Optimal Cap on Claim Settlements Based on Social Benefit Maximation

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Optimal Cap on Claim Settlements Based on Social Benefit Maximization

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Abstract

Caps on damages constitute one of the proposed reforms of the tort system, especially in the U.S. In this paper, we establish models to capture both the claimant’s and the insurer’s behaviors under a system whereby damages are capped. We also establish an objective function of maximizing the social benefit, expressed as the sum of claimant and insurer benefits. We examine the optimal upper limit that balances both claimant and insurer benefits. Our model implies that the optimal value of the upper limit should be the expected value of the random claim payment independent of the type of probability distribution the claim payment follows. Finally, we apply empirical data to our theory and arrive at an estimate of the optimal damage cap.
Introduction

In the ongoing debate concerning tort reform, caps on damages have been proposed as a possible solution to address the problem of increasing claims costs. One of the key purposes of such caps is to control insured losses, making insurance more available and affordable (Feldman, 2003; Gfell, 2003; and Liang, 2004). Supporters assert that caps would inhibit fraudulent claims and eventually help to reduce insurance premiums. Many states in the U.S. are considering passing, or have passed, legislation creating caps on damages, especially for non-economic damages. As an example, the crisis in medical malpractice insurance markets can be especially pronounced, and caps have been proposed as a method to help mitigate against such crises.

There are different views about the efficacy of caps. On one hand, many believe that caps reduce losses for insurers, pointing out reductions in losses in jurisdictions that enacted a cap, when compared with those states that did not. For example, Sloan, Mergenhagen and Bovbjerg (1989) found that, based on closed claim data for 1975 through 1978 (and through 1984), insurers paid 31% less in states with caps on non-economic damages, and 38% less in states with caps on total damages. Kessler and McClellan (1997) found that premiums were reduced by 8.4% in the first three years after a tort reform. Tort reform also reduced the likelihood that a physician would be sued. The U.S. Congressional Budget Office (1998) summarized that caps on non-economic damages “have been found extremely effective in reducing the amount of claims paid and medical liability premiums.” Viscusi and Born (2005) used NAIC data for the period 1984 to 1991 to show that caps on non-economic damages reduced losses by 17% and premiums by 6%. Encinosa and Hellinger (2005) found evidence that states with caps on non-economic damages increased the supply of physicians by 2.2% per capita, as compared to states without caps, after observing the impact of non-economic damage caps from 1985 to 2000.

On the other hand, critics contend that an arbitrary cap amount cannot work for every case. For small damages, the award may still be excessive. For greater damages, the compensation may not be equitable. Also, caps may not necessarily lead to reduction of insurance premium rates, as relatively high insurance premiums on medical malpractice insurance may be caused by other factors such as insurance cycles, weak competition or declines in investment returns earned by insurers (Zuckerman et al., 1990; Richard, 2012; and Paik et al., 2012).

Critics of tort reform often cite the case of California to argue that the non-economic caps do not work to reduce premium rates. When California passed the legislation on caps on non-economic damages at $250,000 in 1975, premium rates were reduced only for a short time and then continued to rise. By 1988, premiums on medical malpractice were up 450% in comparison with 1975. California then enacted California Insurance Code 1861.01, Proposition 103, which required every insurer to reduce its rate by at least 20%. Subsequently, malpractice rates decreased quickly and premium rates decreased by 30% or more within three years.
Many states have passed legislation to impose caps on claim payments. At the national level, the Help Efficient, Accessible, Low-Cost, Timely Healthcare (HEALTH) Act of 2003, which would have capped non-economic damage awards in medical malpractice actions at $250,000, was passed by the U.S. House of Representatives in May 2004 but was not passed in the Senate (Govtrack, 2004).

The literature on caps on claims and/or damages is dominated by legal analysis. Crocker and Morgan (1998) and Crocker and Tennyson (2002) were unique contributions by the virtue of creating a quantitative model. They study optimal insurance contracts and indemnification profile, when controlling for fraudulent claims for both first-party and third-party claim settlements from the insurer’s perspective. They optimize the insurer’s response to a potentially exaggerated or fraudulent claim. However, determining an optimal cap should also consider the benefit to consumers. Regulators, of course, should attempt to balance both claimants’ and insurers’ benefits, and consider all relevant risks. Shoben (2005) proposes a societal (and by implication, regulatory) perspective on the issue of caps on claims and/or damages by proposing the following three elements of a tort reform to address the issues of measured degree of wrongfulness, measured severity of harm and connectedness between the defendant’s wrong and the plaintiff’s injury. Shoben (2005) also proposes replacement of contingent attorney’s fee by an hourly rate for work done.

In our opinion, whether the cap on damages helps to decrease the insolvency probability of insurers, protect consumers, promote the demand and supply of liability insurance, and improve the social fairness depends on how to rationally determine the cap on damages by scientific methods and from the perspective of maximizing the social benefit. Caps that are too high, as well as caps that are too low, are not optimally beneficial to the realization of maximizing social welfare.¹

In our paper, we quantitatively study the optimal cap on claims and/or damages by analyzing both the behavior of claimants and insurers under tort reform law that puts caps on claims and/or damages paid by insurance. We analyze the problem from the regulators’ perspective. We study the following problem: How do we set up an optimal upper limit on claim damages if we want to balance benefits between insurers and claimants? Consumer protection regulators aim for damage awards large enough to properly compensate victims of negligence or of malfeasance. However, insurance regulators also have genuine interest in limiting the awards to levels that would not endanger insurer solvency. Hence, the issue at hand must be cognizant of consumer protection and the prudential regulatory perspectives.

¹ In the notes from Gfell (2004), he points out that while a national cap on non-economic damages in medical malpractice actions may pass constitutional muster, Congress would be wise to attempt less invasive limitations first. That is, Gfell suggests that Congress should seek better economic data upon which to base its decisions, and thus help to assure the crisis would be covered with minimal negative consequences.

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As a preview to our results, we get the intuitive theoretical result that the optimal cap on damages is the expected value of random loss. It implies that a cap on damages is not exogenous to the distribution of random loss. The frequency and severity distribution of liability injuries does affect the caps on damages.\(^2\) Therefore, the injured claimant can obtain fair claim payment. Based on our empirical data, our analysis indicates that the optimal cap on damages is far less than caps found in reality, such as caps for damages related to general liability insurance. For some other types of liability insurance (e.g., medical malpractice liability insurance), our analysis suggests that the insurer’s total claim payment without caps is much greater than that with caps. As more than one-half of U.S. states did not have caps on damages, the absence of caps may be one reason for the medical malpractice insurance crisis (besides long-tail liability and exaggerated losses to obtain higher judgment awards).

Our study is organized as follows: In the next section, we establish models used for the third-party claimant. Then, in the third section, we discuss the determination of optimal caps, based on the criterion of maximizing the social benefit. In the fourth section, we provide two important examples to illustrate the application of our models to the problem. We then present sensitivity analysis, and in the final section, we provide our conclusions.

**Models of Third-Party Claims Settlements**

We consider third-party liability insurance in which we assume the claimant and insurer to be risk-neutral. The claimant has a real loss of \(X\), which is only fully known to the claimant. However, the claimant files a claim of \(s \geq X\). The jurisdiction of the claim has an upper limit of claim damage of \(\theta\). The claim amount of \(s\) may still exceed the amount of \(\theta\), but the indemnification amount of \(I(s)\) paid by insurer must be less than or equal to \(\theta\). If insurer can identify the real amount of damage, then \(I(s) = X\) when \(X \leq \theta\). When the indemnification amount is greater than the real amount of loss, \(I(s) - X\) is the realized exaggerated claim amount for claimant. When the real loss is greater than \(\theta\), the highest claim possible is the amount of \(\theta\), and \(X - \theta\) is the loss for claimant after compensation. Let \(E(Y_1(\theta))\) be the expected terminal wealth of the claimant, and \(E(Y_2(\theta))\) be the expected terminal wealth of the insurer.\(^3\) Using that notation, we can write:

\(^2\) Gfell (2004) points out (in the notes to the article) that reforms that protect the public are what are needed, not reforms that blame the injured, the disabled, and victims of medical ineptitude and neglect. It is in this light that caps, based on the expected loss incurred to the injured, may help maximize social benefit.

\(^3\) When claimant and insurer are risk-neutral, their expected benefit functions are exactly the same as their utility functions. In the context of the theory of the firm, a risk-neutral firm facing risk about the market price of its product, and caring only about profit, would maximize...
Optimal Cap on Claim Settlements

\[ E(Y_1(\theta)) = \int_{\theta}^{\infty} [W_x - C_1(\xi, x, \theta) + I(s) - z] f(x) \, dx + \int_{\theta}^{z} [W_x - C_1(\xi, x, \theta) + \theta - x] f(x) \, dx \]

and

\[ E(Y_2(\theta)) = \int_{\theta}^{\infty} [W_x - C_2(\xi, x, \theta) + I(s) + x] f(x) \, dx + \int_{\theta}^{z} [W_x - C_2(\xi, x, \theta) + \theta + y] f(x) \, dx \]

Where \( W_x \) is the claimant’s initial wealth, and \( W_x \) is the insurer’s initial wealth. Also, \( C_1(\xi, x, \theta) \) represents the costs that the claimant incurs for the direct and indirect expenditures to set up claims. We model those costs as a function of \( \theta \), with \( C_1(\xi) \), and \( \xi \geq 0 \), where \( \xi \) is the cost parameter for the claimant. We assume that the claim costs for claimant under a regime of a cap on damages of \( \theta \) are strictly increasing with the deviation of real loss away from \( \theta \), and represent these costs with the following specific function:

\[ C_1(\xi, x, \theta) = \begin{cases} 
\xi_1(\theta - x)^2 & \text{when } x < \theta \\
0 & \text{otherwise}
\end{cases} \]

While this may seem like a simplification of the reality of costs (all economic costs, not necessarily just accounting costs) incurred by the claimant, we suggest that it is a reasonably good model of economic reality. On one hand, it intends to create a situation where as the real loss gets closer to the upper limit, or \( \theta - x \) is close to zero, the claimant is less likely to increase the costs through some form of exaggeration or misinformation since the exaggeration of claim loss above the upper limit \( \theta \) cannot be compensated by the insurer; and, on the contrary, the expenditures of setting up claims will increase. On the other hand, the smaller the real loss (the real loss being far below the damage cap), the more willing is the claimant to increase the costs.

the expected value of its profit (with respect to its choices of labor input usage, output produced, etc.).

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claimant to exaggerate the claim loss, even at the expense of increasing the cost of setting up claim. Therefore, it is necessary to impose a measure of control on the claim cost using the quadratic function of the difference between the cap on damages and real loss.

Similarly, \( C_2(\xi_2, x, \theta) \) is the insurer’s costs to investigate possible falsification of the claim by the claimant, set up a function of \( \theta, x \), and \( \xi_2 \), with \( \xi_2 \geq 0 \). We also assume that the associated cost to the insurer is increasing with the deviation of the real loss away from \( \theta \). When the loss approaches the cap imposed on the policy payout, the falsification cost is reduced along with the reduced investigation cost of insurer. Cost parameters are different for the two parties. As we stated above, \( \xi_1 \) is the cost parameter for the claimant, and now we introduce a similar parameter: \( \xi_2 \) to capture the insurer’s effects. The insurer’s cost function under a regime of a cap on claims and/or damages payout is expressed as:

\[
C_2(\xi_2, \theta, x) = \begin{cases} 
\xi_2^2(x - \theta)^2 & \text{when } x < \theta \\
0 & \text{otherwise}
\end{cases}
\]  

(4)

The key idea of this simplified costs model is that both the consumer and the insurer cost functions are designed so that large departures from the level of the cap result in costs increasing at an increasing rate.

**Determination of Optimal Cap by Maximizing Social Benefit Under Third-Party Claims**

The values of the cap on claim payments affect the benefits of both claimant and insurer. On one hand, when real damage \( X \) is less than the cap of claim payment, the claimant may tend to claim more payment than real damage, and the insurer will lose money (pay a larger claim) because of exaggerated claim payment. On the other hand, when real damage is larger than the cap of claim payment, the claim payment obtained by the claimant will be reduced in relation to the real loss, but the insurer will benefit because of less money paid than real damages. From the perspective of the insurer, its benefits are maximized via the following optimization problem:
\[
EY_i(\theta) = \max_{\theta} \int_{0}^{\theta} \left( W_i - C_i(x, \theta) + \lambda(x) - x \right) f(x) dx + \int_{\theta}^{\infty} \left( W_i - C_i(x, \theta) + \lambda(x) - x \right) f(x) dx
\]

The optimization problem of the claimant is maximizing his (her) claim benefit. That is,

\[
E(Y_2(\theta)) = \max_{\theta} \int_{0}^{\theta} \left( W_i - C_2(x, \theta) - I(x) - x \right) f(x) dx + \int_{\theta}^{\infty} \left( W_i - C_2(x, \theta) - I(x)^2 - x \right) f(x) dx
\]

Generally, these two objectives cannot be realized simultaneously since the benefits of insurers and the claimants are in conflict. A regulator must consider social fairness, balancing the benefits of both insurer and claimant, and decreasing social costs in determining the cap of the claim. What is optimal for regulators is to determine optimal cap based on the objective of maximizing the social benefit, expressed as the sum of the benefit of the insurers and the claimants\(^4\)—that is, maximizing

\[
E(Y) = E(Y_1(\theta)) + E(Y_2(\theta)) = \int_{0}^{\infty} \left( W_i + W_i - C_1(x, \theta) - C_2(x, \theta) \right) f(x) dx = \int_{0}^{\infty} \left( W_i + W_i \right) f(x) dx - \int_{0}^{\infty} \left( C_1(x) + C_2(x) \right) f(x) dx
\]

We find from objective function (7) that if we determine the optimal cap on damages according to the objective function of \( \max E(Y) \), we can maximize the wealth of both insurer and the claimant (the first term of the right side of objective function (7)), and at the same time, minimize the cost of both insurer and the claimant (the second term of the right side of objective function (7)).

This optimization problem is solved in the Technical Appendix, where it is shown that the solution is surprisingly simple:

\(^4\) The Nash (1950) solution maximizes the value of the product of the two utilities. The Thomson (1981) solution maximizes the sum of the two utilities. Mao and Ostaszewski (2007) determine the optimal participating rate by maximizing the sum of the benefit of the insurer and the insured.

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The optimal level of a cap on damages is the expected value of real economic loss:

$$\theta^* = E(X).$$ (8)

It is also important to note the following two points. One, the optimal cap can easily be dynamic, if the type of distribution of loss remains the same. That is, $\theta^*(t) = E(X_t)$. For example, if the loss follows lognormal distribution with parameters of $\mu_t$ and $\sigma_t$, then the optimal cap is:

$$\theta^*(t) = e^{\frac{1}{2} \sigma^2(t) \cdot \mu(t)}$$ (9)

Therefore, we can dynamically change the optimal cap when the parameters of loss distribution change. Two, the optimal cap is endogenous to the distribution of random loss to the injured and the frequency and severity do affect the value of optimal cap. Therefore, the injured claimant can obtain the fair claim payment. Based on the analysis above, our theoretical model appears to produce a reasonable and intuitively appealing result.

Further, the optimal level of terminal social benefit is:

$$E(Y^*) = W_\xi + W_\gamma - \left( \xi + \xi + \gamma - \gamma \right) \text{Var}(Y),$$ (10)

It is the sum of initial wealth from which we subtract the sum of the cost parameters multiplied by the variance of the real loss. This means that both the riskiness of the real economic loss, represented by its variance, and costs to the claimants and the insurance companies, affect the optimal terminal wealth. Notably, the costs to the claimants and to the insurance company have equally negative effect on the final social outcome (although, of course, the cost parameters may vary between the two, but the key point is that if we increase one of them at the expense of the other, the net effect on the society is zero).

Let us note that the key parameter estimated for the practical application of the model is the expected value of the real economic losses to the claimant. This is, of course, a key parameter sought in actuarial analysis by insurance firms in setting premiums and is likely to be studied by both insurance companies and regulators. Furthermore, it is a relatively simple concept that can be presented to the public in general, and to juries in particular, to justify the existence of a cap on payments.

Finally, there exist many statistical procedures for estimating it, even in the situation when data are limited. If data are perfectly available, a method of moments or a maximum likelihood estimator can be easily applied. But even if data are censored or grouped, certain statistical methodologies can be applied.
only data for cases with caps already applied are available, the data are right-censored. Datta (2005) shows a possible statistical methodology to be applied in such a situation. Below we give an example of estimation of the expected value parameter for grouped data, when only ranges of data are available, and not all individual cases. (This situation may be encountered in practice by both insurance actuaries and insurance regulators.)

Examples to Illustrate Our Results on Optimal Caps

Example 1: General Liability Insurance

Table 1 lists the average claim payment of 217 general liability insurance policies. The claim payment is divided into several intervals (the first column) within the minimum value zero and the maximum value $300,000, which is the policy upper limit. The second and third column, respectively, list the number of claims and the average claim payment in which the claim payment for each time falling in each interval (the data are used by Xiao, 2008, and originates from Klugman et al., 1998).5

We will now illustrate our result by calculating an estimate of the parameter of the mean economic loss, which in the model proposed here is equal to the optimal level of damages cap. We could estimate it from the sample mean, but given that the data are grouped, it is more reasonable to attempt to fit a probability distribution and then use an estimation of that distribution’s mean. By examining the data, we hypothesize that the lognormal distribution is a good fit. In the Appendix, we perform a test of this hypothesis (the chi-square goodness of fit test) and find that the distribution can be used to model this data. We also find (in the technical calculation) the estimates of the distribution’s parameters, and we use them in the analysis that follows.

5. We use general liability insurance as an example since firms generally purchase this coverage as one of the first steps to protect their assets. This safety net is critical in a society in which the number of lawsuits and the value of judgment awards have increased over time (Howell, Commercial General Liability Insurance Definition]: www.ehow.com/about_5184654_commercial-general-liability-insurance-definition.html).
Table 1:  
Average Claim Payment in Dollars

<table>
<thead>
<tr>
<th>Claim payment</th>
<th>Number of claims</th>
<th>Average claim payment in dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0–$2,500</td>
<td>41</td>
<td>$1,389</td>
</tr>
<tr>
<td>$2,500–$7,500</td>
<td>48</td>
<td>$4,661</td>
</tr>
<tr>
<td>$7,500–$12,500</td>
<td>24</td>
<td>$9,991</td>
</tr>
<tr>
<td>$12,500–$17,500</td>
<td>18</td>
<td>$15,482</td>
</tr>
<tr>
<td>$17,500–$22,500</td>
<td>16</td>
<td>$20,232</td>
</tr>
<tr>
<td>$22,500–$32,500</td>
<td>14</td>
<td>$26,616</td>
</tr>
<tr>
<td>$32,500–$47,500</td>
<td>16</td>
<td>$40,278</td>
</tr>
<tr>
<td>$47,500–$67,500</td>
<td>12</td>
<td>$56,414</td>
</tr>
<tr>
<td>$67,500–$87,500</td>
<td>6</td>
<td>$74,985</td>
</tr>
<tr>
<td>$87,500–$125,000</td>
<td>11</td>
<td>$106,851</td>
</tr>
<tr>
<td>$125,000–$225,000</td>
<td>5</td>
<td>$184,735</td>
</tr>
<tr>
<td>$225,000–$300,000</td>
<td>4</td>
<td>$264,025</td>
</tr>
<tr>
<td>$300,000*</td>
<td>3</td>
<td>$300,000</td>
</tr>
</tbody>
</table>

* Here the claimants with real loss in excess of $300,000 can only obtain the claim payment of $300,000 from the insurer due to that being the upper limit set by the insurer.

Therefore, the estimated optimal value of the cap on the damages award is the expected value of that lognormal distribution:

\[
\Theta^* = E(X) = e^{\hat{\mu} + \frac{\hat{\sigma}^2}{2}}
\]  
(11)

and the optimal expected value of social benefit is:

\[
E(Y^*) = W_{\hat{\mu}} + W_{\hat{\sigma}} \left( e^{\hat{\mu} + \frac{\hat{\sigma}^2}{2}} - 1 \right)
\]  
(12)

Substituting the estimates of the parameters \(\hat{\mu} = 9.29376, \hat{\sigma} = 1.62713\) into equation (11), we obtain an estimate of the optimal damages cap \(\Theta^* = 40844.85\). Figure 1 is the empirical function of cumulative probability distribution fitted using the data in Table 1. It should be noted that while we do not know the exact number of policies/claims affected by the cap, the number represents only approximately 25% of all claims; this does not appear to be an overwhelming restriction, but assessment of how significant the restriction is depends on one's perspective on the effect of the cap on consumers' rights, insurance companies' solvency and overall societal welfare. The optimal social benefit is, of course, dependent on the wealth levels and risk parameters. (But, let us note, the optimization process itself is independent of those quantities, as the optimal cap is...
set without reference to them; it is derived only as the mean of the economic loss random variable.)

Figure 1:
Empirical Function of Cumulative Probability Distribution of Claim Payment Fitted Using the Data in Table 1

It is important to note the contrast between the cap determined here based on the expected value of insured loss and caps in reality. The example discussed by us shows that the cap in the real world ($300,000) is much greater than the cap determined by us (about $41,000). In fact, Table 1 shows that only three claims appear in which the real loss is greater than $300,000, while the total number of claims is as large as 217. Thus, only 1.4% of claims exceed the $300,000 limit. Therefore, high values of caps play little role in decreasing claim payment by insurers. On the contrary, high caps will encourage claimants to take risks without experiencing the true costs associated with these risks, thus inviting moral hazard.6

Example 2: Medical Malpractice Insurance

The professional liability insurance (PLI) system is the primary funding mechanism for defending medical malpractice claims and indemnifying successful

6. Eling (2012) used the indemnity loss data of general liability from Free and Valdez (1998) (which was randomly chosen from late settlement lags and were provided by the Insurance Services Office) to fit the empirical distribution of the indemnity loss using the goodness-fit-test. Those results show that the log-normal distribution is one of best distributions to fit the indemnity loss. The expected indemnity loss they estimate is $41,210, and the average upper limit of policies is $509,598. Comparing the result from Eling (2012) to our result, we find that the two estimates of the expected indemnity loss for general liability insurance are quite similar. However, the average upper limit of policies for Eling is even larger than that for our example, which further illustrates that the upper limits for general liability insurance in U.S. are relatively high.
negligence lawsuits (Amon and Winn, 2004). Thus, large claim payments on medical liability insurance by insurers may be one important reason for liability insurance crisis. Several empirical papers study medical malpractice insurance markets (e.g., Karl and Nyce, 2014; Born et al., 2009; Lei and Schimit, 2006; and Kane and Emmons, 2006). In this second example, we study medical malpractice insurance from a different perspective. We use our theoretical model to determine the optimal cap with the empirical data from the “real world.” Table 2 shows the number of claims by size of indemnity payment of medical malpractice insurance in Connecticut from the 4th quarter of 2005 through 2007.

Table 2: Size of Indemnity Payments (2005 4th Q–2007)

<table>
<thead>
<tr>
<th>Indemnity Payment</th>
<th>Number (%) of Claims with Indemnity Payments</th>
<th>Total (%) Indemnity Payments</th>
<th>Average Indemnity Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1–$59,999</td>
<td>281 (41.1%)</td>
<td>$19,022,842 (2.4%)</td>
<td>$38,871</td>
</tr>
<tr>
<td>$100,000–$109,999</td>
<td>70 (10.2%)</td>
<td>$810,704,918 (2.3%)</td>
<td>$162,027</td>
</tr>
<tr>
<td>$200,000–$299,999</td>
<td>45 (6.6%)</td>
<td>$11,463,291 (2.5%)</td>
<td>$254,740</td>
</tr>
<tr>
<td>$300,000–$399,999</td>
<td>46 (6.7%)</td>
<td>$16,110,001 (3.6%)</td>
<td>$354,565</td>
</tr>
<tr>
<td>$400,000–$499,999</td>
<td>36 (5.3%)</td>
<td>$16,971,917 (3.7%)</td>
<td>$466,137</td>
</tr>
<tr>
<td>$500,000–$599,999</td>
<td>13 (1.9%)</td>
<td>$7,190,000 (1.6%)</td>
<td>$550,769</td>
</tr>
<tr>
<td>$600,000–$699,999</td>
<td>17 (2.5%)</td>
<td>$11,359,923 (2.4%)</td>
<td>$650,584</td>
</tr>
<tr>
<td>$700,000–$799,999</td>
<td>31 (4.5%)</td>
<td>$23,200,716 (5.1%)</td>
<td>$761,313</td>
</tr>
<tr>
<td>$800,000–$899,999</td>
<td>19 (2.8%)</td>
<td>$16,197,500 (3.5%)</td>
<td>$852,500</td>
</tr>
<tr>
<td>$900,000–$999,999</td>
<td>26 (3.8%)</td>
<td>$25,569,184 (5.6%)</td>
<td>$984,584</td>
</tr>
<tr>
<td>$1,000,000 and over</td>
<td>100 (14.6%)</td>
<td>$30,792,097 (67.3%)</td>
<td>$3,087,521</td>
</tr>
<tr>
<td>Total</td>
<td>684 (100%)</td>
<td>$45,591,591</td>
<td>$670,455</td>
</tr>
</tbody>
</table>

* Since the range of $1 million and over in the last line of Table 2 is so large, it results in a very large number and percentages of claims falling in this interval. We address this aspect of the data by dividing this portion of the data into four intervals and assume the number of claims uniformly falls in these four internals.

Source: Connecticut Insurance Department, Connecticut Medical Malpractice Annual Report, March 2008

Figure 1 describes the empirical function of cumulative probability distribution (CDF) using the data in Table 2. The data clearly fit the lognormal distribution quite well. We calculate the values of parameters of lognormal distribution by maximum likelihood estimation and obtain \( \mu = 12.1015 \), \( \sigma = 1.4577 \). We use the Kolmogorov-Smirnov test and obtain the value of the test statistic STAT=0.2682. Since the critical value for determining whether to reject
the null hypothesis is 0.3912, which is greater than the value of the test statistic, we do not reject the null hypothesis.

Figure 2:
Empirical Probability Distribution of Claim Payment Fitted Using the Data in Table 2

Thus, our theoretical model calculates that, based on the data, the optimal damages cap should equal:

\[
\theta^* = e^{\frac{1}{2} \hat{\sigma}^2 + \hat{\mu}} = e^2 \cdot 4.4577 = $521,230 \text{ (dollars)}.
\]

We know from Avraham (2014) that the state of Connecticut has not set a cap on damage for medical malpractice insurance. Thus, the total claim payments here are relatively large. Setting the damage cap at the amount suggested by our model, $521,230, would reduce the total claim loss paid by insurers. The total claim payment with this cap is about 24% of that without the cap.

In Appendix Table A2, we list the caps of 20 states set by state legislation from 2005 to 2007. Comparing the data in Table A2, the cap of $521,230 from our analysis here is close to those set by five states: Florida, Illinois, Mississippi, North Dakota and Utah. The cap we calculate is lower than that set by Maryland, and it is higher than caps set by the states of Alaska, California, Colorado, Georgia, Idaho, Kansas, Missouri, Nevada, Oklahoma, South Carolina and West Virginia. We note that more than one-half of the U.S. states did not set caps, and this may be one of the important reasons related to the medical malpractice crisis in the U.S., along with other reasons such as long-tail liability and exaggerated losses to obtain higher judgment awards.
Sensitivity Analysis in the Lognormal Model of Claims Distribution

Taking the partial derivative of equation (11) with respect to the parameters $\mu$ and $\sigma$ of the lognormal distribution used in that model, we obtain:

\[
\frac{\partial \theta^*}{\partial \mu} = e^{\frac{\sigma^2}{2}} > 0 \tag{12}
\]

\[
\frac{\partial \theta^*}{\partial \sigma} = e^{\frac{\sigma^2}{2}} \mu > 0 \tag{13}
\]

From equations of (12) and (13), we see that the optimal value of the cap is an increasing function of both $\mu$ and $\sigma$ parameters of the loss distribution under the assumption that the claim loss follows the lognormal distribution. By dividing equation (12) by equation (13), we also obtain:

\[
\frac{\partial \theta^*}{\partial \mu} \cdot \frac{\partial \theta^*}{\partial \sigma} = e^{\frac{\sigma^2}{2}} \mu > 0 \tag{14}
\]

Equation (14) shows that when $\sigma > 1$, the sensitivity of the cap on payments to the parameter $\mu$ is smaller than its sensitivity to the parameter $\sigma$, and the opposite is true when $\sigma < 1$. In fact, the ratio of sensitivity to $\sigma$ to sensitivity to $\mu$ equals exactly $\sigma$, which is, let us recall, the standard deviation of the normal distribution obtained by taking the natural logarithm of the lognormal random variable. Since lognormal distribution is a reasonable model for many realistic models of claims distributions, our work suggests that for more volatile claims distributions, caps on claims will be more sensitive to the volatility parameter of the claim distribution, while for more stable claims distributions, sensitivity to the parameter $\mu$ will dominate.

---

7. The distributions of loss often used in actuarial science generally have the characteristics of asymmetric, non-negative and with fat tail, etc. Based on these characteristics, we usually select models with two parameters, such as: lognormal distribution, Weibull distribution, Gamma distribution (Xiao, 2008). We have tested that we can use lognormal distribution to describe the individual claim distribution in our example.
Implications and Conclusion

This paper develops models to analyze both claimant and insurer behaviors with caps on claim damage for third-party insurance. We establish the optimal strategy for regulators to set the cap to balance both the claimant and insurer’s benefits, considering different risks, based on the criterion of maximizing social benefit. The cap and the cost parameter can be used to control the claimant’s claim inflation. As there is information asymmetry for the amount of damage, the regulator and insurer hardly capture the actual loss amount, especially for the non-economic loss. Our analysis suggests that the optimal value of the cap, considering the maximization of social benefit, should be the expected value of random loss amount independent of the kind of probability distribution it follows.

For losses that are relatively easy to evaluate in terms of their real amount (e.g., economic losses), regulators may consider capping the damage awards on a case-by-case basis, following the principles of equitable justice. But the principle developed here is a simple and practical guide even for such case-by-case evaluations. We acknowledge that our paper utilizes a static equilibrium model, and this is undoubtedly its limitation. There are significant dynamic processes involved in consideration of incentives of all parties involved in legal damages caps. But, such dynamic processes require a more complex multi-period model, and must include incentives faced by the injured party, insurance company and political decision-makers. We consider our work to be a first step toward such a complex model, and creation of such a model is reserved for a far larger and longer-term research project.

Our calculation with empirical data indicates that the cap determined by us in general liability policies is much less than caps observed in the real world. Our other example for medical malpractice insurance indicates that the insurer's total claim payment is much higher without caps than that with caps determining based on the expected loss. The fact that many states have not set caps on damage might be one of the main reasons for the crisis of medical practice insurance in the U.S. We believe that our work may be a valuable contribution in the ongoing debate on managing the cost of claims and the issue of imposing a legal cap on them.

Because insurance regulators are focused on the solvency of insurers, regulators may tend to favor damage award caps in order to reduce the likelihood of insurer insolvency. Similarly, insurance regulators are concerned with insurance pricing, and regulators also may tend to favor caps on damage awards as a way to reduce the expected costs of insurance. Our analysis on optimal damage caps provides insurance regulators with results that shed light on optimum cap levels. The analysis, thus, can help insurance regulators to better achieve the goals of insurer solvency and consumer protection. Of course, others may also need to consider factors such as trying to limit frivolous litigation, decreasing moral hazard and holding parties responsible for their behavior, which might suggest increases in the level of caps or even the removal of caps on damage awards.

In future work, we hope to focus on the reasons that for some liability
insurance (e.g., general liability insurance) the value of optimal cap observed in reality, while for other types of liability insurance (e.g., medical malpractice), the value of the optimal cap is close to that observed in reality. Another further study may focus on determining optimal cap on damages and corresponding premium considering dynamic incentives of the potential injurers and corresponding injury phase of the environment.  

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8. We thank an anonymous reviewer for this suggestion.
Technical Appendix

1. Derivation of the Optimal Solution to the Problem Stated in Equation (7)

In order to maximize the quantity in equation (7), we use the Leibniz formula with equation (7) and obtain the following equation:

\[
\frac{dE(Y)}{d\theta} = \int_0^\theta \frac{d}{d\theta} \left( \xi_1 + \xi_2 \right) (\theta - x)^i f(x) dx - \left( \xi_1 + \xi_2 \right) (\theta - \ell)^2 f(\theta)
\]  

\[= \int_0^\theta (\xi_1 + \xi_2) (\theta - x) f(x) dx \]  

(A1)

Setting equation (A1) equal to zero, we obtain:

\[
\frac{dE(Y)}{d\theta} = \int_0^\theta (\xi_1 + \xi_2) (\theta - x) f(x) dx = 0 \]  

(A2)

Note that since

\[
\frac{\partial^2 E(Y)}{\partial \theta^2} = -\int_0^\theta 2(\xi_1 + \xi_2) f(x) dx < 0,
\]

i.e., when the first derivative is zero, the second derivative is negative, the optimal value obtained by solving the equation (A2) will yield a maximum. By solving the equation (A2), we can obtain the optimal cap of claim \( \theta^* \) maximizing the social benefit. From equation (A2), we see that the optimal solution \( \theta^* \) satisfies the condition \( E(X - \theta^*) = 0 \) so that

\[
\theta^* = E(X) = \frac{\xi_1 + \xi_2}{1 + \varrho}
\]  

(A3)

From the equation (A3), we see that the cap of claim is unrelated to the parameters of claim cost and settlement cost \( \xi_1 \) and \( \xi_2 \), while it is only dependent on the expected value of the loss distribution. Substituting equation (A3) into equation (7), we obtain the optimal social benefit:
\[ E(Y^*) = \int_0^\infty \left( W_{\gamma_1} - W_{\gamma_2} \right) f(x)dx + \frac{1}{\sigma} \left( -\xi_1 (x - E(x))^2 - \xi_2 (x - E(x))^2 \right) f(x)dx \]
\[ = W_{\gamma_1} + W_{\gamma_2} - \left( \frac{\xi_1^2 + \xi_2^2}{\sigma^2} \right) \text{var}(X). \]

(A4)

2. Chi-Square Goodness of Fit Test for the Lognormal Distribution
(For this appendix, we refer to Xiao, 2008.)

1) Use \( \chi^2 \) goodness of fit test and based on its outcome assuming that claim payment can be taken to originate from a lognormal distribution. Its density function is:

\[
f(x) = \begin{cases} 
\frac{1}{\sigma \sqrt{2\pi x}} e^{-\frac{1}{2} \left( \frac{\ln x - \mu}{\sigma} \right)^2} & x \geq 0, \\
0 & x < 0, 
\end{cases}
\]

(A5)

2) Perform a hypothesis test with the null hypothesis \( H_0 : F(x) = F_0(x, \mu, \sigma) \) and \( H_1 : F(x) \neq F_0(x, \mu, \sigma) \), where \( F(x) \) is the cumulative distribution function of the lognormal distribution, and \( \mu, \sigma \) are its parameters. (They are not the mean and variance of the lognormal distribution, but of the normal distribution equal to the natural logarithm of the lognormal variable.)

3) Use the distribution function chosen to calculate the expected values:

\[ E_0 = n F_0(c_0, \hat{\mu}, \hat{\sigma}), \]

(A6)

\[ E_j = n \left( F_0(c_j, \hat{\mu}, \hat{\sigma}) - F_0(c_{j-1}, \hat{\mu}, \hat{\sigma}) \right), j = 1, \ldots, r - 1, \]

(A7)

\[ E_r = n \left( 1 - F_0(c_r, \hat{\mu}, \hat{\sigma}) \right), \]

(A8)
Where \( n \) is sample size, and \( \hat{\mu}, \hat{\sigma} \) are values obtained from maximum likelihood estimation and consider the following statistic:

\[
Q = \sum_{j=1}^{r} \left( \frac{n_j - E_j}{E_j} \right)^2,
\]

where \( Q \sim \chi^2(r - k - 1) \) and \( k \) is the number of unknown parameters. If

\[
Q > \chi^2_{(r - k - 1)},
\]

reject the hypothesis of \( H_0 \) and the distribution assumed is not a suitable distribution for the data.

(4) Calculate the values of parameters by maximum likelihood estimation and obtain: \( \hat{\mu} = 9.29376, \hat{\sigma} = 1.62713 \). Using the equations (A6), (A7) and (A8), the following results are obtained:

\[
E_0 = 217\Phi\left( \frac{\ln(2500) - 9.29376}{1.62713} \right) = 39.75,
\]

and similarly \( E_1 = 49.17, E_2 = 27.00, \ldots \), etc. can also be obtained. The results are listed below in Table A1.
<table>
<thead>
<tr>
<th>Claim Payment</th>
<th>Number</th>
<th>$E_j$</th>
<th>$Q_j = \frac{(n_j - E_j)^2}{E_j}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–$2500</td>
<td>41</td>
<td>39.75</td>
<td>0.04</td>
</tr>
<tr>
<td>$2500–$7500</td>
<td>48</td>
<td>49.17</td>
<td>0.03</td>
</tr>
<tr>
<td>$7500–$12,500</td>
<td>24</td>
<td>27.00</td>
<td>0.33</td>
</tr>
<tr>
<td>$12,500–$17,500</td>
<td>18</td>
<td>17.55</td>
<td>0.01</td>
</tr>
<tr>
<td>$17,500–$22,500</td>
<td>16</td>
<td>12.48</td>
<td>0.51</td>
</tr>
<tr>
<td>$22,500–$32,500</td>
<td>14</td>
<td>16.70</td>
<td>0.44</td>
</tr>
<tr>
<td>$32,500–$47,500</td>
<td>16</td>
<td>14.77</td>
<td>0.10</td>
</tr>
<tr>
<td>$47,500–$67,500</td>
<td>12</td>
<td>11.18</td>
<td>0.06</td>
</tr>
<tr>
<td>$67,500–$87,500</td>
<td>6</td>
<td>6.71</td>
<td>0.07</td>
</tr>
<tr>
<td>$87,500–$125,000</td>
<td>11</td>
<td>7.22</td>
<td>1.98</td>
</tr>
<tr>
<td>$125,000–$225,000</td>
<td>5</td>
<td>7.68</td>
<td>0.94</td>
</tr>
<tr>
<td>$225,000–</td>
<td>7</td>
<td>6.79</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Sum | 4.51 |
Since

\[ Q = 4.51 < \chi^2_{0.05}(12 - 2 - 1) = 16.92, \]

it is failed to reject the hypothesis \(H_0\), and thus we proceed with the model that takes the lognormal distribution as a suitable one for representing the amounts of claims in this context.

Table A2:
The Values of Caps of Medical Malpractice Insurance for 20 States in the U.S. in 2005 4th Q to 2007\(^{(9)}\)(Thousand Dollars)

<table>
<thead>
<tr>
<th>Name of State</th>
<th>Cap in 2005</th>
<th>Cap in 2006</th>
<th>Cap in 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>California</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Colorado</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Florida</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Georgia</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Hawaii</td>
<td>375</td>
<td>375</td>
<td>375</td>
</tr>
<tr>
<td>Idaho</td>
<td>260</td>
<td>270</td>
<td>280</td>
</tr>
<tr>
<td>Illinois</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Kansas</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Maryland</td>
<td>645</td>
<td>660</td>
<td>675</td>
</tr>
<tr>
<td>Mississippi</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Missouri</td>
<td>580</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Nevada</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>North Dakota</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>South Carolina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Dakota</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Texas</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Utah</td>
<td>430</td>
<td>430</td>
<td>430</td>
</tr>
<tr>
<td>West Virginia</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
</tbody>
</table>

9. The data in this table is selected from the database (in the clever file) of Avraham, Ronen (May 2014). The states that are not listed in the table have not set caps during these three years.
References


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