricted the analysis to policies that were active on October 1, 2023, were identified as a single-family residence, and were associated with a single policy. Also, only homes with an estimated replacement cost of less than $5 million were considered.

First, policies were partitioned into bins defined by $10,000 intervals of building replacement cost as estimated by the insurer. Within those bins, CBO then computed the share of policies for which building coverage equaled or exceeded the replacement cost or was equal to $250,000 (see Figure A-1). Ninety percent of policies were found to carry the full coverage (either building replacement cost or $250,000), and those policies represent 93 percent of the total building replacement cost in CBO's sample. For policies with a building replacement cost under $250,000, 86 percent of policies carry the full coverage. For policies with higher building replacement costs, the proportion increases to nearly 97 percent. On average, policyholders with a building replacement cost under $250,000 carry coverage above the building's replacement cost (see Figure A-2).

The gap between the coverage of CBO's modeling approach and the average coverage of observed policies is less than $12,000 per property across all bins and below $5,000 per property for many bins (see Figure A-3). That finding suggests that CBO's modeling approach is unlikely to significantly underestimate the subsidy cost from flood damage.

Figure A-1.

Flood Insurance Policies With Full Building Coverage or Maximum Allowable Coverage

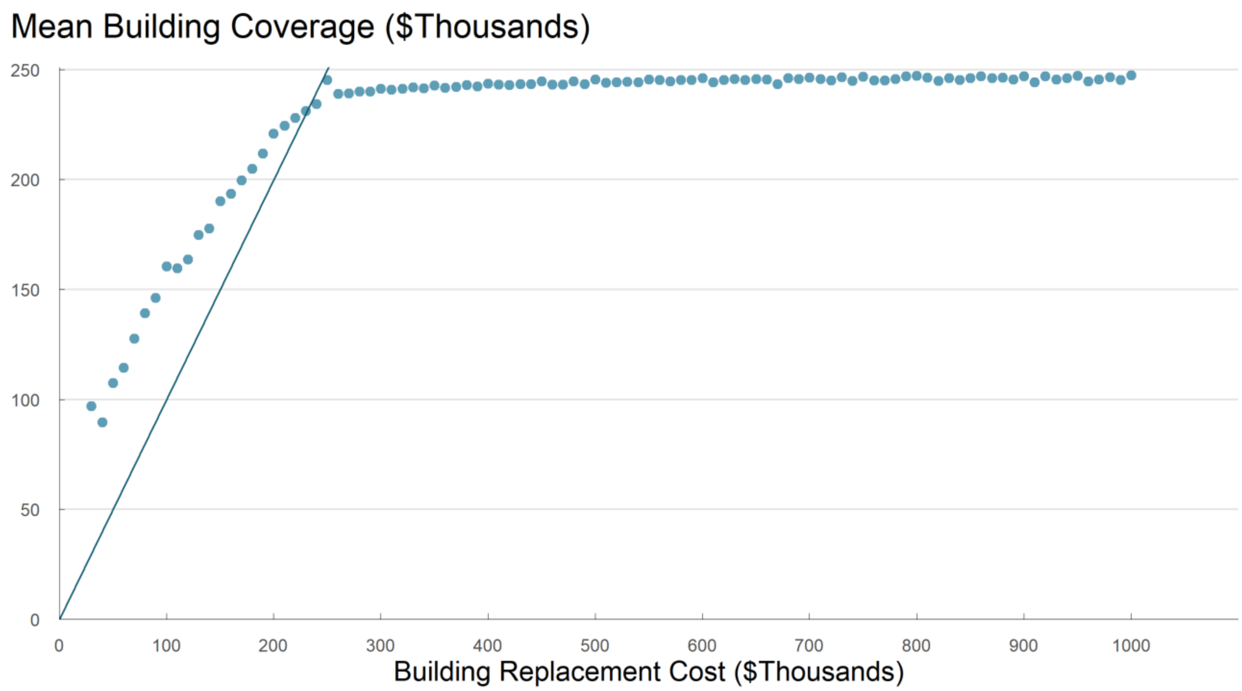


Data source: Congressional Budget Office, using data from FEMA, www.fema.gov/openfema-data-page/fima-nfip-redacted-policies-v2.

Full building coverage means that the policy's building coverage is at least as large as the building's replacement cost. For properties with replacement cost over $250,000, the plot shows the share of properties with the maximum building coverage of $250,000.

Figure A-2.

Average Building Coverage, by Building Replacement Cost

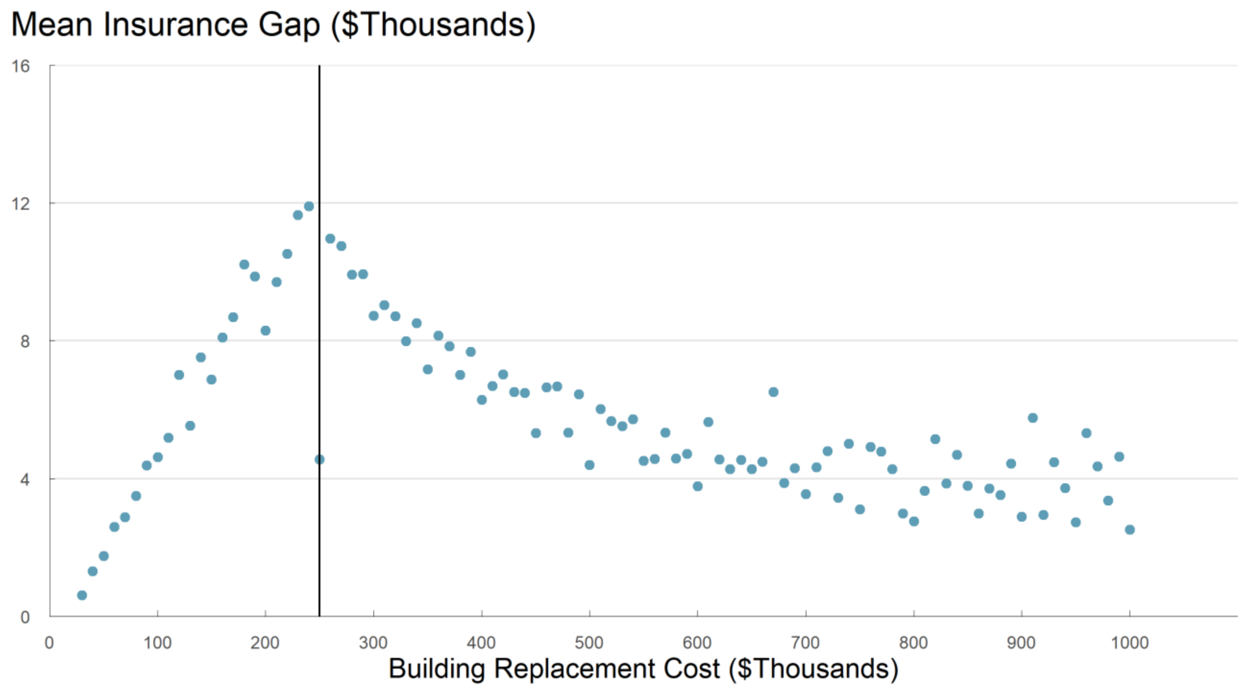


Data source: Congressional Budget Office, using data from FEMA, www.fema.gov/openfema-data-page/fima-nfip-redacted-policies-v2.

The line shows where a building's average coverage would exactly equal that building's replacement cost.

Figure A-3.

Gap Between Full Coverage and Actual Coverage



Data source: Congressional Budget Office, using data from FEMA, www.fema.gov/openfema-data-page/fima-nfip-redacted-policies-v2.

Full coverage means either the building's replacement cost or $250,000. If a policy has full coverage, the gap is set to zero.

Appendix B: Analyzing the Effects on Subsidy Rates

This appendix describes how the Congressional Budget Office decomposed differences in the effects of flooding across mortgage programs and presents the details behind the regression analyses.

Differences in Flood Effects

The changes in the subsidy rate between mortgages held by government-sponsored enterprises (GSEs) and other mortgages can be decomposed into two components, as follows:

$$\Delta SR_{GSE} - \Delta SR_{Other} = \sum_i w_{GSE,i}\,\Delta SR_{GSE,i} - \sum_i w_{Other,i}\,\Delta SR_{Other,i}$$

$$= \sum_i w_{GSE,i}\,\Delta SR_{GSE,i} - \sum_i w_{GSE,i}\,\Delta SR_{Other,i} + \sum_i w_{GSE,i}\,\Delta SR_{Other,i} - \sum_i w_{Other,i}\,\Delta SR_{Other,i}$$

$$= \underbrace{\left\{\sum_i w_{GSE,i}\left(\Delta SR_{GSE,i} - \Delta SR_{Other,i}\right)\right\}}_{\{subsidy\ rate\ effect\}} + \underbrace{\left\{\sum_i (w_{GSE,i} - w_{Other,i})\Delta SR_{Other,i}\right\}}_{\{location\ effect\}}$$

where ΔSR_{GSE} (ΔSR_{Other}) is the change in the subsidy rate of GSE mortgages (the other mortgages), $w_{GSE,i}$ ($w_{Other,i}$) is the ratio of GSE mortgages (the other mortgages) in census tract *i* among all census tracts, and $\Delta SR_{GSE,i}$ ($\Delta SR_{Other,i}$) is the change in the subsidy rate of GSE mortgages (the other mortgages) in census tract *i*. The first term turns out to contribute more to the difference than the second term, as the following equation shows:

$$\Delta SR_{GSE} - \Delta SR_{Other} = 1.58bp$$

$$\sum_i w_{GSE,i}\left(\Delta SR_{GSE,i} - \Delta SR_{Other,i}\right) = 1.47bp$$

$$\sum_i (w_{GSE,i} - w_{Other,i})\Delta SR_{Other,i} = 0.11bp$$

Detailed Results of Regression Analyses

CBO implemented two regression analyses in this paper to see why GSE mortgages are more exposed than other mortgages to flood damage. The first regression analysis was implemented to test the following two hypotheses:

- The subsidy rate of GSE mortgages increases as a result of flood damage more than the subsidy rate of other mortgages because flood damage of GSE mortgages is more likely to be greater than the flood insurance cap, or

- The subsidy rate of GSE mortgages increases as a result of flood damage more than the subsidy rate of other mortgages because GSE mortgages tend to have lower loan-to-value ratios.

To test the above hypotheses, CBO estimated the following regression model:

$$\Delta SR_{2020,GSE,i} - \Delta SR_{2020,Other,i} = f(\Delta SR_{nocap,GSE,i}, -\Delta SR_{nocap,Other,i};$$

$$LTV_{GSE,i}, -LTV_{Other,i}; LoanAmt_{GSE,i} - LoanAmt_{Other,i};$$

$$SR_{base,GSE,i} - SR_{base,Other,i}; ShareOutsideRisk_i) + u_i$$

where $\Delta SR_{2020,GSE,i}$ ($\Delta SR_{2020,Other,i}$) is the change in the subsidy rate of GSE mortgages from flood damage in census tract *i* under current climate conditions.

$\Delta SR_{nocap,GSE,i}$ ($\Delta SR_{nocap,Other,i}$) is the change in the subsidy rate of GSE mortgages (the other mortgages) in census tract *i* between the case in which the flood insurance cap applies and the case in which the cap does not apply. That variable is included to test the first hypothesis (namely, whether GSE mortgages tend to have more flood damage that surpasses the cap). A positive coefficient would support that hypothesis.

$LTV_{GSE,i}$ ($LTV_{Other,i}$) is the average LTV ratio of GSE mortgages (the other mortgages) in census tract *i*, and $LoanAmt_{GSE,i}$ ($LoanAmt_{Other,i}$) is the average loan amount of GSE mortgages (the other mortgages) in census tract *i*. Those variables are included in the regression analysis to test the second hypothesis (namely, whether GSE mortgages tend to have greater flood damage because they have lower LTV ratios). That hypothesis would be supported by data if the coefficient of $LTV_{GSE,i} - LTV_{Other,i}$ was estimated as negative and the coefficient of $LoanAmt_{GSE,i} - LoanAmt_{Other,i}$ as positive.

$SR_{base,GSE,i}$ ($SR_{base,Other,i}$) is the subsidy rate without flood simulation of GSE mortgages (the other mortgages) in census tract *i*. That variable is included to control for differences in the model, and $ShareOutsideRisk_i$ is included to control for differences in the flood risk.

The regression results show that the two hypotheses are supported by the data (see Table 3). First, the significantly positive sign of the coefficient of $\Delta SR_{nocap,GSE,i} - \Delta SR_{nocap,Other,i}$ indicates that GSE mortgages tend to have more flood damage that surpasses the flood insurance cap than the other mortgages do. Based on the R squares in the analysis, that effect accounts for about half of the explained subsidy rate effect. The R square of the model with only

$\Delta SR_{nocap,GSE,i} - \Delta SR_{nocap,Other,i}$ (Model 1 in Table 3) is about half that of the model with all the variables (Model 3 in Table 3).

Second, the significantly negative sign of the coefficient of $LTV_{GSE,i} - LTV_{Other,i}$ implies that GSE mortgages, when they have the same loan amounts as the other mortgages, have a larger increase in the subsidy rate from flood damage partly because of their lower LTV ratios. However, the increase in the adjusted R square is relatively small when $LTV_{GSE,i} - LTV_{Other,i}$ and $LoanAmt_{GSE,i} - LoanAmt_{Other,i}$ are included in the regression model, which implies that those terms do not account for much of the variation in the difference between the increases in the subsidy rate.

The second regression analysis tests the location effect, which is whether more GSE mortgages are located in flood-prone census tracts than in less risky census tracts, using the following model:

$$w_{GSE,i} - w_{Other,i} = f(ShareOutsideRisk_i; Coastal_i; TotalLoanAmount_i; StateDummies_i) + u_i$$

where $w_{GSE,i}$ ($w_{Other,i}$) is the share of GSE mortgages (other mortgages) in census tract *i* among all census tracts. $ShareOutsideRisk_i$ is the share of properties at risk of flood damage and outside of Special Flood Hazard Areas in census tract *i*. That variable measures the degree of flood risk in each census tract. The reason that CBO does not include properties at risk of flooding and inside SFHAs is that most flood damage in those areas is covered by flood insurance. (The results are similar when the share of all properties at risk of flooding is included instead of $ShareOutsideRisk_i$.) $Coastal_i$ indicates whether a census tract is coastal, and $StateDummies_i$ indicates the state to which a census tract belongs. $TotalLoanAmount_i$ is the total loan amount in census tract *i* and is included in the analysis to control for the mortgage size.

The positive and significant coefficient of $ShareOutsideRisk_i$, when $Coastal_i$ is not included in the model, supports the location effect that more GSE mortgages are in risky areas than in less risky areas. When $Coastal_i$ and its interaction with $ShareOutsideRisk_i$ are included in the analysis, the coefficient of $ShareOutsideRisk_i$ becomes insignificant, which implies that the location effect is not found in noncoastal census tracts. However, the coefficient for whether a census tract is coastal ($Coastal_i = 1$) is positive and significant, which means that more GSE mortgages are located in coastal census tracts, which tend to be prone to flooding (see Table 4).

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