Insurance Claim Operations: The Role of Economic Incentives

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Abstract

We develop a theory of insurance claim settlement whose structure embodies an insurer's capacity decision and negotiation between the insurer and claimant in an asymmetrically informed environment. We offer a solution to an insurer's choice of upfront claim settlement amount under a plausible set of assumptions. Implications from theory are tested with a large sample of liability insurance claims collected over two years in the state of Texas and we find that insurer's deployment of more capacity to handle a claim and longer settlement times occur for claims with more uncertainty. The empirical results also reveal factors relevant to insurer's operational choices. Descriptive features of a claim, the age of the claimant and attorney representation on the plaintiff's side are important determinants of the final settlement amount.

Keywords: insurance, claims, economic incentives, capacity

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1. Introduction

Consider parties to an insurance claim each of whom has an interest in a fair settlement outcome. The insurer, who bore the risk originally, is interested in paying the appropriate amount for the claim given the contract it sold, including the elements of risk it thought it had assumed when it received actuarially determined consideration at original issuance. The insured party, who transferred the risk originally and paid a premium for the opportunity, is interested in immunizing its balance sheet when an insured event occurs. In a liability context, the injured party who was neither party to the original insurance contract nor expecting to incur a loss, now must engage with the insurer to restore the loss it incurred because of negligence by the insured. Multiple parties with their independent interests and each possessing different levels of information characterize the claim process which we explore in this paper.

Our approach is driven by an interest in connecting optimizing operational claim behavior of insurers with the interests of their claimants. Beginning with this operational perspective, we approach the problem as one of claim cycle time, that is, the time interval between when a claim is introduced to the insurer and the claim is settled. There are two intervals in this cycle. The first interval is the time between which the insurer is notified of a claim and a determination about claim validity is made. The second interval, conditional upon the first, is the length of time until the claim is settled once the claim was determined to be valid. The interest of the insurer is to settle a valid claim for a fair price in a reasonable time frame without either paying too much for a claim or paying it too soon. The insurer's problem is complicated because the claimant brings a different interest to bear along with a different level of knowledge. We assume an insurer is constrained to act in good faith since to not pay fairly a claim subjects the insurer to a potential bad faith penalty and a reputation cost.[1] One question we address in this research is when does the optimal claim value determination and settlement time occur?

[1] See Browne et al. [2004] for an empirical assessment bad faith statutes and their association with damages of different types.

To understand the relationship between the timing of claim settlement and the nature of the claim, we assume that the insurer employs adjuster resources that act with the best interests of the insurer in mind.[2] The expected total time to process a claim will depend on the level of resource allocation by the insurer and its capacity; however the actual cycle time will depend greatly on the negotiation between the parties involved. For example, the end points of settlement time outcomes will either be short if the insurer is willing to offer a liberal settlement to the claimant, or long if the settlement offer is low and the negotiation becomes protracted. In general, offering a higher settlement amount at the initial stage of negotiation will be sub-optimal from a firm's perspective because of the inherent uncertainty that any claim presents. Obtaining additional information to ascertain the nature of the claim will reduce the upfront uncertainty and allow the firm to converge to the "fair" settlement amount. In contrast, an upfront settlement will be preferable to the claimant because a drawn out investigation introduces waiting costs. An implication is that the claimant may accept a lower settlement amount if the insurer offers an immediate settlement. The question for the insurer is how low to go in the initial offer?

Our approach to identifying the optimal settlement amount involves understanding the claimant's implicit cost of waiting because that determines how the initial settlement offer should be determined. Typically, the waiting cost is private information to each insurance claimant that depends on the type of claim and the knowledge of the claimant. When information about waiting cost or claim knowledge differs between claimant and insurer, segmentation along these dimensions has added value. This also nudges the theoretical set-up closer to the real world since a fuller understanding of the settlement process is ascertained.

Equally important is the role of the insurer's "capacity" decision. For any given claim and negotiation process, higher capacity can enable a faster, more accurate claim value determination. However, interactions between the insurer's capacity decision and the incentives of the different economic agents exist. On the one hand, higher insurer capacity could make the claimant more willing to reject an early offer and wait for a higher offer because the higher capacity could facilitate a quicker settlement. On the other hand, it is possible that the shorter cycle time enabled

[2]There may be imperfections in the adjusting process that we understand to be rare that are important to consider when describing how insurers' process claims. First, an adjuster may not accurately assess the needs of a specific claim which could represent poor training. Second, the adjuster may have an incentive to process claims quickly in order to get paid or inflate claim amounts if their fee schedule is tiered. Third, the adjuster could pad a claim if they have alternative financial incentives such as a "brother in the repair business."

by higher capacity permits the insurer to offer a lower settlement amount that is subsequently accepted by the claimant. Our model of the claim settlement process endogenizes these trade-offs while characterizing the effect of the operational "choices" on the incentives of different economic agents.

The remainder of this paper is organized as follows. In Section 2, we review and analyze the literature. Subsequently, in Section 3 we develop a model of claim settlement that captures the interaction between the insurance firm and the claimant which solves for the optimal settlement time as a function of both the claim characteristics and the capacity decision of the firm. The optimal claim settlement time and settlement amount depend on both the uncertainty in the claim distribution and the capacity or resource allocation decision of the insurer. These variables are also affected by the cost incurred by an insurer to process a claim and the waiting costs of the claimant. Testable hypotheses are explored with an empirical model in Section 4 using liability claims data from the insurance market collected by the Texas Department of Insurance. We find that longer settlement times and the allocation of more capacity are associated with claims in which the level of initial uncertainty is greater. The empirical results also shed light upon the operational choices of the insurer during its claim settlement process. The particular nature of the claim, the claimant's characteristics and attorney involvement are important determinants of the final settlement amount. Section 5 offers concluding remarks and managerial implications including directions for future research.

2. Relevant Literature

While the literature on cycle time in insurance is scarce, there is a literature on claiming behavior, claim verification and claim fraud. Clauretie and Jameson [1990] develop testable hypotheses about the effect of interest rates on a lender's claiming behavior when a loss is triggered because of borrower default; a loss insured by FHA mortgage insurance for certain types of home buyers. While this paper focuses on claiming behavior rather than settlement behavior, the texture of both problems is similar. van Dongen et al. [2008] show that the cycle time of claim can be computed using historic information in the event logs of systems supporting the administrative processes. By comparing the activities performed for a current claim against that for past ones and running non-parametric regression on historical data, one can predict the time it would take to settle the claim. Biddle [2001] focuses on claims handling in the workers compensation market by testing whether insurer's claim handling behavior influences claim filing rates by injured workers. In particular, he finds support for the hypothesis that an increase in denial rates by insurers for worker's compensation claims is associated with a reduction in subsequent filing rates by workers who are injured. Biddle argues that as insurers use a more rigorous claims-screening process that such information is available to workers and has the effect of increasing the costs to workers who file claims. The role of auditing as a deterrence device is also illustrated by Dionne et al. [2009] who show that the optimal auditing strategy should be determined by an insurance firm with explicit consideration of the results from employing a scoring model; a result that holds whether individual claimants are assumed to know well the probability of being audited or simply have a "belief" about being audited. They show that the optimal strategy is of the form of a "type-dependent red flags strategy" wherein the scoring mechanism signals to the insurer which claims to transfer to a special investigations unit for further consideration.

The literature on auditing and claim verification has focused on the activities of an insurer relative to the claimant's behavior without explicit consideration about the role of negotiation in the manner in which we have an interest in this research. The nature of this approach is presented in Crocker and Tennyson [2002] who discuss two strategies that can be used by insurers to reduce fraudulent and inflated claims. The first is auditing a claim by those characteristics that are observable to the insurer, effectively separating the good from the bad claims. The solution is to have valid separation which has a chance only if there is cost-effective technology, e.g., software, modeling and so forth, that can accurately employ the observable claim attributes. The second strategy is to systematically underpay claims for which there do not exist clearly observable traits, that is, for claims when auditing is less effective. The Crocker and Tennyson reasoning and primary focus of their work is when claims are systematically underpaid it will lead to a marginal reduction in the activities by claimants to inflate claims therefore fraudulent claiming will be reduced because there is less to gain by doing so. They tested their theory using data from actual third-party auto bodily injury claims from a large sample of insurers and found evidence that insurers were underpaying claims that were more prone to fraudulent activity, everything else equal; underpayment of claims by insurers was done with the objective of reducing the value to a dishonest claimant of inflating a claim.

The literature on claims fraud has become extensive and a summary is presented by Derrig [2002]. As Derrig suggests the literature recognizes claimants as the focus of claiming fraud, and that statistical tools to effectively sort incoming claims into categories of "express" claims and "target" claims (claims that are suspicious) are being tested, extended or redeveloped scientifically. In this same issue of the *Journal of Risk and Insurance*, Artiz et al. [2002], Brockett et al. [2002] and Viane et al. [2002] offer techniques that aid the sorting process. Rather than working on developing a more productive audit technology, Tennyson and Salsas-Forn [2002] tested for characteristics of automobile claims that were chosen to be audited and found that claims that were "illegitimate" or subject to more "buildup" were frequent audit candidates and that the impact of auditing by insurers was two pronged: to both detect and deter claims that were subject to "opportunism." As can be seen by this segment of the literature, the focus has been on finding a solution to the "valid claim" problem which exists because of an immoral hidden action outcome offered by the presence of what an insurance contract promises. By contrast, we assume good faith and that insurers must employ resources to accurately assess a claim's specific value.

In contrast to the existing literature, we focus on the interaction between an insurance firm and its claimants while exploring the firm's claims process capacity decision under the assumptions that both parties while acting on self-interest, do maintain good faith. In the next section, we build an analytical model that captures these elements and yields testable hypotheses in addition to characterizing the strategic value of capacity planning in the insurance firm.

3. Model

The starting point for the model's development is the claim settlement process in which an insured or injured party incurs and reports a loss to the insurance firm. Consistent with what is observed in practice, we assume that the claimant knows the true value of the loss he incurs while the insurer has only imperfect information about it. Let v represent the actual loss that is incurred by the claimant.

We sequence the settlement process as follows: After incurring the loss, the injured party reports the loss to the insurer. The insurer then undertakes a preliminary investigation, which reveals the loss distribution, but not its true value. In reality this could be because the insurer is able to pin down the loss to a specific category, and the historical data of this category could provide the insurer with valuable information of the claim nature. The stochastic nature of the claim is characterized by a distribution function $\Phi(\cdot)$ and density function $\phi(\cdot)$ and has a support in the range $[a, b]$. In addition to the usual assumptions that $\Phi(\cdot)$ is increasing and that $\Phi(a) = 0$ and $\Phi(b) = 1$, we also assume that claim value distribution has the increasing failure rate (IFR) property i.e., $h'(\cdot) > 0$ where

$$h(z) = \frac{\phi(z)}{1 - \Phi(z)}$$

Many commonly used distributions for modeling consumer characteristics, like Normal, Uniform, Gamma and Exponential distributions satisfy this property.

After obtaining information about the nature of the claim, the insurer makes an initial settlement offer, V_i, to the claimant. The information of the underlying distribution forms the basis for this initial settlement offer. The claimant may elect to accept V_i, but if it does not, we assume the firm further investigates to determine the true value of the claim. The interesting question is how the insurer would find the optimal initial settlement offer, V_i^*, *ex ante* before placing the offer into the claimant's domain to accept or reject.

To explore this question, we assign the firm and claimant a cost structure during the claim settlement process. The firm incurs a cost to investigate the claim which is increasing in both the time it takes to investigate the claim and the firm's capacity decision. We denote the firm's capacity decision by the parameter λ which determines any investment or resource allocation decision that it makes towards investigating the claim. A higher resource allocation towards claim settlement should result in the firm being able to obtain information earlier, resulting in an earlier settlement of the claim. As a result, we assume that the expected settlement time is decreasing in the capacity decision λ. The firm incurs a cost of c per unit time for every unit of capacity it allocates for the settlement process. In addition, despite the best intentions of the firm, idiosyncrasies in the claim process could delay the investigation. To accommodate this, we assume that while the capacity choice directly impacts only the expected settlement time, the time taken to investigate the claim is exponentially distributed according to the probability distribution function $\lambda e^{-\lambda t}$. Note that the mean settlement time if the claim settlement follows the above distribution is $\frac{1}{\lambda}$ and it is decreasing in the capacity decision of the firm. Given these assumptions, we have that the firm would incur a cost of $ct\lambda$ when it makes a capacity decision of λ.

In addition, legal guidelines require that the insurer acts in good faith and settles the claim in a timely manner. In most cases, unusual delays in claim settlement can result in the insurer be charged a penalty or the claim becoming a lawsuit and as a consequence, significantly higher expenses. Let T represent the time range within which the insurer has to settle the claim. In the eventuality that the claim is not settled within this timeframe, we assume that the insurer would incur a cost or penalty amount of p. To ensure that the insurer has sufficient incentive to invest in capacity, we assume that p is sufficiently high.

Although the claimant does not incur an explicit cost if he rejects the settlement offer before the investigation stage, the claimant does incur an indirect cost because the settlement amount would be received only after the investigation is complete. To capture this, we assume that the future cash flows of the claimant are discounted according to the rate δ.[3] To rule out trivial cases, we assume that $\lambda > \delta$. If this assumption were not true, then the capacity costs are so small that it is in the best interest of the insurer to investigate all claims, irrespective of its characteristics.

Optimal decisions in the model above are derived by backward induction. So, to proceed with the analysis, we first determine which claimants refuse the upfront settlement characterized in **Lemma** 1 below.

Lemma 1. *a) There exists a threshold, v_m, on the claimant's claim value such that iff $v > v_m$, then the claimant prefers to delay settlement.*
b) v_m is increasing in δ and V_i and decreasing in λ.

Lemma 1 shows that whether a claimant accepts the upfront settlement amount V_i or refuses it depends on the true value of the loss. If the claimant believes that the loss is sufficiently high in comparison to V_i, then the claimant will prefer to enter into the investigation so as to receive a higher indemnity. We also see that v_m is increasing in the discount factor δ and decreasing in the insurance firm's capacity λ. As the discount rate for the claimant increases, the cost of waiting increases; hence even claimants with higher claims choose to accept the initial offer. Similarly, if

[3] The discount factor for claimants could also be considered as an inconvenience cost when the claims are not received immediately.

the firm were to offer a higher initial settlement amount, a claimant will be more willing to accept it and hence v_m is increasing in V_i. However, as the capacity of the firm increases, the firm is able to process and investigate the claims faster, thereby reducing the time and cost of waiting. As a result, more claimants will be willing to wait until the investigation is over and hence v_m is decreasing in λ.

A claimant's decision to accept or reject the initial settlement offer influences the firm's payout. Note that all claimants with valuations lower than v_m would receive the upfront settlement amount V_i and all claimants with valuations above v_m receive the value of their actual loss. It follows that the expected payout of the firm would be

$$\begin{aligned} P &= V_i \int_a^{v_m} \phi(x)\,dx + \int_{v_m}^{b} x\phi(x)\,dx \\ &= V_i \Phi(v_m) + \int_{v_m}^{b} x\phi(x)\,dx \end{aligned}$$

In addition, the insurance firm also incurs costs for investigating a claim if the claimant decides to refuse the upfront settlement offer. The probability that this occurs is $(1-\Phi(v_m))$. If the claim is settled at time t, the total capacity costs are $c\lambda t$. It follows that the total expected cost incurred by the firm in this case can be represented as follows

$$\begin{aligned} C &= (1-\Phi(v_m))\left(c\lambda^2 \int_0^{\infty} \left(\lambda t e^{-\lambda t}\right) dt\right) \\ &= c\,(1-\Phi(v_m)) \end{aligned} \tag{3.1}$$

The third part of the cost incurred by the insurer is the penalty that it has pay if the settlement time is greater than T. The probability that this occurs when it makes a capacity decision of λ is $e^{-\lambda T}$ and the corresponding expected amount

$$N = pe^{-\lambda T}(1-\Phi(v_m))$$

It follows that the total expenditure of the firm would be the sum of the payoffs, capacity costs and penalty costs which gives us:

$$\begin{aligned} TC &= P + C + N \\ &= V_i \Phi(v_m) + \int_{v_m}^{b} x\phi(x)\,dx + c\,(1 - \Phi(v_m)) + pe^{-\lambda T}(1 - \Phi(v_m)) \\ &= V_i \Phi(v_m) + \int_{v_m}^{b} x\phi(x)\,dx + \left(c + pe^{-\lambda T}\right)(1 - \Phi(v_m)) \end{aligned} \tag{3.2}$$

in other words, the indemnities and loss adjustment expenses.

Proposition 1. *a) There exists optimal upfront settlement amount, V_i^* that minimizes the total costs of the insurer.*
b) V_i^* is decreasing in p and increasing in c.
c) V_i^* is decreasing in λ.

Thus, as we see above, the optimal upfront settlement amount depends both on the claimant's preferences, the informational assumptions about the underlying loss distribution and the cost structure of the insurer. As we saw under Lemma 1, when the firm increases the upfront settlement offer, more claimants will be willing to accept that offer. This allows the firm to avoid the investigation costs and hence is a strategic alternative for the firm. However, increasing the upfront settlement amount also implies that claimants with lower claim values are paid the high settlement amount V_i. As a result, the firm's interest is to balance these different objectives by offering V_i^*.

We also see that V_i^* is decreasing in the insurer's capacity decision λ. Essentially, when the firm increases its capacity, it is able to resolve the upfront uncertainty faster and thus able to settle claims sooner. As a result, the firm is no longer constrained to offer a high upfront settlement amount to reduce the claim settlement time. We also see that V_i^* is increasing in the unit capacity cost c and decreasing in the penalty cost p. Essentially, when the firm faces higher capacity costs, it becomes important for the insurer to avoid the investigation altogether (due to the prohibitive costs that capacity utilization entails) and this can be achieved only by offering a higher upfront settlement amount. In contrast, when p increases, the optimal response of the firm is to increase the initial offer. This is because despite the best efforts of the firm in terms of higher resource allocation, it might still not be able to settle the claim within time T. Again, by offering a higher initial settlement offer, the insurer is able to reduce the probability that the claim goes into the investigation process and in that manner reduce the chances that it has to pay a penalty cost. As a result, V_i^* is increasing in p.

Having determined the optimal claim settlement amount, we now turn our attention to the more interesting question relating to the effect of capacity of the insurer's total costs. First we look at the effect of the capacity decision on the net payout relating to the claim. Subsequently, we look at the firm's capacity choice more closely and determine the amount of capacity it should allocate to the claim settlement process.

Proposition 2. *The net payout is increasing in c. In addition, it is decreasing in λ if $c > \bar{c}$.*
b) There exists an optimal capacity that λ^* which minimizes the total cost of the insurer.

The effect of claim characteristics and capacity levels on the total expected costs incurred by the insurer and the expected payout to a claimant confirms intuition about the claim settlement process. We find that while an increase in capacity costs increases the total indemnity payout, an increase in capacity itself could result in lower total indemnity payout. When the capacity costs increase, the firm is forced to offer higher initial offers to offset the chance the claim settlement goes into the investigation stage. These higher initial offers result in higher expected payout.

However, when the firm is able to make decisions on the level of capacity to be allocated, the net payout could be lower for higher capacity levels. In fact, when c is sufficiently high, the insurer could benefit immensely from reducing the settlement time by investing in higher capacity. More importantly, higher capacity also allows it to make a lower initial settlement offer. These two factors cause the total indemnity payout to be decreasing in λ for $c > \bar{c}$.

Most interestingly, we find that the firm's capacity decision is an important lever to manage its total costs. One the one hand, higher capacity results in high claim expenses and coincidentally higher costs. However, higher capacity also allows a firm to reduce the total indemnity payout and increases the probability the claim is settled within the reasonable time-frame T. It is important for the firm to balance these tradeoffs and make a capacity decision that minimizes the total costs. Our analysis shows that there is indeed a capacity choice that allows the firm to achieve this objective.

Hypotheses from the Model

The implications from the theory we developed above are three testable hypotheses about the settlement behavior in the insurance market. We list these hypotheses below.

H1: Longer settlement time is associated with larger claim uncertainty.

Our first hypothesis captures the relationship between the settlement time for a claim and the amount of uncertainty present in that claim. Recall from the model that this uncertainty could be the result of claim attributes and informational asymmetry. In cases when this uncertainty is high, the extent of disagreement between the claimant and insurer is higher, resulting in longer settlement time. Also, a longer settlement time will enable a firm to obtain more information regarding a claim, thereby bringing the final offer closer to the claimant's actual economic loss. These two factors in conjunction will lead to longer settlement times being associated with those claims with higher uncertainty.

H2: Larger capacity costs are associated with greater uncertainty

The capacity decision is an important operational choice of the insurer. When an insurer's adjuster receives the initial notification and attributes of a claim, they are confronted with more or less uncertainty about how to bring the claim to closure. Expending more resources when a claim is more uncertain reduces time costs to the claimant and thereby reduce the expected payouts for the claim.

H3: Larger capacity costs are associated with a higher initial settlement offer.

This hypothesis follows directly from **Proposition** 1 and follows from **H2**. When the cost of settling a claim increases, offering a high initial settlement offer will enable the insurer to avoid the investigation costs. As a result, higher capacity costs would result in an insurer making larger initial offers.

4. The Empirical Model and the Data

We undertake testing of our hypotheses with closed claim data from 2004 and 2005 provided by the Texas Department of Insurance through its annual closed liability claim annual report.[4] The data include the details of a closed claim from line of business and injury type to amounts paid in settlement and time taken to close a claim; nearly 220 different fields of information. Insurers, while complying with Texas insurance law, report the details of a claim in either a "short form" or "long form" version where the distinguishing characteristic is the amount of the closed claim: bodily injury final amounts between $10,000 and $25,000 permit the use of the short form and amounts greater than $25,000 require the long form.[5]

We approach the testing of our hypotheses by formulating an empirical model that treats the actual paid amount of the claim observed in the data relative to its initial value estimate as a function of the insurer's unit capacity costs, settlement time and a variety of control variables relevant to this insurance market. The model in log-linear form is specified as

$$\begin{aligned} \ln(\text{claimerror}) \quad = \quad & \beta_0 + \beta_1 \ln(\text{SettlementTime}) + \beta_2 \ln(\text{Capacity}) + \beta_3 \ln(\text{Age}) + \beta_4(\text{Suit}) \\ & + \beta_5(\text{Employment}) + \beta_6(\text{WorkerComp}) + \beta_7(\text{Coll}) + \sum_{8}^{10} \beta_i \left(\text{Attorney}_i\right) \\ & + \sum_{11}^{27} \beta_i \left(\text{Injury}_i\right) + \sum_{28}^{40} \beta_i \left(\text{Peril}_i\right) + \beta_{41} \left(\text{Occurrence}\right) + \sum_{42}^{63} \beta_i \left(\text{Busclass}_i\right) \\ & + \sum_{64}^{173} \beta_i \left(\text{County}_i\right) + \beta_{174}(\text{Year}) + \epsilon \qquad (4.3) \end{aligned}$$

where the claimerror is the paid claim amount divided by the adjuster's initial estimate. As a result, claimerror is capturing uncertainty because an adjuster's initial estimate is based on an information set that is enhanced over time culminating in sufficient if not full information at the point the claim is closed.

[4] Insurance closed claim data from the Texas Department of Insurance (http://www.tdi.state.tx.us/reports/report4.html) has been utilized recently by Hersch, O'Connell and Viscusi [2007] who examined early offer reform in medical malpractice, and Hersch and Viscusi [2007] who explored the transaction costs of tort liability claims by defendants.

[5] http://www.tdi.state.tx.us/reports/pc/documents/taccar2004.pdf

4.1 Variables Whose Test is Focused on Our Hypotheses

To begin, we examine the time necessary to process a claim. Liability claims have so-called "long tails" because third-party insurance involves at least an additional party that has rights to investigate and oftentimes the liability contract is insuring a bodily injury in which indemnification to a point of termination can take a number of years. While various definitions of time lengths help to answer specific questions about the legal process of an insurer's internal operational management efficacy, our hypothesis on cycle time is captured by the variable Settlement Time whose value for each individual claim is measured by the time between the date the claim was reported to the insurer and the date the claim was closed. Across all the data, the fewest number of days in which a claim was closed after being reported was 4 days and the mean value was about 916 days.

The second variable of interest is Capacity which is approximated by the daily cost to administer the handling of a claim. We calculate Capacity for each claim by dividing the loss adjustment expense associated for each claim by the number of days to close the claim once the claim had been reported to the insurer. In this fashion, we have a daily cost per claim (cost per unit of time in theory) that can be associated empirically with the total claim indemnification. It is worthwhile noting that this variable is a measure of both the capacity decision of the insurer and as well as the cost of deploying these resources. Clearly an increase in either of these factors would contribute to an increase in Capacity. Although it would be valuable to separate these effects, the limitations in the data sample preclude us from being able to make that distinction.[6] Our theory predicts that insurers will make a strategic decision to employ higher levels of capacity when presented with claim characteristics that result in more uncertainty about the actual value of a claim. Moreover, when a firm dedicates more resources to the claim settlement process, lesser should be the claim settlement time. Hence, we expect the more costly it is to adjust a claim, the lesser will be the settlement time.

[6] Please refer to section 4.3 for some more discussion on the amount of capacity and its cost.

4.2 Control Variables

The theory and our hypotheses focus on behavioral phenomena that we expect to be components of a liability claim. The ultimate value of an insured liability claim is, in part, attributable to characteristics of the injured party, the characteristics of the incident and its venue, the insurance coverage relevant to the claim and the legal players and legal process when there is a dispute. On a by-claim basis we are able to control for many exogenous factors relevant to a claim's value, and we do know the injured party's age which we capture on the model's right-hand side.

To begin, we know whether a claim was settled or entered the legal system and are able to control for the potential bias attributable to an extended time when a claim involves a lawsuit. We include a control variable, Suit, which takes the value of 1 for when a claim is involved in a suit and 0 otherwise. While claims involving a lawsuit likely have legal representation noted, claims settled before entering the legal system may have attorneys, too. We have three variables to control for attorney involvement depending on the party that is represented. Attorney_8 takes the value of 1 when a claim involves an attorney who is representing the plaintiff, and 0 otherwise. Attorney_9 takes the value of 1 when a claim involves an attorney who is representing the insurer associated with the underlying policy, and 0 otherwise. Attorney_{10} takes the value of 1 when the insured associated with the policy retains legal counsel, and 0 otherwise. In our data 98% of claims have representation for the plaintiff, 92% for the insurer, and 11% for the insured. Everything else equal, we would expect that attorney involvement in any form would be associated with higher claim amounts and more uncertainty about the ultimate payout.

We include three variables which are present in the data which can impact the value of a claim. First, we are interested in whether the injured party was employed (Employment = 1) or not, and additionally whether there was any workers compensation benefits available to the insured (Workers Comp =1) and whether any other sources are available, Coll = 1.[7] Collateral sources include, for example, whether the injured party could also receive social security benefits, medical insurance, medicare, etc.

We have 18 categories of injuries from death to spinal cord injuries to a catch-all category "Other". The set of variables Injury_{11} to Injury_{27} capture the categories, and we use the "Other"

[7]In preliminary testing we found that a fourth variable, whether the injury was "work-related", was highly correlated with our Workers Comp variable so we removed it from consideration.

category as our benchmark. Similarly, we have 13 categories of perils that describe an element of the loss attributable to causing the injury. For example, if the injury involved a motor vehicle. Peril_{28} to Peril_{40} capture these categories, and we use the "Other Peril" category as our benchmark. The data also distinguish by policy type and policy form. The variable Occurrence takes the value of 1 for an occurrence based policy form and 0 for a claims-made form.

We control for the 23 business class categories with the variable Busclass_i. The business class category represents an underwriting categorization of the underlying policy and is displayed in Table 6. Busclass_{43} take the value of 1 for Agriculture, and 0 otherwise, Busclass_{44} takes the value of 1 for Mining, and 0 otherwise, etc. By count we can observe that among known categories of claims that Transportation, Wholesale-Retail Trade and Construction claims are most numerous. Finally, we control for both the county in which the loss was incurred, County_i and the calendar year in which it was incurred, Year_i.

4.3 Description of Final Sample

We began with two large datasets from 2004 and 2005 where the total number of liability claims closed and reported to the State of Texas was 9,019 and 9,211, respectively. Because the "long form" utilized by insurers to report to the TDI contains much more information, we begin our focus only on those claims which yield 5,410 claims from 2004 and 5,440 claims from 2005. Since our theory focuses on how individual claims are expedited we further reduce the sample to include only those claims where there was one defendant associated with the liability claim; we anticipate that multi-party claims would not permit us to focus as precisely on the theoretical implications. Furthermore, there were claims in the data in which no loss adjustment expenses or claim payments were recorded and there were extremely underrepresented business classes and counties. We removed those business classes where there was only 1 claim and those counties where there were fewer than 7 claims.[8] The final dataset includes 4,828 claims across 23 business classifications and 111 counties in Texas.

Settlement time is a major focus of this paper and many different time intervals are present in

[8] We also removed claims when the initial indemnity projection by the adjuster took on a value less than \$300. During an initial testing there were around 2.5% of claims below the \$300 threshold, raising questions about data input errors were raised. For example, where the initial indemnity reserve was \$1 and the ultimate payout was nearly \$500,000. It is important to note that when we removed the 116 claims that had an initial indemnity amount of \$300, the statistical significance of our findings did not change.

the data, in part, determined by the various mileposts once a claim enters the legal system. For example, the length of time between when trial occurs and when a suit is filed is characteristic of the time-element data fields. Our interest is less on legal status for we differentiate between claims that involved a lawsuit and those that did not, and more on the time between which the insurer is notified about a loss and the claim is closed. Table 1 describes various time metrics that are of interest to us.

Elapsed time in Table 1 is reported in days and summarizes the final sample, 2004 and 2005 observations inclusive. The terminal points of the time line for a claim in the data stretch from the date of injury to the date a claim is closed. Since oftentimes it takes time to wrap-up and close a claim after settlement the number of days between initial injury and the settlement date is fewer. Furthermore, since the claims are liability claims the time to close is relatively lengthy and in our data the "tail" has a mean value of 1,061 days (nearly 3 years) from the date of initial injury.

<< Insert Table 1 about here >>

The texture of the theoretical model requires us to focus on the time when an injury first becomes information to the insurer because it is only at that point where settlement behavior between parties becomes of interest. Therefore, the time value used in the empirical model for each observation is the last row of Table 1, the difference between an insurer closing a claim and first being notified, which has a mean value of about 916 days across the sample.

The second important variable is Capacity. We were interested in finding a measure for the resources employed by the insurer to handle and administer a claim, yet our data were not revealing of the insurers associated with specific claims.[9] One piece of valuable information in the data is the total amount of loss expenses allocated by the insurer to a specific claim. We assume that insurers are able to evidence their capacity by the quantity of resources they devote to a claim, and we measure capacity by normalizing the total amount of loss adjustments expenses by the difference in number of days in which the claim was within the knowledge of the insurer until a claim closed. On average, insurers in our final sample spent $33,837 to handle a claim with an average

[9]This is a feature of the insurance law in the state of Texas in which insurers are kept anonymous in this filing. As we were advised by Ms. Vicky Knox at the Texas Department of Insurance, "This information is confidential by statute. See § 38.162 of the Texas Insurance Code." This presents us an empirical difficulty in the estimating the resource allocation decision of an insurer.

loss amount of $181,387, or 18.60%. Given the mean number of days insurers process a claim until it is closed the daily cost carried a mean value of $41.99 per day in our final sample. This capacity measure is widely variable from a minimum of $0.006 per day to a maximum of nearly $2,197 per day with an overall standard deviation of about $74 per day.

<< Insert Table 2 about here >>

Since the value of a claim can be attributable to the injured party's demographic traits we were interested in controlling for those elements and the data included only the individual's age. We found that the mean age of an injured party in our sample was 42.3 years. Legal status is present in our data and examination of Table 3 reveals the large proportion of claims that have an associated lawsuit, 86.5%. We differentiate our data by "suit or no suit", and include in the no suit definition those claims where settlement was reached without a lawsuit via alternative dispute resolution. Not surprisingly, almost 97% of all claims where settled prior to a trial.

<< Insert Table 3 about here >>

There are a number of other descriptions of the data which are noteworthy, including the frequency of the types of injuries and the peril causing the loss. The injury types listed in Table 4 correspond to control variables $Injury_{11}$ to $Injury_{27}$ moving downward with the "Other" category established as the benchmark category in the regressions. In Table 5, $Peril_{28}$ to $Peril_{40}$ are associated with peril-like characteristics of the claim from "off road vehicle" through "oil & gas extraction", with the "Other" category for perils as the benchmark. Since the claims involve individual commercial liabilities, it is not surprising that the data reveal that automobile use, medical malpractice and routine slips and falls mostly produce claims that involve back injuries, multiple injuries or death.[10]

<< Insert Table 4 about here >>

<< Insert Table 5 about here >>

[10]There are instances in the data where multiple injury categories were selected by the adjuster. We re-classified these observations as "Multiple Injuries" and the proportions reported in Table 4 reflect that change. Similarly, a few observations had more than one category selected for the peril, and these have been re-classified as "Other" perils. That change is reflected in Table 5.

Features of the underlying insurance contract are also present in the data and we find that about 16.5% of the claims involve a general liability contract; 56% of the claims involve a commercial auto liability contract; 12% of the claims involve a Texas commercial multi-peril contract; 14.3% of the claims involve a medical professional liability contract and less than 2% involve other professional liability claims. We considered introducing a variable that would control for policy type but found that for medical liability contracts that the surgery/medical peril variable was highly-correlated. Therefore, we removed our policy type control variables from the empirical model.

Another policy feature is whether the contract was written on an occurrence or claims-made basis, the distinguishing characteristic is the time at which the insured contract represented in the reported data was responsible for an individual claim. When a policy covers claims on an occurrence basis it is covering a claim that is valid plus the date of the injury arose during the coverage period. By contrast, a valid claims-made claim need not have the injury be incurred during the coverage period, only that a valid claim was filed during the coverage period. In our final sample, about 88% of the claims were associated with occurrence-based policy language.

To complete the description of the data we explored the type of businesses that produce the liability claims that comprise the final sample. Table 6 shows incidents that involve transportation and construction firms, wholesale and retail operations, and physicians/surgeons carry much of the weight in the loss data reflecting the inherent safety challenges of these businesses.

<< Insert Table 6 about here >>

Our final set of control variables control for the year of the data and the county in which the injury was incurred. The data are about evenly split between 2004 and 2005 (mean value of the Year variable is 2004.49) and we have 111 counties in Texas that are represented by at least 6 observations in the data. The majority of liability claims are attributed to high population areas. 19.95% of the claims come from Harris County (Houston) and 10.38% of the claims come from Dallas County. 6.46% of the claims arose in Bexar County (San Antonio) and 6.17% of the claims were incurred in Tarrant County (Fort Worth).

4.4 Hypothesis Testing

In our estimation of equation (4.3) we consider two approaches. First, we estimate via OLS and report estimated coefficients and statistical significance in Table 7 for all variables except our County_i controls. The overall model was statistically significant (F = 4.42) with an R^2 of 0.111. We test for heteroskedasticity using the Bruesch-Pagan test and rejected the null hypothesis of homoscedasticity given the value of the test statistic was $\chi^2 = 30.0$. The standard errors underlying the t-statistics are adjusted and robust. Second, we estimate our empirical model with an instrumental variables approach under the assumption that the decision to file a lawsuit is endogenous in our model.[11]

In our model, we assume that insurers have the ability to determine the amount of resources to be allocated to claim settlement process. However, while making this decision, the insurer has information only about the distribution of claim values i.e., how likely it is for an initial settlement offer by the insurer to be close to the actual loss incurred by the claimant. In the empirical model, given that the firm acted in good faith and that the investigation reveals the true value of the claimant's loss, the variable claimerror would appropriately capture this parameter. This also implies that capacity and claimerror are not co-determined. Our hypothesis is that an insurer is more likely to invest in higher resources when it is less certain that it has good information about the claim; in other words, when there is greater uncertainty about the claim values. This hypothesis would be true if higher claimerror values are associated with greater resource allocation by the insurer.

In the first-stage, Suit is regressed against all explanatory variables plus an additional time instrument that capture the date from the injury until the date that event is reported to insurer. In the second-stage, the predicted value of Suit is included as an instrument for Suit and the full model is estimated. We report the results of the IV estimation in Table 8.[12] Given our data include exogenous dummy variables that do not differentiate themselves on the Suit dimension; observations had to be removed to undertake the first-stage Probit estimation. 230 observations

[11] We rely on the work of Browne and Puelz (1999) who examined the role of tort reforms and other factors (including the decision to file a lawsuit) on the value of an automobile liability claim. In that paper, lawsuit was treated as endogenous.

[12] We use Stata for the analysis. In the first-stage we utilize probit, then in the second-stage we use ivreg2. Standard errors are corrected. See http://www.stata.com/statalist/archive/2004-09/msg00352.html for a discussion.

across 24 variables (most of them counties) had to be dropped resulting in a sample size of 4,598 observations for the IV procedure.

Our hypotheses predict a positive relationship between settlement time and claim error, and between capacity and claim error. Examining Tables 7 and 8 simultaneously we see that, regardless of estimation procedure, the coefficients on both of these variables are positive and statistically significant. For an insurer, the longer time to settle is associated with more initial uncertainty about the value of a claim consistent with theory. Moreover, we find that higher levels of capacity are deployed when insurers and their adjusters confront larger differentials between what is actually paid to settle claims and their initial estimates. Stated another way, if insurers possess less uncertainty about a liability claim, the data reveal that insurers make a lower investment in capacity to process the claim.

We also found a number of our control variables statistically significant and consistent with our expectation. Focusing on the estimates in Table 8, workers who are employed and older workers have higher uncertainty margins. When collateral sources are available there is also a higher difference between the actual claim payment and the initial reserve, yet when workers compensation benefits are available there is no statistically significant relationship. Another interesting finding is that among injury types, back injuries are associated with more uncertainty in the claim payout, while death is associated with a smaller difference between initial reserve and actual payout, reflecting less uncertainty among adjusters in valuing and processing these claims.

Among legal variables, we found that when the claim is associated with a lawsuit that uncertainty about the payout is lower. To explore this further we found that the mean number of days for a claim to reported to the insurer was 145, while the mean number of days to file a lawsuit was about 486. While one might expect that the filing of a lawsuit would be associated with higher claim payouts relative to initial reserves, adjusters may possess information about certain types of claims in which they more accurately reserve up front. This is partially corroborated by the coefficients on legal representation where neither the attorney representing the insurer nor the attorney representing the insured is associated with a change in uncertainty. We do find, however, that when the injured is represented by an attorney that larger differences between the actual paid claim and the initial reserve exist.

Our last hypothesis to be tested, H3, is that higher initial settlement offers are associated with higher capacity costs. Our empirical model is adjusted only by changing the dependent variable to a proxy for initial offer which is captured by the adjuster's initial estimate of the indemnity amount. The 2-step instrumental variable procedure was carried out and IV results are reported in Table 9. Focusing on the coefficients for Capacity and Settlement Time the data report that when insurers incur higher capacity costs that their initial settlement offers are higher. Moreover, lower settlement times are statistically related to higher initial settlement offers reflecting that claimants are accepting offers sooner when initial settlement amounts are higher.

Among legal variables, we find that while attorney representation for the injured party is associated with a lower initial indemnity reserve, when the insured has retained counsel it has done so under the circumstance a higher initial indemnity reserve. While the latter result is intuitively appealing, the former result may arise because claimants who are dissatisfied with lower initial offers consequently retain legal counsel, although the data do not tell us the date post-injury when a plaintiff's attorney was retained. Among injury types there is a strong positive correlation between death and a higher settlement offer. Perils causing the injuries are less conclusive and when workers' compensation benefits are available to the injured party there exist a higher initial settlement offer on average.

<< Insert Table 7 about here >>

<< Insert Table 8 about here >>

<< Insert Table 9 about here >>

5. Conclusions

In this paper, we examine the role of operational choices in an insurance claim settlement process. Specifically, we develop a theory of insurance claim settlement whose structure embodies an insurer's capacity decision and negotiation between the insurer and claimant in an asymmetrically informed environment. The analytical model we develop offers a solution to an insurer's choice of upfront claim settlement amount that an insurer should offer to a claimant. This settlement amount depends both on the insurer's capacity decision as well as the breadth of claim distribution.

Our analysis reveals that it is important for a firm to respond to claim distribution uncertainty by allocating more resources to settle the claim. Interestingly, this operational flexibility, in addition to managing the claim settlement time, also influences the claimant's incentives. Although more claimants choose to wait for the claim investigation prior to the settlement when the insurer increases the capacity, total indemnities are lower because the insurer can offer lower upfront settlement amounts. In addition, as the discount rate for claimants increases, claimants are more willing to settle for lower early offers.

Consistent with what the theory predicts, we find that insurer's deployment of more capacity to handle a claim occur for claims which had more uncertainty. Similarly, claims that had more uncertainty also had longer settlement times. Interestingly, this is further corroborated when we examine the claim characteristics more closely. For example, claims related to back injuries whose liability impact could be more uncertain than claims that resulted in death, have longer claim settlement times and higher capacity allocations by the insurer. The empirical results also revealed other claim characteristics that are relevant to an insurer's operational choices.

Finally, an important aspect of liability claims is a claimant's decision to file a lawsuit. An implication of our results is that the probability of suit would reduce if a firm were to invest in higher capacity. In many instances, lawsuits occur because of disagreements between a claimant and insurer about the actual value of a claim and an appropriate or fair settlement amount. Assuming that all parties are acting in good faith, this disagreement would be less if there is less informational asymmetry. When a firm invests in higher capacity for claim settlement, it will be able to obtain more information about a claim faster thereby reducing the effect of informational asymmetry. As a result, a higher capacity investment by an insurer could reduce the probability that a claim meanders into a lawsuit. Since claims that end up as a lawsuit would cause an insurer to incur additional expenses and hence could cause greater financial burden, higher capacity investments could provide an insurer the strategic benefit of direct cost savings in addition to reduction in claim settlement time.

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A. Tables

Table 1: Elapsed Time (in days)

Time Definition	Mean	Std. Dev.	Min	Max
Between date of injury and date reported to insurer	145.72	400.65	0	12,354
Between date of injury and date of settlement	977.79	577.30	6	12,554
Between date of injury and date claim closed	1,061.64	600.25	9	12,591
Between date reported to insurer and date claim closed	915.92	483.56	4	5,263

Table 2: Claim Expenses
(n = 4,828)

	Mean	Std. Dev.	Min	Max
Amount paid by primary insurer	$181,387	$307,587	$1,250	$9,500,000
Total allocated loss adjustment expenses	$33,837	$51,917	$3	$658,950

Table 3: Form of Settlement
(n = 4,828)

Legal Stage where settlement reached	Freq. %
Alternative dispute resolution: no suit	2.88%
No suit filed	10.65%
Alternative dispute resolution: with suit	37.63%
Suit filed, settled before trial	45.86%
During trial, before court verdict	0.64%
Court verdict	1.01%
Settlement reached after verdict	0.81%
Settlement after appeal filed	0.52%
Case dismissed or summary judgment	0%

Table 4: Injury
(n = 4,828)

	Freq %
Death	10.58%
Amputation	0.97%
Burns (heat)	0.64%
Burns (chemical)	0.17%
Systemic poisoning (toxic)	0.23%
Systemic poisoning (other)	0.17%
Eye injury (blindness)	0.83%
Respiratory condition	0.27%
Nervous condition	0.08%
Hearing loss or impairment	0.10%
Circulatory condition	0.12%
Multiple injuries	39.11%
Back injury	25.35%
Skin disorder	0.25%
Brain damage	0.91%
Scarring	0.62%
Spinal cord injuries	0.72%
Other	18.87%

Table 5: Peril
(n = 4,828)

	Freq %
Off road vehicle	1.08%
Railway	0.25%
Other motor vehicle	54.95%
Surgical/medical care	13.90%
Falls	14.08%
Drowning	0.33%
Use of defective product	0.99%
Fire	0.23%
Firearm	0.27%
Pollution/Toxic exposure	0.33%
Explosions	0.12%
Use of agricultural machinery	0.12%
Oil & gas extraction	0.33%
Other	13.01%

Table 6: Business Classification
(n = 4,828)

Agriculture	1.88%
Mining	0.12%
Manufacturer chemical/allied products	0.70%
Medical products manufacturer	0.23%
Drug manufacturers	0.19%
Other products manufacturers	4.20%
Transportation	22.16%
Wholesale-retail trade	16.18%
Municipal/public liability	2.15%
Schools (public & private)	1.18%
Daycare centers	0.68%
Liquor liability	0.10%
Non-profit organizations	0.79%
Construction firms	12.12%
Oil wells & drillings	2.20%
Apartments, townhomes, and condos.	1.72%
Office	1.06%
Churches	0.72%
Physicians & surgeons	10.63%
Dentists	0.60%
Hospital	2.07%
Nursing Home	1.68%
Other	16.63%

Table 7: Estimates of Empirical Model
OLS with robust standard errors
n = 4,828

Dependent Variable: ln(claimerror)		
	Coeff.	**t-stat**
Constant	143.8178	1.72
ln Settlement Time	0.227603	5.69
ln Capacity	0.120657	6.34
ln Age	0.03754	1.99
Suit	0.184895	2.21
Employment Status	0.136096	2.96
Worker Comp	-0.00357	-0.05
Collateral Sources	0.158014	3.33
Attorney:		
Attorney involvement - plaintiff	0.199959	1.39
Attorney involvement - insurer	-0.31476	-3.28
Attorney involvement - insured	-0.02437	-0.31
Injury Types:		
Death	-0.40783	-4.69
Amputation	-0.10015	-0.36
Burns (heat)	-0.27121	-0.92
Burns (chemical)	-0.04064	-0.11
Systemic poisoning (toxic)	0.225692	0.75
Systemic poisoning (other)	-0.17357	-0.4
Eye injury (blindness)	0.350272	1.61
Respiratory condition	-0.3416	-1.11
Nervous condition	-1.10131	-4.85
Hearing loss or impairment	-0.96762	-3.27
Circulatory condition	-0.12679	-0.28
Multiple injuries	0.048071	0.78
Back injury	0.217186	3.2
Skin disorder	0.533458	1.12
Brain damage	0.116318	0.42
Scarring	0.045591	0.19
Spinal cord injuries	0.313826	1.28
Perils:		
Off road vehicle	0.095062	0.39
Railway	0.356063	0.65
Other motor vehicle	0.110909	1.47
Surgical/medical care	-0.06155	-0.38
Falls	-0.03287	-0.39

Drowning	0.102762	0.23
Use of defective product	-0.25589	-1
Fire	0.029286	0.06
Firearm	-0.78483	-2.25
Pollution/Toxic exposure	-0.57409	-1.7
Explosions	-0.23166	-0.33
Use of agricultural machinery	-0.75553	-1.43
Oil & gas extraction	-0.61181	-1.69
Occurrence	0.095077	0.87
Business Classes:		
Agriculture	-0.271	-1.8
Mining	-0.38965	-0.67
Manufacturer chemical/allied products	-0.16851	-0.55
Medical products manufacturer	0.044706	0.08
Drug manufacturers	0.00462	0.01
Other products manufacturers	0.153978	1.24
Transportation	-0.12411	-1.79
Wholesale-retail trade	0.154127	2.08
Municipal/public liability	-0.51864	-3.69
Schools (public & private)	-0.08026	-0.41
Daycare centers	-0.32847	-1.66
Liquor liability	-0.01595	-0.02
Non-profit organizations	-0.1779	-0.81
Construction firms	0.067753	0.85
Oil wells & drillings	-0.23653	-1.37
Apartments, townhomes, and condos.	0.126279	0.71
Office	0.024624	0.11
Churches	0.212272	0.9
Physicians & surgeons	-0.20951	-1.12
Dentists	-0.97303	-3.84
Hospital	-0.94699	-4.78
Nursing Home	-0.37823	-1.71
Year	-0.07205	-1.73
Note: F-stat = 4.42; R^2 = 0.111		

Table 8: Estimates of Empirical Model
2-stage IV
n = 4,598

Dependent Variable: ln(claimerror)		
	Coeff.	**t-stat**
Constant	172.0481	2.02
ln Settlement Time	0.3450655	6.83
ln Capacity	0.1684457	7.54
ln Age	0.0488039	2.29
Suit	-0.656667	-2.96
Employment Status	0.1565446	3.25
Worker Comp	-0.0032662	-0.05
Collateral Sources	0.1470896	2.96
Attorney:		
Attorney involvement - plaintiff	0.410154	2.43
Attorney involvement - insurer	0.1300825	0.87
Attorney involvement - insured	0.004653	0.07
Injury Types:		
Death	-0.4404406	-5.12
Amputation	-0.2230295	-1.01
Burns (heat)	-0.3157955	-1.14
Burns (chemical)	-0.0131456	-0.03
Systemic poisoning (other)	0.1046553	0.19
Eye injury (blindness)	0.3258426	1.39
Hearing loss or impairment	-1.350789	-2.09
Circulatory condition	-0.1500571	-0.26
Multiple injuries	0.0424234	0.66
Back injury	0.2340182	3.29
Skin disorder	0.4920633	1.14
Brain damage	0.1280272	0.56
Scarring	0.0399185	0.15
Spinal cord injuries	0.3042401	1.23
Perils:		
Off road vehicle	0.0946879	0.45
Railway	0.460909	1.01
Other motor vehicle	0.1122543	1.52
Surgical/medical care	-0.0797878	-0.5
Falls	-0.0315016	-0.38
Drowning	-0.0496888	-0.12
Use of defective product	-0.194985	-0.89
Fire	-0.06228	-0.14

Firearm	-0.857239	-2.13
Explosions	-0.3535144	-0.55
Use of agricultural machinery	-0.5769905	-0.79
Oil & gas extraction	-0.5196137	-1.22
Occurrence	0.1433564	1.28
Business Classes:		
Agriculture	-0.2658268	-1.6
Manufacturer chemical/allied products	-0.1595953	-0.59
Medical products manufacturer	-0.0726262	-0.17
Drug manufacturers	-0.1094916	-0.23
Other products manufacturers	0.1215141	1.04
Transportation	-0.144861	-2
Wholesale-retail trade	0.1420235	1.92
Municipal/public liability	-0.5250063	-3.35
Schools (public & private)	-0.0782361	-0.39
Daycare centers	-0.3309319	-1.29
Liquor liability	-0.1438542	-0.23
Non-profit organizations	-0.2305554	-0.93
Construction firms	0.0428968	0.53
Oil wells & drillings	-0.2757664	-1.63
Apartments, townhomes, and condos.	0.1116412	0.66
Office	-0.0302147	-0.14
Churches	0.1988233	0.8
Physicians & surgeons	-0.1518176	-0.82
Dentists	-0.9192628	-3.08
Hospital	-1.021018	-4.96
Nursing Home	-0.3024264	-1.5
Year	-0.0866859	-2.04
Note: F-stat =3.41; centered R^2 = 0.084; uncentered R^2 =0.6109		

Table 9: Estimates of the Empirical Model
2-stage IV
(n=4,598)

Dependent Variable: ln(initial indemnity reserve)		
	Coeff.	**t-stat**
Constant	-11.618	-0.14
ln Settlement Time	-0.1913851	-3.94
ln Capacity	0.1655708	7.71
ln Age	-0.0438943	-2.14
Suit	-0.1758599	-0.82
Employment Status	-0.0298454	-0.64
Worker Comp	0.1585037	2.46
Collateral Sources	-0.0105305	-0.22
Attorney:		
Attorney involvement - plaintiff	-0.414605	-2.55
Attorney involvement - insurer	0.1238702	0.86
Attorney involvement - insured	0.1898879	2.77
Injury Types:		
Death	1.141572	13.8
Amputation	0.2849303	1.34
Burns (heat)	0.3834256	1.44
Burns (chemical)	-0.2522376	-0.52
Systemic poisoning (other)	-0.0463666	-0.09
Eye injury (blindness)	0.0461043	0.2
Hearing loss or impairment	0.7761867	1.25
Circulatory condition	0.2033873	0.36
Multiple injuries	0.1393129	2.26
Back injury	-0.1603887	-2.35
Skin disorder	0.1450482	0.35
Brain damage	0.67766	3.09
Scarring	0.1178178	0.46
Spinal cord injuries	0.3903878	1.64
Perils:		
Off road vehicle	0.066379	0.33
Railway	-0.0039463	-0.01
Other motor vehicle	0.0265083	0.37
Surgical/medical care	0.1831316	1.19
Falls	-0.0209176	-0.26
Drowning	0.3051431	0.79
Use of defective product	0.2687032	1.27
Fire	0.3820218	0.88

Firearm	0.5842172	1.51
Explosions	-0.322142	-0.52
Use of agricultural machinery	-0.069589	-0.1
Oil & gas extraction	0.8284297	2.03
Occurrence	-0.1033922	-0.96
Business Classes:		
Agriculture	0.2823716	1.77
Manufacturer chemical/allied products	0.4252537	1.63
Medical products manufacturer	0.0585671	0.14
Drug manufacturers	-0.0557107	-0.12
Other products manufacturers	-0.0416429	-0.37
Transportation	0.2012152	2.89
Wholesale-retail trade	-0.1220665	-1.72
Municipal/public liability	0.1295462	0.86
Schools (public & private)	-0.1132248	-0.59
Daycare centers	0.3476155	1.4
Liquor liability	0.3039544	0.5
Non-profit organizations	0.1389674	0.58
Construction firms	0.1072573	1.38
Oil wells & drillings	0.6331509	3.9
Apartments, townhomes, and condos.	-0.1410265	-0.86
Office	-0.0622243	-0.3
Churches	-0.3704404	-1.55
Physicians & surgeons	0.2392994	1.35
Dentists	0.7844663	2.73
Hospital	0.8632769	4.37
Nursing Home	0.3763225	1.94
Year	0.01126	0.028
Note: F-stat =7.92; centered R^2=.2113; uncentered R^2=.9814		

B. Proofs

Lemma 1. *a) There exists a threshold, v_m, on the claimant's claim value such that iff $v > v_m$, then the claimant prefers to delay settlement.*

b) v_m is increasing in δ and V_i and decreasing in λ.

Proof. To determine whether a claimant wants to delay settlement, we have to find the expected value if the claimant were to wait until the investigation is over. Let the time at which the settlement occurs be t. Then the discounted value of the settlement amount for the claimant whose claim value is v would be $ve^{-\delta t}$. Given that the firm's capacity is λ, the *expected discounted settlement* amount S_L for the claimant is

$$\begin{aligned} S_L &= vE\left[e^{-\delta t}\right] \\ &= \frac{v\delta}{\lambda + \delta} \end{aligned} \tag{B.1}$$

By not delaying the settlement and accepting the firm's initial offer, a claimant would receive V_i. This characterization now allows us to find the marginal customer who would be indifferent between accepting the initial offer or not. We do that by equating eq. B.1 to V_i. Thus if v_m is the marginal claim value, then we have that

$$V_i = \frac{v\lambda}{\lambda + \delta}$$

Solving for v_m would then give us the characterization of the marginal claim value which would be

$$v_m = \frac{(\delta + \lambda)V_i}{\lambda} \tag{B.2}$$

b) Differentiating v_m *w.r.t.* to V_i, λ and δ we have that

$$
\begin{aligned}
\frac{\partial v_m}{\partial \delta} &= V_i > 0 \\
\frac{\partial v_m}{\partial V_i} &= \frac{\delta+\lambda}{\lambda} > 0 \\
\frac{\partial v_m}{\partial \lambda} &= -\frac{V_i \delta}{\lambda^2} < 0
\end{aligned}
$$

□

Proposition 1. *a) There exists optimal upfront settlement amount, V_i^* that minimizes the total costs of the insurer.*

b) V_i^* is decreasing in p and increasing in c.

c) V_i^* is decreasing in λ.

Proof. a) Differentiating eq. 3.2 *w.r.t.* V_i twice, we have that

$$
\begin{aligned}
\frac{\partial TC}{\partial V_i} &= \frac{\partial}{\partial V_i}\left(V_i \Phi(v_m) + \int_{v_m}^{b} x\phi(x)\,dx + \left(c\lambda + pe^{-\lambda T}\right)(1-\Phi(v_m)) \right) \\
&= \Phi(v_m) + \left(\frac{\delta+\lambda}{\lambda}\right) V_i \phi(v_m) - \left(\frac{\delta+\lambda}{\lambda}\right)^2 V_i \phi(v_m) - \left(\frac{\delta+\lambda}{\lambda}\right)\left(c + pe^{-\lambda T}\right)\phi(v_m) \\
&= \Phi(v_m) - \left(\frac{\delta+\lambda}{\lambda}\right)\left(pe^{-\lambda T} + c + \frac{\delta V_i}{\lambda}\right)\phi(v_m) \qquad \text{(B.3)}
\end{aligned}
$$

At optimality $\dfrac{\partial TC}{\partial V_i} = 0$ which gives us that

$$
V_i^* = \left(\frac{\lambda}{\delta}\right)\left(\left(\frac{\lambda}{\lambda+\delta}\right)\left(\frac{\Phi(v_m)}{\phi(v_m)}\right) - \left(pe^{-\lambda T} + c\right)\right) \qquad \text{(B.4)}
$$

However, we also need to check whether second order conditions are satisfied for this point. Differentiating once more we have that

$$
\begin{aligned}
\frac{\partial^2 TC}{\partial V_i^2} &= \frac{\partial}{\partial V_i}\left(\left(\frac{\delta+\lambda}{\lambda}\right)\left(pe^{-\lambda T} + c - \frac{\delta V_i}{\lambda}\right)\phi(v_m) + \Phi(v_m)\right) \\
&= \left(\frac{\delta+\lambda}{\lambda}\right)\left(-\left(\frac{\delta+\lambda}{\lambda}\right)\left(pe^{-\lambda T} + c - \frac{\delta V_i}{\lambda}\right)\phi'(v_m)\right) + \left(\frac{\delta+\lambda}{\lambda} - \left(\frac{\delta+\lambda}{\lambda}\right)\frac{\delta}{\lambda}\right)\phi(v_m) \\
&= \left(\frac{\delta+\lambda}{\lambda}\right)\left(-\left(\frac{\delta+\lambda}{\lambda}\right)\left(pe^{-\lambda T} + c - \frac{\delta V_i}{\lambda}\right)\phi'(v_m) + \left(\frac{\lambda-\delta}{\lambda}\right)\phi(v_m)\right) \qquad \text{(B.5)}
\end{aligned}
$$

First consider the first differential w.r.t. V_i. When $V_i = a$, it can be seen that expression is negative as long as p is not too high. Secondly, when V_i^* satisfied equation B.4, we have that

$$\frac{\partial^2 TC}{\partial V_i^2} = -\frac{(\delta+\lambda)\left(\lambda\phi'(v_m)\Phi(v_m)+(\delta-\lambda)\phi(v_m)^2\right)}{\lambda^2\phi(v_m)} \tag{B.6}$$

In addition, note that for distributions which have increasing failure rates (IFR), $\phi(z)^2 - (\Phi(z) - 1)\phi'(z) > 0$ which implies that $\phi'(z) < \dfrac{\phi(z)}{\Phi(z)-1}$. Substituting this into eq. B.6, we have that

$$\begin{aligned}\frac{\partial^2 TC}{\partial V_i^2} &= -\frac{(\delta+\lambda)\left(\lambda\phi'(v_m)\Phi(v_m)+(\delta-\lambda)\phi(v_m)^2\right)}{\lambda^2\phi(v_m)} \\ &> \frac{(\delta+\lambda)\phi(v_m)\left(\delta\Phi(v_m)-\delta+\lambda\right)}{\lambda^2\left(1-\Phi(v_m)\right)} > 0\end{aligned}$$

Thus the second order conditions are also satisfied which means that the optimal initial settlement offer is given by eq. B.4.

b) For the second part of the proposition, let us differentiate the optimal V_i^* by the different parameters of interest. First consider the differential w.r.t. c. We have that

$$\frac{\partial TC}{\partial c\partial V} = -(\delta+\lambda)\phi(v_m) < 0$$

Since we have that at optimality $\dfrac{\partial^2 TC}{\partial V_i^2} > 0$, $\dfrac{\partial V_i^*}{\partial c} > 0$ [Topkis, 1998].

Differentiating with respect to p, we have that

$$\frac{\partial TC}{\partial p\partial V} = \frac{e^{-T\lambda}(\delta+\lambda)\phi(v_m)}{\lambda} > 0$$

Since we have that at optimality $\dfrac{\partial^2 TC}{\partial V_i^2} > 0$, $\dfrac{\partial V_i^*}{\partial c} < 0$ [Topkis, 1998].

c) First let us look at the implicit equation that defines V_i^* (eq. B.4). First we substitute for $V = v_m\left(\dfrac{\lambda}{\lambda+\delta}\right)$. Let v_m^* be the equilibrium marginal consumer when the initial settlement offer is V_i^*. Then the above substitution would result in the following equation as the first order condition:

$$\left(\frac{\lambda}{r+\lambda}\right)\Phi\left(v_m^*\right)-\phi\left(v_m^*\right)\left(c+pe^{-T\lambda}+\left(\frac{\delta}{\delta+\lambda}\right)v_m^*\right) \quad = \quad 0$$

Let us differentiate this w.r.t λ we have that

$$\frac{\partial^2 TC}{\partial\lambda\partial v_m} \quad = \quad \left(\frac{\delta}{(\delta+\lambda)^2}\right)\Phi\left(v_m^*\right)+\phi\left(v_m^*\right)\left(pTe^{-T\lambda}+\left(\frac{\delta}{(\delta+\lambda)^2}\right)v_m^*\right)>0$$

Since we have that at optimality $\frac{\partial^2 TC}{\partial v_m^2}>0$, $\frac{\partial v_m^*}{\partial\lambda}<0$ [Topkis, 1998]. Since $V_i^*=\left(\frac{\lambda}{\lambda+\delta}\right)v_m^*$, it follows that $\frac{\partial V_i^*}{\partial\lambda}<0$. □

Proposition 2. *The net payout is increasing in c. In addition, it is decreasing in λ if $c>\bar{c}$.*

b) There exists an optimal capacity that λ^* which minimizes the total cost of the insurer.

Proof. a) First let us look at the net payout and the sensitivity w.r.t. c. We have that

$$\begin{aligned}\frac{\partial P}{\partial c} &= \frac{\partial P}{\partial V}.\frac{\partial V}{\partial c}\\ &= \left(\frac{\lambda^2\Phi\left(v_m\right)-rV_i^*\left(r+\lambda\right)\phi\left(v_m\right)}{\lambda^2}\right).\frac{\partial V}{\partial c}>0\end{aligned}$$

For the second part of the proposition, note that

$$\frac{\partial P}{\partial\lambda} \quad = \quad \frac{r^2\left(V_i^*\right)^2\phi\left(v_m\right)}{\lambda^3}+\left(\frac{\lambda^2\Phi\left(v_m\right)-rV_i^*\left(r+\lambda\right)\phi\left(v_m\right)}{\lambda^2}\right)\left(\frac{\partial V_i^*}{\partial\lambda}\right)$$

Since $\frac{\partial V_i^*}{\partial\lambda}<0$, this expression is negative only if V_i^* is sufficiently high. Since, $\frac{\partial V_i^*}{\partial c}>0$, this implies c should be sufficiently small for the expression to negative. It follows that there would exist a threshold on the capacity cost, $\bar{c}$, such that if $c>\bar{c}$, then the net payout is decreasing in λ.

b) Now let us look at how the total costs are affected by changes to capacity. We have that

$$\begin{aligned}
\frac{\partial TC\left(V_i^*\right)}{\partial \lambda} &= \frac{\partial TC}{\partial \lambda} \\
&= \frac{\left(rV_i^*\phi\left(v_m\right)\left(\left(c+rV_i^*\right)+p\lambda e^{-T\lambda}\right)-\lambda\left(c+pe^{-T\lambda}T\lambda^2\right)\Phi\left(v_m\right)\right)}{\lambda^3} \qquad \text{(B.7)}
\end{aligned}$$

Clearly, the optimal capacity can be determined by equating the above expression to zero. For sufficiently high p (which is true by assumption) this equation will have a solution. But we also need to check for second order conditions. We have that

$$\begin{aligned}
\frac{\partial^2 TC\left(V_i^*\right)}{\partial \lambda^2} &= \frac{\partial}{\partial \lambda}\left(\frac{\left(rV_i^*\phi\left(v_m\right)\left(\left(c+rV_i^*\right)+p\lambda e^{-T\lambda}\right)-\lambda\left(c+pe^{-T\lambda}T\lambda^2\right)\Phi\left(v_m\right)\right)}{\lambda^3}\right) \\
&= \frac{\begin{array}{l}\left(\lambda^2\left(2c+pT^2\lambda^3e^{-T\lambda}\right)\Phi\left(v_m\right)-r^2\left(V_i^*\right)^2\phi'\left(v_m\right)\left(\left(c+rV_i^*\right)+p\lambda e^{-T\lambda}\right)\right. \\ \left.-\, rV_i^*\lambda\phi\left(v_m\right)\left(\left(4c+3rV_i^*\right)+2p\lambda(T\lambda+1)e^{-T\lambda}\right)\right)\end{array}}{\lambda^5}
\end{aligned}$$

As before, for a sufficiently high value of p, this expression is positive which implies that the solution to eq. B.7 would be the optimal capacity that minimizes the total costs. □