Behavioral Models of Insurance: The Case of the California Earthquake Authority*

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1. INTRODUCTION

Standard economic and finance theories indicate that active private markets should exist for insurance against catastrophic risks such as earthquakes, hurricanes, and floods. After all, on the demand side, risk averse households should be willing to pay the actuarial cost, and perhaps more if necessary, to purchase insurance against the loss of their most valuable asset, their home. And on the supply side, a significant number of insurance firms, large and small, regional, national, and international, specialized and general, are all in the business of underwriting insurance risks. Nevertheless, we observe highly imperfect markets for catastrophe insurance. Outside the United States, catastrophe insurance is virtually everywhere provided by the government. Within the United States, flood insurance has been provided by the federal government since 1961, and private markets for earthquake and hurricane risks were largely replaced by state plans following the Andrew Hurricane of 1992, the Iniki Hurricane of 1992, and the Northridge earthquake of 1994.[1]

In this paper, we use the state response to the failure of the private market for earthquake insurance in California to study the behavior of economic agents in catastrophe insurance markets: consumers, insurance firms, reinsurers, and capital market investors. More precisely, we use the California Earthquake Authority (CEA) --the quasi-state agency organized to replace the private market for earthquake insurance in California--and its customers for California earthquake insurance as our test bed for analyzing observed behavior. Several factors led us to choose the creation and development of the CEA as the event to study:

[1] As a result of these events, Florida set up a Joint Underwriting Association and a state reinsurance fund for hurricane risks, California set up the California Earthquake Authority, and Hawaii set up the Hawaii Hurricane Relief fund. Although there are important structural differences among these state plans, their goals and the general methods for reaching these goals are very similar.

1) Among the three major state catastrophe plans, Florida and Hawaii for hurricanes and California for earthquakes, the CEA has the most transparent structure that incorporates the key features of all the plans.

2) Since its inception, the CEA has received a great deal of attention, regarding both political and economic issues, all of which have been widely reported in the press.[2] Furthermore, many of the issues raise interesting questions of "behavioral insurance".

3) There is an ongoing research project to survey the earthquake insurance preferences of a set of California homeowners, the results of which will permit an empirical analysis of various hypotheses concerning “behavioral insurance”. [3]

The agenda for this paper is as follows. In part 2, we discuss the structure, goals, and *modus operandi* of the California Earthquake Authority. In part 3, we present a model of how the CEA operates and evaluate the related hypotheses. In part 4, we present a model of how consumers choose incomplete insurance, and evaluate the related hypotheses. Part 5 provides our conclusions.

2. <u>THE STRUCTURE OF THE CALIFORNIA EARTHQUAKE AUTHORITY</u>

The California Earthquake Authority (CEA) was created in 1996 by Act of the California Legislature and operates as a privately financed, publicly managed, state chartered, insurance company. It has no financial ties to the State of California. It was created in the aftermath of the

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[2] For example, in the *Wall Street Journal* of December 1, 1999, in the article "Quake Agency Chief's Job Proves to Be a Hard Draw", it is suggested that it is proving difficult to fill the job of Chairman of the CEA due to the high risk that the Authority might not be able to meet its claims in the event of a "big one".

[3] In carrying out the survey project, we are cooperating with John Landis from the College of Environment Design, UC Berkeley, and Howard Kunreuther and Lisa George from the Wharton School, University of Pennsylvania.

Northridge earthquake of 1994, when the major firms selling earthquake insurance in California announced their intention to stop writing such insurance. The publicly stated reason was that, as a result of the new information provided by the Northridge quake, the firms feared they now faced a serious "risk of ruin" were a major earthquake to hit downtown Los Angeles or San Francisco.[4] Since the California state insurance code required any insurance firm selling homeowner insurance to offer an earthquake insurance rider, the decision to stop selling earthquake insurance was easier to make than to implement. There followed an extended negotiation between the firms and the California state Legislature regarding the "exit tax" that would be required. In the end, firms representing slightly more than 70% of the state's homeowner insurance industry participated in the CEA plan and committed to transfer capital to the new CEA (see Figure 1 and discussion below), in exchange for a release from their obligation to offer earthquake insurance on their own account.

The Failure of Private Markets for Catastrophe Insurance

Although this paper takes the failure of the private market for catastrophe insurance as a given, it is useful first to review briefly the possible reasons for the market failure that have been advanced in the literature. We summarize the possible explanations under 3 major categories:

Capital Market Imperfections

Catastrophe insurance firms face a significant "risk of ruin"--the possibility that a mega-disaster could bankrupt a company--so that imperfect access to capital would be a key issue for these firms, and there is evidence this is a serious problem. For one thing, the literature on

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[4] This is a reasonable concern, given that an event with losses of $100 billion is possible, and that an insurance company's total capital is potentially at risk to pay claims.

insurance market premium cycles provides evidence that insurance firms may not have ready access to traditional debt and equity markets, especially after a period of high claims (see Gron and Lucas [1998] and literature cited). For another, Froot [1999] and Froot and O'Connell [1999] have pointed out that shareholders in insurance firms appear to include a risk premium in their required return, even though most insurance company risk is idiosyncratic (i.e. diversifiable). On a related point, Jaffee and Russell [1997a] have pointed out that accounting rules and tax laws are biased against the accumulation of capital reserves to pay for the losses of a catastrophic event that has not yet occurred; and any reserves which a company did accumulate would make it prey for a takeover. It is noteworthy that the CEA's quasi-public structure provides "solutions" to these issues.

Asymmetric Information

Asymmetric information, where the insured knows more about the risk than the insurance company, is a traditional explanation for insurance market failure. With respect to catastrophe insurance, however, it is unlikely that homeowners know more than the insurance company either about the probability of the catastrophic event or about the conditional expected loss on the particular property (i.e, property location, construction quality, and mitigation efforts can be readily observed by the insurance company). On the other hand, Doherty [1997] has argued that asymmetric information between insurance companies and reinsurance companies, or between the insurance industry and capital markets (in the case of the securitization of catastrophe risks) might significantly raise the cost of reinsurance or of capital-market risk transfer. Thus, a failure to solve asymmetric information problems could be an additional reason why private companies may have wanted to leave the catastrophe insurance market.

Pricing and Regulatory Issues

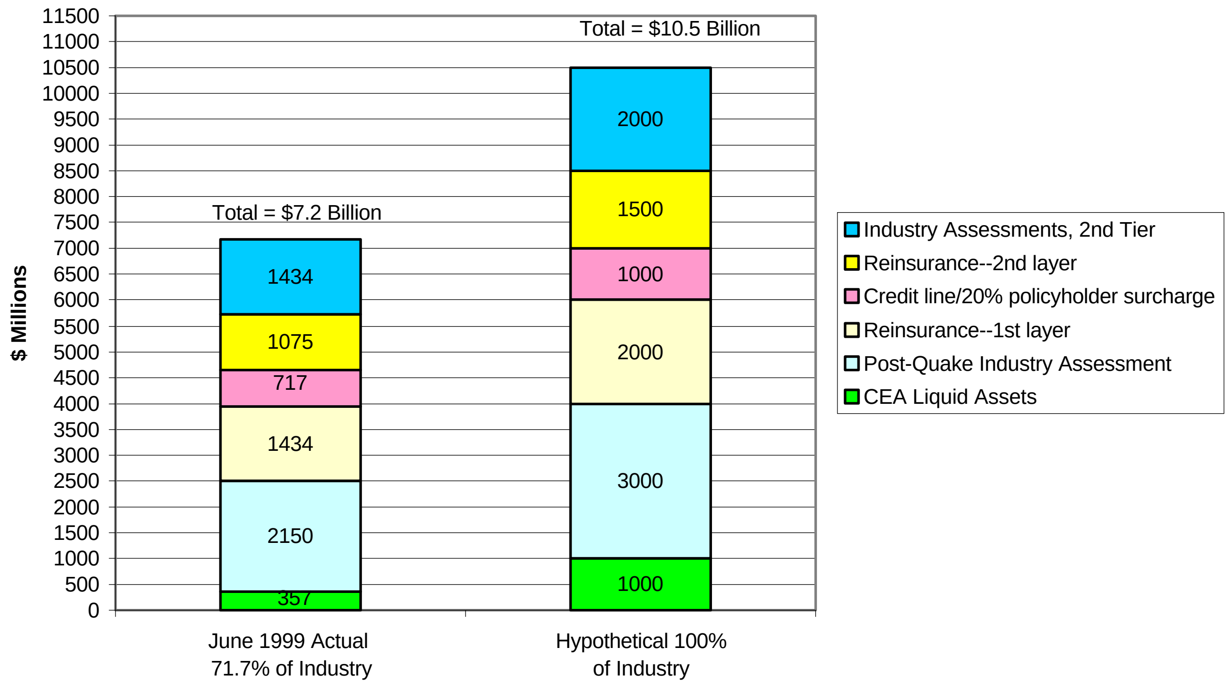
The losses expected by the insurance industry due to catastrophes rose significantly as a result of the new information created by Hurricane Andrew and the Northridge earthquake, making it important for the firms to raise their premiums.[5] This raised two serious issues for the insurance firms. First, the state insurance commissioners resisted approving the desired premium increases. Second, many consumers felt the increases were unwarranted (i.e. consumers and firms had different views of the expected losses). Given that catastrophe insurance represents a small and possibly unprofitable line for the major insurance firms, in comparison to other consumer lines such as homeowner insurance , it is not surprising that many of the companies preferred to avoid the risk and to protect their reputations by simply not offering catastrophe insurance.

The Structure of the California Earthquake Authority

Following extended negotiations between the insurance industry and the California state legislature, the CEA was set up with sufficient reserves to cover an event with double the physical losses of the Northridge quake, based on the CEA's new "mini" earthquake policy. Since the "mini" policy reduced the expected level of claims by more than half compared to the standard policy in effect at the time of Northridge, the dollar value of the CEA's claims-paying capacity is roughly the same as the actual Northridge payouts. Companies representing 71.7% of the state's homeowner insurance industry joined the CEA. The Internal Revenue Service provided the CEA with an exemption from federal income taxes that is not otherwise available to private sector insurance firms. The following notes describe the key structural aspects of the CEA.

[5] Most of this new information concerned the expected property losses, given that a catastrophe has occurred. For example, with Andrew it was discovered that building codes had not been enforced in many cases, leading to higher than expected losses. It is less clear whether the recent events have provided information that would cause insurance companies to raise the expected probability of future catastrophes.

Figure 1: CEA Claims Paying Capacity



Claims Paying Capacity

As of June 1999, the CEA's claims-paying capacity was $7.2 billion. The components are shown in Figure 1, where the left column represents the actual situation in which 71.7 % of the homeowner insurance industry in California joined the CEA, while the right column shows the corresponding values based on a hypothetical 100% industry participation. The components are further described as follows (dollar values refer to the actual values of the left column):

- Liquid assets of $357 million. This represents the portion of CEA capital available for claims-paying purposes (= initial industry capital contribution of about $700 million, plus additions to earned surplus, less capital allocated to fixed assets or otherwise unavailable to pay claims).[6]

- 1st tier of post-quake industry assessments of $2.15 billion. This represents the commitment of CEA participating firms to provide additional funds if needed for paying claims. The commitment remains in place until the year 2008, at which point it vanishes completely.

[6] The right column for the hypothetical 100% industry participation includes neither additions to earned surplus nor reductions due to fixed asset purchases.

- 1st layer of reinsurance of $1.434 billion. The contracts call for payments of up to about $1.434 billion in insured losses, whenever claims exceed the CEA's capacity to pay based on its available liquid assets and the 1st tier of industry assessments.

- Credit line/policy holder surcharges of $717 million. The CEA is allowed to borrow up to $717 million, with the loans to be repaid with surcharges (up to 20% of premiums) imposed on policy holders. This represents an ex-post "mutual" transfer from all policy holders to those actually suffering losses.

- 2nd layer of reinsurance of $1.075 billion. This is sometimes referred to as the "Warren Buffet" layer, as it was initially purchased (and recently renewed) with a firm that is part of Warren Buffet's insurance conglomerate.

- 2nd tier of post-quake industry assessments of $1.434 billion. As with the 1st tier, this commitment remains in place until the year 2008, at which point it too vanishes.

Structure of the Insurance Policies

The CEA initially provided a single contract, called the "Mini Policy," on which the coverage was substantially less than was previously available from the private companies. Its key limiting features were:

- Claims are subject to a deductible that is 15% of the primary dwelling;
- The policy does not cover associated structures (such as pools and detached garages);
- Personal property/loss of use coverage is only $5,000/$1,500.

Beginning in 1999, the CEA began to offer an expanded menu of coverage, with the following options available:

- Deductible buy downs to 10% are available on the primary dwelling;
- Personal property/loss of use coverage limits are available at 5 different levels, going as high as 100,000/15,000.

Premium Setting

The CEA legislation required that premiums be based on actuarial estimates of the expected losses. The CEA used an earthquake risk modeling firm, EQE International, to provide estimates of expected losses across the state. The estimates were developed from two basic sources of information: a) estimates of earthquake probabilities by magnitude and geographic location, from the US Geological Survey; and b) the expected losses, conditional on the occurrence of an earthquake of specific magnitude and location, computed by the firm's proprietary loss model. The expected losses were computed at the geographic level of individual zip codes.

The initial premium setting, however, was subject to political and consumer pressure.[7] In particular, the CEA is allowed discretion with regard to the size of the geographic zones used for premium setting. At one extreme, a single premium could be used for the entire state, with the expected loss model indicating a state-wide premium of about $3.50 per $1,000 of coverage. At the other extreme, very small rating areas could be used, even to the level of an individual address. Since the expected loss model predicted a substantial variation in expected losses across regions, the corresponding premiums could have ranged from a high of over $10 per $1,000 coverage to a low of below $1 per $1,000 coverage. To moderate these extremes, the CEA adopted a system based on only 19 rating zones, and also reduced the overall level of premiums, especially in the highest risk area. The effect, of course, was both to lower the average level of premiums and to reduce the amount of premium variation across geographic regions.

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[7] Auto insurance premiums in California have faced similar pressures. Jaffee and Russell [1997] investigated the possible roles of fairness and self-interest with regard to the voting patterns on California's proposition 103, which imposed restrictions on the level and variation allowed on auto insurance premiums.

Table 1: CEA Premiums by Date and Rating Territory				
(annual premiums as price per $1,000 coverage)				
Territory	Area	Nov-96	Nov-97	Nov-98
2	Imperial	5.25	5.25	5.25
4	Riverside	4.75	4.33	5.25
5	Riverside	5.12	4.68	5.25
6	Riverside	1.17	1.05	2.05
7	Los Angeles	3.19	2.90	2.80
8	Riverside	3.19	2.90	3.90
11	Los Angeles	1.81	1.66	2.66
12	Los Angeles	4.64	4.24	4.98
13	Ventura	1.98	1.82	2.76
15	Santa Barbara	1.14	0.99	1.99
18	SLO	5.25	2.84	1.11
19	Monterey	5.03	4.54	3.73
20	Bay Area	2.88	2.64	2.59
22	Bay Area	5.25	4.57	4.41
23	Bay Area	5.25	4.57	3.76
24	Mendocino	1.17	1.05	1.90
25	Humboldt	1.17	1.05	2.05
26	Napa/Sonoma	4.90	2.74	2.69
27	Rest of State	1.17	1.05	1.05
Statewide Average		3.29	2.92	2.79
Source: California Earthquake Authority				

The “Nov-96” column of Table 1 shows the first premiums announced by the CEA-- in November 1996, just before its start of business in December 1996--for the 19 rating zones. Although these premiums had already been tempered and lowered relative to the initial EQE expected loss estimates, political protests continued. Furthermore, the initial market response to the CEA contract was disturbing --only about 50% of homeowners with earthquake policies were adopting CEA policies when first forced to switch from their existing policy to the CEA contract (or to no earthquake insurance at all). As a result, the premium structure was reduced by an average of 11% in November 1997. The rate reduction was officially attributed to a “review of the evidence of seismic modeling performed on behalf of the CEA” (see California Department of Insurance [1998a]). Most recently, in November 1998, there was a further 4.5% reduction in premiums, attributed to the falling cost of reinsurance and a less risky book of business than had been anticipated (see California Department of Insurance [1998b]).

Reducing premiums below the actuarially expected losses has two key implications:

1) Lower premiums tend to reduce the quality of CEA insurance (i.e. the CEA will be less likely to pay all its claims) for two reasons. First, when premium income is reduced, the CEA's direct claims-paying resources are reduced and/or the amount of reinsurance the CEA can purchase is reduced. Second, lower premiums will normally raise the number of policies sold, causing the fixed component of the CEA's capital to be spread over a larger amount of potential claims. On the other hand, the CEA’s average costs also fall as the result of distributing the CEA's fixed costs over a larger consumer base, which provides an opportunity to raise insurance quality. Given the relatively small amount of the CEA’s fixed costs (see Table 2 below), the likely net effect of lower premiums is a reduction in policy quality.

2) When the CEA opted for larger rating zones and administratively lowered premiums in the higher risk regions, this represented a cross subsidization of the more risky regions by the less risky ones. There are a number of implications of such a cross subsidization policy. For one thing, when the cost of earthquake insurance in the (presumably) riskier areas is reduced, then the incentive for consumers to locate their homes in these areas is raised. For another thing, the policy provides competitors a chance to enter the market and offer more favorable rates to customers in the less risky areas. For both of the above reasons, the relative demand for CEA earthquake insurance in the riskier areas is likely to rise, which will raise the likelihood of a CEA bankruptcy, assuming that premiums in the more risky areas are subsidized.

Policy Sales and Claim Settlement

CEA policies are sold through the participating insurance companies. These companies offer all their homeowner insurance customers the option to purchase the CEA policy, payment for which is made through the insurance company. For this service, the companies are paid a commissions equal to 10% of premiums written plus an operating cost reimbursement equal to 3.65% of premiums written. In the event of an insured loss, claims are serviced by adjusters from the same participating insurance firm, and the firm is reimbursed for its expenses.

Performance Guarantees

Although claims are processed through the CEA participating insurance firms, the payments come entirely from CEA resources (including the two tiers of industry capital assessments and the two tiers of reinsurance). If losses exceed these CEA resources, then all policy holders will be required to pay a 20% premium surcharge, to provide additional funds to pay claims. If these total resources are still insufficient to pay all claims, then payments to policyholders will be prorated, and claims will be paid in full only if and when more resources become available (such as from future premiums). Neither the state nor the participating insurance companies have any responsibility to backstop the CEA. In addition policyholders have no recourse to the state's insurance guarantee fund. Of course, in the event of a CEA bankruptcy, it is possible that either the state of California or the federal government will intervene to bail out policy holders.

Role for a Separate Private Market

The CEA legislation anticipated the existence of a separate private market for earthquake insurance. Indeed, earthquake insurance continued to be offered directly by those firms that decided not to join the CEA--representing about 30% of the homeowner insurance market. Furthermore. since the creation of the CEA, a number of new firms have entered the state's private earthquake insurance market. It appears these firms are "cherry-picking," by attracting customers in those regions of the state where the CEA premiums seem high relative to the expected loss. This allows a new entrant to set premiums at a level that creates expected profits for the firm, yet are attractive to CEA customers. New entrants have also offered policies with more complete coverage, in terms of lower deductibles and higher personal property and loss of use coverage. The increased availability of deductible and personal property coverage options on CEA policies in 1999 can be seen as a response to this competition.

Income Statements and Balance Sheets for the California Earthquake Authority

The CEA has been operating since December 1, 1996. Balance sheets and income statements are available for periods ending December 31 1997 and 1998, and through the 2nd quarter of 1999. Table 2 shows the CEA income statements for the 3 reporting periods. The CEA is modestly profitable in each of these periods. Gross premium income has been running steadily at an annual rate of about $400 million. Most of this income, however, is netted against the cost of reinsurance, so that net premiums earned is much smaller. The primary expenses are the commissions and reimbursed expenses of the participating insurers and reinsurance brokers. Overall, these are the expected results for an insurance company that has used reinsurance to transfer most of its risk, and, fortunately, has received no claims since its inception.

Table 2: CEA Income Statements	(in $ Millions)		
	13 Months to 12/31/97	12 Months to 12/31/98	6 Months to 06/30/99
Underwriting income:			
Preiums written	388	394	206
Less premiums ceded (reinsurance)	-237	-354	-133
Net change in unearned premiums	-92	48	-8
Policy refunds	-13	-22	0
Net Premiums Earned	46	66	65
Expenses:			
Participating insurer commissions	15	39	21
Participating insurer operating costs	5	14	7
Reinsurance broker commissions	11	11	5
Line of credit fees	4	4	3
Other underwriting expenses	14	17	7
Total Expenses	49	85	43
Underwriting Profit	-3	-19	22
Net Investment and Other Income	18	28	11
Net Income	15	9	33
Source: California Earthquake Authority: Financial Statements, 1997 and 1998,			
and Quarterly Management Report, 2nd quarter 1999			

Table 3: CEA Balance Sheets	(in $ Millions)		
	At		
	12 31 1997	12 31 1998	06 30 1999
Assets			
Total investments and cash	576	452	554
Other assets	413	497	443
Total Assets	989	949	997
Liabilities and Equity			
Unearned premiums, net	238	209	217
Other liabilities	33	3	8
Total Liabilities	271	212	225
Equity:			
Contributed Capital	700	700	700
Retained earnings + tax rebate	18	35	74
Miscellaneous	0	2	-2
Total Equity	718	737	772
Total Liabililities and Equity	989	949	997
Source: California Earthquake Authority: Financial Statements, 1997 and 1998,			
and Quarterly Management Report, 2nd quarter 1999			

Table 3 shows the CEA balance sheet at 3 reporting dates. Total assets (= total liabilities plus equity) are just under $1,000 million. These assets originate from 3 primary sources: $700 million of capital contributed by the participating insurers, something over $200 million of unearned premiums (i.e. premiums received that apply to future periods), and between $18 and $74 million of retained earnings (which includes a tax rebate from the state of California [8]) .

[8] The state of California has an insurance premium tax, from which the California Earthquake Authority is exempted. For accounting purposes, the tax is first deducted from income as an expense, but this expense is then reversed through a direct contribution to the CEA capital account.

Table 4: California Homeowner and Earthquake Insurance Aggregates					
(Premiums written are in $ millions and number of policies are in millions)					
(Homeowner and earthquake insurance "total" includes the CEA)					
	1994	1995	1996	1997	1998
[A]: Homeowner, Total *					
Premiums written			$3,792	$3,652	$3,884
No. of Policies	7.49		7.60	7.90	7.95
Average Premium			$499	$462	$488
[B]: Homeowner, CEA Firms *					
Premiums written			$2,484	$2,428	$2,626
No. of Policies			5.18	5.65	5.64
Average Premium			$479	$429	$466
CEA Firm Market Share	71.7%		65.5%	66.5%	67.6%
[C]: Earthquake, Total					
Premiums written			$778	$608	$583
No. of Policies	2.55		2.39	1.54	1.36
Average Premium			$326	$394	$430
[D]: Earthquake, CEA Firms					
Premiums written			$577	$437	$388
No. of Policies			1.88	1.10	0.92
Average Premium			$306	$396	$424
CEA Firm Market Share			74.1%	71.8%	66.6%
* "Homeowner insurance" is defined to include traditional HO series contracts					
plus rental, condominium, dwelling firm, and mobile home policies.					
Source:California Department of Insurance,					
Tables EQ97SUM and EQ99SUM					

Market Measures of CEA Performance

Table 4 provides California homeowner and earthquake insurance market data since 1994, including the specific performance of the CEA firms. These data proved difficult to obtain and to interpret for a number of reasons. First, the market for homeowner insurance is appropriately defined to include traditional “homeowner” policies (i.e. policies in the “HO” series), as well as “rental”, “condominium”, “dwelling fire”, and “mobile home” policies; the data for these lines must be merged from separate sources. Second, the primary data collected by the California Department of Insurance on earthquake insurance combines residential and commercial earthquake policies, and special tabulations are required to obtain data for residential earthquake policies alone (as shown in Tables 4 and 5). Third, data on homeowner and earthquake insurance was not a priority of the California Department of Insurance prior to 1996. Fourth, the intensity of CEA activity has changed over time, including both a transition period for the original CEA member firms and the entry of additional firms after the CEA began.

Sections A and B of Table 4 show data for the homeowner insurance market in California. The total market appears to have grown slightly between 1996 and 1998, while the market share of CEA participating firms rose steadily from 65.5% in 1996 to 67.6% in 1998. In comparison, the market share of CEA firms in 1994 was 71.1% (at least, this is the official percentage used in determining the capital contributions to the CEA required of the firms that initially chose to participate). Taken at face value, these data suggest an almost 6 percentage point decline in the homeowner insurance market share of CEA firms from 1994 (the time of the Northridge quake) to 1996 (the beginning of the CEA), followed by a rising market share through the date of the latest data. In fact, between 1994 and 1996, many of the CEA firms stopped taking on new customers, and some even cancelled existing customers, while awaiting the outcome of the negotiations over the “exit tax” from California’s earthquake insurance market. So it is sensible that their market share fell at first, but has subsequently been returning toward the initial level.

Section C of Table 4 shows the aggregate data for the residential earthquake insurance market in California. The total market declined sharply from 1994 to 1998, with the total number of earthquake policies in force declining almost in half, from about 2.5 million in 1994 to less than

1.4 million in 1998. This decline can be attributed to the major rise in insurance premiums that occurred as a result of the Northridge quake in 1994, as well as consumer suspicions that the premium increases were not warranted by actual changes in the expected losses.

The earthquake insurance market for CEA firms has reflected its own dynamic, as shown in part D of Table 4. The key feature is that the number of earthquake policies attributed to CEA firms in 1998 is less than half the amount in 1996, a substantially sharper decline than is evident in Part C of Table 4 for the total earthquake insurance market. This implies that the CEA market share of the California earthquake insurance market fell from 74.1% in 1996 to 66.6% in 1998. Since most customers of CEA firms received their first opportunity to accept or reject the new CEA policy in 1997, and some customers received this opportunity only in 1998, the sharp decline between 1996 and 1998 in the CEA market share can be reasonably interpreted as the first round response to the new CEA policy, including successful competition from non-CEA firms and new entrants to the earthquake insurance market.

In interpreting these data, it is important to recall that the primary goal of the CEA participating firms was to combine a continuing participation in California's homeowner insurance market with a graceful exit from the earthquake insurance market. The data in Table 4 show a rising homeowner insurance market share and a falling earthquake insurance share, suggesting that the CEA may be admirably serving its primary purpose. On the other hand, the CEA participating firms also earn commissions from the sale of CEA earthquake policies, and from this viewpoint the CEA's falling share of the earthquake insurance market would be disappointing.

More generally, the declining earthquake market share of CEA firms is suggestive that the CEA contract could be made more attractive to consumers. Indeed, the recent introduction by the CEA of a 10% deductible option, as an alternative to the 15% deductible required on the basic

CEA "mini" policy, indicates that the CEA is trying to improve its competitive position.[9] The success of the new entrants to the earthquake insurance market in selling earthquake insurance also raises a potentially very serious risk to the *homeowner insurance* business of the CEA member firms. The risk is that the new entrants, who so far are selling *only* earthquake policies, begin to leverage their consumer base in the earthquake line to offer homeowner insurance policies as well. We conjecture that the CEA member firms would treat such a development very seriously, and would respond either by making the CEA contracts more competitive or by reintroducing their own earthquake insurance policies.

CEA Risk Exposure

As of December 1999, the CEA had 881,983 policies in force, representing approximately $162 billion in exposure. As shown earlier in Figure 1, the total CEA claims-paying capacity is about $7.2 billion, summing the CEA's own resources, potential assessments on CEA participating insurance firms and CEA policy holders, and reinsurance. Clearly, the CEA could fail to meet its obligation, since even a single "big one" hitting downtown San Francisco or Los Angeles could very well create $100 billion in insured losses.

CEA management, of course, recognizes this risk and has adopted a probabilistic strategy for evaluating and controlling the bankruptcy likelihood. The strategy is to choose a specific probability for the "risk of ruin", such as 5%, and then manage the CEA's risk consistent with this objective. The purchase of reinsurance is the most obvious instrument for this purpose, although other decision variables, such as premium level and contract structure (deductibles, co-insurance,

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[9] The CEA is required to provide a "competitive market analysis" report annually. The 1999 Report states that the CEA is competitive with the new entrants "overall", but that the entrants are successful in finding relatively low-risk locations within the highest risk-rated CEA regions and then are undercutting the CEA premiums for customers with residences in these areas (see California Earthquake Authority [1999a]).

insurance limits, etc.) can also influence this probability. The CEA has recently carried out a major strategic management evaluation, the report of which is expected to be released shortly . Advance word is that a recent updating of the expected losses model results (including favorable changes in the risk structure of the customer base) has lowered the probability of the “risk of ruin”. It is thus quite likely that the CEA will maintain a “steady as it goes” strategy.

Summary Features of California Earthquake Authority Insurance

We conclude this section with a summary of the key features of the CEA:

1) The CEA offers only partial insurance since claims cannot be paid in full for events with insurable losses that exceed about $7.2 billion.

2) CEA insurance takes the form of a co-insurance contract, in which the consumer’s co-insurance share rises, the larger the loss (for large losses requiring prorated payments).

3) The CEA contract initially provided only a high (15%) deductible and a low set of secondary coverages.

4) The CEA has acted to reduce premiums in high-risk areas, a form of cross subsidization. In the process, some premiums may have been reduced to below the actuarial level.

5) Firms representing approximately 30% of the earthquake insurance in force failed to join the CEA initially. Since then, new firms have entered the private earthquake insurance market. These firms appear to "cherry-pick" CEA customers.

6) Recently, in late 1999, the CEA introduced more variety in its policies, including a deductible choice of 10 or 15%, and a choice of 5 different levels of secondary coverage.

In the following two sections, we evaluate how well expected utility and "behavioral" models of insurance perform in explaining these features. We first consider models of CEA behavior, then turn to models of individual behavior.

3. MODELS OF A STATE CATASTROPHE INSURANCE PLAN

In this section, we model a state catastrophe insurance plan--such as the California Earthquake Authority (CEA)--as a passive conduit, which issues policies, holds capital, and purchases reinsurance, all presumably in the best interests of its policyholders. We determine the behavioral implications of this mode of operation and compare this behavior with the observed features of the actual CEA, as summarized at the end of the previous section. In carrying out this analysis, we pay special attention to the possibility that the state plan and its customers maintain different expectations regarding the probability of the catastrophe and the expected losses.

A Basic Model of a State Catastrophe Insurance Plan

We begin with a particularly simple structure, based on the following assumptions:

- There are no frictions or transaction costs in operating the plan or underwriting policies.
- All consumers are identical and share the same information with the state plan regarding the catastrophe probability and the expected losses thereby created.
- The catastrophe occurs with an annual probability P, comes in only one size, and creates a loss of L for each consumer when one does occur. There is thus no opportunity for the insurance firm to diversify its risks across customers.
- Policies provide coverage of a fixed amount Q, so that Q becomes a measure of policy quality.
- The actuarially fair value for the annual policy premium R is PQ, given no operating costs.
- The state plan is operated in order to maximize consumers' expected welfare W.

To develop the basic welfare proposition of insurance, we let the state plan choose the policy quality Q so as to maximize the representative consumer's expected welfare W:

(1) $$W = PU[W_0 - R - L + Q] + (1 - P)U[W_0 - R].$$

where for each consumer, U is the utility function and W_0 is the consumer's wealth independent of catastrophe insurance and losses. After substituting the actuarially fair premium PQ for R in equation (1), we have:

(2) $$W = PU[W_0 - PQ - L + Q] + (1-P)U[W_0 - PQ].$$

The first order condition for maximizing expected welfare W with respect to policy quality Q is:

(3) $$\frac{\partial W}{\partial Q} = P(1-P)U'[W_0 - PQ - L + Q] - P(1-P)U'[W_0 - PQ] = 0, \textit{ implying that } Q^* = L.$$

The second order condition, which ensures a welfare maximum, requires that the utility function reflect risk aversion (that is, U'[] > 0, U''[] < 0). The result that the optimal insurance coverage Q* equals the expected loss L, of course, just restates the standard result that risk averse agents should choose "complete insurance" when the premiums are actuarially fair.

Differing Estimates of Catastrophe Probabilities

It is useful to extend the basic result to a situation in which the state plan's estimated probability of the catastrophe P_s differs from the consumers' estimated probability P_c, still assuming that the state plan wishes to maximize consumer welfare. The probability used to weight utility should then be based on the consumer’s value P_c in order to reflect consumer preferences, while the probability used to determine the actuarial premium should be based on the plan’s value P_s in order to reflect the budget constraint. Equation (2) is then rewritten as:

(4) $$W = P_c U[W_0 - P_s Q - L + Q] + (1-P_c)U[W_0 - P_s Q].$$

The first order condition to maximize expected welfare W with respect to policy quality Q is then:

(5) $$\frac{\partial W}{\partial Q} = P_c(1-P_s)U'[W_0 - P_s Q - L + Q] - P_s(1-P_c)U'[W_0 - P_s Q] = 0.$$

Equation (5) implies that:

$$(6) \qquad Q^* \overset{>}{\underset{<}{=}} L \text{ as } P_c \overset{>}{\underset{<}{=}} P_s.$$ [10]

That is, the state plan should offer more than complete, just complete, or less than complete insurance as the consumers' estimate of the probability of the catastrophe exceeds, equals, or is below the state plan's estimate. This is consistent with the standard result that when insurance premiums are favorable, consumers may choose to purchase more than complete insurance (that is, to gamble) and when premiums are unfair, consumers may choose incomplete insurance.

It is worth emphasizing that the case with $P_c < P_s$ corresponds to actuarially unfair insurance from the consumer's standpoint, since the premiums are based on the state plan's probability P_s which consumers feel overstates the actual likelihood of the catastrophe. In this case, the optimal amount fixed coverage Q is less than the expected loss L. In our particularly simple case, the incomplete insurance can be interpreted as either a deductible (the deductible amount equals L – Q) or as co-insurance (the consumer self-insures 1- (Q/L)). In Section 4 below, we will look at more complex cases in which deductibles have more distinctive properties as components of incomplete insurance contracts.

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[10] To see this, note, for example, that when equation (5) is evaluated for Q = L, we have:

$$\partial W / \partial Q = P_c(1-P_s)U'[W_0 - P_sQ - L + Q] - P_s(1-P_c)U'[W_0 - P_sQ] > 0 \text{ as } P_c > P_s.$$

Therefore, welfare is improved by making $Q^* > L$ whenever $P_c > P_s$.

Differing Estimates of Expected Catastrophe Losses

The state plan and its customers can also have different views toward the expected losses conditional on the catastrophe occurring, aside from different estimates of the probability of the catastrophe as just considered. The expected loss appears as the variable L in our basic consumer welfare equation (2). We are now suggesting, however, that there may be 2 values for this variable, L_s being the value estimated by the state plan and L_c being the value estimated by the consumers. In solving the welfare maximization problem, we saw that the optimal amount of coverage Q depends directly on the expected loss L, so which estimate of L is used by the state plan will determine a key feature of the insurance contract. Although the variable L appears just once in equation (2), it actually has an impact on two separate aspects of consumer welfare:

1) Most directly, L represents the average per capita loss that is expected if and when the catastrophe occurs. We refer to this as the *ex post* aspect of L, since it is an estimate of the actual loss. For example, this aspect of L would be relevant for the purposes of evaluating the state plan's capital resources to pay claims. Since L_s represents the state plan's best estimate of the expected loss, it would seem L_s should be used to determine the contract quality Q.

2) L also represents, however, the amount of risk the consumer faces, in the sense that it is the amount of coverage the consumer requires in order to feel protected from the uncertainty. We refer to this as the *ex ante* aspect of L, since it relates only to the psychic calculus of the consumer, and is independent of what is the "true" expected loss. For this purpose, it would seem that the state plan should base its contract quality Q on the consumers' expected loss L_c.

Given that the state plan and the consumers may not share the same estimate for the expected loss L, and that the expect loss estimate has an impact on two different respects of the consumers' welfare, the question arises as to which value, or what combination of the two values, should be used to determine the actual insurance contract offered by the plan. This is not an easy problem to solve. A simple case can illustrate some of the difficulties. Assume, for example, that the consumer's expected loss L_c is much less than the state plan's estimate of the expected loss L_s. The consumers would be satisfied on an *ex ante* basic if the state plan offered a policy with coverage L_c, even though the managers of the plan expect an actual catastrophe would create a much larger *ex post* amount of uninsured losses. But, if the state plan offered a policy with only the higher coverage of L_s, thus eliminating the risk of *ex post* uninsured losses, consumers would see the premium as actuarially unfair and might thereby decide not to buy any insurance, hardly a welfare optimum.

4. INSURANCE WHEN CAPITAL IS LIMITED: BEHAVIORAL ISSUES

The structure of the welfare maximizing insurance contract will depend, of course, on how the potential buyers process the variables which they use to make their insurance purchase decision. There is no point in designing a contract which would be optimal for rational buyers, if no one actually purchases it. The issue of optimal contract design hinges on accommodating the gap between the firm's limited available capital and the large potential size of its insured losses.

The key benefit which the CEA provides for its participating insurance company members is a fixed limit on the total size of the losses which they can incur over the life of the program. Between the program’s inception in December 1996 and December 2008, CEA member insurance companies can lose no more than $4.3 billion. As we have already said, total loss exposure in June 1999 amounted to $163 billion. Moreover, insurance companies receive 10% of all premiums in commission ($39 million in 1998) and only $700 million is required to be committed up front. With total losses controlled, the insurance companies were able and willing to continue writing homeowner's insurance in the state.

On the other hand, with such limited capital, the CEA has had to develop a contract structure which recognizes the fact that it does not have the resources to meet an event or series of events whose losses potentially far exceed available reserves. Given the way in which they chose to meet this challenge, two important questions can be raised.

1) Does the current CEA contract structure best serve the needs of the homeowners in the state, or more generally, what principles should govern the design of an insurance contract when the available capital is known to be limited?
2) Given that the CEA has now been operational for two years, and given that no public money is used in the scheme, why is a similar limited capital arrangement not open to the private sector?

We will argue that the answer to both these questions depends crucially on behavioral issues in the demand for insurance. We consider first the question of optimal insurance contract design with limited capital.

Contract Design When Capital Is Limited

If the CEA management had searched the economics literature for guidance on how to design an optimal insurance contract with limited capital, they would have found very little help. A number of authors discuss rational insurance purchase when there is the possibility of contract non-performance, see e.g. Doherty and Schlesinger [1990] and the references there, but here default is a random event, and the contract is not designed to minimize its effects. More recently, and clearly not available to the managers of the CEA at its inception, Louberge and Schlesinger

[1999] have discussed issues of optimal catastrophe contract design, but their model assumes limitless capital.

In the absence of specific recommendations from the economics literature, the CEA developed a contract with the three specific features already discussed:

i) The contract set a fairly high deductible (15%) and provided limited coverage (the mini policy).

ii) The contract contained a "mutuality clause" whereby an ex post capital assessment could be made against the policy holders in the event that capital was exhausted.

iii) The contract pro rated indemnification in the event that insured losses exceeded total capital (including the levy in (ii) above).

It is not completely clear why the CEA chose this high deductible limited coverage/pro rata structure. For example, if the CEA expected only one event, a high deductible would not necessarily be preferred by risk averse expected utility maximizers.[11] We illustrate this with the following simple example.

Insurance Payouts with a Single Catastrophic Event: An Illustrative Example

Consider a market with 300 homes, in which there are two levels of earthquakes: with probability p = ½ , 150 homes are affected; and with probability p = ½, all 300 homes are affected. The actual losses on an affected home are 1, 2, or 3, each occurring with a 1/3 probability, depending on how close the home is to the earthquake's epicenter. Suppose the insurance company charges a premium of $1 per house and uses the $300 of premium income to

[11] The assumption that individuals maximize expected utility provides the standard for welfare analysis in the literature. We will relax it shortly.

purchase reinsurance accounts.[12] The insurance contract promises a level of loss indemnification based on actual individual losses, although the payouts will be pro-rated if the claims-paying capacity is exceeded. Prior to the earthquake event and insurance payments, each individual has an initial wealth of 6, which becomes 5 after paying the insurance premium. If we now assume that the earthquake contract has no deductible limits, then, ex ante, the insured faces the following payout structure and end of period wealth:

Case 1A: No Deductible		Insurance Payouts and Wealth Per Home		
Policy has premium of $1.0 (Total premium income = $300)		Distance from Epicenter:		
		Near	Middle	Far
		p = 1/3	p = 1/3	p = 1/3
Little one (p = ½): 150 homes affected (50 in each class)	Actual Loss	3.0	2.0	1.0
	Insurance Payment	3.0	2.0	1.0
	Final Wealth	5.0	5.0	5.0
Total actual claim payments = $300 (All claims paid in full)				
Big one (p = ½): 300 homes affected (100 in each class)	Actual Loss	3.0	2.0	1.0
	Insurance Payment	1.5	1.0	.5
	Final Wealth	3.5	4.0	4.5
Total actual payments = $300 (Payments = 50% prorating of claims)				

In the case of the "little one", the total claims are $300 and the insurance company has exactly the capacity to pay these claims in full. In the case of the "big one", the actual losses (and total claims) are $600, so the insurance company can offer only 50% pro-rated payment, again for a total of $300 in claim payments. In both cases, the insurance firm just breaks even.

[12] This a good approximation to how the CEA actually operates. However, to keep the example simple, we are assuming that an earthquake is a sure thing, which, of course, raises the level of expected losses and premiums compared to what they would be were earthquakes treated as the low probability events that they actually are.

Now let the insurance firm offer a contract with a $1.0 deductible, charging the actuarially fair premium of $0.75 per home (total premium income = $225), again using the premium income to purchase reinsurance. Each individual then has a wealth of 5.25 after paying the insurance premium, but before losses occur or insurance payments are received. With the deductible contract, the insured face the following payout structure and end of period wealth:

<table>
<tr><td colspan="2"><u>Case 1B: Deductible</u></td><td colspan="3"><u>Insurance Payouts and Wealth Per Home</u></td></tr>
<tr><td colspan="2" rowspan="2">Policy has a deductible of $1.0 and premium of $0.75
(Total premium income = $225)</td><td colspan="3"><u>Distance from Epicenter</u>:
Near Middle Far</td></tr>
<tr><td>p = 1/3</td><td>p = 1/3</td><td>p = 1/3</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3"><u>Little one</u> (p = ½):
150 homes affected
(50 in each class)</td><td>Actual Loss</td><td>3.0</td><td>2.0</td><td>1.0</td></tr>
<tr><td>Insurance Payment</td><td>2.0</td><td>1.0</td><td>0</td></tr>
<tr><td>Final Wealth</td><td>4.25</td><td>4.25</td><td>4.25</td></tr>
<tr><td colspan="2">Total actual claim payments = $150
(All claims paid in full)</td><td></td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3"><u>Big one</u> (p = ½):
300 homes affected
(100 in each class)</td><td>Actual Loss</td><td>3.0</td><td>2.0</td><td>1.0</td></tr>
<tr><td>Insurance Payment</td><td>2.0</td><td>1.0</td><td>.0</td></tr>
<tr><td>Final Wealth</td><td>4.25</td><td>4.25</td><td>4.25</td></tr>
<tr><td colspan="2">Total actual claim payments = $300
(All claims paid in full)</td><td></td><td></td><td></td></tr>
</table>

In the case of the "little one", the total claims (after the deductible) are $150 and these are paid in full. In the case of the "big one", the total claims (after the deductible) are $300 and these too are paid in full. The expected payout by the insurance company is $225 (= (.5)($150)+(.5)($300)), which matches the premium income, so expected profits are zero.

We can now compare the results for the contracts with and without the deductible. First compare the two contracts when all 300 homes are affected (the "big one"). Given this situation, a rational risk averse agent unambiguously prefers the deductible contract since the certain final wealth of $4.25 (independent of the home location) dominates in the sense of a mean preserving spread the final wealth values which arise with the no-deductible contract. Next, compare the deductible and no-deductible contracts in the "small one" situation where a total of 150 homes are affected. In this situation, the no-deductible contract creates a final wealth of $5.00, which dominates the final wealth which arises from the deductible contract. Thus, looking at both situations (the "little one" and the "big one"), we see that each contract (i.e. with or without the deductible) dominates in one of the two situations, so that which contract a given consumer would actually prefer will depend on the exact features of the consumer's utility function.

Results with Multiple Possible Catastrophes

On the other hand, it is possible that what motivated the CEA was a desire to survive more than one event. Suppose, for example, that precisely 2 events will occur, (say one in N. California and one in S. California). Suppose that which one occurs first is a random event with probability p = 1/2. Suppose again that insured losses are 3, 2, or1 with equal probabilities, and that only large events can occur (all 300 homes are affected). The policy premium is set at $1 per home and is used to purchase a total of $300 of reinsurance. Starting with the no-deductible case, we have the following outcomes:

Case 2A: No Deductible		Insurance Payouts and Wealth		
"Big one" in which 300 homes are affected (100 homes in each distance category) (Probability of 1st quake in N. or S. = ½)		Distance from Epicenter: Near	Middle	Far
		p = 1/3	p = 1/3	p = 1/3
Payout to residents of zone where 1st earthquake occurs	Actual Loss	3.0	2.0	1.0
	Insurance Payment	1.5	1.0	0.5
	Final Wealth	3.5	4.0	4.5
Total actual claim payments = $300				
Payout to residents of zone where 2nd earthquake occurs	Actual Loss	3.0	2.0	1.0
	Insurance Payment	0	0	0
	Final Wealth	2.0	3.0	4.0
Total actual claim payments = $0				

The result is that \$300 of claims are paid to the residents of the zone facing the 1st earthquake, which leaves no resources available to the residents of the zone in which the 2nd earthquake occurs. The insurance company has both premium income and loss payments of \$300, so it breaks even. Given that each resident faces a 50% chance of living in the zone of the 2nd earthquake, the final wealth distribution created by this contract would appear undesirable.

As an alternative, now consider a contract with a deductible d, with d = 1.75. The policy premium is again set at \$1 per home and is used to purchase a total of \$300 of reinsurance. We then have the following outcomes:

Case 2B: Deductible (d = 1.75)		Insurance Payouts and Wealth		
"Big one" in which 300 homes are affected (100 homes in each distance category) Probability of 1st quake in N. or S. = ½)		Distance from Epicenter: Near	Middle	Far
		p = 1/3	p = 1/3	p = 1/3
Payout to residents of zone where 1st earthquake occurs	Actual Loss	3.0	2.0	1.0
	Insurance Payment	1.25	.25	0
	Final Wealth	3.25	3.25	4.0
Total actual claim payments = \$150				
Payout to residents of zone where 2nd earthquake occurs	Actual Loss	3.0	2.0	1.0
	Insurance Payment	1.25	.25	0
	Final Wealth	3.25	3.25	4.0
Total actual claim payments = \$150				

The result is that \$150 of claims are paid to the residents of each zone, so the payout is independent of whether the resident lives in the zone receiving the 1st or 2nd earthquake. The insurance company has both premium income and loss payments of \$300, so it breaks even.

The deductible contract 2B is preferred by all risk averse individuals, since the final wealth created by the no-deducible contract 2A is a mean preserving spread of the final wealth created by the deductible contract 2B. This preference may have been what motivated the CEA to offer a contract with a very large deductible. In any case it is clear that a contract with a large deductible was viewed as a way of conserving limited capital and lowering the amount and/or occasions when they would need to pro-rate.

Ex-Post Assessments

Turning to the other key aspect of the contract, it has recently been shown by Louberge and Schlesinger [1999] that under a certain condition an ex post assessment is expected utility increasing for an agent who is not fully insured. The condition is that the ex post assessment be made against a risk pool which is not perfectly correlated with the insured's own risk. This condition is met in the CEA contract because losses in say the northern part of the state are not perfectly correlated with losses in the southern part of the state. On the other hand it should be noted that in the case of the CEA, the ex post assessment is voluntary since all an insured has to do to avoid paying it is to cancel the policy.

Behaviorial Assumptions

From the point of view of an expected utility maximizer, then, the CEA contract may be thought to do a reasonable job. From a marketing standpoint, however, the contract has not been a success. The CEA's own prediction was premiums written of $1 billion by the end of the first full year of operation. The actual premiums seem to be settling down to about $400 million annually, 40% of what was expected. There may be many explanations for this. Here we examine the possibility that in fact purchasers of insurance are not expected utility (EU) maximizers, and that the features of the contract which might be appealing to agents with that preference structure are viewed as undesirable by agents with preference structures more in line with those proposed by behaviorists.

Indeed, in the case of insurance demand, the assumption of expected utility maximization seems particularly difficult to justify. For example, it is known that individuals choose levels of deductibles below that predicted by the EU hypothesis. The first empirical study to find this, (a study of demand for deductibles in auto insurance), Pashigian et.al. [1966], concluded as follows"

> "The results of these preliminary tests suggest that consumers do not act in accordance with the EU hypothesis when selecting a deductible for collision loss."

Although this conclusion is not independent of the functional form chosen by these investigators, as noted by Johnson et al [1993, p.36]:

> "there is abundant evidence, although much of it is anecdotal, that consumers do not make these choices rationally."

This suggests that it would be useful to consider the question of insurance contract design not under the EU hypothesis, but rather under the assumption that individuals exhibit the behavioral regularities now known to characterize decision making under uncertainty. This process has been started by Rode, Fischhoff, and Fischbeck [1999] in the context of private markets. The importance of behavioral variables is also stressed by Bantwal and Kunreuther (forthcoming) in their analysis of the pricing of insurance based assets. We concentrate here on the fact that the CEA can offer only partial insurance. [13]

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[13] The CEA explicitly recognizes the partial nature of its insurance. The contract states " In accordance with California Insurance Code Section 10089.35, if at any time the available capital of the CEA is insufficient to meet anticipated losses… the CEA may pay claims on a pro rata basis from the remaining funds available.

Consumer Demand for Partial Insurance: Behavioral Issues

The offer of partial insurance is an inevitable consequence of the under funding of the scheme, though it is certainly possible that this fact is not recognized by those who purchased CEA policies. Indeed the very use of the word California in the title of the agency sets up a number of framing questions. For example, it would not seem unreasonable for consumers to assume that a CEA policy issued under the auspices of the Commissioner of Insurance of the State of California is backed by the full faith and credit of state government. We return to this issue in the next section.

Partial Insurance

We begin by defining partial insurance. Partial insurance arises whenever an insurer lacks sufficient capital to pay claims in the event of a large loss. From the consumer's viewpoint, partial insurance is a form of lottery.[14] We use the following notation:

Define L_i as the insured loss sustained by individual i in the event of a catastrophe.

Define I as the total insured catastrophe loss of the company that carries individual i's policy.

Define K as the capital available to this insurer to meet this catastrophe loss.

The payoff from this lottery is determined by the probability of total insured loss I relative to available capital K. Partial insurance will be said to exist whenever the purchaser of insurance recognizes ex ante that:

if $K \geq I$, the insured will receive full compensation for insured loss L_i.

if $K < I$, the insured will receive an indemnity pro-rated in some way to exhaust available capital. (For example, payouts determined by strict pro-ration would equal $(K/I)(L_i)$).

[14] More technically, partial insurance is a rather complex form of put option. The purchaser of the insurance has the right to sell the loss at a fixed price provided the amount of total loss does not exceed some threshold. Beyond that a varying fraction of the loss can be sold.

For a given quantity of capital, an insurance provider can vary the contractual terms of a partial insurance contract in a number of ways. Different contracts are then associated with different lotteries. What determines the demand for these different partial insurance contracts? The standard textbook answer to this question assumes that individuals maximize expected utility. This hypothesis was first applied to insurance demand in the early 1960s as an application of the then newly revived Bernoulli doctrine, see Arrow [1965] and Borch [1990].

In probabilistic terms, the purchase of insurance, full or partial, is the exchange of one probability distribution function over wealth w, say $F^1(w)$, for a less risky probability distribution function say $F^2(w)$, where the premium is included in $F^2(w)$. For an expected utility maximizer, (and even, in some cases for a Machina Generalized Expected Utility maximizer see Russell [1997]), the only question is whether the expected utility of $F^1(w) = \int u(w)dF^1(w)$ exceeds or falls short of the expected utility of $F^2(w) = \int u(w)d\, F^2(w)$.

The behavioral analysis of the insurance purchase decision departs from this hypothesis in two major ways:

a. In evaluating probability distribution functions, the EU maximization hypothesis is replaced with a descriptive hypothesis that is consistent with subject's observed behavior in the laboratory. At this time, the best developed behavioral hypothesis is Prospect Theory; see Kahneman and Tversky [1979], which is the hypothesis which will be used here.

b. Unlike the EU maximization hypothesis which reduces choice under uncertainty to a comparison of probabilities distribution functions, behavioral decision theory recognizes that the words used to describe choices can influence the outcome of choices whose probability density functions are identical. The presence of such 'framing' effects in insurance demand is well documented by Slovic et al [1982a].

We begin by examining partial insurance demand in terms of prospect theory.

Partial Insurance Demand and the Certainty Effect

One of the key differences between EU theory and Prospect Theory is the latter's prediction of a 'Certainty Effect,' in which 'the reduction of the probability of an outcome by a constant factor has more impact when the outcome was initially certain than when it was merely probable,' Tversky and Kahneman [1981] p.455. This 'certainty effect' already presents an obstacle to the selling or partial insurance. When Kahneman and Tversky gave subjects a choice between full insurance which the subjects found just acceptable and partial insurance (one half the coverage at one half the premium) 80 % of subjects preferred the full insurance though partial insurance in this case gives higher expected utility, see Kahneman and Tversky [1979].
Full insurance, of course, is not an option when capital is limited, but in this case the insured could be given a choice among several kinds of partial insurance contracts. The contract terms can be varied with respect to a) the deductible, b) the extent of coverage, and c) the size of the premium.

Deductibles

From the viewpoint of the certainty effect, an increase in the size of a deductible has two opposing consequences. In the first place, it clearly reduces the share of the loss taken by the insurance company and increases the share that falls on the insured. This moves the insured away from certainty. On the other hand, an increase in a deductible, by reducing required total capital in the event of loss, increases both the amount which can be paid per contract and the probability that the contracted amount will actually be paid. This moves the insured in the direction of certainty.

Which of these two effects will dominate is an empirical question. Because the size of the deductible is clear on the face of the contract, whereas the probability of being paid is more vague, we hypothesize that increases in the size of the deductible will reduce the number of policies sold. This hypothesis can be tested since, as of 1999, the CEA has offered two levels of deductible, allowing consumers the right to choose their preferred plan at some fixed cost.

Aside from the certainty effect, the large size of the deductible in the CEA policy seems to have also had a significant loss aversion effect. Many of our neighbors, for example, who live in homes with an insured value of say $400,000 [15] reason as follows. Since my deductible is $60,000, I will not be paid anything unless loss is quite substantial. In most earthquakes I will simply "lose" $60,000. This $60,000 is treated as a cost. As compared with this certain loss when I do buy insurance, if I do not buy insurance I risk an uncertain loss. But by the convexity of the prospect valuation function in the domain of losses, the gamble (to not insure) is chosen over the certain loss (of the deductible). Mental accounting like this clearly challenges the wisdom of the CEA's decision to conserve capital by having such a large deductible.

Extent of Coverage

Another way to make available capital go further is to limit the extent of the coverage of the contract. For example coverage can be restricted to the primary residential structure excluding garages, outhouses, swimming pools, etc. Again, limiting coverage has two effects vis a vis certainty. It moves the insured away from full coverage on the total property at risk. However it moves the insured closer to full coverage on that property which is actually insured. We

[15] For those not familiar with Northern California real estate prices, this sum represents a remarkably modest residence.

hypothesize that this second effect dominates in that consumers prefer full coverage of part of their property to partial coverage of all.

This hypothesis is consistent with the pseudo-certainty effect of Slovic, et al (1982b). They found that 40% of 211 subjects chose to be vaccinated against a disease when vaccination protected ½ of the recipients. However 57% of subjects chose to be vaccinated against 2 diseases when told vaccination would protect against one disease but not the other. Again, since the CEA now offers five different coverage options, this effect can be examined in the data.

Premiums

Exactly as in the other two cases, an increase in premiums has two effects. First higher premiums produce higher quality contracts by enlarging the resources available to pay claims. Second, as with any demand curve, higher premiums reduce the number of policies sold. Since demand is reduced by an increase in premiums but quality is increased, it is an empirical question whether higher premiums raise or lower demand. (In other areas of property casualty insurance, i.e. in auto insurance, the estimates of premium elasticity are quite high, see Jaffee and Russell [1997b]).

In each of these cases--deductibles, extent of coverage, and premiums--actions taken by an insurance provider to protect and enhance capital can, by reducing sales of policies, actually reduce capital. Whether or not this is the case requires detailed empirical analysis. Once we know how consumers are allocating themselves across the various deductible/coverage options, we will be in a better position to assess the welfare implications of different plan designs.

Could the CEA be Privatized? The Role of Framing

Since the CEA receives no public funds [16], the question arises as to why the private insurance industry did not come up with a similar scheme. One possible explanation is that by combining exposures from 12 insurance companies in one scheme, the CEA is able to diversify its risk. On the other hand a large insurance company such as Allstate or State Farm presumably already has risks spread throughout the state, so these firms are already geographically diversified. The fundamental advantage enjoyed by the CEA seems rather to be the benign behavioral response of the buyers of partial insurance to a contract offered under the imprimatur of the State of California . Consider how a limited liability private contract of insurance would need to be written:

> "In return for payment of premium, we agree to indemnify you for all insured losses unless total insured losses exceed X in which case we will see."

Aside from the legal question of whether or not such a contract would satisfy the obligation to offer earthquake insurance as a rider on homeowner's policies, it is clear that such an unusual contract (making the customer in effect the insurance company's reinsurer) would be met with very strong resistance.

Why has the CEA not encountered this problem? For us it is an open question whether or not the average purchaser is even aware that

i) The State of California has no liability for loss.

ii) The CEA can pro rate losses.

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[16] Strictly speaking, the CEA does receive a small indirect subsidy from both the Federal and the State government. For example, the net income of the CEA is accumulated free of Federal income tax. For 1997 and 1998, total net income amounted to $23m). Moreover, there is no state tax on premiums written. Also the CEA is not required to buy into the State Indemnity Fund. In addition the CEA's accumulated reserves now amounting to some $500m are immune from takeover by outside firms. These special benefits, however, seem very small in dollar terms.

iii) Assessments can be levied on the premiums to pay off bonds.

Since the scheme came out of the state legislature, it would not seem unreasonable for consumers to assume that a CEA policy issued under the auspices of the Commissioner of Insurance of the State of California is backed by the full faith and credit of state government. Again detailed empirical work is necessary to determine how this contract is being 'framed' in the buyer's mind.

5. CONCLUSIONS

Catastrophe insurance requires a very large pool of capital if there is to be a high degree of confidence that resources will be available to pay the claims that could be expected to result from the very largest events. In principle, this capital could be provided by private primary insurance companies or by quasi-state agencies. In fact, neither one is willing to provide this capital. The private insurance companies seem willing to pass up the likely profits of selling catastrophe insurance in order to avoid the "risk of ruin from a big one." State governments seem equally unwilling to place public resources at risk. The result is that the quasi-state catastrophe plans can do little more than use their premium income to purchase reinsurance.

Because capital is limited, the resulting policies reflect partial insurance. Higher premiums, however, may reduce the degree to which insurance is partial, since higher premiums allow more reinsurance to be purchased. Thus, while higher premiums raise the cost of the insurance, they also raise the insurance quality. It is therefore is an empirical question whether higher premiums raise or lower demand. If it is the case that consumers are unwilling to pay the higher premiums that are necessary to finance complete insurance contracts, this leaves the managers of the state plans in the quandary that they are damned if they do provide a complete coverage contract (because they premiums are then unacceptably high) and they are damned if they don’t (because consumers then lobby for more complete coverage).

Plan managers should also consider carefully how they design the various terms of the partial insurance, such as the deductible and the extent of coverage. These contract terms affect the demand for the insurance, although the direction of the effect is unclear, since it may depend on the consumers’ tradeoff between higher expected value versus higher certainty, on how the issues are framed, and similar issues. Were consumer preferences on these issues known, the partial insurance contracts could be designed to satisfy consumers as much as possible. We hope to shed light on these questions in our future empirical research.

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