Foreclosure and Catastrophe Insurance*

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Abstract

The foreclosure law in California protects homeowners against losses caused by devastating earthquakes. Banks do not require homeowners to purchase earthquake insurance to protect their mortgages. While banks may have a comparative advantage over insurance companies in dealing with earthquake risk (through securitization and avoiding insurers' risk of default), banks might also find it less costly to bear catastrophic risk because of bailouts and deposit insurance. We find that this type of implicit insurance is negatively related to explicit earthquake insurance coverage and positively to the sale of mortgages to government-sponsored enterprises (GSEs). Moreover, banks price implicit earthquake insurance coverage, which is cheaper than explicit insurance for some risk factors.

Key words: catastrophe insurance, foreclosure, bank bailouts

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1. Introduction

Nearly everyone in California lives within 30 miles of an active fault that could cause a damaging earthquake.[1] Yet, in 2013, only 10% of houses in California had earthquake insurance coverage.[2] The lack of coverage against earthquake insurance triggered an intensive debate. The reasons that are discussed range from homeowners' heuristics and behavioral biases to imperfect capital markets. We point to another possible reason: homeowners do not purchase earthquake insurance when they are implicitly insured through their mortgage loan.

The foreclosure law in California implies that a loan contract effectively contains an insurance component. If a homeowner defaults on the mortgage, the bank can take the house and sell it (foreclosure). In the case of a non-recourse mortgage, the bank cannot go after the homeowner's personal wealth if the proceeds from the sale are lower than the outstanding mortgage. California is known as a non-recourse state. Purchase money loans that are taken on initially to purchase an owner-occupied property are generally non-recourse. While the treatment of loans taken on to refinance the initial loan was less clear, a change in regulation in January 2013 established that these loans are non-recourse loans. If a homeowner defaults on a $300,000 non-recourse mortgage loan and the bank sells the house for $100,000, the homeowner is not liable for the deficiency of $200,000. When a house is severely damaged by an earthquake, it is then optimal for the homeowner to exercise the option to default on the loan instead of continuing making further payments to the bank.

With a non-recourse loan, the homeowner is implicitly insured against severe damages caused by an earthquake up to the mortgage loan. Thus, the homeowner's exposure to earthquake risk is limited by the mortgage used to finance the house, which in some cases might be close to the value of the house. Looking only at explicit earthquake insurance coverage therefore yields a distorted picture of actual exposure of homeowners to earthquake risk. Implicit insurance through the possibility to default on non-recourse mortgage loans, reduces homeowners' demand for explicit insurance coverage.

The prevalence of non-recourse mortgage lending does not automatically imply that earthquake risk is shifted to banks. Banks could require borrowers to purchase earthquake insurance coverage and name them as beneficiaries in the case of an earthquake. After all, banks generally require homeowners to purchase homeowners insurance. While such policies typically exclude

[1] California Faults and Quakes (California Earthquake Authority): http://www.californiarocks.com/california-faults-quakes

[2] 2013 CA EQ Premium, Exposure, and Policy Count Data Call Summary (California Department of Insurance): http://www.insurance.ca.gov/0400-news/0200-studies-reports/0300-earthquake-study/upload/EQEXP2013.pdf (Total Residential Market)

earthquake risk, insurance companies that provide homeowners insurance policies are legally obliged to also offer earthquake insurance as a supplementary policy. This supplementary policy is generally not required by banks. While about 75% of owner-occupied homes were financed with mortgages in California in 2013, the earthquake insurance take-up rate, which is defined as the number of earthquake policies divided by the number of homeowners insurance policies, was only 10%. If mortgages imply implicit insurance against earthquake risk, the puzzle is not why homeowners do not purchase explicit earthquake insurance, but why banks do not require the purchase of explicit insurance when providing mortgages to homeowners. After all, while homeowners might yield to behavioral biases, it is less clear that financial institutions such as banks do.

Banks can price the lack of earthquake insurance coverage and the possibility of default. Thus, homeowners do not automatically get a free lunch when using implicit insurance through banks. In a competitive market with zero frictional cost (loading) of insurance and competitively priced lending, full insurance of earthquake risk is optimal. Thus, rational homeowners are indifferent between explicit insurance and implicit insurance only if their home is 100% debt financed. Homeowners might prefer explicit insurance coverage to avoid the cost associated with a deterioration of their personal credit score when defaulting on their loan. However, while non-recourse loans implicitly cover damages against the entire property including the land, standard earthquake insurance policies only cover damages against the construction. In areas in which the value of the land constitutes the major part of the value of the property, and there is a high risk of a landslide in case of an earthquake, implicit coverage provides substantially more coverage than explicit earthquake insurance.

Moreover, catastrophe insurance is very costly because of high frictional cost of dealing with catastrophic risk events (Froot, 2001). Therefore, full earthquake insurance coverage is not optimal anyway. Homeowners may then prefer implicit insurance through their mortgage even if they bear part of the earthquake risk through their equity stake in their home, which bears resemblance to a deductible in explicit insurance. The question is whether insurers or banks bear the risk at lower cost; that is, who can provide the risk transfer to homeowners at lower cost.[3]

Froot (2001) discusses several frictions related to using (re)insurance markets to transfer catastrophe risk. The challenge in insuring catastrophic events involves the high correlation of risks that requires large amounts of risk capital to bear the possible losses. This increases the cost of funding the losses and exposes policyholders to a potential counterparty risk if the insurer cannot pay in the case of a catastrophic event. For risk averse policyholders, counterparty risk

[3]In the presence of behavioral biases, the benefit may also lay in bundling products and a joint pricing.

can be very costly. Implicit insurance avoids counterparty risk for policyholders. Indeed, the implicit nature of providing insurance through non-recourse mortgage lending, reverses the payment structure between the homeowner and the financial institution involved in the risk transfer: the homeowner receives the mortgage, and does not repay in case of a catastrophic event (similarly to catastrophe bond). If the bank requires explicit insurance instead, it would be exposed to the counterparty risk of the insurer. In addition, the bank may actually be better able to handle and transfer catastrophic risk than insurers. Holding large amounts of capital to bear possible losses can be costly for insurers or reinsurers since the capital might be diverted to other uses. Catastrophe bonds avoid this problem, but they are not used much. One problem of catastrophe bonds is that they require full collateralization, abandoning the (re)insurance principle of economizing on collateral through diversification (Lakdawalla and Zanjani, 2012). Implicit insurance through banks does not require idle collateral but ties it to the mortgage that the policyholder needs. Banks can transfer credit risk to capital markets through securitization, thereby also transferring catastrophic repayment risk to the capital market. Thus, securitization of loans has elements of a catastrophe bond, but involves illiquid mortgage backed securities, combining the benefits of refinancing illiquid loans with the benefits of transferring catastrophic risk to the capital market.

However, even if banks do not transfer catastrophic risk to the capital market through securitization, they might be more willing to bear this type of risk than insurers since they have a more direct access to external funding through deposit insurance and bailouts. Indeed, banks' shareholders have incentives to increase their exposure to systemic risk because of deposit insurance and bailouts. The deposit insurance rate is not fully risk-adjusted, e.g., it does not depend on whether houses in the banks' loan portfolio are explicitly insured or not. Banks' incentives to increase their exposure to earthquake risk result in banks being willing to provide implicit earthquake insurance to homeowners at a favorable rate. Thus, banks may crowd out private catastrophe insurance markets even when they are not more efficient in bearing the risk. Moreover, the distorted price for the implicit insurance of earthquake risk can distort homeowners' decision to build homes in high-risk areas.

Thus, banks might be able to provide insurance at lower costs for two reasons. First, banks may have a comparative advantage in providing catastrophe insurance by bundling lending and insurance. Second, banks may have a comparative advantage in transferring the risk to other parties that do not price this risk (bailouts and deposit insurance). The two reasons have very different implications for optimal risk sharing. While the former would contribute to efficient risk transfer, the latter could distort an efficient risk allocation.

We develop a theoretical model to formalize the effects of foreclosure on the private market for earthquake insurance in California. Our model yields several predictions that implicit provision of earthquake insurance by banks has. Most importantly, implicit insurance is a substitute for explicit provision of coverage provided by the private insurance market for earthquake risk and increases homeowners' incentives to choose a high loan-to-value ratio when financing their home. If banks have a comparative advantage in transferring earthquake risk, we should observe a positive relation between the use of implicit insurance and the sale of loans through securitization or to government-sponsored enterprises (GSEs) such as Fannie Mae and Freddie Mac. The implicit provision of earthquake insurance through banks reduces homeowners' cost for earthquake risk. The finding sheds a new light on why few homeowners in California purchase explicit earthquake risk, arguing that it is "too expensive."

2. Earthquake Insurance and Mortgage Market in California

2.1. Earthquake insurance market

California is exposed to earthquake risk, which can cause severe damages to or total destruction of properties located in affected areas. While a standard homeowners insurance policy in California covers losses caused by fire, hurricane, hail, lightening, or other disasters that are specified in the policy, it typically excludes damages caused by an earthquake. However, this coverage is readily available in the insurance market. Since 1985, California law requires insurers underwriting homeowners' insurance to also offer earthquake coverage policies. In turn, homeowners can only purchase earthquake coverage bundled with their homeowners insurance policy issued by the same insurer. Moreover, insurance companies can choose to offer earthquake coverage through the California Earthquake Authority (CEA). The CEA was established after the Northridge earthquake (1994) which caused insured losses that exceeded the $3.5 billion in earthquake premiums collected by all earthquake insurers in California from 1969 through 1994 by a factor of four. In response, many insurers restricted the sale of new homeowners policies given the obligation to offer earthquake insurance as well.[4] Today, with a market share of 75%, the CEA is the main earthquake insurance provider in California.[5]

When purchasing earthquake coverage, homeowners have to choose the identical insurance limit as in their homeowners policy, but they can choose a fixed deductible between 5% and

[4]http://www.rstreet.org/2014/06/12/the-california-earthquake-authority-a-confused-success-story/

[5]http://www.insurance.ca.gov/0400-news/0200-studies-reports/0300-earthquake-study/upload/EQEXP2013.pdf

25% of the insured value.[6] Importantly, earthquake insurance, including the policies offered through the CEA, only provides coverage against earthquake hazard to the structure of the house, not the land.[7]

The premium for the earthquake insurance policy is determined by the earthquake risk of the location of the house, the insured value and characteristics of the house (i.e., construction type, age, foundation type, and number of stories), and by the policy's coverage, limit and deductible.[8]

2.2. Mortgage market

The residential mortgage market in California is the largest in the US. In 2013, the total amount of loans originated exceeded $400 billion, which is approximately 22% of the total amount of loans originated in the US that year. Moreover, nearly 75% owner-occupied housing units in California have a mortgage, which translates into more than 5 million housing units. In addition, California is known as one of the borrower-friendliest state in the US due to the legal environment that regulates homeowners' defaults on their mortgage loans.

If a homeowner stops making payments and defaults on the mortgage loan, the bank can take the house and sell it, i.e., foreclose the house. Depending on the type of loan, the bank might or might not have the right to go after other financial assets of the homeowner to recover any debt that is outstanding after foreclosure. If the homeowner defaults on a recourse loan, the bank can bring legal action against the homeowner, garnish wages, levy bank accounts, and use other methods to collect the outstanding debt. If the homeowner defaults on a non-recourse loan, however, the bank has no such right. The bank has to absorb any deficiency as a loss.

California is known to be a non-recourse state. Typically, purchase money loans are non-recourse. The proceeds of these loans are used to buy a property that is owner-occupied and consists of up to four units. Since January 1, 2013, loans that are taken out to refinance purchase money loan are also non-recourse loans, except to the extent that the new principal was advanced which is not applied to the purchase-money loan (fees, costs, or related expenses of the refinance are also not covered by the anti-deficiency protection).[9]

[6] http://www.earthquakeauthority.com/insurancepolicies/home/Pages/Coverage.aspx

[7] CEA earthquake insurance policy covers up to $10,000 for the cost, including engineering cost, to replace, rebuild, stabilize or otherwise restore the land (CEA Earthquake Basic policy)

[8] http://www.earthquakeauthority.com/insurancepolicies/home/Pages/Rates-and-Premiums.aspx

[9] http://www.alllaw.com/articles/nolo/foreclosure/deficiency-laws-in-california.html

2.3. Insurance requirements for mortgaged houses

If a homeowner finances the purchase of a property through a loan, then the bank requires the purchase of a homeowners insurance policy, which typically excludes losses caused by earthquakes.[10] Banks generally do not demand earthquake insurance coverage.[11] For example, Wells Fargo requires homeowners to purchase homeowners insurance (protection in case of fire or other common disasters), wind insurance (protection against damage from wind and/or hail), and flood insurance (in case the mortgaged house is located in special flood hazard areas and flood insurance is required by the Federal Law) which have "to cover at least 100% of the estimated replacement cost for your home and any improvements to your property."[12]

Banks sell a significant share of their mortgage loan portfolio to the government-sponsored enterprises (GSEs) such as Fannie Mae and Freddie Mac. If a GSE purchases a loan, it generally also does not require the mortgaged house to be insured against earthquake hazards. Fannie Mae, for example, requires earthquake insurance for all buildings located only in Puerto Rico.[13]

Without any formal requirement, it is up to the homeowner to decide whether to purchase earthquake coverage for the mortgaged house or not. Anderson and Weinrobe (1986) found that in a sample of residential mortgage properties damaged by the 1971 San Fernando earthquake in California none of the properties were insured against earthquake damage. If the homeowner decides to purchase earthquake insurance, then he has to insure the house up to the full value as the homeowner is required to purchase homeowners insurance up to the full value of the house and as the two limits have to be the same (as noted in the CEA Earthquake Basic Policy).

3. The Model

3.1. Setting

We consider a setting with two periods, $t = 0$ and $t = 1$. A risk-averse individual with strictly increasing and concave utility function u receives income w_0 and w_1 in period $t = 0$ and $t = 1$, respectively. In period $t = 0$, the individual purchases a house at its current market value V (which includes the value of the land in addition to the structure of the house).

[10] The fire caused by an earthquake is typically covered by homeowners insurance policy: http://www.insurance.ca.gov/01-consumers/105-type/95-guides/03-res/eq-ins.cfm

[11] http://www.insurance.ca.gov/01-consumers/105-type/95-guides/03-res/eq-ins.cfm

[12] https://www.wellsfargorelo.com/loans/rmw/manage-account/homeowners-insurance.page

[13] https://www.fanniemae.com/content/guide/selling/b7/3/05.html\#Earthquake.20and.20Typhoon.20Insurance

An earthquake may hit the property between the two periods. Insurance companies, which are owned by risk-neutral investors, offer full insurance coverage for damage to the structure of the house, but not for the land. Therefore, it is important to distinguish between the damage caused to the structure (of the house) and to the land, $L_{house} \in [0, V_{house}]$ and $L_{land} \in [0, V_{land}]$ respectively. The total loss from the earthquake is $L = L_{land} + L_{house}$, and we assume that the maximum possible total loss equals the current value of the house, i.e., $V = V_{land} + V_{house}$. For example, if the property is located at the ocean, then an earthquake may swallow the property. For simplicity, we ignore other costs that such a devastating earthquake would have.

The insurance market is perfectly competitive, but there are two frictions. The first friction is that holding capital to cover catastrophic events is costly. For diversifiable risks such as, e.g., car insurance, this type of cost might be negligible as the average insured loss approaches the expected loss in a diversified portfolio. This is not true for catastrophic events where losses are highly correlated and the average loss conditional on an earthquake is considerably higher than the a priori expected loss. Given the high cost of holding capital to cover all claims after an earthquake, it is not optimal that insurers hold sufficient capital to cover all possible claims. Thus, there is a risk that the insurer cannot pay after an earthquake, which is the second friction. To model this counterparty risk in earthquake insurance, we assume that the insurer defaults with probability ρ after an earthquake and does not make any payment to policyholders. The premium for full insurance is given by $P = (1 + \alpha)(1 - \rho) E[L_{house}]$, where α captures the cost of insuring catastrophic events. For $\alpha = 0$, the premium equals the expected payment from the insurer (fair premium).

The purchase price exceeds the individual's period $t = 0$ income, i.e., $V > w_0$. A bank offers a loan of size $X \in [0, V]$ in period $t = 0$ with repayment obligation R in period $t = 1$. The bank is owned by risk-neutral owners, and the loan market is perfectly competitive. The risk-free interest rate is zero. If the individual fails to fulfill the repayment obligation R, then the bank can initiate foreclosure. In foreclosure, the bank receives the minimum of its claim and the value of the property $min\{R, V - L\}$. Whether the bank can recover the possible difference between the repayment obligation R and the proceeds from selling the house, $R - (V - L)$, depends on the type of loan contract. Under a recourse loan, the bank can recover the outstanding debt by going after the private wealth of the individual, which is not possible under a non-recourse loan. If the house is insured, however, then the bank recovers part of the outstanding debt from the insurance payment related to the loss to the house.

In case of a non-recourse loan without insurance, the loss in the case of non-repayment of the loan for the bank is $R - min\{R, V - L\} = max\{R - (V - L), 0\}$. The a priori expected loss that the bank has to bear depends on the individual's incentives to repay the loan after an earthquake. We assume that the individual bears a cost of not fulfilling the repayment obligation of the loan, e.g., from increased difficulties of receiving loans in the future due to the deterioration of the personal credit score. This cost of foreclosure to the individual is captured by a disutility, equivalent to a monetary loss δ. It is then optimal for the individual to repay the loan if and only if the repayment obligation does not exceed the value of the house and disutility from foreclosure, $R \leq V - L + \delta$. If $R > V - L + \delta$, the individual does not make the repayment, and the bank initiates foreclosure and recovers $V - L$. Thus, the bank's expected loss is $E[L - (V - R) | L > (V - R) + \delta]$. We assume that the bank prices loans to reflect this expected loss and charges a fee of $C = (1 + \beta) E[L - (V - R) | L > (V - R) + \delta]$. Thus, the homeowner gets a loan equal to $X = R - C$ in $t = 0$ with a repayment obligation R in $t = 1$. In a competitive market without frictions, $\beta = 0$ and the fee equals the expected loss, i.e., $C = E[L - (V - R) | L > (V - R) + \delta]$. β captures market frictions of bearing losses, similar to the case of an insurer. If the cost of bearing losses are lower for a bank than for an insurer, $\beta < \alpha$. For example, transferring the risk to the capital market through securitization might involve lower cost than using catastrophe bonds given the higher transaction volume of securitization and given that the loans are securitized anyway. That is, the transfer of the credit risk in securitization comes as a by-product of the refinancing of loans rather than being the main objective of the transaction. In this case, a lower cost of implicit insurance stems from more efficient risk financing. However, banks may also be willing to offer implicit catastrophe insurance at a lower price than insurers if guarantees and bailouts provide banks with incentives to seek this type of highly correlated risk and thus distort the pricing of the risk. Indeed, if banks have an incentive to engage in risk shifting or do not take into account the risk borne by their debt holders, β can even be negative.

The individual's total income $w_0 + w_1$ is sufficiently high to afford to purchase the property and full insurance. For simplicity, we assume that $w_0 \geq P$ so that the individual does not need a loan to purchase insurance.

3.2. Recourse loan and explicit earthquake insurance

The individual chooses the level of the loan X and decides whether to purchase earthquake insurance to maximize the expected utility of final wealth at $t = 1$. With earthquake insurance, the final wealth is $W(L) = w_0 + w_1 + X - P - L_{land} - R$ in case the insurer fulfills its insurance obligation and $W(L) = w_0 + w_1 + X - P - L - R$, otherwise. If the individual does not purchase earthquake insurance, then the final wealth is $W(L) = w_0 + w_1 + X - L - R$.

The loan X must be high enough to purchase the property. With a recourse loan, the bank can go after the private wealth of the individual to recover any outstanding obligation if the individual fails to repay the loan. Since $w_0 + w_1$ is sufficiently high, debt is risk free. Perfect competition in the loan market implies that $R = X$, and the loan cancels out in the individual's final wealth. Thus, the individual is indifferent with respect to any level of the loan that allows the purchase of the property, and $X^* \in [V - w_0 - P, V]$. Moreover, the pricing of the loan as well as the decision to purchase earthquake insurance are independent of the level of the loan.

It is optimal for a risk-averse individual to purchase earthquake insurance at a premium $P = (1+\alpha)(1-\rho) E[L_{house}]$ if the premium loading α and the couterparty risk ρ are not too large. The expected utility of final wealth with insurance is

$$\begin{aligned} EU &= (1-\rho) E[u(w_0 + w_1 - (1+\alpha)(1-\rho) E[L_{house}] - L_{land})] \\ &\quad + \rho E[u(w_0 + w_1 - (1+\alpha)(1-\rho) E[L_{house}] - L)]. \end{aligned}$$

The individual has to bear the risk of the uninsurable loss from the land and the risk of default by the insurer.

3.3. Non-recourse loan and implicit earthquake insurance

With a non-recourse loan, the individual is not liable for the repayment obligation R with the private wealth. The bank can only initiate foreclosure and recover the value $V - L$ if the individual does not repay the loan after an earthquake.

Suppose the individual does not purchase earthquake insurance. It is then optimal for the individual to repay the loan if and only if the repayment obligation does not exceed the value of the house and disutility from foreclosure, $R \leq V - L + \delta$. If $R > V - L + \delta$, the individual does not make the repayment, and the bank initiates foreclosure and recovers $V - L$. The final wealth is $W(L) = w_0 + w_1 + X - L - min\{R, V - L + \delta\}$. We assume that the minimum loan required to purchase the house is sufficiently low so that $R \leq V + \delta$ can be satisfied; that is, either the loan repayment obligation is sufficiently low, or the disutility from foreclosure is sufficiently high, so that the individual is willing to repay the loan when there is no earthquake. Otherwise, the individual would never repay the loan and financing the property is not possible.

The optimal loan contract (X, R) is given by the following optimization problem

$$max_R EU = E\left[u\left(w_0 + w_1 + X - L - min\left\{R, V - L + \delta\right\}\right)\right],$$

with $R = X + C = X + (1+\beta) E\left[R - (V - L) \left| R - (V - L) > \delta\right.\right]$.

A non-recourse loan provides the individual with implicit insurance as the individual can walk away from the loan if the loss is high. Rearranging the objective function yields

$$max_R EU = E\left[u\left(w_0 + w_1 - L - (R - X) + max\left\{0, L - (V - R) - \delta\right\}\right)\right],$$

where $w_0 + w_1 - L$ is equivalent to the total payoff with a recourse loan and no insurance. With a non-recourse loan, the individual gains $max\left\{0, L - (V - R) - \delta\right\}$, which resembles the payoff from an explicit insurance contract that fully indemnifies losses in excess of a deductible of $(V - R) + \delta$. For this implicit insurance, the individual has to pay $C = R - X$, which can be interpreted as the lending premium for implicit insurance.

For $\beta = \delta = 0$, the individual always defaults if $R - (V - L) > 0$ and $X = R - E\left[max\left\{0, R - (V - L)\right\}\right]$. In this case, the optimization problem is

$$max_R EU = E\left[u\left(w_0 + w_1 - L - E\left[max\left\{0, R - (V - L)\right\}\right] + max\left\{0, R - (V - L)\right\}\right)\right],$$

and it is optimal for the individual to choose $R^* = V$ so that the total payoff is equivalent to the payoff with full explicit insurance at a fair premium, $EU = u\left(w_0 + w_1 - E\left[L\right]\right)$.

Thus, a non-recourse mortgage involves implicit insurance against earthquake risk. With $V = R$, the individual is fully insured. However, as $V = R$ implies $V > X$ since $R - X = C$, the individual has an equity stake in the property equal to the "cost of implicit insurance", which bears resemblance to the premium for explicit insurance. With a limit on the maximum loan-to-value ratio, the individual cannot fully insure the loss through the loan, if the limit implies $V > R$. If $V > R$, the equity stake exceeds the implicit insurance premium, and the excess resembles a deductible in explicit insurance. Thus, a limit on the loan-to-value ratio is equivalent to a minimum deductible in explicit insurance. Increasing the disutility δ has a similar effect: using implicit insurance involves foreclosure that is personally costly for the individual and implies that the individual will not use the implicit insurance when losses are lower than δ. Both effects limit the attractiveness and ability to use implicit insurance through non-recourse financing. However, there are also two important potential advantages associated with implicit insurance. First, implicit insurance "covers" also the loss to the land, not only the loss to the house. Thus, even if the loan-to-value ratio is low, if the risk to the value of the land is high, implicit insurance may still involve more coverage of the total loss than explicit insurance that only covers the structure of the house. Second, implicit insurance does not involve counterparty risk for the individual. The negative effect of counterparty risk on the individual's expected utility can be higher than from foreclosure.

Increasing $\beta > 0$ has an effect that is similar to increasing the premium loading α. It makes it less attractive to implicitly insure the property through a non-recourse home-purchase loan. However, it the risk is not correctly priced and $\beta < 0$ because of bank bailouts, the result is reversed.

3.4. Non-recourse loan and explicit earthquake insurance

With a non-recourse loan, the homeowner is fully insured against losses caused by an earthquake to both the land and the house above a deductible level $V - R + \delta$. Whether the homeowner purchases earthquake insurance or not depends on the characteristics of the loan contract, the insurance contract, the distribution of losses to the land, and the cost of foreclosure to the homeowner. If $V - R$ is large, then the deductible level of implicit insurance is large and the homeowner is more likely to purchase explicit earthquake coverage. The positive effect on the demand for explicit coverage is similar if the cost of foreclosure to the individual, δ, is high, if the potential loss to the land, L_{land}, is low relative to the loss to the house, L_{house}, or if the cost to the bank of bearing earthquake risk, β, is high. If the premium loading of the insurance contract, α, and/or the counterparty risk of the insurance company, ρ, are sufficiently low, then explicit insurance is more attractive to the homeowner.

In any case, implicit insurance reduces incentives to use explicit insurance unless banks require explicit insurance or loan prices are sufficiently sensitive to having explicit insurance.

4. Empirical Evidence

4.1. Empirical relations

The existence of implicit insurance against earthquake risk has several implications. One implication is that it is not sufficient to look at explicit earthquake insurance. In California, looking only at the earthquake insurance take-up rate gives a distorted picture of the extent to which homeowners bear earthquake risk. Our analysis suggests that implicit insurance through mortgages is a substitute for explicit insurance. As a consequence, implicit insurance and explicit insurance should be negatively related. Moreover, the use of implicit insurance increases in the loan-to-value ratio as a higher mortgage implies a higher level of implicit insurance.

Unless banks engage in risk shifting, it is likely that their comparative advantage from bearing earthquake insurance risk stems from their ability to transfer the risk through securitization or sale to GSEs. As a consequence, we expect a positive relation between the level of implicit insurance and the sale of mortgages.

We expect that implicit earthquake insurance coverage is priced and reflected in the interest rate on the mortgage loan. Homeowners should use implicit insurance if it costs less than explicit earthquake insurance coverage. Thus, we expect that for some risk factors, implicit earthquake insurance coverage costs less than explicit earthquake insurance coverage.

4.2. Data

We collect data from different sources and focus on the year 2013 to give an overview of the relation between mortgage and earthquake insurance markets.

Earthquake insurance data The data on insurance policies is from the California Department of Insurance (CDI). It includes the aggregate number and type of homeowners and earthquake insurance policies by a 5-digit ZIP code in California. We consider standard homeowners insurance policies (HO-03 type, 55% of the sample) and dwelling owner-occupied policies (similar to standard homeowners insurance but with more restricted coverage, 3% of the sample) and earthquake coverage provided for those policies. We exclude renter's insurance policies (covering only contents but not the structure of the house, 16% of the sample), dwelling tenant-occupied policies (covering the structure of a house which is rented, 15% of the sample) and others (e.g., mobile homes, condominium forms, unoccupied, etc.). Since earthquake coverage can only be purchased together with homeowners insurance, we derive the earthquake insurance take-up rate by dividing the number of earthquake policies by the number of homeowners insurance policies.

As shown in Table 2 Panel A, the earthquake insurance take-up rate has been steadily decreasing from 13.8% in 2005 to 11.9% in 2013 (coverage provided by both the CEA and private insurance companies).

Earthquake risk data California is not uniformly exposed to the level of earthquake risk. We adopt earthquake risk ratings by ZIP codes from the California Earthquake Authority

(CEA) Premium Calculator.[14] The CEA uses 18 rating zones and the earthquake insurance premium in the highest risk zone is about nine times higher than in the lowest risk zone. While CEA earthquake risk ratings do not represent the earthquake risk precisely due to cross-subsidization, they are a reasonable proxy for the actual earthquake risk in a ZIP-code.[15]

Figure 1 shows the CEA earthquake insurance premium rates calculated for a house built in 2005 with a frame construction and one store for an insurance policy with a 15% deductible. Based on the change in the earthquake insurance premium rates across risk zones, we divide them into three groups: low (zone 1), medium (zones 2-12) and high (zones 13-18).

Mortgage loan data We obtain loan-level mortgage data from the Home Mortgage Disclosure Act (HMDA) database, which we supplement with the Freddie Mac and Fannie Mae's loan level origination dataset.

The HMDA database is the most comprehensive source of publicly available information about the mortgage market in the United States. It contains detailed information about the residential mortgage loans originated in a given year. We select conventional mortgage loans originated in California in 2013. In our sample, we include home-purchase and refinancing loans that are secured by a first lien and the mortgaged house is owner-occupied and has 1-to-4 family units. We are able to identify whether the loan was sold in a calendar year and, if applicable, the type of the purchaser (Fannie Mae, Freddie Mac, Ginnie Mae, Farmer Mac, commercial bank, mortgage bank, credit union, etc.).[16] This data set, however, does not provide the exact ZIP-code where the mortgaged house is located. We identify the exact 5-digit ZIP-code of the location of the mortgaged house by its census tract which is provided in HMDA database. If one census tract falls into several 5-digit ZIP-codes, we assign the corresponding share of the mortgage loan to each related 5-digit ZIP-code. The matching procedure is described in detail in the Appendix. Moreover, HMDA database lacks important loan characteristic such as the original loan-to-value (LTV) ratio or the interest rate. We obtain this information from Fannie Mae's and Freddie Mac's loan level origination data sets.

Fannie Mae's and Freddie Mac's loan level origination data sets include Fannie Mae's and Freddie Mac's 30-year, fully amortizing, full documentation, single family conventional fixed-rate mortgage loans.[17] We choose principal-occupancy single-family property mortgage loans

[14] http://www2.earthquakeauthority.com/Pages/Calc.aspx

[15] As discussed by Lin (2016), CEA rates are closely tied to the Peak Ground Acceleration, which is a measure of earthquake acceleration on the ground to be experienced in a region along with a probability of exceedance (such as 10% in 50 years).

[16] If the loan is sold to more than one purchaser, only the purchaser with the greatest interest is identified.

[17] Adjustable-rate, balloon, interest-only mortgage loans, government-insured, Home Affordable Refinance Program (HARP) and non-standard mortgage loans as well as mortgage loans with prepayment penalties

for which we observe the original interest rate, the original loan-to-value ratio, the purpose of the loan (purchase, cash-out or no cash-out refinance), original loan amount, origination channel (retail, broker or correspondent) as well as borrower's characteristics such as credit score, debt-to-income ratio and number of borrowers. The data set provides the 3-digit ZIP code within which the house securing the mortgage loan is located. As this data set is based on the date when the loan was purchased by Fannie Mae and Freddie Mac, it might included loans that were originated before 2013. However, in Fannie Mae's data set the origination date is provided, and all loans were originated in the same year as purchased, which suggests that banks sell their loans right after their origination. Therefore, while Freddie Mac does not provide the origination date, we assume that loans are sold to Freddie Mac in the same year as originated. This data set does not provide information about whether a mortgaged house is insured against earthquake hazard or not.

We assign average loan-to-value ratios obtained from Fannie Mae and Freddie Mac's data set to the HMDA data set in the following way. We calculate the average original loan-to-value ratio of mortgage loans in Fannie Mae and Freddie Mac's data set for each 3-digit ZIP-code by its purpose (home-purchase or refinancing) and the range of loan amount. Loan amounts are assigned into 40 different groups ranging from below $50,000 to above $1,000,000 with interval size of $25,000 (e.g. $100,000-$125,000, $125,001-$150,000, etc.). Then we assign average loan-to-value ratios to the corresponding loans in HMDA data set by its location, purpose, and range of loan amount.

The average original LTV ratio, which we obtain from Fannie Mae's and Freddie Mac's loan-level origination data sets, is 63.35%. On average, home purchase loans have 78.8% LTV ratio, which is close to the commonly accepted limit above which the private mortgage insurance is required (80%).

Other data We use US Census Bureau Fact Finder to collect demographics data for every 5-digits ZIP code.[18] We collect the median household income, the unemployment rate of a civilian labor force, the share of the population that is at least 25 years old and has a high school education or higher, and the mortgage take-up rate in every 5-digit ZIP-code. The mortgage take-up rate is calculated as the number of owner-occupied housing units with a mortgage over the number of the owner-occupied housing units within a ZIP code. This rate includes not only newly originated loans, but all valid owner-occupied housing units with a mortgage, irrespective of the year of origination.

are not included.

[18]http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

4.3. Analysis

4.3.1. Relation between explicit and implicit earthquake insurance

To identify the relation between implicit and explicit earthquake insurance coverage, we would ideally like to observe for each homeowner, the level of (explicit) earthquake insurance coverage purchased and the LTV ratio (implicit insurance coverage) of the mortgage. Unfortunately, we neither observe the explicit earthquake insurance coverage nor the LTV ratio for each homeowner. We therefore have to rely on proxies and use aggregate measures for insurance coverage on a 5-digit ZIP-code level. We measure explicit earthquake insurance coverage by an earthquake insurance take-up rate in a 5-digit ZIP-code ($EqRate$). The implicit earthquake insurance coverage is measured by two variables: average LTV ratio ($AvgOLTV$) and mortgage take-up rate ($MrtgRate$). All variables are defined in Table 1 Panel A.

We obtain the average LTV ratio ($AvgOLTV$) from Fannie Mae and Freddie Mac loan-level data set aggregated on a 3-digit ZIP-code level, which is assigned to each 5-digit ZIP-code falling into that 3-digit ZIP-code.[19] It measures the average LTV ratio of newly originated mortgage loans (both home-purchase and refinancing) with certain characteristics that were sold to Fannie Mae and Freddie Mac in 2013. A higher average LTV ratio in an area implies a higher level of implicit coverage. Therefore, we expect to find a negative relation to the earthquake insurance take-up rate.

The mortgage take-up rate ($MrtgRate$) is the share of the owner-occupied housing units with a mortgage in a particular 5-digit ZIP-code and it includes all existing mortgages irrespective of their characteristics (in particular, irrespective of the age of the loan and the LTV ratio). A higher mortgage take-up rate should imply a lower demand for explicit coverage. However our measure of implicit coverage is noisy as it includes also mortgages with a high down payment or mortgages close to their maturity.

We run the following OLS regression:

$$EqRate_i = \alpha + \beta AvgOLTV_{i3} + \gamma MrtgRate_i + \delta X_i + \varepsilon_i,$$

where i indicates variables related to 5-digit ZIP-code area i and $i3$ variables to the 3-digit ZIP-code area, corresponding to the related 5-digit ZIP code areas i.

X is the vector of our control variables. We control for the natural logarithm of the median household income ($ln(Inc)$), the share of unemployed civilian labor force ($Unemployment$)

[19]For example, 5-digit ZIP-codes 90011, 90012, and 90013 correspond to the 3-digit ZIP code 900

and the share of the population that is at least 25 years old and has a high school education or higher (*Education*) in the 5-digit ZIP-code. In a variation of the regression equation we also include the level of earthquake risk ($Medium$, $High$; *Low* is used as a reference group).

We present our results in Table 3.[20] Across all specifications, the average LTV ratio ($AvgOLTV$) has a negative and statistically significant effect on the explicit earthquake insurance coverage measured by the earthquake insurance take-up rate (*EqRate*) in a ZIP-code. As exhibited in column (6), a 10 percentage points (pp) increase in the average LTV ratio (from 64.5% to 74.5%) reduces the earthquake insurance take-up rate by 2.84 pp, i.e. from 10.9% to 8.1% which translates into a 26.1% decrease. However, the mortgage take-up rate ($MrtgRate$) has no significant effect on the earthquake insurance take-up rate (*EqRate*) in a ZIP-code. Overall, these findings show that there is a negative relation between implicit and explicit coverage. Compared to the low earthquake risk zone, a medium risk zone is related to a higher earthquake insurance-take up rate while the high risk zone is related to a lower earthquake insurance take-up rate.

We also find that demographic characteristics of a ZIP-code area and the earthquake insurance take-up rate are related: median household income (*ln*(Inc)) and the share of the population that is at least 25 years old and has a high school education or higher (*Education*) have a positive relation while the unemployment rate ($Unemployment$) has a negative relation with the earthquake insurance take-up rate (*EqRate*).

4.3.2. Implicit insurance coverage and risk transfer

To test the relation between implicit insurance coverage and the share of risk transferred to GSEs, we would ideally like to observe for each loan, whether it is covered by (explicit) earthquake insurance coverage. Again, we do not have this data. We use the share of loans (in units) sold to GSEs ($SoldGSE$) in a 5-digit ZIP-code in 2013 as a measure for implicit earthquake insurance transferred from the bank to investors. The explicit insurance coverage is measured by the earthquake insurance take-up rate (*EqRate*) in a 5-digit ZIP-code and the implicit coverage is measured by the average LTV ratio ($AvgOLTV$) in a 3-digit ZIP-code which is assigned to each 5-digit ZIP-code falling into that 3-digit ZIP-code. All variables are defined in Table 1 Panel A. A higher use of implicit coverage should lead to a higher level of risk transfer to the GSE. Therefore, the share of loans transferred to GSEs should increase

[20] 4.2% of ZIP-codes have an earthquake insurance take-up rate equal to 0%. Therefore, we also run a Tobit regression (untabulated) and calculate marginal effects of the explanatory variables on the expected value of the dependent variable evaluated at the mean values of the explanatory variables. We find that these marginal effects are close to the OLS estimates.

as the earthquake insurance take-up rate (explicit coverage) decreases but increase as the average LTV ratio (implicit coverage) increases. We also include the level of earthquake risk ($Medium$, $High$; Low is used as a reference group).

We run the following OLS regression:[21]

$$SoldGSE_i = \alpha + \beta EqRate_i + \gamma AvgOLTV_{i3} + \delta X_i + \varepsilon_i,$$

where i indicates variables related to the 5-digit ZIP-code area i and $i3$ variables to a 3-digit ZIP-code area, corresponding to the related 5-digit ZIP code areas i.

The vector of controls X_i contains the share of loans with higher rate spread ($HighSpread$), which identifies the lower quality borrower, and the share of home-purchase loans ($Purchase$) in a 5-digit ZIP-code.[22]

Table 4 presents the results. We find that controlling for the riskiness of the loan ($HighSpread$) and its purpose ($Purchase$), the earthquake insurance take-up rate has a negative effect on the share of loans sold to GSEs while the average LTV ratio has a positive effect. As exhibited in column (4), a 10 pp increase in the earthquake insurance take-up rate (from 10.9% to 20.9%) is associated with a decrease in the share of loans sold to GSEs by 5.85 pp, i.e. from 63.4% to 57.6%, which translates into a 9.2% decrease. On the other hand, a 10 pp increase in the average LTV ratio (from 64.5% to 74.5%) increases the share of loans sold to GSEs by 5.54 pp, i.e. from 63.4% to 68.8% which translates into a 8.6% increase. This result provides evidence that the use of implicit coverage increases the earthquake risk transfer from the bank to the GSE.

4.3.3. The cost of implicit insurance coverage

To test whether implicit insurance coverage costs less than explicit insurance coverage, we would ideally like to observe, on a loan level, the premium rate the homeowner pays through the loan interest rate for implicit insurance coverage and the premium rate for explicit insurance coverage. Since we do not have the data, we derive the premium rate for implicit insurance coverage by estimating the effect that the purchase of explicit insurance coverage ($EqRate_{i3}$) has on the interest rate of the loan ($IntRate$). Earthquake insurance take-up rate is calculated on a 3-digit ZIP-code level ($EqRate_{i3}$) as the location of the mortgaged house

[21]Only 2 ZIP-codes have the share of loans sold to GSEs equal to 0%.

[22]The spread between the Annual Percentage Rate (APR) and a survey-based estimate of APRs currently offered on prime mortgage loans of a comparable type. The survey collects data for a hypothetical, "best quality," 80% loan-to-value, first-lien loan (https://www.ffiec.gov/ratespread/newcalchelp.aspx).

in Fannie Mae and Freddie Mac data set is identified by a 3-digit ZIP-code. All variables are explained in Table 1 Panel B. For the premium rate of explicit earthquake coverage, we use the CEA Premium Calculator which provides premium rates as a function of specific characteristics (risk factors) of the house. Those characteristics, however, are not provided in the Fannie Mae and Freddie Mac loan-level data set that we use to estimate the premium rate for implicit insurance coverage. It is thus difficult to compare the respective premium rates.

As a first step, we test whether the purchase of explicit insurance coverage reduces the interest rate of the loan. Finding such a relation implies that implicit insurance coverage is priced through the interest rate of the loan. In a second step, we compare the magnitude of this effect with a range of premium rates for explicit insurance coverage by varying the characteristics of the house for the CEA Premium Calculator.

To derive the price for implicit earthquake coverage, we run the following OLS regression:

$$IntRate_{ji3} = \alpha + \beta EqRate_{i3} + \delta X_{ji3} + \varepsilon_{ji3},$$

where $IntRate_{ji3}$ is the original interest rate on a loan j in 3-digit ZIP code area $i3$ from the Freddie Mac and Fannie Mae loan origination data set. As this data set does not specify whether the mortgaged house is explicitly insured against earthquake hazard or not, we use the average earthquake insurance take-up rate in a 3-digit ZIP-code level, $EqRate_{i3}$. The vector of controls, X contains the following loan level data: LTV ratio ($OLTV$), debt-to-income ratio (DTI), borrower's credit score ($CScore$), whether there are more than two borrowers ($NumBorrow2$), loan amount ($Amount$), channel ($Channel$: broker, correspondent, retail), and purpose of the loan ($Purpose$: purchase, cash-out refi, no cash-out refi).

We present the results in Table 5. The purchase of explicit earthquake insurance coverage has a statistically significant negative effect on the interest rate of the loan. Banks price the provision of implicit insurance coverage with an average premium rate of 0.2%. To estimate the price for explicit earthquake insurance coverage, we use the CEA Premium Calculator. The following house characteristics (risk factors) are required by the CEA Premium Calculator to determine the premium: the ZIP-code of the house, the year the house was built, the insured value of the house, whether the house has more than one store, the foundation type of the house, whether the house was built with a frame construction, and the deductible level of 10% or 15%. The ZIP-code reflects the exposure to earthquake risk and has a significant effect on the premium rate. We provide the range of premium rates from low risk zones to high risk zones. While the number of stores, the frame construction, and the deductible level also have a significant effect on the premium rate, the year the house was built, the insured value of the house, and the foundation type of the house do not matter. We choose 2005 as the year the house was built and slab as the foundation type. By varying those characteristics, the premium rates do not change significantly. For the insured value of the house, we choose $422,312 which reflects the average insured value of houses in the Fannie Mae and Freddie Mac loan-level data set. In Table 6, we provide the premium ranges from low risk zones to high risk zones (based on the ZIP-code) for different house characteristics.

The risk zone (ZIP-code) and whether the house is built with a frame or not are the two most important risk factors. Our estimate for the average premium rate for implicit insurance (0.2%) is lower than the premium rate for explicit insurance coverage in high risk zones across all specifications (risk factors). However, for low risk zones, the average premium rate for implicit insurance is higher than the premium rate for explicit insurance coverage. It would be ideal to compare the implicit and explicit insurance premium rates on a risk zone level. However, the risk zone level is defined by the CEA Premium Calculator on a 5-digit ZIP-code level but the loan level data of the Freddie Mac and Fannie Mae data set identifies the location of the house on a 3-digit ZIP-code level only. We are thus not able to match a risk zone to a specific loan as there are many risk zones (defined on 5-digit ZIP-code) within a loan-specific 3-digit ZIP-code.

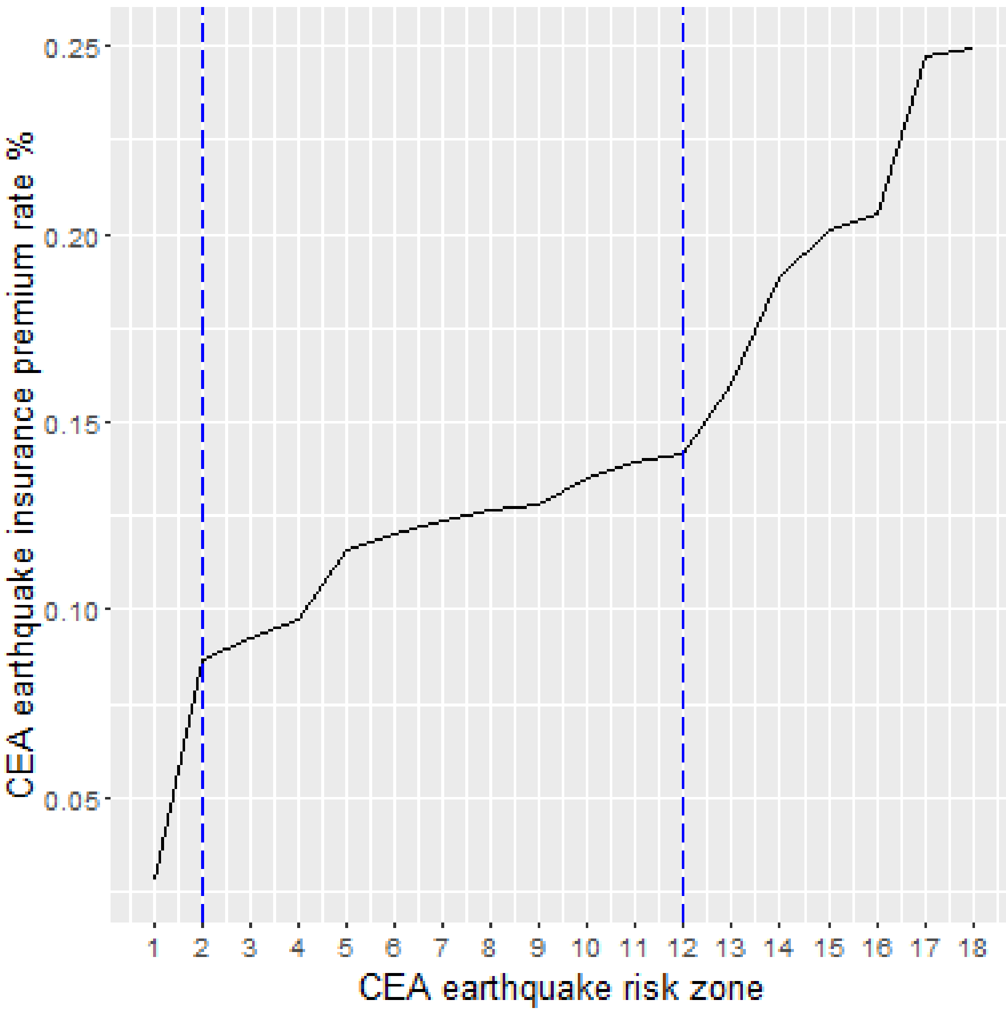

Figure 1: CEA earthquake risk zones and insurance premium rates, 2013

Table 1: Description of variables

Variable	Description	Source
	Panel A: On a ZIP-code level	
EqRate	Earthquake insurance take-up rate on a 5-digit ZIP-code level. $EqRate_3$ is earthquake insurance take-up rate on a 3-digit ZIP-code level It includes standard homeowners and dwelling owner-occupied insurance policies.	CDI
AvgOLTV	Average original loan-to-value ratio of loans sold to Fannie Mae and Freddie Mac and satisfying certain criteria in a 3-digit ZIP-code	Fannie Mae & Freddie Mac
MrtgRate	Share of owner-occupied housing units with a mortgage in a 5-digit ZIP-code	U.S. Census Bureau
SoldGSE	Share of loans sold to Fannie Mae and Freddie Mac in a 5-digit ZIP-code	HMDA
High, *Medium*	Grouped earthquake risk zones on a 5-digit ZIP-code level obtained from CEA Premium Calculator	CEA
Income	Median household income in a 5-digit ZIP-code	U.S. Census Bureau
Unemployment	Unemployment rate of a civilian labor force in a 5-digit ZIP-code	U.S. Census Bureau
Education	Share of population of 25 years old and over with a high school education or higher	U.S. Census Bureau
Purchase	Share of home-purchase loans originated in a 5-digit ZIP-code	U.S. Census Bureau
HighSpread	Share of loans originated with a higher interest rate spread	U.S. Census Bureau
	Panel B: On a loan level	
IntRate	Original interest rate set on the mortgage loan	Fannie Mae & Freddie Mac
Amount	Original loan amount	Fannie Mae & Freddie Mac
OLTV	Original loan-to-value ratio	Fannie Mae & Freddie Mac
DTI	Homeowner's debt-to-income ratio	Fannie Mae & Freddie Mac
CScore	Homeowner's credit score	Fannie Mae & Freddie Mac
FreddieMac	1 if the loan was sold to Freddie Mac and 0 if it was sold to Fannie Mae	Fannie Mae & Freddie Mac
$NumBorrow2$	1 if the number of borrowers is 2 or more and 0 otherwise	Fannie Mae & Freddie Mac
Channel	Channel through which the mortgage loan was originated: correspondent, retail, broker (reference group)	Fannie Mae & Freddie Mac
Purpose	Purpose of the loan: home-purchase, no cash-out refinance, cash-out refinance (reference group)	Fannie Mae & Freddie Mac

Table 2: Descriptive statistics of earthquake insurance market in California (2005-2013)

Statistic	2013	2011	2009	2007	2005
Panel A: Earthquake insurance take-up rate on a 5-digit ZIP-code level					
EQ insurance policies ('000)	723	765	808	823	810
Homeowners insurance policies ('000)	6,068	6,088	6,407	6,398	5,878
EQ insurance take-up rate (%)	11.9	12.6	12.6	12.9	13.8
Panel B: Earthquake insurance take-up rate: by risk zones					
Low-risk zone	9.7	9.8	9.4	9.3	9.4
Medium-risk zone	14.5	15.5	15.8	16.1	17.8
High-risk zone	9.3	10.1	10.5	11.1	12.3

Table 3: Relation between explicit and implicit earthquake insurance in California, 2013

This table shows results of an OLS model in which the data is aggregated on a 5-digit ZIP-code level. *EqRate* is earthquake insurance-take up rate calculated as the number of earthquake insurance policies over the number of homeowners insurance policies in a 5-digit ZIP-code (%) and serves as a measure of the explicit insurance coverage. *AvgOLTV* is the average loan-to-value ratio obtained from Fannie Mae and Freddie Mac dataset and is averaged over a 3-digit ZIP-code level. *MrtgRate* is the mortgage take-up rate which measures the share of owner-occupied housing units with a mortgage (%) in a 5-digit ZIP-code (US Census Bureau). Both *AvgOLTV* and *MrtgRate* are used as proxies for an implicit earthquake insurance coverage. *Medium* and *High* are dummy variables indicating whether the 5-digit ZIP-code is assigned to medium or high earthquake risk zone, respectively; low earthquake risk zone is a reference group. *ln(Inc)* is the natural logarithm of a median household income, *Unemployment* is the share of unemployed civilian labor force and *HighSchool* is the share of 25 years-old and over which is a high school graduate or higher in a 5-digit ZIP-code (US Census Bureau).

	Dependent variable:					
	EqRate					
	(1)	(2)	(3)	(4)	(5)	(6)
AvgOLTV	-0.357^{***}			-0.276^{***}		-0.284^{***}
	(0.032)			(0.033)		(0.033)
MrtgRate		-0.004			-0.026^{*}	-0.018
		(0.016)			(0.016)	(0.015)
D.Medium			5.384^{***}	4.012^{***}	5.530^{***}	4.105^{***}
			(0.438)	(0.461)	(0.439)	(0.460)
D.High			0.021	-1.329^{**}	0.223	-1.159^{*}
			(0.635)	(0.643)	(0.631)	(0.638)
log(Inc)	4.554^{***}	5.440^{***}	4.536^{***}	4.261^{***}	4.750^{***}	4.231^{***}
	(0.592)	(0.714)	(0.601)	(0.591)	(0.693)	(0.681)
Education	0.176^{***}	0.156^{***}	0.173^{***}	0.180^{***}	0.167^{***}	0.178^{***}
	(0.017)	(0.018)	(0.016)	(0.016)	(0.017)	(0.017)
Unemployment	-0.072^{**}	-0.150^{***}	-0.075^{**}	-0.053^{*}	-0.111^{***}	-0.091^{***}
	(0.030)	(0.032)	(0.029)	(0.029)	(0.030)	(0.030)
Constant	-29.555^{***}	-59.426^{***}	-54.319^{***}	-33.657^{***}	-53.980^{***}	-30.964^{***}
	(6.685)	(6.780)	(6.122)	(6.502)	(6.566)	(6.964)
Observations	1,661	1,643	1,661	1,661	1,643	1,643
R^2	0.280	0.238	0.299	0.327	0.314	0.343
Adjusted R^2	0.278	0.236	0.297	0.325	0.311	0.341
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 4: Relation between earthquake risk transfer and use of implicit insurance coverage in California, 2013

This table shows results of an OLS model in which the data is aggregated on a 5-digit ZIP-code level. *SoldGSE* is the share of loans sold to GSEs (%) in a 5-digit ZIP-code (HMDA). It measures the magnitude of the earthquake risk transfer from the bank to GSEs. *EqRate* is earthquake insurance-take up rate calculated as the number of earthquake insurance policies over the number of homeowners insurance policies in a 5-digit ZIP-code (%) and serves as a measure of the explicit insurance coverage. *AvgOLTV* is the average loan-to-value ratio obtained from Fannie Mae and Freddie Mac dataset and is averaged over a 3-digit ZIP-code level. It is used as a proxy for an implicit earthquake insurance coverage. *Medium* and *High* are dummy variables indicating whether the 5-digit ZIP-code is assigned to a medium or a high earthquake risk zone, respectively, where the low earthquake risk zone is a reference group. *HighSpread* is the share of loans which are issued to lower-quality borrowers in a 5-digit ZIP-code (HMDA). *Purchase* is the share of loans which are issued for home-purchase in a 5-digit ZIP-code (HMDA).

	Dependent variable:			
	SoldGSE			
	(1)	(2)	(3)	(4)
EqRate	-0.585^{***}			-0.538^{***}
	(0.027)			(0.028)
AvgOLTV		0.554^{***}		0.301^{***}
		(0.045)		(0.046)
D.Medium			-4.818^{***}	0.012
			(0.640)	(0.626)
D.High			-5.602^{***}	-3.361^{***}
			(0.921)	(0.853)
HighSpread	0.155	0.408^{***}	0.376^{**}	0.034
	(0.132)	(0.142)	(0.147)	(0.131)
Purchase	-0.158^{***}	-0.276^{***}	-0.209^{***}	-0.166^{***}
	(0.034)	(0.036)	(0.037)	(0.033)
Constant	72.836^{***}	32.883^{***}	69.957^{***}	53.650^{***}
	(0.791)	(2.941)	(0.876)	(3.116)
Observations	1,713	1,713	1,713	1,713
R^2	0.243	0.117	0.077	0.277
Adjusted R^2	0.242	0.116	0.074	0.275
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table 5: The effect of an explicit insurance coverage on the interest rate

This table shows results of an OLS model for the Fannie Mae and Freddie Mac loan-level data. *IntRate* is the interest rate on the loan (%). *EqRate* is earthquake insurance take-up rate calculated as the number of earthquake insurance policies over the number of homeowners insurance policies in a 3-digit ZIP-code (%) and serves as a measure of the explicit insurance coverage. Other variables include: the natural logarithm of the loan amount (*ln(Amount)*), the loan-to-value ratio (*OLTV*), the borrower's credit score (*CScore*), the dummy variable if the GSE is Freddie Mac (*D.FreddieMac*), the dummy variable indicating whether there are more than two borrowers (*D.NumBorrow2*), the dummy variable for the channel (*D.Channel*), the dummy for the purpose of the loan (*D.Purpose*)

	Dependent variable:	
	InRate	
	(1)	(2)
EqRate	-0.007^{***}	-0.002^{***}
	(0.0001)	(0.0001)
ln(Amount)		-0.038^{***}
		(0.002)
OLTV		0.004^{***}
		(0.0001)
DTI		0.004^{***}
		(0.0001)
CScore		-0.003^{***}
		(0.00002)
D.FreddieMac		0.028^{***}
		(0.002)
D.NumBorrow2		0.008^{***}
		(0.002)
D.Channel: Correspondent		-0.024^{***}
		(0.002)
D.Channel: Retail		0.039^{***}
		(0.002)
D.Purpose: Purchase		0.069^{***}
		(0.003)
D.Purpose: No Cash-Out Refi		-0.154^{***}
		(0.002)
Constant	4.029^{***}	6.163^{***}
	(0.002)	(0.028)
Observations	271,337	271,267
R^2	0.009	0.205
Adjusted R^2	0.009	0.205
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 6: CEA earthquake insurance premium ranges from the lowest to the the highest risk zone by risk factors

Risk Factors			CEA Premium Rate Range
Deductible, %	Frame Construction	Stories	from the Lowest to the Highest Risk Zone, %
15	Yes	1	0.03 - 0.25
15	Yes	>1	0.03 - 0.28
15	No	1	0.08 - 0.68
15	No	>1	0.08 - 0.75
10	Yes	1	0.04 - 0.33
10	Yes	>1	0.04 - 0.36
10	No	1	0.10 - 0.89
10	No	>1	0.11 - 0.99

A. Assigning a 5-digit ZIP-code to the census tract in HMDA

In the HMDA database, the location of the mortgaged house is identified by census tracts, which are "small, relatively permanent statistical subdivisions of a county or equivalent entity that are updated by local participants prior to each decennial census as part of the Census Bureau's Participant Statistical Areas Program".[23] (The latest data is for the year 2010.) To be able to match earthquake insurance policy data (which is on a 5-digit ZIP code level) and Freddie Mac and Fannie Mae's data (which is identified by 3-digit ZIP code) with HMDA data, we need to convert census tract into a ZIP code for which we used a public file from the Missouri Census Data Center.[24] This file allows to match each census tract with a relevant ZIP Tabulation Area (ZCTA) Code, which are generalized areal representations of United States Postal Service (USPS) ZIP Code service areas[25]. If a census tract does not fall fully into a given ZCTA, but instead falls into several different ZCTAs, this file indicates which share of that census tract should be assigned to a particular ZCTA. For example, it shows that a census tract 4039.00 should be assigned to two ZCTA in the following way: 96.3% of it is assigned to 94610 ZCTA and 3.7% to 94611 ZCTA. As a result, if the mortgaged house is located in 4039.00 census tract we assign 0.963 of it to 94610 ZCTA and 0.037 to 94611 ZCTA. ZCTAs are a very close approximation of the area covered by a ZIP code therefore in our analysis we treat ZCTA as the ZIP code.

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