Foreclosure and Catastrophe Insurance*

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Abstract

The foreclosure law in California provides homeowners with the option to walk away from their loan repayment obligation, leaving the bank with the value of the home. Thus, a loan contract contains implicit insurance against a loss in property value after an earthquake. Banks require homeowners insurance for mortgage loans, but they generally do not require earthquake coverage, which homeowners insurance contracts exclude. 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 earthquake risk because of bailouts and deposit insurance. We find that implicit earthquake insurance through lending is negatively related to explicit earthquake insurance coverage and that banks price implicit earthquake coverage, which is cheaper than explicit insurance for some risk factors. Moreover, higher implicit earthquake insurance is positively associated with a higher sale of mortgages to government-sponsored enterprises (GSEs).

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.[3] We point to another possible reason: homeowners do not purchase earthquake insurance when their mortgage loan provides implicit insurance against losses from an earthquake.

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 as well. 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 an earthquake severely damages a house, it is optimal for the homeowner to exercise the option to default on the loan instead of continuing making further payments to the bank.

A non-recourse loan provides the homeowner with implicit insurance against severe damages caused by an earthquake up to the mortgage loan. Thus, the mortgage used to finance the house, which in some cases might be close to the value of the house, limits a homeowner's exposure to earthquake risk. 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.

[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)

[3] For example, Kunreuther et al. (2001) argue that individuals have difficulties in evaluating very low probabilities without having access to comparison information about events that are meaningful to them. Kunreuther and Pauly (2004) show that search costs for obtaining information about low probabilities can explain the lack of insurance demand for low-probability, high-consequence events. Froot (2001) provides a detailed analysis of the (re)insurance market for catastrophic risks and concludes that capital market imperfections and market power of reinsurers explain high premiums and capital shortage in this market.

The prevalence of non-recourse mortgage lending does not automatically imply that banks have to bear earthquake risk. 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. Even though such policies typically exclude earthquake risk, insurance companies that provide homeowners insurance policies are legally obliged to offer earthquake insurance as a supplementary policy. This supplementary policy is generally not required by banks. While about 75%[4] 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%.[5] 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 of insurance and lending, full insurance of earthquake risk is optimal. Rational homeowners are indifferent between explicit insurance and implicit insurance through a loan with a repayment obligation equal to the value of the house. Homeowners might prefer explicit insurance coverage if there is a cost associated with a deterioration of their personal credit score when defaulting on their loan. However, non-recourse loans implicitly cover damages against the entire property including the land, whereas 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.

Important differences between explicit and implicit insurance stem from differences in risk transfer. Catastrophe insurance is very costly because of high frictional cost of dealing with catastrophic risk events (Froot, 2001). Therefore, full earthquake insurance coverage is generally not optimal anyway. Homeowners might then prefer implicit insurance through their mortgage even if they bear part of the earthquake risk through their equity stake in their home, which is equivalent to a deductible in explicit insurance. The question is whether

[4] U.S. Census Bureau, American Fact Finder: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

[5] 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)

insurers or banks bear the risk at lower cost. That is, who can provide the risk transfer from homeowners to the capital market at lower costs?[6]

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 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 a catastrophe bond). If the bank requires explicit insurance instead, it bears 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 they might divert the capital 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 insurers could bear the risk more efficiently (at lower social cost). Moreover, the distorted price for the implicit insurance

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

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. 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; they may indeed find it "too costly" relative to the cost of implicit insurance.

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. 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.[7] Today, with a market share of 75%, the CEA is the main earthquake insurance provider in California.[8]

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 25% of the insured value.[9] 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.[10]

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 (for example, construction type, age, foundation type, and number of stories), and by the policy's coverage, limit and deductible.[11]

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. In contrast, if the homeowner defaults on a non-recourse loan, the bank has no such right. The bank has to absorb any deficiency as a loss.

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

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

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

[10] 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)

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

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 to refinance purchase-money loans are generally also non-recourse loans.[12]

2.3 Insurance requirements for mortgaged houses

If a homeowner finances the purchase of a property through a loan, the bank requires the purchase of a homeowners insurance policy, which typically excludes losses caused by earthquakes.[13] Banks generally do not demand earthquake insurance coverage.[14] 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."[15]

Banks sell a significant share of their mortgage loan portfolio to 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 only for buildings located in Puerto Rico.[16]

Without any formal requirement by the regulator or bank, it is up to the homeowner to decide whether to purchase earthquake coverage for the mortgaged house or not. Anderson and Weinrobe (1986) find 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 or she 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).

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

[13] 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

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

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

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

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 property at its current market value V (which includes the value of the land in addition to the structure of the house).

An earthquake may hit the property between the two periods. Insurance companies, which are owned by risk-neutral investors, offer full earthquake 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 property, 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, 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. With 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 frictional cost of insuring catastrophic events. For $\alpha = 0$, the premium equals the expected payment from the insurer to the policyholder (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 investors, 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 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. However, if the house is insured, the bank recovers part of the outstanding debt from the insurance payment related to the loss to the house.

Given a non-recourse loan without insurance, the loss in the case of non-repayment of the loan for the bank is $R - min\{R, V - L\} = max\{R - (V - L), 0\}$. 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 repay the loan, and the bank initiates foreclosure and recovers $V - L$. Thus, the bank's expected loss is $E\left[(L - (V - R)) \cdot \mathbb{1}_{\{L > V - R + \delta\}}\right]$. We assume that the bank prices loans to reflect this expected loss and charges a fee of $C = (1 + \beta)\, E\left[(L - (V - R)) \cdot \mathbb{1}_{\{L > V - R + \delta\}}\right]$. Thus, the homeowner gets a loan equal to $X = R - C$ in period $t = 0$ with a repayment obligation R in period $t = 1$. In a competitive market without frictions, $\beta = 0$ and the fee equals the expected loss, i.e., $C = E\left[(L - (V - R)) \cdot \mathbb{1}_{\{L > V - R + \delta\}}\right]$. 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 volume of securitization by banks. Moreover, the bank might securitize the loans anyway, and the transfer of the earthquake risk comes as a by-product of refinancing the loans rather than being the main objective of the transaction. Thus, a lower cost of implicit insurance might stem from more efficient risk financing. However, banks might 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 Explicit earthquake insurance in the absence of implicit insurance

If the bank has recourse to the private wealth of the individual, any loan X to purchase the property is risk free since the individual's total wealth $w_0 + w_1$ is sufficiently high, debt is risk free. 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 $W(L) = w_0 + w_1 + X - L - R$.

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.

The expected utility of final wealth without insurance is

$$EU = E\left[u\left(w_0 + w_1 - L\right)\right]$$

The expected utility of final wealth with insurance is

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

The individual has to bear the risk of the uninsurable loss from the land and the risk of default by the insurer. It is optimal for a risk-averse individual to purchase earthquake insurance at a premium $P = (1+\alpha)(1-\rho) E\left[L_{house}\right]$ if the premium loading α and the counterparty risk ρ are not too large.

3.3 Implicit earthquake insurance with non-recourse loans

With a non-recourse loan, the individual is not liable for the repayment obligation R. If the individual does not repay the loan after an earthquake, the bank can only initiate foreclosure and recover the value $V - L$. Thus, a non-recourse loan provides implicit insurance against earthquake risk, encompassing implicit elements of an insurance premium, deductible, and upper limit similar to explicit insurance

To focus on the comparison between implicit and explicit insurance, we assume this subsection that 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.)

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 $R = X + C = X + (1+\beta)\, E\left[(R - (V - L)) \cdot \mathbb{1}_{\{R-(V-L)>\delta\}}\right]$.

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

A non-recourse mortgage involves implicit insurance against earthquake risk that bears a resemblance to explicit insurance. For $V = R$, the individual is fully insured. $V = R$ implies $V > X$ since $R - X = C$. Thus, the individual has an equity stake in the property equal to C, where C can be interpreted as the "cost of implicit insurance", similar to a premium for explicit insurance. If $V > R$, the individual is not fully insured, and the equity stake exceeds the implicit insurance premium. $V - R$ resembles a deductible in explicit insurance, which may stem, for example, from a (regulatory) limit on the maximum loan-to-value ratio. The personal cost from foreclosure δ has a similar effect as the individual will not use implicit insurance when losses are lower than δ. A low loan-to-value ratio and a high personal cost of foreclosure limit the attractiveness of implicit insurance through non-recourse financing. However, there are also two important potential advantages associated with implicit insurance. First, implicit insurance "covers" also the damage to the land, not only the damage to the structure of 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, which 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, if the risk is not correctly priced and $\beta < 0$ because of bank bailouts, the result is reversed.

3.4 Explicit earthquake insurance in the presence of non-recourse mortgages

With a non-recourse mortgage, the homeowner is fully insured against losses caused by an earthquake to both the land and the house above an implicit 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 lending rates are sufficiently sensitive to having explicit insurance.

3.5 Implications and predictions

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 for owner-occupied homes, as owner-occupied loans are non-recourse loans. Thus, explicit earthquake insurance and implicit earthquake insurance are negatively related. Moreover, the benefits of implicit insurance over explicit insurance for owner-occupied houses increases in the loan-to-value (LTV) ratio as a higher mortgage implies a higher level of implicit insurance coverage.

Catastrophic risks are costly to insure, and banks might be able to bear catastrophic risks at lower cost than insurers because of lower cost of risk transfer or bailouts. If banks have lower cost of bearing catastrophic events, they will require borrowers to purchase insurance for risks that are easily diversifiable, but not for catastrophe risks. When homeowners choose implicit insurance, then they have an incentive to choose a high loan-to-value ratio. Thus, mortgage lending in states with non-recourse mortgages and high catastrophe risk will be higher than in states with recourse lending and low catastrophe risk.

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. Therefore, we expect a positive relation between the level of implicit insurance and securitization and sale to GSEs.

We expect that banks price implicit earthquake insurance coverage through adjusting the interest rate on the mortgage loan. Thus, mortgage loans where the homeowner purchases explicit earthquake insurance should ceteris paribus have a lower interest rate than mortgage loans without earthquake insurance. Mortgage rates might be insensitive to the purchase of explicit insurance if banks want to bear the earthquake risk.

If bailouts and risk-shifting incentives distort bank's pricing of the earthquake risk, implicit insurance distorts homeowners' incentives to take measures against earthquake risk and build homes at exposed locations, where they would otherwise not build a house.

Unfortunately, testing our predictions is difficult due to a lack of data on the purchase of earthquake insurance, value of the house, and outstanding mortgage for individual homeowners.

4 Hypothesis and Empirical Strategy

4.1 Relation between explicit and implicit earthquake insurance

The lack of information on whether individual borrowers purchase earthquake insurance severely limits the ability to test our predictions empirically. The California Department of Insurance (CDI) biannually provides information on the aggregate number and type of homeowners and earthquake insurance policies in a 5-digit ZIP-code area in California. We use this data to derive the average earthquake insurance take-up rate (*EqRate*) for owner-occupied homeowners for each 5-digit ZIP-code area in California in 2011 and 2015. The fact that we have a measure only on the average use of earthquake insurance limits the predictions we can test and affects our empirical strategy. For example, instead of testing whether homeowners with a higher loan-to-value ratio of the home are less likely to purchase earthquake insurance, we can only test whether there is a negative association between the earthquake insurance take-up rate and the average level of implicit insurance in a 5-digit ZIP code area. We describe the data sources and derivation of our variables in the Data section, and all variables are defined in Table 1.

We use two measures to proxy for implicit insurance ($ImplIns$). Our first measure is the average loan-to-value ratio ($AvgLTV$) of owner-occupied, first lien, 1-to-4 units, conventional mortgages in a 5-digit ZIP-code area. A higher average LTV ratio in an area implies a higher level of implicit coverage. Therefore, we predict a negative relation between the earthquake insurance take-up rate and the average LTV ratio.

Our second proxy is the mortgage take-up rate ($MrtgRate$). The mortgage take-up rate is the share of all owner-occupied housing units with a mortgage in a 5-digit ZIP-code area. A higher mortgage take-up rate should be related to a lower demand for explicit coverage. The drawback of this measure is that it also includes mortgages with a very low LTV ratio for which the level of implicit insurance is low.

We run the following OLS regression:

$$EqRate_i = \alpha + \beta ImplIns_i + \delta X_i + \varepsilon_i,$$

where i indicates variables related to a 5-digit ZIP-code area i.

X_i is the vector of -control variables. We control for the income of households, using the natural logarithm of the median household income ($log(Inc)$), the share of unemployed civilian labor force ($Unemployment$), and the share of the population that is at least 25 years old and has a high school education or higher ($Education$) on a 5-digit ZIP-code level. Income and unemployment are important determinants of insurance demand, which is subject to income and wealth effects. We include education as the behavioral literature on catastrophe insurance suggests that economic literacy is an important determinant of the demand for earthquake insurance. We also include the level of earthquake risk ($Medium$ and $High$, where Low is used as a reference group).

4.2 Implicit insurance coverage and risk transfer

To test whether banks retain the exposure to earthquake risk on their balance sheet or whether they are more likely to sell (securitize) loans that are exposed to earthquake risk, we would like to explicitly control for whether a mortgage borrower purchased earthquake insurance. Again, we do not have this information on loan level. Instead, we use the earthquake insurance take-up rate ($EqRate$) for owner-occupied homeowners in a 5-digit ZIP-code area in California. We test whether there is a positive or negative association between the insurance take-up rate and the share of loans sold to GSEs ($SoldGSE$) on a 5-digit ZIP-code.

Another important variable is the average LTV ratio ($AvgLTV$) of loans. A higher LTV ratio implies a higher risk for banks in the case of default.

We run the following OLS regression:

$$SoldGSE_i = \alpha + \beta EqRate_i + \gamma AvgLTV_i + \delta X_i + \varepsilon_i,$$

where i indicates variables related to a 5-digit ZIP-code area.

The vector of controls X_i contains the average credit score of borrowers ($AvgCreditScore$) and the share of home-purchase loans ($Purchase$) in a 5-digit ZIP-code area. We also control for the income of households, using the natural logarithm of the median household income ($log(Inc)$), and the share of unemployed civilian labor force ($Unemployment$) on a 5-digit ZIP-code level. Income and unemployment are important factors in determining the riskiness of the loan. We also include the level of earthquake risk ($Medium$ and $High$, where Low is used as a reference group).

4.3 The cost of implicit insurance coverage

To test whether the bank prices implicit earthquake insurance coverage, we would like to run the following regression:

$$IntRate_j = \alpha + \beta ExplIns_j + \delta X_j + \varepsilon_j,$$

where $IntRate_j$ is the original interest rate on a loan j that a homeowner has to pay; $ExplIns_j$ is a dummy that equals 1 if the homeowner purchased earthquake insurance, and X_j is a set of controls including the average LTV ratio and borrower characteristics.

As we do not have this data, to test whether explicit insurance coverage is negatively related to the interest rate of the loan, we run the OLS regression on an aggregate level. We use the average interest rate set on the mortgage loans ($AvgIntRate$) in a 5-digit ZIP-code area as a depenedent variable and replace $ExplIns_j$ by the insurance take-up rate $EqRate$ in the 5-digit ZIP-code area where the mortgage loan is originated.

The vector of controls X contains the following loan level data: average loan-to-value ratio ($AvgLTV$), average borrower's credit score ($AvgCreditScore$), the natural logarithm of the average unpaid principal balance ($log(UPB)$), and the share of the purchase loans ($Purchase$).

We obtain explicit earthquake insurance premiums using the CEA Premium Calculator.

5 Data

We merge data from different sources and focus only on California and on the years 2011 and 2015.

Explicit insurance: earthquake insurance take-up rate The California Department of Insurance (CDI) provides data on insurance policies. It includes the aggregate number and type of homeowners and earthquake insurance policies in a 5-digit ZIP-code area in California that were in place as of the calendar year-end, i.e. December 31, 2011 and 2015. We use the data to obtain standard owner-occupied 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.[17]

[17] We do not consider renter's insurance policies covering only contents but not the structure of the house (16% of the sample). We also exclude dwelling tenant-occupied policies covering the structure of a house

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.

Implicit insurance We did not find any data set containing information about whether (individual) loans are insured through earthquake insurance. As a proxy for the potential protection against earthquake risk though mortgage loans, we use the average loan-to-value ratio in a 5-digit ZIP-code area provided by LPS.[18] The average loan-to-value ratio is calculated for all conventional, owner-occupied, first lien, and 1-to-4 units mortgage loans in a 5-digit ZIP-code area in California. It includes all existing mortgage loans as of the calendar year-end, i.e. December 31, 2011 and 2015.

We obtain the mortgage take-up rate, calculated as the number of owner-occupied housing units with a mortgage over the number of the owner-occupied housing units, in a 5-digit ZIP-code area from the US Census Bureau Fact Finder.[19] We also use the U.S. Census Bureau Fact finder to obtain the controls that we use in our regression on the relation between explicit and implicit insurance, on a 5-digit ZIP code area level: median household income, unemployment rate of the civilian labor force, and the share of the population of 25 years old and over with a high school education or higher.

Risk transfer We use the share of mortgage loans that were sold to GSEs (Fannie Mae and Freddie Mac) as a measure of earthquake risk transfer from banks to GSEs. This data is provided by LPS and is for conventional, owner-occupied, first lien, 1-to-4 units mortgage loans. We use the average borrowers' credit score and the share of home purchase loans in a 5-digit ZIP-code area as controls (LPS). We also control for the median household income and unemployment ratio in a 5-digit ZIP-code area which we obtain from U.S. Census Bureau.

Cost of implicit insurance We use the average interest rate set on the mortgage loans from LPS data set to calculate the premium rate of implicit insurance. This data set provides

that is rented (15% of the sample), since mortgages for tenant-occupied homes are generally recourse loans.

[18]LPS stands for Lender Processing Services, former known as McDash. Mortgage data provided by LPS is used in a number of academic papers, e.g. in Adelino et al (2016). The data is collected from mortgage servicers and covers about 65% of the U.S. residential mortgage market. It contains detailed information on residential mortgages loans. However, due to legal restrictions we were allowed to only use data aggregated on a 5-digit ZIP-code level. The data we use includes only conventional, owner-occupied, first lien, and 1-to-4 units mortgage loans.

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

the average interest rate in a 5-digit ZIP-code area for mortgage loans that are conventional, first-lien, owner-occupied, and 1-4 units.

Earthquake risk data California is not uniformly exposed to the same level of earthquake risk. We adopt earthquake risk ratings by 5-digit ZIP codes from the California Earthquake Authority (CEA) Premium Calculator.[20] 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 5-digit ZIP-code area.[21]

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 earthquake insurance premium rates, we divide them into three groups: low (zone 1), medium (zones 2-12), and high (zones 13-18) risk zones.

6 Results

We present the descriptive statistics and correlation coefficients of our main variables in Tables 2 and 3, respectively.

Explicit and implicit insurance We present our results on the relation between explicit and implicit earthquake insurance for years 2011 and 2015 in Table 4 and Table 5, respectively. Across all specifications, the average LTV ratio ($AvgLTV$) has a negative and statistically significant relation to the explicit earthquake insurance coverage measured by the earthquake insurance take-up rate ($EqRate$) on a 5-digit ZIP-code level. As exhibited in column (4) in Table 4, a 10 percentage points (pp) increase in the average LTV ratio (from 63.55% to 73.55%) is related to a decrease in the earthquake insurance take-up rate by 5.56 pp, i.e. from 11.88 % to 6.32 % which translates into a 53.2 % decrease. The relation between the mortgage take-up rate ($MrtgRate$) and the earthquake insurance take-up rate ($EqRate$) in a 5-digit ZIP-code area is also negative and significant, as shown in column (5). Overall, these findings suggest that there is a negative relation between implicit and explicit coverage. Compared to the low

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

[21] 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).

earthquake risk zone, a medium risk zone is related to a higher earthquake insurance-take up rate while the high risk zone has no statistically significant difference.

We also find that demographic characteristics of a ZIP-code area and the earthquake insurance take-up rate are related: median household income ($log(Inc)$) 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*).

Risk transfer Tables 6 and 7 contain our results on earthquake insurance and risk transfer in years 2011 and 2015, respectively. We find that, controlling for the average borrowers' credit score (*AvgCreditScore*), its purpose (*Purchase*), the homeowner's income ($log(Inc)$), and unemployment (*Unemployment*), the earthquake insurance take-up rate is negatively related to the share of loans sold to GSEs while the average LTV ratio is positively related. As exhibited in column (4) in Table 6, a 10 pp increase in the earthquake insurance take-up rate (from 11.88% to 21.88%) is associated with a decrease in the share of loans sold to GSEs by 1.84 pp, i.e., from 66.97 % to 65.13 %, which translates into a 2.74 % decrease. On the other hand, a 10 pp increase in the average LTV ratio (from 63.55% to 73.55 %) is related to a higher share of loans sold to GSEs by 6.31 pp, i.e., from 65.13% to 71.44 % which translates into a 9.69 % increase. Our results suggest that implicit earthquake insurance and the transfer of risk from banks to GSEs are positively related.

Cost of (implicit) insurance The results in Table 8 and 9 show that there is a statistically significant negative association between the purchase of explicit earthquake insurance coverage and the interest rate of a loan. Our evidence suggests that 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 5-digit 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 5-digit 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. For the insured value of the house, we choose $420,000. In Table 10, we provide the premium ranges from low risk zones to high risk zones (based on a 5-digit ZIP-code level) for different house characteristics.

The risk zone (5-digit ZIP-code area) 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.

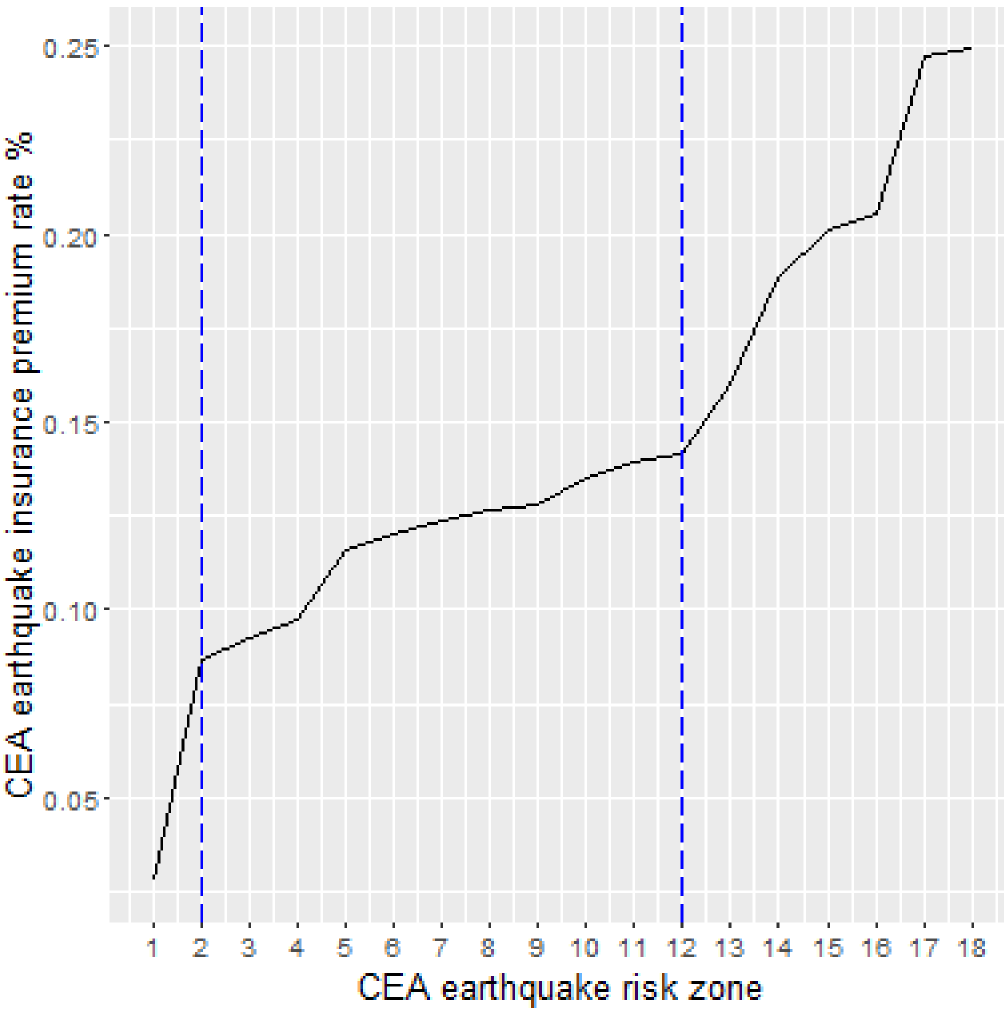

Figure 1: CEA earthquake risk zones and insurance premium rates

This figure shows the CEA earthquake insurance premium rates (Premium/Insured Amount) calculated for a house built in 2005 with a frame construction and one store for an insurance policy with a 15% deductible across earthquake risk zones. We divide earthquake risk zones into 3 groups: low (zone 1), medium (zones 2-12), and high (zones 13-18).

Table 1: Description of variables aggregated on a 5-digit ZIP-code level

Variable	Description	Source
Panel A: Earthquake risk data		
EqRate	Earthquake insurance take-up rate (%). It includes standard homeowners and dwelling owner-occupied insurance policies.	CDI
High, *Medium*	Grouped earthquake risk zones obtained from Premium Calculator	CEA
Panel B: Mortgage loan data		
AvgLTV	Average loan-to-value ratio (%)	LPS
Purchase	Share of home-purchase loans (%)	LPS
SoldGSE	Share of loans sold to Fannie Mae and Freddie Mac (%)	LPS
AvgInt	Average interest rate on the mortgage loans (%)	LPS
UPB	Average outstanding unpaid principal balance of the mortgage loans (USD)	LPS
CreditScore	Average credit score based on FICO calculations or re-calibrated FICO scores	LPS
Panel C: Demographic characteristics		
MrtgRate	Share of owner-occupied housing units with a mortgage (%)	U.S. Census Bureau
Inc	Median household income (USD)	U.S. Census Bureau
Unemployment	Unemployment rate of a civilian labor force (%)	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

Table 2: Descriptive statistics

This table shows descriptive statistics of the variables aggregated on a 5-digit ZIP-code level in 2011 (Panel A) and 2015 (Panel B). *EqRate* is the earthquake insurance take-up rate (%) calculated as the number of owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code area (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). *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 area (U.S. Census Bureau). *SoldGSE* is the share of number of loans sold to GSE (%) in a 5-digit ZIP-code (LPS). *Unemployment* is the share of unemployed civilian labor force (%), *Education* is the share of 25 years-old and over which is a high-school graduate or higher (%), and *Inc* is the median household income (USD) in a 5-digit ZIP-code (U.S. Census Bureau).

Statistic	N	Mean	St. Dev.	p01	p25	p50	p75	p99
				Panel A: 2011				
EqRate, %	2,109	11.88	14.63	0.00	2.70	7.28	16.76	69.88
AvgLTV, %	2,692	63.55	12.03	25.00	57.75	64.92	70.03	92.00
MrtgRate, %	1,690	68.56	17.81	0.00	63.10	72.90	79.20	100.00
SoldGSE, %	2,701	66.97	26.24	0.00	61.23	70.83	79.19	100.00
Unemployment, %	1,594	11.32	7.52	1.90	7.40	9.70	13.20	37.10
Education, %	1,715	82.43	15.23	35.60	75.20	87.00	93.80	100.00
Income, USD	1,690	62,181	27,520	15,047	42,532	57,271	76,963	150,918
				Panel B: 2015				
EqRate, %	1,867	11.35	13.88	0.00	3.11	7.14	15.82	50.00
AvgLTV, %	2,243	66.42	12.93	26.00	59.27	67.65	75.00	100.00
MrtgRate, %	1,661	67.14	14.99	19.7	60.70	70.40	76.40	100.00
SoldGSE, %	2,249	66.18	24.16	0.00	60.00	70.37	78.03	100.00
Unemployment, %	1,604	11.26	8.10	2.00	7.10	9.60	13.30	38.90
Education, %	1,705	83.37	14.33	36.60	76.70	87.70	94.00	100.00
Income, USD	1,629	63,612	29,130	22,304	42,141	57,417	78,457	158,162

Table 3: Correlation

This table shows the Pearson correlation coefficients between the key variables in 2011 (Panel A) and 2015 (Panel B). *EqRate* is the earthquake insurance take-up rate (%) calculated as the number of owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code (%) (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). *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 area (U.S. Census Bureau). *SoldGSE* is the share of number of loans sold to GSE (%) in a 5-digit ZIP-code (LPS).

	EqRate, %	AvgLTV, %	MrtgRate, %	SoldGSE, %
		Panel A: 2011		
EqRate, %	1.00			
AvgLTV, %	-0.26^{***}	1.00		
MrtgRate, %	0.08^{***}	-0.03^{***}	1.00	
SoldGSE, %	-0.12^{***}	0.10^{***}	-0.06^{***}	1.00
		Panel B: 2015		
EqRate, %	1.00			
AvgLTV, %	-0.23^{***}	1.00		
MrtgRate, %	0.06^{**}	-0.05^{*}	1.00	
SoldGSE, %	-0.12^{***}	0.07^{***}	-0.17^{***}	1.00
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 4: Explicit and implicit earthquake insurance in California, 2011

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 owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). *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 (U.S. Census Bureau). Both *AvgLTV* 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 (CEA Premium Calculator). *log(Inc)* is the natural logarithm of a median household income, *Unemployment* is the share of unemployed civilian labor force (%), and *Education* is the share of 25 years-old and over which is a high school graduate or higher in a 5-digit ZIP-code (%) (U.S. Census Bureau).

	Dependent variable:				
	EqRate				
	(1)	(2)	(3)	(4)	(5)
AvgLTV	-0.618^{***}			-0.556^{***}	
	(0.030)			(0.030)	
MrtgRate		-0.029^{*}			-0.056^{***}
		(0.016)			(0.016)
D.Medium			6.030^{***}	3.806^{***}	6.310^{***}
			(0.464)	(0.439)	(0.468)
D.High			0.128	-1.071^{*}	0.483
			(0.658)	(0.601)	(0.663)
log(Inc)	2.100^{***}	5.989^{***}	4.493^{***}	1.912^{***}	5.224^{***}
	(0.603)	(0.728)	(0.635)	(0.593)	(0.698)
Education	0.099^{***}	0.166^{***}	0.189^{***}	0.116^{***}	0.177^{***}
	(0.016)	(0.019)	(0.017)	(0.016)	(0.018)
Unemployment	-0.097^{***}	-0.159^{***}	-0.113^{***}	-0.086^{***}	-0.122^{***}
	(0.030)	(0.034)	(0.033)	(0.030)	(0.034)
Constant	20.923^{***}	-63.787^{***}	-54.302^{***}	16.063^{**}	-57.466^{***}
	(7.207)	(7.043)	(6.493)	(7.037)	(6.739)
Observations	1,583	1,579	1,577	1,577	1,573
Adjusted R^2	0.405	0.245	0.327	0.446	0.332

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5: Explicit and implicit earthquake insurance in California, 2015

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 owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). *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 (U.S. Census Bureau). Both *AvgLTV* 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 (CEA Premium Calculator). *log(Inc)* is the natural logarithm of a median household income, *Unemployment* is the share of unemployed civilian labor force (%), and *Education* is the share of 25 years-old and over which is a high school graduate or higher in a 5-digit ZIP-code (%) (U.S. Census Bureau).

	Dependent variable:				
	EqRate				
	(1)	(2)	(3)	(4)	(5)
AvgLTV	−0.617***			−0.599***	
	(0.034)			(0.035)	
MrtgRate		−0.037			−0.063***
		(0.024)			(0.024)
D.Medium			4.905***	1.407**	5.119***
			(0.630)	(0.615)	(0.635)
D.High			−1.339	−3.810***	−1.181
			(0.906)	(0.846)	(0.909)
log(Inc)	−0.672	4.495***	3.606***	0.047	4.517***
	(0.878)	(1.059)	(0.937)	(0.886)	(1.053)
Education	0.142***	0.210***	0.236***	0.138***	0.215***
	(0.024)	(0.027)	(0.025)	(0.024)	(0.027)
Unemployment	−0.002	−0.252***	−0.145***	0.010	−0.191***
	(0.051)	(0.058)	(0.054)	(0.050)	(0.057)
Constant	48.719***	−49.837***	−47.691***	39.727***	−51.281***
	(10.121)	(10.116)	(9.506)	(10.143)	(10.046)
Observations	1,573	1,565	1,568	1,568	1,560
Adjusted R^2	0.314	0.170	0.207	0.330	0.214
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 6: Earthquake risk transfer and implicit insurance coverage in California, 2011

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 number of loans sold to GSEs (%) in a 5-digit ZIP-code (LPS). 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 owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). 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 (CEA Premium Calculator). *AvgCreditScore* is the average of borrowers' credit score in a 5-digit ZIP-code (LPS). *Purchase* is the share of loans which are for home-purchase in a 5-digit ZIP-code (LPS). *log(Inc)* is the natural logarithm of a median household income and *Unemployment* is the share of unemployed civilian labor force (%) in a 5-digit ZIP-code (U.S. Census Bureau).

	Dependent variable:			
	SoldGSE			
	(1)	(2)	(3)	(4)
EqRate	-0.312^{***}			-0.120^{***}
	(0.024)			(0.026)
AvgLTV		0.760^{***}		0.631^{***}
		(0.039)		(0.044)
D.Medium			-4.567^{***}	-2.263^{***}
			(0.475)	(0.450)
D.High			-4.641^{***}	-3.673^{***}
			(0.675)	(0.615)
AvgCreditScore	0.049^{***}	0.101^{***}	0.024^{***}	0.105^{***}
	(0.009)	(0.010)	(0.009)	(0.010)
Purchase	−0.017	-0.290^{***}	−0.012	-0.254^{***}
	(0.029)	(0.031)	(0.030)	(0.032)
log(Inc)	-7.006^{***}	-45.799^{***}	-7.814^{***}	-4.888^{***}
	(0.607)	(0.577)	(0.610)	(0.574)
Unemployment	-0.077^{**}	−0.013	−0.057	−0.010
	(0.036)	(0.033)	(0.038)	(0.034)
Constant	116.018^{***}	18.601^{*}	140.946^{***}	15.860
	(8.582)	(10.297)	(8.366)	(10.240)
Observations	1,574	1,574	1,569	1,569
Adjusted R^2	0.221	0.307	0.192	0.341
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 7: Earthquake risk transfer and implicit insurance coverage in California, 2015

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 number of loans sold to GSEs (%) in a 5-digit ZIP-code (LPS). 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 owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). *AvgLTV* is the average loan-to-value ratio (%) in a 5-digit ZIP-code area (LPS). 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 (CEA Premium Calculator). *AvgCreditScore* is the average of borrowers' credit score in a 5-digit ZIP-code (LPS). *Purchase* is the share of loans which are for home-purchase in a 5-digit ZIP-code (LPS). *log(Inc)* is the natural logarithm of a median household income and *Unemployment* is the share of unemployed civilian labor force (%) in a 5-digit ZIP-code (U.S. Census Bureau).

	Dependent variable:			
	SoldGSE			
	(1)	(2)	(3)	(4)
EqRate	-0.310^{***}			-0.184^{***}
	(0.024)			(0.024)
AvgLTV		0.704^{***}		0.542^{***}
		(0.036)		(0.040)
D.Medium			-4.875^{***}	-1.688^{***}
			(0.599)	(0.563)
D.High			-6.546^{***}	-5.390^{***}
			(0.854)	(0.782)
AvgCreditScore	0.069^{***}	0.130^{***}	0.018	0.138^{***}
	(0.014)	(0.014)	(0.014)	(0.014)
Purchase	0.195^{***}	−0.041	0.144^{***}	0.020
	(0.040)	(0.039)	(0.041)	(0.039)
log(Inc)	-9.566^{***}	-6.476^{***}	-9.682^{***}	-6.018^{***}
	(0.795)	(0.779)	(0.826)	(0.766)
Unemployment	0.051	−0.019	0.035	−0.036
	(0.052)	(0.049)	(0.053)	(0.048)
Constant	122.166^{***}	−1.737	161.244^{***}	0.540
	(11.010)	(13.250)	(10.713)	(13.073)
Observations	1,562	1,562	1,558	1,558
Adjusted R^2	0.255	0.334	0.221	0.374
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 8: Cost of implicit earthquake insurance in California, 2011

This table shows results of an OLS model in which the data is aggregated on a 5-digit ZIP-code level. *AvgIntRate* is the average interest rate on the mortgage loans (%) in a 5-digit ZIP-code area (LPS). *EqRate* is earthquake insurance take-up rate (%) calculated as the number of owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). Other variables include: the natural logarithm of the average outstanding unpaid principal balance (*log(UPB)*), the loan-to-value ratio (*AvgLTV*), the borrower's credit score (*AvgCreditScore*), and the purpose of the loan (*Purchase*) (LPS).

	Dependent variable:	
	AvgIntRate	
	(1)	(2)
EqRate	-0.009^{***}	-0.002^{**}
	(0.001)	(0.001)
log(UPB)		-0.447^{***}
		(0.021)
AvgLTV		-0.003^{**}
		(0.001)
AvgCreditScore		-0.001^{***}
		(0.000)
Purchase		-0.000
		(0.001)
Constant	5.345^{***}	11.787^{***}
	(0.020)	(0.366)
Observations	2,701	2,301
Adjusted R^2	0.019	0.194

Standard errors in parentheses

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

Table 9: Cost of implicit earthquake insurance in California, 2015

This table shows results of an OLS model in which the data is aggregated on a 5-digit ZIP-code level. *AvgIntRate* is the average interest rate on the mortgage loans (%) in a 5-digit ZIP-code area (LPS). *EqRate* is earthquake insurance take-up rate (%) calculated as the number of owner-occupied earthquake insurance policies over the number of owner-occupied homeowners insurance policies in a 5-digit ZIP-code and serves as a measure of the explicit insurance coverage (CDI). Other variables include: the natural logarithm of the average outstanding unpaid principal balance (*log(UPB)*), the loan-to-value ratio (*AvgLTV*), the borrower's credit score (*AvgCreditScore*), and the purpose of the loan (*Purchase*) (LPS).

	Dependent variable:	
	AvgIntRate	
	(1)	(2)
EqRate	-0.014^{***}	-0.002^{**}
	(0.001)	(0.001)
log(UPB)		-0.539^{***}
		(0.020)
AvgLTV		-0.004^{***}
		(0.001)
AvgCreditScore		-0.002^{***}
		(0.000)
Purchase		-0.000
		(0.001)
Constant	4.595^{***}	12.636^{***}
	(0.021)	(0.396)
Observations	2,249	2,026
Adjusted R^2	0.050	0.327

Standard errors in parentheses

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

Table 10: 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

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