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# ANALYSIS OF S.637, THE "EARTHQUAKE INSURANCE AFFORDABILITY ACT"

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## ABSTRACT

Senate Bill 637, introduced by Sens. Barbara Boxer and Dianne Feinstein, D-Calif., would displace an existing private market by replacing private reinsurance with a federal government debt guarantee in the capital structure of the California Earthquake Authority (CEA). This study evaluates the feasibility of S.637, and considers its expected cost. Objective analysis of the bill demonstrates it cannot meet expectations to radically reduce the cost of or drastically increase the take-up of earthquake insurance. While proponents of the bill project it would produce a 33 percent reduction in premiums and an 85 percent increase in policyholder take-up, this study concludes a best case scenario of an 8 percent decrease in the cost of CEA coverage and a 3.5 percent increase in take-up. In addition, S.637 would shift the cost of California earthquake risk forward in time; increasing post-loss premiums to pay for pre-loss discounts. Finally, the assumed cost neutrality to the U.S. Treasury takes as given that Treasury will charge adequate, risk-based premiums to the CEA for providing a guarantee of post-event capital. Other federal risk transfer programs have made similar promises, but S. 637 would be unique if it actually achieved such an outcome. Policymakers should consider S.637 in light of this analysis.

## EXECUTIVE SUMMARY

Residents of California face substantial exposure to the earthquake peril. The U.S. Geological Survey predicts that there is a 99.7 percent chance that a magnitude 6.7 earthquake (equal in strength to the 1994 Northridge quake) will strike in California in the next 30 years and that there is a 46 percent chance that a magnitude 7.5 earthquake (45 times stronger than M6.7) will strike in California in the next 30 years. The most damaging earthquakes in recent U.S. history have occurred in California. In response to these events, the state created the California Earthquake Authority (CEA), a (largely) privately financed, publicly run insurance mechanism to improve availability and affordability of insurance. Nonetheless, at present, less than 12 percent of homeowners have insurance that will respond to earthquakes.

A secure, forward-looking capital structure currently supports the CEA's ability to pay claims. It relies on a combination of risk-pooling, standard capital, syndication via reinsurance markets, and assessment of participating insurers. These methods, as currently applied, protect Californians against the earthquake peril without shifting this burden from current California residents to future California residents and residents of other states.

In an effort to increase market penetration, Senators Boxer and Feinstein proposed S.637, the Earthquake Insurance Affordability Act. The salient feature of this bill is to replace a large portion of the private capital securing California homeowners against earthquake damage with a federal government debt guarantee.

Supporters of S.637 attribute a number of potential benefits, for consumers and for the federal government, to the bill.[2] They claim it could reduce the cost of earthquake insurance by up to one third. Some also claim it would alternatively or simultaneously allow the CEA to decrease deductibles. At the same time, this bill is intended to increase market penetration of earthquake insurance in California. In one instance, Sen. Feinstein asserted market penetration would increase by as much as 700,000 policies, or 85 percent.[3] They claim increased market penetration will save the federal government disaster-relief dollars. Finally, all of this is presumably done at no cost to taxpayers or the U.S. Treasury.

Objective analysis of the earthquake peril and the CEA demonstrates these outcomes are individually unlikely and mutually exclusive. In addition, at CEA's request, the RAND Institute for Civil Justice reviewed and largely rejected the possibility that increased CEA market penetration could reduce expected cost of federal disaster relief.[4]

The potential cost savings attributed to S.637 are overstated. My analysis shows that full implementation of S.637 would result in an 8 percent cost reduction. This would lead to a 3.5

percent increase in take up of earthquake insurance.

If we ignore that the benefits attributed to S.637 are grossly overstated, we are still left with the claim that it will be cost neutral to the Treasury. Objective analysis demonstrates that the CEA's ability to repay a loan guaranteed by the Treasury is quite limited following a large earthquake. Therefore, it is important that Treasury charge an adequate, risk-based premium for such a loan guarantee. The federal government has a miserable record in such matters. For example, underpricing by the National Flood Insurance Program has created taxpayer liabilities exceeding $17 billion.

In summary, S.637 cannot achieve its stated goal of a material increase in penetration of earthquake coverage. Under ideal conditions, the best likely outcome is an 8 percent decrease in the current cost of CEA earthquake insurance and a coinciding 3.5 percent increase in take-up of CEA coverage.[5] However, my analysis suggests when a loss occurs that triggers the debt guarantee, the CEA will fail and the U.S. Treasury will be forced to cover any guaranteed loans. Furthermore, if Treasury provides such capital, it will not result in significant federal disaster aid savings following the next catastrophic earthquake.

Given these small expected effects on both savings and take-up, coupled with the large eventual loss to the Treasury, the Senate should carefully consider this analysis in any deliberations of S.637.

## INTRODUCTION

While Californians enjoy many geographic benefits, such as a mild climate and miles of coastline, one unfortunate consequence of a Golden State address is exposure to the unforgiving earthquake peril. Given the state's active fault lines and the close proximity of these fault lines to high-value property, exposure to earthquake risk is greater in California than in other states.

The 1994 Northridge Earthquake resulted in approximately $19 billion in real (2012) insured losses.[6] Importantly, prior to this event, neither insurance companies nor consumers were aware of the underground fault leading to such large damages. With this new information, the expected value of earthquake losses changed. As a result, increases in cost and decreases in availability of insurance followed immediately thereafter.

These events prompted the California Legislature to form the California Earthquake Authority (CEA). The CEA is a publicly-managed, (mostly) privately financed entity offering earthquake insurance to California residents.[7] For nearly two decades, the CEA has served Californians without substantially disadvantaging residents of other states. Today, the CEA has more than 800,000 policies in force covering almost $300 billion dollars of exposed property for annual premium of just under $600 million. With claims-paying capacity of $9.582 billion, actuaries estimate the CEA is prepared to pay for losses resulting from a 1-in-477-year earthquake. It is also important to note that the current capital structure is paid for in real time and does not benefit today's policyholders at the expense of tomorrow's policyholders and taxpayers in other states.

S. 637 would try to replace part of the CEA's ex ante private financing mechanism with ex post debt financing guaranteed by the federal government. CEA management has indicated (without offering supporting proof) that S.637 would permit an immediate 33 percent decrease in earthquake insurance premiums.[8] The stated purpose of this effort is to reduce price, thereby increasing market penetration of earthquake insurance. In one instance, Sen. Feinstein asserted market penetration would increase by as much as 700,000 policies, or 85 percent.[9] Supporters claim that increased market penetration will save the federal government disaster relief dollars following the next earthquake. Finally, they state that S.637 is "fiscally responsible" and that it will result in "zero costs to the federal government."[10]

Unfortunately, objective analysis demonstrates that claims of cost savings are substantially overstated and the estimated take-up of policies is vastly exaggerated. In addition, at CEA's request, the RAND Institute for Civil Justice reviewed and largely rejected the possibility that increased CEA market penetration could reduce the expected cost of federal disaster relief.[11] Finally, claims of zero cost are tenuous, at best.

This bill would also make a dangerous transition from ex ante financing, in which the CEA pays for funding as it assumes risk, to ex post financing, where the CEA would pay for capital after a loss. This is an important distinction. A loan guarantee is not money. It is similar to mortgage insurance or a credit default swap for the CEA's prospective creditors if it has to borrow money in the future. While this may improve the availability and price of borrowing, the CEA would still have to try to repay the loan with premiums collected after the loss. Because the CEA is required by state law to charge actuarially sound premiums, it acknowledges that repayment of bonds would require a rate increase or a policyholder surcharge after the loss occurs.

My analysis estimates the required increase in premium for debt service to be more than $300 per policy, or 43 percent of the current average premium per policy. Because other companies sell earthquake insurance, it is highly unlikely that the CEA could maintain any market share with a $300 per policy surcharge that does not represent risk of future loss.

Post-loss financing defeats a primary tenant of insurance pricing, which is that insurance prices be "forward-look-

FIGURE I: DAMAGE TO THE FINANCIAL DISTRICT FOLLOWING THE 1906 SAN FRANCISCO EARTHQUAKE

Source: The Virtual Museum of the City of San Francisco, http://www.sfmuseum.org/hist/pix49.html

ing."[12] Insurers should not under-price coverage with the intent of increasing premiums after a loss. The CEA would be burdened with thirty years of $100 million annual debt-service payments, weakening its ability to finance future losses at a time when its capital is depleted. The likely result of this scenario is financial failure of the CEA.

## CALIFORNIA'S EXPOSURE TO THE EARTHQUAKE PERIL

California has experienced several notable earthquakes. Many Americans recall Loma Prieta in 1989 and Northridge in 1994. Some have read about the Great 1906 Earthquake that struck the San Francisco area (See Figure 1 below). However, many do not realize the immense record of earthquakes in California. Seismic activity on the west coast is nearly constant. Beginning with a 6.5 magnitude earthquake in the San Diego region on November 22, 1800, California and surrounding areas incurred 228 substantial seismic events over the following 204 years. In other words, a substantial earthquake has struck the California area on average every 328 days.[13] These events range in magnitude from 5.20 to 8.25 with average magnitude of 6.23.[14]

Earthquakes can quickly devastate large areas, causing hundreds of billions of dollars in economic damage. This potential devastation, coupled with the low market penetration for earthquake insurance, presents huge potential problems for Californians. First and most obvious is the risk of property loss and bodily injury to individuals and businesses with no source of indemnification. Few families can afford to replace their largest assets without insurance coverage.

In addition, several indirect problems stem from residents' inability to rebuild after a quake. Insurance is a necessary component of credit markets for large personal assets. Without insurance coverage, a lender would be remiss to allow a homeowner to borrow money to buy their home using only the property as collateral for the loan. If an uncovered loss occurs, the lender's collateral becomes worthless. Therefore, in most cases, a large portion of uninsured earthquake exposure is passed on to mortgage holders such as Fannie Mae and Freddie Mac.[15]

Several large entities – including the State of California, the federal government, and private risk modeling firms – have employed highly-skilled professionals to predict expected losses and probabilities of catastrophic earthquake events. It is, of course, better to have this information than not to have it. However, by reducing the probability of a catastrophic event to a very small annual number (e.g. 1-in-500), managers and policymakers can be lulled to false certainty. Just as financial modelers of Long Term Capital Management's hedge fund and credit default swaps believed they would never see a black swan, the CEA, by supporting S. 637, seems to be taking a severe gamble on the assumption that small risk and zero risk are the same.

Furthermore, this problem is exacerbated by the additive nature of earthquake risk. Because pressure builds up along faults until it is released, every year we go without a large earthquake, the expected force of the next event multiplies.

## GLOBAL INSURANCE AND REINSURANCE MARKETS

Insurance markets provide value to consumers by reducing risk. In an insurance market, consumers can essentially pay the expected cost of a large loss each year instead of paying the entire catastrophic cost of a loss if or when it happens.

For example, if I face a 1 percent chance of having a $50,000 loss, the expected cost of the loss is $500 (.01 x $50,000 = $500). While the $500 annual payment is affordable, my budget would not accommodate the $50,000 payment in any single year. Therefore, this reduction in risk is obviously valuable to me. In fact, it is sufficiently valuable that I, like most consumers, am willing to pay more than $500 to get this reduction in risk. This lets insurance companies charge more for insurance than the expected cost of losses. The difference in the cost of insurance and the expected cost of losses is called the premium loading. Premium loadings provide funds for insurers to pay for operating costs and to secure capital for financial strength.

"Because pressure builds up along faults until it is released, every year we go without a large earthquake, the expected force of the next event multiplies."

The insurance mechanism relies on the Law of Large Numbers, a fundamental probability theorem first recorded by Swiss mathematician Jacob Bernoulli in the 1680s.[16] The Law of Large Numbers describes the reduction in uncertainty of the average loss for a pool of independent exposures as the number of exposure units in the pool increases.

In the example presented above, without risk pooling, I face two possible outcomes. I either pay nothing (with probability of 99 percent), or I pay $50,000 (with probability of 1 percent). This scenario exposes me to financial ruin. However, if I enter a risk pooling agreement[17] with 9,999 people who face the same type of loss, and the losses are not caused by the same event (i.e., the loses are independent), there is a 96 percent chance my annual payment will be between $400 and $600. Importantly, my chance of paying a catastrophic amount approaches zero.[18]

Today's global insurance and reinsurance markets take this basic idea several steps further to address problems that would otherwise confound insurance mechanisms. One such problem addressed by global markets is that of an extraordinarily large loss. Extremely large losses can occur for two reasons. First, someone could insure one very valuable asset and it experiences a loss. Second, a large number of people could insure assets that are exposed to a common peril such as an earthquake. Insurance and reinsurance markets use two complementary strategies, diversification and syndication, to mitigate such problems.

The first strategy is diversification. If an insurer has a large number of independent and similar exposures in its risk pool, the law of large numbers reduces the aggregate risk to the group. However, in the case of extremely large exposure units, this can be difficult to accomplish. Insurers look for similar exposures with losses caused by unrelated events. For example, an insurer that underwrites earthquakes in California can also insure earthquakes in other locations (e.g. the New Madrid fault, the East Coast faults, Japan, Chile, and Taiwan) and exposure to other perils around the globe (e.g. windstorm, hurricane, flood, wildfire, typhoon, terrorism, and others). Importantly, intuition and evidence support the conclusion that these events are uncorrelated.[19]

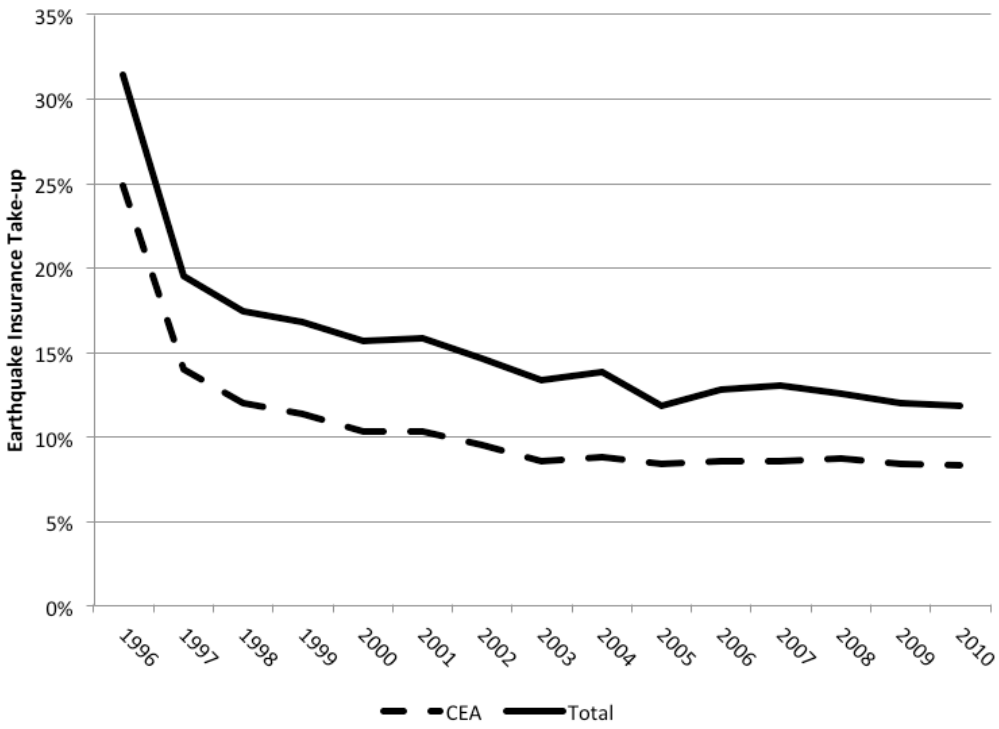
When an insurer does not have sufficient capital to insure large exposures, it can use a syndication approach to make any catastrophic exposure match its existing portfolio of risks. In this case, multiple insurance companies and reinsurance companies will cooperate to insure small shares of a large exposure.

The process is remarkably efficient. A risk seller approaches the market for catastrophe re/insurance. Many reinsurers will study the risk and decide if they want to participate in insuring the risk. One insurer can underwrite as much or as little of the risk as it feels comfortable with at the negotiated price. It is common for primary insurance companies to reinsure their catastrophe exposure with anywhere from a few, to several dozen supporting reinsurers.

It is also important to note that the structure of insurance and reinsurance markets is designed to maximize the diversification of risk through reinsurance. Almost all direct insurance companies (i.e. those that sell insurance to consumers) operate in only one country, or smaller geographic area. While nearly all reinsurers of catastrophic risk have global operations.

As a result of syndication, the largest reinsurers in the world often have some exposure to almost every large loss that

FIGURE 2: TAKE-UP RATE FOR EARTHQUAKE INSURANCE IN CALIFORNIA, 1996 – 2010




Source: California Department of Insurance

occurs; however, no one loss (or any combination of several losses) could potentially cause those reinsurers to fail.

Rhetoric surrounding S.637 and previous attempts at similar legislation (e.g. S. 2555 in 2010) incorrectly implies that reinsurance prices are excessive. Several times, CEA management has pleaded for government funding by pointing out that the CEA has paid more in reinsurance premiums than it has received in reinsurance claims payments.[20] Indeed, if the CEA's policyholders wanted to flaunt a misunderstanding of insurance, they could point out that they have paid nearly $6.7 billion in premiums and received just over $4 million in claims payments.

Catastrophe insurance is supposed to work this way. Policyholders pay the expected loss plus loading costs each year. When a catastrophic loss happens, insurers are able to pay claims.

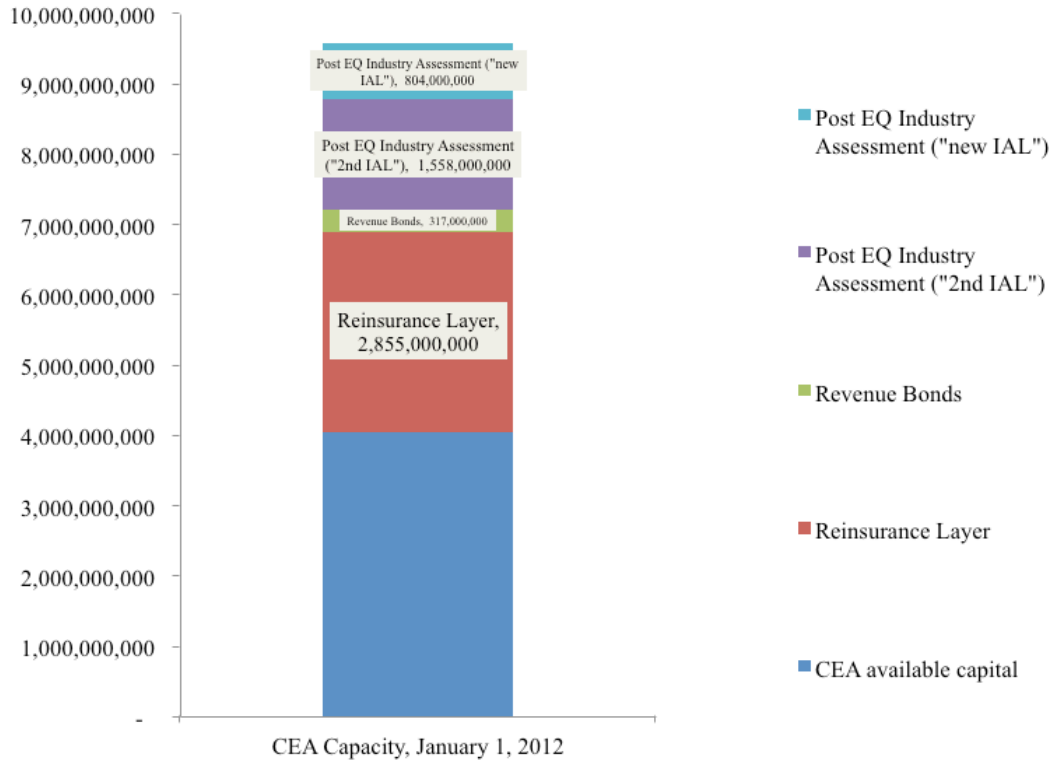
## THE CALIFORNIA EARTHQUAKE AUTHORITY

Prior to the 1971 San Fernando Earthquake, Californians purchased very little earthquake insurance. From 1971 until 1996, there was significant growth in availability and take-up of such coverage. Figure 2 displays take-up rates for earthquake insurance in California from 1996 through 2010. The take-up rate for residential earthquake insurance peaked at 31 percent in 1996. Since then, the combination of increasing cost and a relative lull in earthquake damage have reduced take-up to about 12 percent of residential property owners.

Following the 1994 Northridge earthquake, homeowners insurance markets contracted. The Northridge earthquake occurred on a previously unknown fault; therefore, insurers had not collected adequate premium for this event. Because all insurers selling homeowners insurance in California must offer earthquake coverage, most lost their appetites for homeowners coverage altogether. In response to this market contraction, the California legislature created the California Earthquake Authority (CEA) in 1996 as a pseudo-voluntary market for earthquake coverage.

It is important to note that the perceived necessity of the CEA, or some other government mechanism, is the direct result of regulation itself. Because insurers in California were forced to offer earthquake coverage to all policyholders, the market for earthquake insurance, and, therefore, homeowners insurance, was especially fragile. When insurers balked at this requirement following Northridge, California lawmakers effectively charged an exit fee in the form of participation in the CEA if an insurer chose not to continue offering earthquake insurance.

FIGURE 3: CEA CLAIM-PAYING CAPACITY BY SOURCE




Source: Minutes of February, 2012 meeting of CEA governing board

The CEA is a publicly run, (mostly) privately financed insurer underwriting earthquake insurance in California. CEA's financial structure is made up of several sources that have changed over time. At inception, sources of capital included participating insurer contributions, premiums, reinsurance contracts, a line of credit, and two industry assessment layers. Initially, participating insurers contributed an amount of capital equal to their market shares as a percentage of $1 billion. Participating insurers represented 70 percent of the homeowners insurance market, leading to $700 million in capital.

## CURRENT FUNDING OF THE CEA

The CEA's ability to pay claims is funded by a combination of current policyholder premiums, accumulated capital from retained earnings, initial capital contributions from participating insurance companies, private reinsurance contracts, proceeds of a 2006 revenue bond issue, and potential assessment of participating insurers. Should the combination of these resources fail, the CEA also has the option to pay policyholders for their losses in future annual installments or decrease total payments to policyholders after a loss.

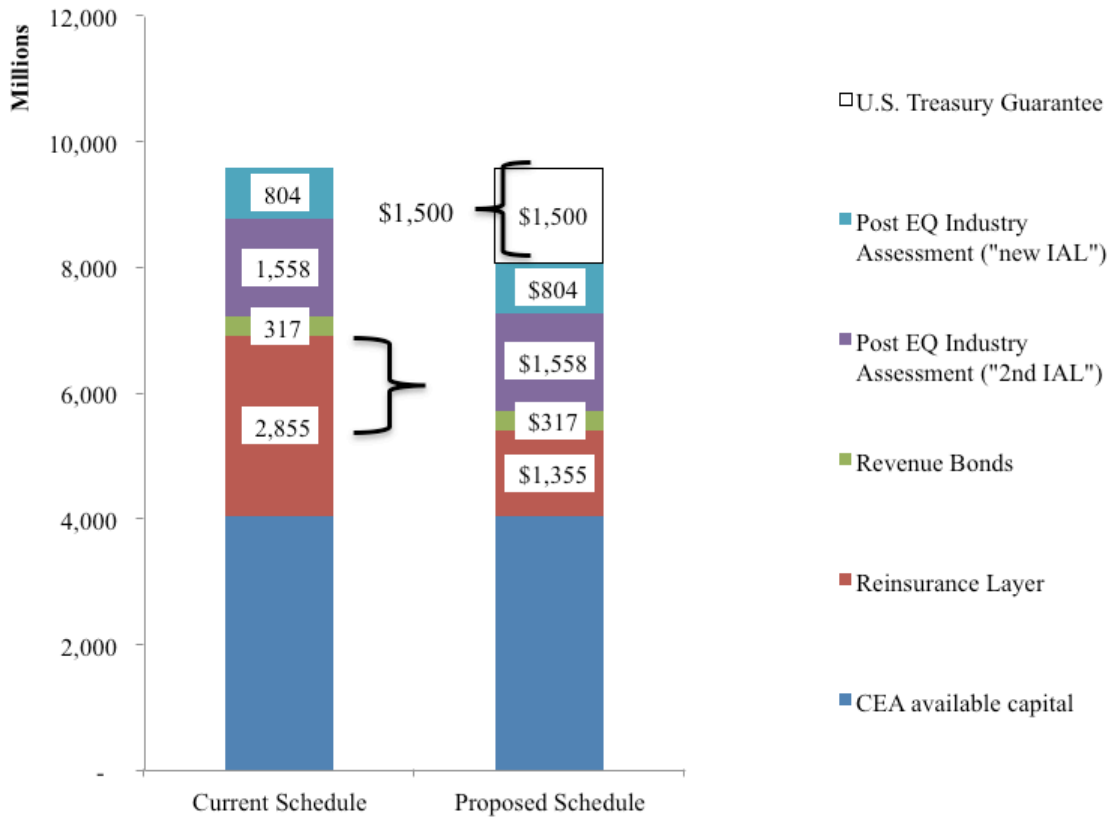
The CEA is not permitted to file bankruptcy; however, this does not mean the CEA cannot fail, only that a bankruptcy court cannot protect it from creditors. In addition, CEA policyholders are not protected by the California Insurance Guarantee Association (CIGA). Policyholders of private insurers that participate in CIGA have some protection against losses even if their insurance company becomes insolvent. Therefore, the importance of the CEA's financial strength cannot be overstated. Figure 3 demonstrates the current sources and amounts of funds available to pay claims.

The sources of payment in Figure 3 respond to losses in order from bottom to top. This means the second source of capital does not pay for losses unless the aggregate amount of losses exceeds the layer below. In Figure 3, for example, annual losses of less than $4,048,000,000 will be paid from CEA capital. The reinsurance coverage will not respond. If losses exceed the CEA capital layer by $10,000,000, the reinsurance companies in the second layer would pay $10,000,000 and the CEA would pay $4,048,000,000. This priority of payments is required by statute.

## PROPOSED FUNDING OF THE CEA UNDER S.637

On March 17, 2011, U.S. Senators Feinstein and Boxer introduced S.637 to the 112th Congress. The bill would replace a large portion of the CEA's private financing with a public debt guarantee from the U.S. Treasury. Specifically, CEA management has indicated its intent to replace private rein-

FIGURE 4: PROPOSED CEA FUNDING




surance coverage with loan guarantees offered in S.637. Comparison of current CEA capitalization and proposed CEA capitalization under S.637 appears in Figure 4.

Public comments and discussion of the bill suggest it would enable the CEA to reduce premiums by up to 33 percent. Sen. Feinstein's comments also assert the CEA could reduce deductibles if S. 637 passes.[22] Both changes are intended to lower cost or price so that more homeowners will purchase CEA coverage. Thus, policymakers sponsoring the bill believe it will reduce premium and/or deductibles while increasing the number of policyholders. The following analysis of the CEA's financial statements does not support these claims. In fact, it shows that, even under the assumption that insured losses will not occur during the analysis period, the immediate (1-year) average price change would be a decrease of 8 percent. Given the -0.44 elasticity estimated by RAND, this price change would cause a 3.5 percent increase in take-up of CEA policies. If we carry this analysis over five loss-free years, average price of CEA insurance would decrease by 16.5 percent. This would increase take up by 7.9 percent. Therefore, those supporting S.637 are offering rhetoric that overstates benefits of the bill substantially. Moreover, if a large earthquake were to strike, the ex post nature of this funding would cripple the CEA and likely increase rather than decrease taxpayers' burden.

Table 1 presents a best-case-scenario, five-year pro forma (abbreviated) financial statement for the CEA. The costs and revenues are based on actual 2011 results. The first four rows of the table display the estimated changes in take-up and average price described above. The first column shows 2011 CEA results. The next five columns present pro-forma estimates of CEA financial statements assuming S.637 passes and no losses occur. In the second column, line five shows end-of-year surplus reported by CEA in 2011. Lines 6 and 7 list the CEA's stated debt service capacity of $100 million and the coinciding maximum loan guarantee of $1.5 billion. These are consistent with comments offered by CEA management and represent a ratio of revenue to debt service that management expects to achieve via a rate increase following a large loss.

The annual debt service payment on a 30-year, $1.5 billion loan at 5.2 percent interest is $100 million. It is important to note that this $100 million per year would come from a premium increase or surcharge following a loss. The CEA is required by statute to charge premiums that are neither excessive, nor inadequate. If the CEA had $100 million slack in its current financial structure, it would be required to reduce premiums.

Line 8 is an estimate of the potential cost savings from

TABLE I: CEA PRO FORMA FINANCIAL MODEL: ASSUMING NO LOSSES

| | | 2011 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|---|---|
| 1 | Policy count | 820,932 | 849,943 | 849,112 | 858,651 | 872,035 | 886,070 |
| 2 | Average premium per policy | $ 747 | $ 687 | $ 688 | $ 671 | $ 647 | $ 623 |
| 3 | Savings % (cumulative) | N/A | 8.0% | 7.8% | 10.2% | 13.4% | 16.5% |
| 4 | Take up % (cumulative) | N/A | 3.5% | 3.4% | 4.6% | 6.2% | 7.9% |
| 5 | Beginning surplus | 3,902,710,605 | 4,220,535,402 | 4,591,717,304 | 4,987,681,461 | 5,393,960,771 | 5,813,137,702 |
| 6 | Assumed debt capacity following loss | N/A | 100,000,000 | 100,000,000 | 100,000,000 | 100,000,000 | 100,000,000 |
| 7 | Treasury Guarantee Amount | N/A | 1,500,000,000 | 1,500,000,000 | 1,500,000,000 | 1,500,000,000 | 1,500,000,000 |
| 8 | Finance savings from guarantee | N/A | 69,750,000 | 69,750,000 | 69,750,000 | 69,750,000 | 69,750,000 |
| 9 | Decrease in finance cost from change in surplus | N/A | N/A | -1,475,217 | 15,757,285 | 39,727,764 | 64,459,203 |
| 10 | Total policyholder benefit | N/A | 69,750,000 | 68,274,783 | 85,507,285 | 109,477,764 | 134,209,203 |
| 11 | Total direct premium | 612,830,953 | 583,527,898 | 584,253,055 | 575,731,758 | 563,992,669 | 552,107,163 |
| 12 | Reinsurance premium | 200,622,675 | 142,456,109 | 122,522,021 | 108,773,441 | 89,747,148 | 70,311,225 |
| 13 | Operating expenses | 116,357,610 | 112,095,240 | 111,684,051 | 110,555,822 | 109,008,198 | 107,454,571 |
| 14 | Gross Losses | 31,538 | 0 | 0 | 0 | 0 | 0 |
| 15 | Loss to guaranteed layer | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | Payment on guaranteed debt | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Underwriting profit | 295,850,668 | 328,976,548 | 350,046,984 | 356,402,495 | 365,237,323 | 374,341,367 |
| 18 | Investment return | 27,894,469 | 42,205,354 | 45,917,173 | 49,876,815 | 53,939,608 | 58,131,377 |
| 19 | Change in surplus | 323,745,137 | 371,181,902 | 395,964,157 | 406,279,310 | 419,176,931 | 432,472,745 |
| 20 | Ending surplus | 4,226,455,742 | 4,591,717,304 | 4,987,681,461 | 5,393,960,771 | 5,813,137,702 | 6,245,610,447 |
| 21 | Reinsurance Coverage | 3,050,000,000 | 1,876,481,455 | 1,610,693,607 | 1,427,379,211 | 1,173,695,312 | 914,549,662 |
| 22 | Revenue Bonds | 317,000,000 | 317,000,000 | 317,000,000 | 317,000,000 | 317,000,000 | 317,000,000 |
| 23 | New Industry Assessment Layer | 804,000,000 | 500,073,431 | 103,887,857 | 0 | 0 | 0 |
| 24 | Second Industry Assessment Layer | 1,558,000,000 | 1,558,000,000 | 1,558,000,000 | 1,558,000,000 | 1,558,000,000 | 1,558,000,000 |
| 25 | Claims capacity | 9,631,710,605 | 9,972,090,288 | 9,961,991,627 | 10,077,748,590 | 10,242,045,405 | 10,417,157,333 |

Notes: Rate-on-line, the cost of reinsurance per dollar of coverage, is a weighted average of cost reported in the CEA Financial Report prepared for Governing Board Meeting, 10/27/2011; Real investment return rate = 1 percent; additions to capital are used to reduce the amount of reinsurance purchased in the following year and to increase maximum claim paying capacity to accommodate new policyholders. Take-up follows the elasticity (-0.44) calculated by RAND (2010).

reducing the amount of reinsurance protection purchased by $1.5 billion, plus any expected annual changes in surplus.[23] It is shown net of the expected fee required by S.637 to be paid to the Treasury. The amount is held constant at $69,750,000, the product of the observed 2011 cost per dollar of reinsurance coverage in the highest layers summing to $1.5 billion[24] (0.059) and $1.5 billion. This number is decreased by the expected cost of issuing this guarantee (0.5 percent) and the expected cost of CEA defaulting on the guarantee (0.75 percent).[25] Line 9 shows the change in reinsurance expense from change in claims-paying capacity. In year two, the increase in retained earnings from year one would offset the New Industry Assessment Layer (NIAL) and the CEA would need to purchase additional reinsurance to cover the additional 5 percent decrease in the NIAL. Therefore, the financing cost increases almost $1.5 million. In year three, the change in surplus from year two, less the remaining NIAL, leads to a cumulative $16.8 million decrease in reinsurance cost. Line 10 represents the total policyholder benefit from this bill. It is the sum of line 8 and line 9. Line 11 is total direct premium written by CEA assuming the savings created by the guarantee is divided between a price reduction for current policyholders and the increased cost of reinsurance to fund growth as a result of decreased prices.[26]

For CEA to maintain its current financial strength, it must still purchase some reinsurance. The expected cost of this reinsurance is represented on Line 12 as the price per dollar of reinsurance times the 2011 claims paying capacity, less other available sources of capital. Line 13 reports estimated operating expenses based on observed expenses in 2011. Insurer commissions, insurer expense payments, and reinsurance brokerage fees are assumed to follow a constant percentage of written premiums and reinsurance premiums, respectively. Other expenses are assumed to be fixed.

Gross losses are reported on line 14 and losses exceeding the CEA's capital – and thus triggering the loan guarantee – are reported on line 15. For this stylized example, losses are assumed to be zero. Such optimism is dangerous. If we could assume away losses, we would have no need for insurance. In fact, Section 2 of S.637 begins with the following statement, "Major earthquakes are likely in the United States. For example, the United States Geological Survey predicts that there is a 99.7 percent chance that a magnitude 6.7 earthquake will strike in California in the next 30 years and that there is a 46 percent chance that a magnitude 7.5 earthquake will strike in California in the next 30 years."

Payment on guaranteed debt is shown on line 16. Because we

assume no losses occur, this amount is fixed at zero. However, if a loss pierced the guaranteed debt layer in the CEA's financial structure, this would be as high as $100 million per year. Underwriting profit, on line 17, is net premium less losses and expenses. Investment return, in line 18, is simplified to the expected interest rate, minus the inflation rate, times beginning surplus (line 5). Change in surplus is the sum of line 16 and line 17. Line 20 shows ending surplus as the sum of line 5 and line 19.

The next three lines represent CEA capital sources other than surplus and loan guarantees from the U.S. Treasury. Line 21 is the level of reinsurance purchased by CEA to maintain target claims-paying capacity of 2011 surplus adjusted annually for growth in written premium. Line 21 is simply line 25 less the sum of other sources of capital. Line 22 shows the $317 million available surplus from a 2006 revenue bond issue. Line 23 shows capital available to CEA by assessing participating insurers in what is called the "New Industry Assessment Layer (NIAL)." The NIAL began in 2008 when another industry assessment layer was phased out according to its original agreement. The NIAL decreases each year by 5 percent of the total assessment plus the amount of capital accumulated by CEA. Line 24 shows the capital available from CEA's authority to assess participating insurers in what is known as the "Second Industry Assessment Layer (SIAL)." While Table 1 is somewhat dense, it provides important context to claims made in support of S.637. The first-year savings attributed to S.637 is 8.0 percent, coinciding with a 3.5 percent increase in take-up. Over five loss-free years, there is the potential to reduce premiums by up to 16.5 percent, coinciding with 7.9 percent increase in take-up. Both estimates are substantially less than the one-third figure assumed in discussion of the bill. However, this possibility must be accompanied by several important, and thus far absent caveats which render it useless. First, it depends on the reckless assumption that large insured earthquake losses will not occur. This is clearly contrary to the impetus of the bill and the CEA.

Second, results in Table 1 reflect expected changes in take-up coinciding with estimated changes in price. The price elasticity used to calculate expected take-up was calculated by RAND at the request of CEA. The 7.9 percent increase in take-up over five years falls far short of the 700,000 policies (85 percent increase) suggested by Sen. Feinstein speaking in support of the bill.

Finally, if a loss occurs that requires the CEA to borrow funds under its debt guarantee, there is very little chance the CEA could repay the loan. This would leave taxpayers in other states on the hook for California's losses. Table 2 illustrates the effects of a large loss on the price and quantity sold of CEA coverage.

TABLE 2: SUMMARY OF EFFECTS OF A LARGE LOSS ON CEA PRICE AND TAKE-UP

| | Before Loss | After Loss |
|---|---|---|
| Average premium | $687 | $1,647 |
| Number of policyholders | 849,943 | 326,570 |
| Cost of debt service per policyholder | N/A | $306 |
| Competitors' average price | $1,128 | |

Assume a loss large enough to trigger the guaranteed loan occurs during Year 1 in the previous example. A loss of $9.42 billion would leave the CEA with only the minimum required capital of $300 million. In this scenario, the CEA would have to purchase additional reinsurance at a higher price. In addition, CEA would have to increase its rate to make payments on the borrowed $1.5 billion that is guaranteed by the U.S. Treasury. Both of these increases in price would decrease take-up of CEA policies.

We can estimate the effects on price and take-up by solving for *Premium 2* in the following equation (Eq.1):

$$(Premium2\text{-}Premium1) \times Policyholders2 = Debt\ Service + \triangle Reinsurance\ Cost \quad \text{(Eq.1)}$$

Where
*Premium*1 = Premium charged per policy before the loss ($687 in our example);

*Premium*2 = Premium charged per policy after the loss;

*Policyholders*2 = Number of policyholders that purchase CEA coverage after the price increase, assuming no other coverage is available at a lower price;

*Debt Service* = Annual payment on loan guaranteed by Treasury ($100,000,000 in our example); and

$\triangle$*Reinsurance Cost* = Change in reinsurance cost following the loss.

Equation 1 simply demonstrates that average premium per policy will be increased to cover debt service and the increased cost of reinsurance for those policyholders who continue to purchase coverage from CEA. To solve for *Premium*2 we represent terms in Equation 1 with relationships to and known constants.[27] Solving for *Premium*2 we get the following equality:

$$\$1{,}647\text{-}\$687 \times 326{,}570 = \$100{,}000{,}000 + \$213{,}774{,}025$$

Therefore, the average price of CEA earthquake insurance following a large loss would be $1,647. This price increase is problematic for CEA because it faces competition in the market from insurers with more diversified exposure. The average earthquake premium for non-CEA policies was $1,128 in 2010.[28] It is not clear why consumers would pur-

chase CEA coverage if the CEA is nearly insolvent, is not covered by the guaranty fund, has the option to legally pay partial claims, and it charges a higher price than the competition. In addition, we note the extreme attrition in the number of policyholders. As the premium increases from $687 to $1,647, the number of policyholders decreases from 849,943 to 326,570.[29] Therefore, the average policyholder's portion of the $100,000,000 annual debt service is $306.

It is important to note that I make a conservative assumption for parsimony. Throughout this exercise, the rate-on-line, or price per dollar of coverage for reinsurance, remains fixed at 0.076 (the CEA's cost of reinsurance in 2011). In practice, as the attachment point of the reinsurance decreased to meet capital on hand, the rate on line could easily double, exacerbating the price increase.

Given the CEA's weakened financial condition and increase in price, it is likely that consumers would buy coverage from other entities. Without sufficient volume, the CEA would be unable to service its debt to the Treasury. Because the CEA cannot reorganize in bankruptcy, it would either simply fail to pay claims, or seek a bail out from the federal government.

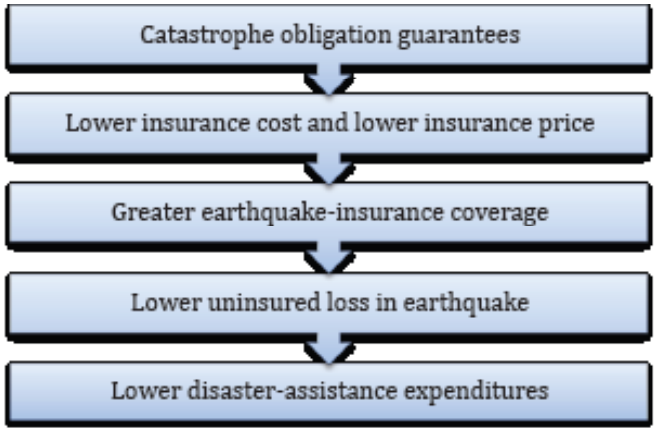
## THE EFFECT OF S.637 ON FEDERAL DISASTER AID

Supporters of S.637 and its companion bill in the House of Representatives have suggested one possible offset to the cost of loan guarantees for the CEA is a coinciding reduction in federal disaster aid following the next big earthquake. While this might strike readers as intuitive, it is contradicted by evidence.

In 2010, the CEA hired the RAND Institute for Civil Justice to estimate the savings to federal disaster assistance from increasing CEA take up.[30] RAND produced a technical report[31] on this topic titled "Earthquake Insurance and Disaster Assistance: The Effect of Catastrophe Obligation Guarantees on Federal Disaster-Assistance Expenditures in California." The authors of the study concluded that any savings from additional take up would be negligible.

The purpose of the study was to determine how much money the federal government could save in disaster aid by guaranteeing loans in the capital structure of the CEA. Therefore, the RAND report is directly informative of S. 637. The anticipated effect of catastrophe obligation guarantees on disaster assistance is hypothesized to occur as depicted in the following figure reproduced from Figure 1 of the RAND report.

RAND REPORT FIGURE I: ANTICIPATED EFFECT OF CATASTROPHE OBLIGATION GUARANTEES ON DISASTER ASSISTANCE




For some time, the CEA had been touting this effect as a reason for additional federal intervention in pricing of catastrophe coverage. In short, RAND's conclusion was that any potential savings would be negligible. They estimated that catastrophe obligation guarantees could reduce disaster-assistance costs by $3 million to $7 million for every $10 billion in total earthquake loss. Nonetheless, and surprisingly, CEA management has continued to espouse this type of savings as a benefit of S.637, even after the report was released.

## RAND ANALYSIS

The elasticity analysis performed by the authors was as rigorous as possible given available data. However, they note their reliance on CEA's estimate of the effect of catastrophe obligation guarantees on the price of CEA coverage. They cite the 30 percent savings estimate, upon which I cast substantial doubt in the proceeding sections. My analysis concludes the immediate savings would be 8 percent.

After accepting CEA's estimated price effect, RAND estimated the price elasticity for CEA coverage in two ways. Averaging the results of both methods [—(.4814+.3952)/2] yields elasticity of =-.4383, which they round to -.44. In other words, a 10 percent decrease in price should cause a 4.4 percent increase in take-up of CEA earthquake insurance. Therefore, they assume take-up will increase by 13.2 percent [ —.30x—.44=.132] following implementation.

RAND's estimate of insurance coverage is based on the ratio of covered property to total property. They estimate this to be 10.9 percent. Furthermore, they note that CEA only represents 61 percent of the market for earthquake insurance. Therefore, a 13.2 percent increase in 61 percent of the market takes the estimate from 10.9 percent to 11.8 percent; an 8.3 percent increase in total coverage.

Next, they estimate the effect of increasing insurance coverage on disaster aid expenditures. The two types of aid most

likely to be affected are tax deductions and Small Business Administration (SBA) loans. They estimate that the change in uninsured loss per dollar of premium decrease is bounded by -0.32 percent and -0.71 percent, depending on the magnitude of the earthquake.[32] In addition, the cost of providing federal aid is approximately .235 times the uninsured loss. Therefore, in the event of a $10 billion earthquake loss, this legislation would decrease uninsured loss by between $14.7 million and $31.5 million. As a result, the cost of government aid would decrease by between $3.45 million and $7.41 million. RAND notes that this is an insignificant savings for the federal government.

As noted above, my estimate of savings is significantly smaller than that of CEA. If we assume the savings produced by S.637 is 8 percent (only 26.6 percent of the estimate provided by CEA), the savings per $10 billion of earthquake loss is between $0.92 million and $1.98 million.

## EVALUATING PRESUMED COST NEUTRALITY OF S.637

Proper assessment of public policy should consider both benefit and cost. The preceding sections demonstrate the limited effects of S.637 on price and take-up of CEA earthquake insurance, and on federal disaster aid savings following an earthquake. S.637 would require the CEA to pay a fee equal to the expected cost to the Treasury of providing the loan guarantee. This would include the administrative cost and the expected cost of default. If Treasury calculates this amount appropriately and the CEA pays it, the expected cost to the Treasury theoretically would be zero. However, this result requires the agreement to be in place for an infinite time period so that years with a loss and years without a loss would offset perfectly.

At Senator Feinstein's request, the Congressional Budget Office (CBO) confirmed her assertion that S.637 would not impose substantial expected cost on the Treasury. Details of the CBO's analysis are not available; however, analysis of a similar previous bill is instructive. In its June 2, 2010 cost estimate for H.R. 2555 (the "Homeowners Defense Act"), CBO offers the following with regard to loan guarantees for state-run insurers including the CEA:

> "Federal expenditures resulting from a default on a debt guarantee made under the bill would likely be infrequent (due to the low probability that a major disaster causing a participating insurer or reinsurer to borrow funds to pay claims would occur and the low probability that the issuing program would default on such borrowing). CBO's estimate of this provision is an annualized cost that reflects those low probabilities. **However, if a large-scale natural disaster were to occur and if a state program were to default, spending would be much greater than the expected costs included in this estimate**." (emphasis added)[33]

Indeed, for S.637, the rub lies in timing of payments and losses, and the CEA's ability to repay a post-event loan. As noted above, given the existence of competing sources of earthquake coverage in the private market, it is unlikely that the CEA could retain its policyholders if its capitalization were thin, or its price increased.[34] Therefore, it is logical to assume that the CEA would default on such a loan – triggering the Treasury guarantee – if the $1.5 billion was borrowed.

This suggests two necessary caveats to the assumption of zero cost. First, Treasury must include a loading cost to account for additional risk assumed in the contract. Second, Treasury must consistently charge a risk-based premium that includes this loading cost. If the past or present provides any information about the future, it is highly unlikely that a government entity will charge adequate, risk-based premiums. For example, the National Flood Insurance Program has accumulated more than $17 billion in debt, and the Pension Benefit Guaranty Corporation has accumulated a running deficit of $26 billion over 37 years.[35]

Given the federal government's record of inadequate pricing for catastrophe risk, it is natural for one to doubt even its intention of charging risk-based rates. In fact, for the CEA to actually pay adequate fees for debt guarantees would be identical in promise, but unique in delivery among government-sponsored insurance programs. Therefore, interested parties must assume that these debt guarantees impose a positive and substantial cost to the U.S. Treasury. In other words, the cost of California earthquakes will be borne by residents of other states.

## CONCLUSION

California is burdened with an unfortunate exposure to the earthquake peril. In response to catastrophic damages caused by the Northridge earthquake in 1994, public and private interests created the California Earthquake Authority (CEA) in 1996. The CEA insures almost $300 billion dollars of exposed property for annual premium of just over $600 million. Its cost is largely set by market forces in competitive global capital markets and borne, as it should be, by policyholders in California. In other words, the cost represents an unbiased estimate of the risk.

Global markets for risk capital are well-suited to indemnify policyholders for catastrophic losses. Using proven methods of risk pooling and syndication, insurance and reinsurance markets divide large potential losses into smaller shares. Then they pool shares of these losses with other potential

losses of similar size and scope around the world. Importantly, these losses are not positively correlated with each other, or with market risk,[36] allowing for risk reduction.

S. 637, sponsored by California's elected U.S. senators, would change the financing mechanism of the CEA. It would replace private reinsurance capital with federal loan guarantees. The purpose of this bill is to reduce the cost of earthquake insurance sold by the CEA so that more residents will purchase earthquake insurance.

Supporters of S. 637 claim it will decrease price by up to one third, resulting in a large increase in market penetration. They claim that this increase in coverage will lead to a substantial decrease in federal disaster aid following the next big earthquake loss. Furthermore, they claim this legislation will not create financial liability for the U.S. Treasury.

Objective analysis of S.637 demonstrates that none of these claims is accurate. First, for the injection of public capital to affect price in a meaningful way, California must not experience a substantial insured earthquake loss for a number of years. This assumption is both reckless, and contrary to supporting information written in the bill.

Second, the expected effects of the bill on price and take-up are drastically overstated by supporters of the S.637. By replacing $1.5 billion of reinsurance coverage with a government debt guarantee, the CEA could reduce premiums by 8 percent in the first year. This coincides with an expected 3.5 percent increase in take-up. Assuming there are no losses for five years, total premium reduction could reach 16.5 percent, suggesting 7.9 percent increase in policies sold.

Third, decreasing the cost of earthquake insurance via government debt guarantees would not lead to material savings in federal disaster aid. CEA hired the RAND Institute to estimate this effect. RAND concluded that any savings would be insignificant at $3 million to $7 million per $10 billion of earthquake damage. My analysis suggests that the savings calculated by RAND were overstated by more than 75 percent, due to their reliance on CEA's flawed estimate of savings produced by the bill. I show that the actual federal aid savings we might expect from S. 637 range from $0.9 million to $2 million per $10 billion of earthquake damage.

Finally, it is extremely likely that the bill would pose a significant expected cost to the Treasury. If an earthquake triggers the loan guarantee, the CEA has no legitimate chance of repaying the loans. For this to be cost neutral for the Treasury, the CEA must pay risk-based fees for the guarantee. Furthermore, these fees should include a charge for the cost of capital and the likely imbalance of duration caused by the CEA's probable default. Given the horrendous record of government insurance programs, future deficits in this program are nearly certain. The burden of this deficit will be shared with tax payers across the country.

Given that this bill cannot deliver any of the benefits promised by its supporters without endangering the market for earthquake insurance, jeopardizing financial strength of the CEA, or spreading the financial burden of California's earthquake exposure to taxpayers in other states, it would be wise to drop S.637 and pursue a feasible strategy to improve take-up of earthquake insurance.

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## APPENDIX – SOLVING FOR TAKE-UP AND PREMIUM AFTER A LARGE LOSS

Assume a loss large enough to trigger the guaranteed loan occurs during Year 1 in the previous example. A loss of $9.42 billion would leave the CEA with only the minimum required capital of $300 million. In this scenario, the CEA would have to purchase additional reinsurance at a higher price. In addition, CEA would have to increase its rate to make payments on the borrowed $1.5 billion that is guaranteed by the U.S. treasury. Both of these increases in price would decrease take-up of CEA policies.

We can estimate the effects on price and take-up by solving for in the following Equation (Eq.1):

$$(Premium2\text{-}Premium1) \times Policyholders2 = Debt\ Service + \triangle Reinsurance\ Cost \quad \text{(Eq.1)}$$

Where
*Premium*1 = Premium charged per policy before the loss ($687 in our example);

*Premium*2 = Premium charged per policy after the loss;

*Policyholders*2 = Number of policyholders that purchase CEA coverage after the price increase, assuming no other coverage is available at a lower price;

*Debt Service* = Annual payment on loan guaranteed by Treasury ($100,000,000 in our example); and

$\triangle$*Reinsurance Cost* = Change in reinsurance cost following the loss.

Equation 1 simply demonstrates that average premium per policy will be increased to cover debt service and the increased cost of reinsurance for those policyholders who continue to purchase coverage from CEA. To solve for *Premium*2 first we represent terms in the equation with relationships to *Premium*2 and known constants.

The cost of reinsurance will increase because the CEA must replace its surplus with reinsurance to maintain financial strength.

Let *Capital*2 equal the amount of capital CEA will need to insure the remaining policyholders after a loss. Let *RoL* equal the Rate on Line, or cost per dollar of reinsurance (0.076). Let *Reinsurance*1 equal the premium paid for reinsurance in the year before the loss ($142,456,109 in Table 1). Let *Policyholders*1 equal the number of policyholders insured by CEA before the loss (849,943 in Table 1).

$$\triangle Reinsurance = (Capital2 - 300{,}000{,}000) \times RoL - \frac{Reinsurance1}{Policyholders1} \times Policyholders2 \quad \text{(Eq.2)}$$

Note that *Capital*2 may be written as a function of capital before the loss (*Capital*1 = $9,972,090,288), estimated elasticity (*E* = —0.44) *Premium*1, and *Premium*2 as follows.

$$Capital2 = Capital1 + \frac{premium2 - premium1}{premium1} \times E \times Capital1 \quad \text{(Eq.3)}$$

Likewise, Policyholders2 may be written as a function of policyholders before the loss (*policyholders*1 = 849,943), estimated elasticity (*E* = —0.44), *Premium*1, and *Premium*2 as follows.

$$Policyholders2 = Policyholders1 + \frac{premium2 - premium1}{premium1} \times E \times Policyholders1 \quad \text{(Eq.4)}$$

Substituting Equation 3 and Equation 4 into Equation 2 yields Equation 5:

$$\triangle Reinsurance = ((Capital1 + \frac{premium2 - premium1}{premium1} \times E \times Capital1) - 300{,}000{,}000) \times RoL - \frac{Reinsurance1}{Policyholders1} \times (Policyholders1 + \frac{premium2 - premium1}{premium1} \times E \times Policyholders1)$$

Therefore, we can restate Equation 1 as the following Equation 6.

$$(Premium2 - Premium1) \times (Policyholders1 + \frac{premium2 - premium1}{premium1} \times E \times Policyholders1) = Debt\ Service + ((Capital1 + \frac{premium2 - premium1}{premium1} \times E \times Capital1) - 300{,}000{,}000) \times RoL - \frac{Reinsurance1}{Policyholders1} \times (Policyholders1 + \frac{premium2 - premium1}{premium1} \times E \times Policyholders1) \quad \text{(Eq.6)}$$

Next, we substitute the known constants for variable names.

$$(Premium2 - \$687) \times (849{,}943 + \frac{premium2 - \$687}{\$687} \times .44 \times 849{,}943) = \$100{,}000{,}000 + ((\$9{,}972{,}090{,}288 + \frac{premium2 - \$687}{\$687} \times .44 \times \$9{,}972{,}090{,}288) - 300{,}000{,}000) \times 0.076 - \frac{\$142{,}456{,}109}{849{,}943} \times (849{,}943 + \frac{premium2 - \$687}{\$687} \times .44 \times 849{,}943)$$

With a bit of algebra, this simplifies to the following expression that we may solve via the quadratic equation.

$$545 \times Premium2^2 - 1{,}992{,}513 \times Premium2 + 1{,}804{,}137{,}554 = 0$$

$$Premium2 = \frac{1{,}992{,}513 \mp \sqrt{-1{,}992{,}513^2 - 4 \times 545 \times 1{,}804{,}137{,}554}}{2 \times 545}$$

= $1,647 or $2,011

Choosing the lower premium yields $1,647.

## ENDNOTES

1. I thank Erick Elder, Kyle Ross, and Craig Tillman for helpful comments. Any remaining errors are mine.

2. See A.M. Best interview,"CEA Eyes Federal Legislation, Capital Markets" available from http://bcove.me/lomkodcy accessed 1/27/2012.

3. In a March 17, 2011 press release, Sen. Feinstein describes effects of the bill and asserts "This could allow at least 700,000 additional California homeowners to be covered by earthquake insurance."

4. See, LaTourrette, Tom, James N. Dertouzos, Christina E. Steiner, and Noreen Clancy, 2010, "Earthquake Insurance and Disaster Assistance: The Effect of Catastrophe Obligation Guarantees on Federal Disaster-Assistance Expenditures in California," RAND Institute for Civil Justice, Technical Paper

5. The referenced RAND Technical Paper estimates price elasticity of -0.44. Therefore, a price decrease of 8 percent would increase take-up by 3.5 percent.

6. Damage estimates in 1994 were $12.5 billion. The consumer price index has increased by 52 percent from 1994 to 2012.

7. The State of California has contributed $158,985,185 in unrestricted capital. In addition, the CEA enjoys exemption from federal income taxes.

8. See A.M. Best interview,"CEA Eyes Federal Legislation, Capital Markets" available from http://bcove.me/lomkodcy accessed 1/27/2012, and Hemenway, Chad, 2011. "Bill Would Provide Federal Guarantees For Bonds After Earthquake," National Underwriter Online News Service, March 22, 2011. Available from http://www.propertycasualty360.com/2011/03/22/bill-would-provide-federal-guarantees-for-bonds-af accessed July 9, 2011.

9. In a March 17, 2011 press release, Sen. Feinstein describes effects of the bill and asserts "This could allow at least 700,000 additional California homeowners to be covered by earthquake insurance."

10. See Earthquake Insurance Affordability Act, Protecting Homeowners and Tax Payers, available from the CEA website, http://www.earthquakeauthority.com/UserFiles/File/Release/EIAAFactSheetold.pdf, accessed 2/24/2012. See also a website created to support this bill at http://www.earthquakerecovery.com/about/, and a similar "Fact Sheet" posted there at http://www.earthquakerecovery.com/docs/EIAA_Fact_Sheet.pdf, accessed 2/24/2012

11. See, LaTourrette, Tom, James N. Dertouzos, Christina E. Steiner, and Noreen Clancy, 2010, "Earthquake Insurance and Disaster Assistance: The Effect of Catastrophe Obligation Guarantees on Federal Disaster-Assistance Expenditures in California," RAND Institute for Civil Justice, Technical Paper. The Appendix describes analysis and conclusions of the RAND study.

12. See Harrington, Scott E. and Greg Niehaus, 2003, Risk Management and Insurance, 2nd Edition.

13. Data are from the United States Geological Survey http://earthquake.usgs.gov/regional/sca/ca_eqs.php accessed July 9, 2011

14. It is important to recognize the Richter magnitude scale is not linear. It increases on the function . Therefore, an M7 earthquake is 31.62 times stronger than an M6 earthquake and an M8 earthquake is 1,000 times stronger than an M6 earthquake.

15. FNMA (Fannie Mae) 2010 annual report on SEC form 10k shows that approximately 18 percent, or $507 billion, of its loan portfolio represents homes in California. FHLMC (Freddie Mac) 2011 quarterly filing shows 16 percent of its exposure is in California.

16. Jacob Bernoulli, 1713, *Ars Conjectandi*, MDCCXII (published posthumously by Jacob's nephew Nicholas Bernoulli)


IACOBI BERNOULLI,
ARS CONJECTANDI,
TRACTATUS
DE SERIEBUS INFINITIS,
DE LUDO PILÆ RETICULARIS.
BASILEÆ,

17. In a pooling agreement, members of a risk pool agree to share the total losses of the group in equal shares. For example, with ten participants in a risk pool, if the sum of the participants' losses is $1,000, each participant must pay one tenth of the total, or $100.

18. The probability of an individual in this pool paying more than $660 is less than 0.001. The probability of paying more than $825 is one in one billion.

19. See Swiss Re Sigma, 1/2002 available from http://media.swissre.com/documents/sigma1_2002_en.pdf accessed 7/12/11.

20. See, for example, Testimony of Glenn Pomeroy, Chief Executive Officer, California Earthquake Authority, before the House Committee on Financial Services Subcommittee on Capital Markets, Insurance, and Government-Sponsored Enterprises. Hearing on "Approaches to Mitigating and Managing Natural Catastrophe Risk: H.R.2555, The Homeowners' Defense Act." March 10, 2010. See also, Glenn Pomeroy, Tim Richison, & Daniel Marshall, 2011, "Affordable & Affordable Earthquake Insurance: Underscoring the Need for Risk-Transfer Diversification,"June 2011, OECD (Paris) available from http://www.earthquakeauthority.com/UserFiles/File/Release/CEA%20-%20Diversifying%20Risk%20Transfer%20Sources%20-June%202011%20-%20OECD.pdf accessed 2/09/2012.

21. Representative John Campbell of California has introduced H.R. 3125, the House version of S.637.

22. See "Campbell Proposes House Bill to Lower Cost of Earthquake Insurance Congressman John Campbell (R-CA) Introduces H.R. 3125, Earthquake Insurance Affordability Act (EIAA)," http://campbell.house.gov/index.php?view=article&catid=41%3Apress-releases&id=3083%3Arelease-rep-campbell-proposes-house-bill-to-lower-cost-of-earthquake-insurance-&format=pdf&option=com_content&Itemid=300032, and http://www.feinstein.senate.gov/public/index.cfm/op-eds?ID=8aafd3d8-5056-8059-760a-f60d6369c200.

23. Note that in years without a loss, the CEA adds more than $300 million to surplus even without the guarantee. The effect of the guarantee is to accelerate the accumulation of capital.

24. This price is also known as the "rate-on-line." It is the reinsurance premium divided by the amount of coverage. For example, if a reinsurance treaty that could pay up to $1,000,000 sells for premium of $50,000, the rate-on-line would be 0.05.

25. The administrative fee of 0.5 percent is assumed in the statute. The 0.75 percent probability of default is the midpoint of the CEA's estimates of the probability of borrowing funds with the guarantee. This was presented in Pomeroy's testimony before Congress referenced above. I assume that the CEA cannot repay such a loan by increasing premiums. Therefore, the expected cost of default is 0.0075 times $1.5 billion, or $11,250,000 per year.

26. I solve for the increase in take-up and decrease in price simultaneously as two equations with one unknown variable.

27. See the Appendix for a detailed solution.

28. California Department of Insurance

29. This result is consistent with the elasticity estimated by RAND: $\frac{1{,}647-687}{687}$ x −0.44 = −0.616; −0.616 x 849,943 = 523,373; 849,943 − 523,373 = 326,570

30. LaTourrette, Tom, James N. Dertouzos, Christina E. Steiner, and Noreen Clancy, 2010, "Earthquake Insurance and Disaster Assistance: The Effect of Catastrophe Obligation Guarantees on Federal Disaster-Assistance Expenditures in California," RAND Institute for Civil Justice, Technical Paper.

31. RAND Technical Reports undergo rigorous peer review to ensure that they meet high standards for research quality and objectivity.

32. Stronger earthquakes are more likely to cause losses greater than the deductible included in earthquake insurance policies.

33. CBO estimate available from http://www.cbo.gov/ftpdocs/115xx/doc11548/hr2555.pdf. Accessed 11/26/2011

34. See Zangani (2008), "Public vs. Private Underwriting of Catastrophe Risk: Lessons from the California Earthquake Authority," in *Risking House and Home: Disasters, Cities, Public Policy*, John M. Quigley and Larry A. Rosenthal (eds.), Berkeley: Berkeley Public Policy Press (2008).

35. See "PBGC Reports Record $26 Billion Deficit for 2011" http://www.pbgc.gov/news/press/releases/pr12-06.html accessed 1/27/2012

36. See Hoyt, Robert E. and Kathleen A. McCullough, "Catastrophe Insurance Options: Are They Zero-Beta Assets?" *Journal of Insurance Issues*, Fall 1999, Vol. 22: 147-163.