# The Economics of Insurance Fraud Investigation: Evidence of a Nash Equilibrium

by

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Abstract

The behavior of insurance companies investigating insurance fraud follows one of several Nash Equilibria under which companies consider the cost savings on a portion, or all, of the total claim. This behavior can reduce the effectiveness of investigations and cost reductions if the suboptimal equilibrium prevails and lead to higher insurance premiums. Alternative cooperative arrangements are examined that could reduce or eliminate this potential inefficiency.

Keywords: Insurance fraud, Nash equilibrium, Automobile medical payments, Liability insurance

A number of recent studies have examined claim settlement behavior by insurers as it relates to insurance fraud (Crocker and Tennyson (2002), Derrig (2002), Derrig and Weisberg (2004) and Dionne, Giuliano and Picard (2003)). In this paper, a model combining the cost of claims, the cost of investigating claims and the potential for reducing claim costs is developed and analyzed in a game theoretic approach. The presence of a Nash Equilibrium, in which no player in a simultaneous non-cooperative game can unilaterally improve its position by shifting its strategy for investigating claims, is observed under a variety of different market conditions. (For a more complete description of game theory economics and Nash Equilibrium, see Montet and Serra, 2003.) In most cases, the Nash Equilibrium is not at the globally optimal claim investigation strategy.

Claims presented to an insurance company for payment may include a variety of different components. One component is a valid expense that should be paid in full by the insurer, since both the amount is appropriate and the coverage is applicable. Another component could be an excessive charge on a claim that would otherwise be covered. A charge is considered excessive if it is judged by the insurer to be "unreasonable"; most insurance policies cover only "reasonable" charges with reasonability defined by context and ultimately determined by negotiation, arbitration or, if necessary, lawsuit. A third component could be a claim for a service that is not covered although other services would be covered. A final component could be for an incident that is not covered by the insurance policy. Sorting out the different components of a claim efficiently is a constant process with a claims department.

For automobile insurance coverage in the United States, bodily injury claims can consist of two different insurance coverages. Medical expenses incurred by the policyholder or anyone else insured under the policy (family members, anyone occupying the covered vehicle) as the result of an automobile accident are covered, subject to policy limits, by the insurance company providing medical payments or personal injury protection coverage without regard to fault. If someone is injured as the result of the fault of another person, then that injured party could pursue a liability claim against the responsible party, depending on the tort threshold applicable under the policy (Insurance Research Council, 2003, Chapter 2). The insurance company of the responsible party would be liable for the damages incurred by the injured person, subject to policy limits and degree of fault, under the liability insurance policy. Bodily injury liability damages consist of such tangible expenses as medical expenses and loss of income, which are termed special damages, and intangible components such as pain-and-suffering, loss of consortium or hedonic damages, which are termed general damages. The insurer that paid the medical expenses under the medical payments policy may also be able to recoup its payments from the liability insurer under subrogation.

In some cases the same insurer is responsible for both the medical expenses and the bodily injury liability payment. This would occur when the driver is responsible for an injury to a passenger, or if the same insurer covered the injured person under medical payments coverage and the responsible party under a different liability insurance policy. When a single insurer is responsible for all payments, determining the appropriate level of fraud investigation considers the entire cost of the claim.

## Claim Investigation

Several types of claim investigation are commonly used by automobile insurers. The most common method is an Independent Medical Examination (IME), in which a doctor selected by the insurer examines the injured claimant and develops an independent assessment of the injury and the appropriate treatment. If the IME indicates a different level of injury or treatment than the claimant has reported through his or her medical care provider, then the claims department has a stronger case for denying some or all of the medical expenses that have been, or are likely to be, submitted. Another type of investigation is a Medical Audit (MA), in which the medical expenses are reviewed by a specialist or an expert system. Unusual factors that appear in the medical audit may provide the claims department with justification to reduce the claim payment. A third alternative is to refer the claim to a Special Investigation Unit (SIU), where specifically trained personnel are assigned to investigate claims with unusual questions in order to determine whether, and how much of, the claim should be paid.

IMEs and MAs can be used to reduce the amount of claim payments for medical expenses. SIUs can also reduce these expenses, but can also impact other expenses or even determine if the claim is valid at all. One level of investigation would be to investigate all claims where the expected savings from the investigation exceed the cost of the investigation. We call that approach "tactically optimal." Another level of investigation would vary according to the characteristics of the claim so that the savings net of costs for the entire portfolio of claims is optimal in some way. We call this approach "strategically optimal." In order to measure the expected savings, the insurer needs to ascertain the chance of finding unreasonable or fraudulent activity and the potential savings if that activity is discovered. We now turn to a formalization of the cost/savings process.

## Savings versus Cost

The following notation will be used:

Cost of claim without any investigation:

PIP claim = P
Liability claim (excess of PIP) = L
Total Compensation = P+L

Subscripts on P and L:

First subscript indicates company responsible for PIP
Second subscript indicates company responsible for Liability (0 if no liability)

$P_{1,0}$ represents a PIP claim where company 1 has the PIP coverage and there is no liability
$P_{1,1}$ represents a PIP claim where company 1 has the PIP coverage and the liability coverage
$P_{1,2}$ represents a PIP claim where company 1 has the PIP coverage and company 2 has the liability coverage
$P_{1,\bullet}$ represents the sum of all PIP claims where company 1 has the PIP coverage
$L_{1,1}$ represents a liability claim where company 1 has the PIP coverage and the liability coverage
$L_{2,1}$ represents a liability claim where company 2 has the PIP coverage and company 1 has the liability coverage
$L_{\bullet,1}$ represents the sum of all liability claims where company 1 has the liability coverage

Savings from investigations:

Savings on PIP claims = SP
Savings on Liability claims = SL
Savings on Total claim = ST = SP + SL

Level of investigation:

No investigation = 0
Optimal investigation based on first party claims = A
Optimal investigation based on both first party and liability claims = B

Subscripts on SPA, SPB, SLA and SLB:

First subscript indicates company responsible for PIP

Second subscript indicates company responsible for Liability (0 if no liability)

$SPA_{1,0}$ represents the savings on PIP claims from an A level investigation where company 1 has the PIP coverage and there is no liability
$SPA_{1,1}$ represents the savings on PIP claims from an A level investigation where company 1 has the PIP coverage and the liability coverage

Investigation cost:

Cost of an A level investigation = IA
Cost of an B level investigation = IB

Subscripts on IA and IB:

First subscript indicates company responsible for PIP
Second subscript indicates company responsible for Liability (0 if no liability)

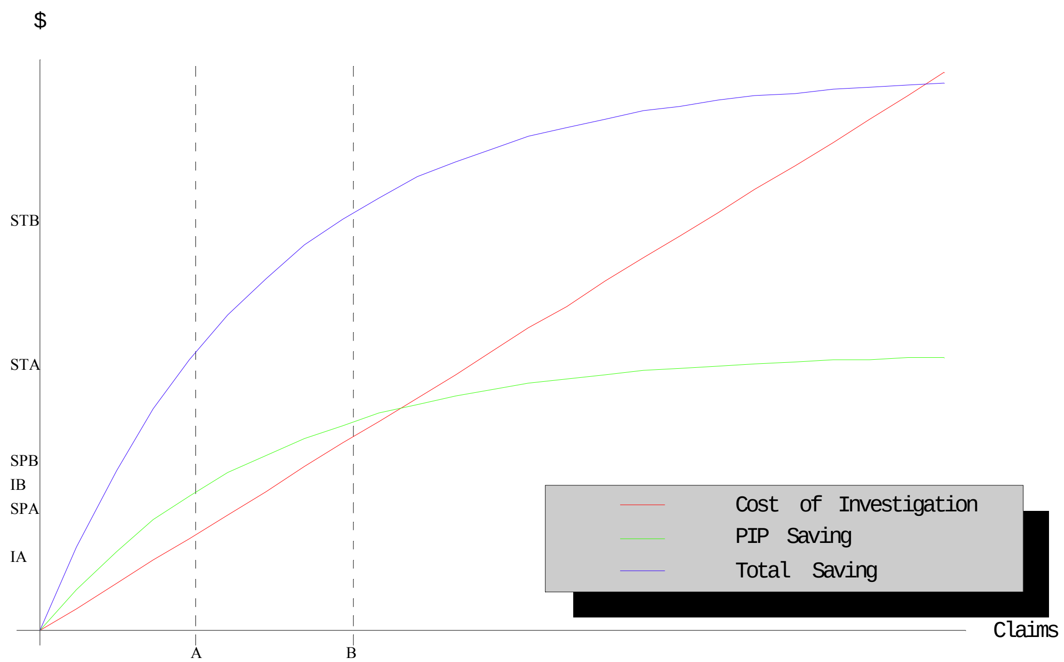
$IA_{1,0}$ represents the cost of an A level investigation where company 1 has the PIP coverage and there is no liability
$IA_{1,1}$ represents the cost of an A level investigation where company 1 has the PIP coverage and the liability coverage
$IA_{1,2}$ represents the cost of an A level investigation where company 1 has the PIP coverage and company 2 has the liability coverage

The relationships between the cost of investigation and expected savings, as well as the determination of the optimal levels of investigation under different circumstances, are illustrated in Figure 1. The x axis represents the number of claims. The y axis indicates dollar values. The claims are ordered in decreasing size of expected savings from claim investigations. The cost of investigations (I) function is a straight line under the assumption that each investigation has the same expected cost.[1] Two functions represent the expected savings from an investigation. The lower curve, labeled SP, represents the savings on first party claims and the higher curve, labeled ST, represents the savings on the total claim including both PIP and Liability payments. ($SP'$, $ST' > 0$ and $SP''$, $ST'' < 0$) A point will be reached where all the remaining claims are completely valid, so no additional savings are achieved by additional investigation.

[1] Insurers generally pay, for example, a fixed amount for an IME. If the claimant does not appear for the examination, the fee is reduced, but the insurer would not know, when requesting the IME, if the claimant will appear for it or not. SIU investigations cost more than IMEs and Medical audits cost less. The use of multiple techniques is relatively small. Thus, the assumption is made that the expected cost of an investigation is the same for each claim, and the function is linear.

The optimal level of investigation is determined when the slopes of the cost of investigation line and the savings are equal. The optimal number of claims to investigate, based on first party claims, is A. The cost of this investigation is IA, the savings on first party claims is SPA, and the savings on total claims is STA = SPA + SLA.

Figure 1




Some of the relationships that develop from this approach are:

SPB > SPA
IB > IA

SPA > IA
SPB > IB
SPB – SPA > IB – IA

## Single Insurer Case

When a single insurer writes the entire automobile insurance market, this company will be responsible for paying both the medical expenses and the liability award resulting from every automobile accident. In this case, the company can weigh the potential cost savings on the total claim against the cost of this investigation. The optimal level of investigation would be to investigate all claims where the expected savings from the investigation exceed the cost of the investigation. This is the situation we will consider first.

The three choices a single insurer faces regarding the level of claim investigation are displayed in Table 1. The insurer can perform no investigations and simply pay the amount claimed. This situation is displayed in the first box. Alternatively, the insurer can investigate A claims. The additional cost is $IA_{1,0} + IA_{1,1}$ and the associated savings are $SPA_{1,0} + SPA_{1,1} + SLA_{1,1}$. Since the savings on the PIP claims alone, $SPA_{1,0} + SPA_{1,1}$ exceed the cost of the investigations, the insurer would prefer this option over the case of no investigations. The third choice, though, where the insurer investigates B claims, is the optimal choice. The cost of this additional investigation is IB – IA. The additional savings are SPB + SLB – SPA – SLA. Since the slope of the Total Savings curve exceeds the slope of the cost of investigations curve over the range form A to B, then the savings exceed the costs, and the insurer would minimize net claim costs by investigating B claims.

This strategy will have the benefit of reducing the cost of unreasonable medical treatment to the lowest feasible level considering the cost to investigate claims. This strategy also reduces liability awards and the cost of automobile insurance, to the lowest level feasible given the cost of investigating these claims. Additional reductions in claims costs could be obtained, but the additional investigation expenses would exceed the claim cost savings, so insurance premiums would actually increase.

The other expenses of the insurer, including underwriting expenses and normal loss adjustment expenses (other than investigating for fraud) are not included in this analysis, since they will be the same regardless of the level of investigation for claims fraud.

## Two Insurer Case: No Subrogation

Assume the market consists of two competing insurers of equal size, with similar claim distributions (the SP and ST curves are the same for each insurer). Assume the claim settlement system does not permit the recovery of the claim payment and adjustment expense from any at-fault party through subrogation. Then they would each face a decision about the appropriate level of investigation of claims fraud, but their net claim costs would depend both on their own decision and the decision of their competitor. The outcomes, in the case where there is no subrogation, are shown on Table 2. The upper segment of each cell denotes the position of insurer 1; the lower segment that of insurer 2.

If both insurers were to investigate optimally based on aggregate claim costs, then each insurer would bear the cost of investigating B claims, and benefit from the savings in claim costs on both PIP and Liability claims. This situation is represented in cell (B, B) and resembles the optimal position for the single insurer case. Unreasonable medical expenses are reduced to the lowest economically efficient level, liability costs are minimized and the total cost of auto insurance is kept at the lowest level.[2]

However, this is not a stable situation. Insurer 1 might be better off if it only investigated claims at the A level, which would lower its cost of investigations by (IB – IA), and only increase claim costs by ($SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SPA_{1,1}$), which could be less than the costs. If insurer 2 were to continue to investigate claims at the B level, then insurer 1 would benefit on its liability claims on which insurer 2 had the PIP coverage ($SLB_{2,1}$). For the two insurer example, the lower investigation costs may or may not exceed the savings. Although by (IB – IA) > ($SPB_{1,\bullet} - SPA_{1,\bullet}$), whether it also exceeds ($SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SPA_{1,1}$) depends on the relationship between the SP and ST curves and the cost of the claims insurer 1 has both PIP and Liability. However, if it is advantageous for insurer 1 to move to a lower level of investigation, then it would also benefit insurer 2 to move to that level, so the resulting position would be that displayed in cell (A, A).

If the insurers move to cell (A, A), that will prove to be a Nash Equilibrium. Neither insurer can move unilaterally to another position that benefits itself. Insurer A will not stop investigating claims at the A level and move to the no investigation level. If it were to do so, the savings would be IA and the cost would be $SPA_{1,\bullet} + SLA_{1,1}$. Since IA < SPA alone, this change would increase the net cost of claims. Although the overall optimal position would be cell (B, B), that is not a stable equilibrium since one company might benefit by reducing the level of investigations.

Table 3 describes the conditions the lead to each claim investigation strategy for the insurers. Cell (B, B) is a Nash Equilibrium if $IB_{1,\bullet} - IA_{1,\bullet} < SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SLA_{1,1}$. Since

[2] This insurer might prefer to investigate the claims it knows it has the liability insurance coverage on up to the aggregate level, and only investigate the remaining claims on which there is either no liability coverage or coverage provided by the other insurer, if it could identify those claims. However, there are several problems with this strategy. First, an insurer may not know if another company will be liable for a claim or not early enough in the claim process to make this distinction. Second, adopting a claim process that requires claims adjusters to have different strategies for investigation can complicate the process and increase overall costs. Based on discussions with claims personnel, such differential strategies are not common.

both insurers are assumed to be the same size and have the same distribution of claims and costs, then if this relationship holds for insurer 1, it should also apply to insurer 2. This equilibrium would apply if the cost savings for each insurer on claims where it had both the PIP and the liability coverage exceeded the additional cost of investigating claims at the B level. Each insurer would not be assured of receiving the savings of a B level investigation on its liability claims where the other insurer has the PIP claim, since that insurer might elect a lower level of investigation. Alternatively, cell (A, A) would be the Nash Equilibrium if $IB_{1,\bullet} - IA_{1,\bullet} > SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SLA_{1,1}$ and $IA_{1,\bullet} < SPA_{1,\bullet} + SLA_{1,1}$. Since $SPA_{1,\bullet} > IA_{1,\bullet}$ by itself, then cell (0, 0) will never be the Nash Equilibrium if there is no subrogation.

### Two Insurer Case: Subrogation

This situation differs from the no subrogation case in several ways. First, note the each Liability insurer is responsible for paying the PIP claims of the other insurer when liability attaches and the PIP insurer and the Liability insurer are different ($P_{i,j}$ where $i \neq j$). If insurer 1 investigates claims at the A level but insurer 2 does not investigate, insurer 1 does not benefit from the savings on the PIP claims where insurer 2 has the PIP claim but it has the liability ($SPA_{2,1}$). Insurer 2 benefits from the savings on PIP claims, however, where insurer 1 has the PIP claim and insurer 2 has the liability ($SPA_{1,2}$). Thus, the free rider problem may be more severe when subrogation is considered. In this situation, the Nash Equilibrium could be no claims investigation, since the insurer bears the cost of investigating its PIP claims, but benefits only on those claims where there is no liability or if the same company has the liability coverage, unless the other insurer investigates its own PIP claims.

The situation would be exacerbated in a jurisdiction where the liability insurer has to pay a flat percentage of the claim cost as unallocated LAE. If a claim adjuster is considering investigating a claim in which the expected savings will exceed the cost of the investigation, but another company is likely to be liable for the loss, the insurer is saving the other insurer money and reducing its unallocated LAE reimbursement. For example, assume a claim on which one insurer had the PIP coverage and the other insurer had the liability coverage generated \$2200 in claimed medical expenses. The PIP insurer could request and IME that is expected to cost \$300 and that would reduce the medical expenses by \$800, to \$1400. The PIP insurer may not do this investigation under a tactically optimal strategy. If the claim were to qualify for subrogation, then the reimbursement for unallocated LAE declines from $220 (10 percent of $2200) to $140 (10 percent of $1400) even though the claim department puts in more effort due to requesting and reviewing the IME and then negotiating with the claimant to reduce the claim payment. On the other hand, under a strategically optimal strategy, the PIP insurer may well investigate reimbursable PIP claims to reinforce a "hard-line" attitude on unreasonable medical charges in order to maximize savings on its own claims.

Table 5 describes the conditions that lead to each claim investigation strategy for the two insurers when subrogation is introduced. In this case, cell (0, 0) may be a Nash Equilibrium, since each insurer only saves money on claims where there either is no liability or it has the liability claim as well. Insurers no longer save money on PIP claims if another insurer has the liability, since those payments would be reimbursed under subrogation. Thus, subrogation introduces a disincentive to investigating claims for fraud.

### Multiple Insurer Case

The more typical situation is where there are many insurers in the market. Some insurers may write a major share of the market within an individual state, in some cases in excess of 30 percent, but in most states a large number of insurers compete and the market share of most companies represents a small share of the market. Thus, it is less likely for the same insurer to provide PIP coverage under one policy involved in a claim, and liability coverage under another policy. (In other words, with a smaller share of the market, the chance of an accident involving two cars covered by the same insurance company declines.) In this situation, the Nash Equilibrium is even more likely to be the no investigation level, since most of the benefits of the investigations will accrue to other insurers. The relationships for a market with multiple insurers and subrogation are described in Table 6.

### Example

This decision process facing each insurer can be illustrated by an example. A PIP claimant is visiting a physical therapist for treatment. The current cost of the claim is $2000 for medical expenses. Another party is expected to be held liable for the accident. Based on past experience for that type of injury with that physical therapist, the PIP insurer expects the total claim for medical treatment will be $2250. If the PIP insurer orders an IME, which costs $300, the insurer expects to be able to determine that no additional physical therapy is needed, limiting medical expenses to $2000. The liability award for non-economic losses (pain and suffering) is expected to be $4000 if no additional treatment is received, but $4300 if additional treatment is provided. The liability insurer is not in a position to undertake this investigation and reduce its costs, since, by the time a determination of liability is made the full treatment of physical therapy will be completed.

The cost of the IME, $300, exceeds the PIP savings of $250 on this claim, but is less than the total of the PIP and liability savings ($550). In the single insurer case, the insurer will request an IME on this claim and curtail the additional costs. In the two insurer case, if there is no subrogation, the PIP insurer spends $300, saves $250 on the PIP and has a 50% chance of saving $300 more on the liability claim (with only two insurers, the PIP insurer has a 1 in 2 chance of writing the responsible party's liability insurance). Therefore, the PIP insurer would also request the IME on this claim. In the two insurer case where there is subrogation, the PIP insurer faces a 50% chance of saving on the PIP claim and on the noneconomic losses (if it also has the liability), so the expected savings would be $275 (half of the $550 total savings). Thus, the PIP insurer would not investigate this claim unless the allocated LAE is reimbursable. If LAE is not reimbursable, the cost of investigating the claim is $300. If LAE is reimbursable, then the expected cost of the IME is reduced to $150, which would encourage the PIP insurer to undertake this investigation.

In the multiple insurer case, the PIP insurer will have a lower chance of providing the liability coverage on this claim. In this example, if this chance is less than 1 in 6, then the expected savings on the non-economic losses would not be enough to compensate the PIP insurer to undertake this investigation, regardless of whether or not allocated LAE is reimbursable. Thus, the incentive for insurers to be strategically optimal is much lower when a large number of insurers compete.

## Alternative Arrangements

This incentive to under investigate claims can be addressed in several ways. If the claim investigation strategy is viewed as a repeated game, with monitoring of the performance of other insurers, then rules can be established to provide incentives to investigate claims more fully to the mutual benefit of all, leading to the optimal (B, B) equilibrium. The initial strategy described in this paper assumes that insurers make only one choice of investigation after considering the expected costs and savings. Alternatively insurers can switch levels of investigation depending on the behavior of the other insurer, making this situation a repeated non-cooperative game. In this situation, negotiation and monitoring might be able to move the equilibrium position back to cell (B, B). Liability insurers will know, when paying the claim and subrogation expense, whether the claim has been investigated. If a company is not investigating an appropriate proportion of claims (each insurer would know this, since the optimal level of investigation is assumed to be the same among all insurers), other insurers could retaliate against the offending insurer by treating that company's PIP claims differently or provoking regulatory oversight. Of course, in the case of an insurer going insolvent, there is no expectation of the repeated game and that insurer may revert to no investigation without fear of future retaliation. Thus, observing an insurer's claim investigation pattern could prove to be an early warning sign of financial problems.

A second approach to addressing the under investigation problem would be to develop a system under which the claim investigation costs are shared among all insurers. One method of doing this would be to handle claim investigations in a manner similar to a reinsurance pool, where bills are submitted to the pool and any market share adjustments necessary are made at the pool level. Each company is required to pay a proportionate cost of claim investigations, based on market share, regardless of their own investigation strategy. Another method of doing this would be to establish a separate fraud investigation unit, with the costs shared by all insurers, that decide which claims to investigate based on the total cost savings impact, regardless of which insurer will benefit from these savings.

## Empirical Evidence

There is evidence in Massachusetts (Derrig and Weisberg (2003))that insurers follow the strategy of investigating claims at least to the extent that they will derive the cost savings directly (i.e. they are at least tactically optimal). Massachusetts is a no-fault state, with all auto insurance companies required to offer first-party Personal Injury Protection coverage to policyholders. This coverage provides \$8000 of coverage for medical expenses, loss of income, compensation for loss of services and other expenses related to an injury caused by an automobile accident. There is also a \$2000 tort threshold for liability claims. This threshold can be met by eligible medical expenses including ambulance, hospital, physician, chiropractor or physical therapy bills. An injured person can only recover non-economic losses if the accident is the fault of another party and medical expenses exceed $2000. Since medical expenses are covered by the PIP insurance, there is an incentive for a claimant to incur at least this amount in medical bills (Weisberg, et al.(1994)).

If the PIP insurer can contain the medical expenses below $2000, not only will the PIP claim be lower but lower (or no) payments will be made for any non-economic losses. Even if medical expenses exceed the threshold, limiting the total medical expenses can have an additional impact on the liability claim, since the non-economic losses included in liability settlements are directly related to medical expenses. Although demonstrating that the total liability settlement is not simply a multiple of the medical expenses, Derrig and Weisberg (2004) found that the settlements for non-economic losses do increase with the cost of the medical expenses incurred but are reduced in other circumstances (such as high suspicion of fraud) by negotiation. Thus, any impact the PIP insurer can have to restrain medical expenses will have an additional cost savings on the non-economic losses and level B investigation may raise the return to investigation to all insurers.

## Conclusion

Viewing claim investigation strategy in a game theoretic framework demonstrates the incentives and disincentives to investigate automobile insurance claims for excessive claim behavior that currently exist. When subrogation of PIP claims exists, subrogation of allocated expense provides an incentive for investigation but flat reimbursement for unallocated expense provides a disincentive. Based on this analysis, additional cooperative behavior should be encouraged in order to more effectively reduce excessive medical treatment and overall insurance costs. Methods to encourage insurers to engage in strategically optimal approaches to investigating claims should be developed.

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Table 1
Single Insurer Case
Net Cost of Claim and Investigations

| Level of Claim Investigation | | |
|---|---|---|
| None (0) | PIP Based (A) | Total Claim Based (B) |
| $P_{1,0} + P_{1,1} + L_{1,1}$ | $P_{1,0} + P_{1,1} + L_{1,1} - SPA_{1,0} - SPA_{1,1} - SLA_{1,1} + IA_{1,0} + IA_{1,1}$ | $P_{1,0} + P_{1,1} + L_{1,1} - SPB_{1,0} - SPB_{1,1} - SLB_{1,1} + IB_{1,0} + IB_{1,1}$ |

Table 2
Two Insurer Case
Net Cost of Claim and Investigations
No Subrogation

| Insurer 2 Level of Claim Investigation | Insurer 1 Level of Claim Investigation: None (0) | PIP Based (A) | Total Claim Based (B) |
|---|---|---|---|
| 0 | $P_{1,\bullet}+L_{\bullet,1}$<br>$P_{2,\bullet}+L_{\bullet,2}$ | $P_{1,\bullet}+L_{\bullet,1}-SPA_{1,\bullet}-SLA_{1,1}+IA_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SLA_{1,2}$ | $P_{1,\bullet}+L_{\bullet,1}-SPB_{1,\bullet}-SLB_{1,1}+IB_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SLB_{1,2}$ |
| A | $P_{1,\bullet}+L_{\bullet,1}-SLA_{2,1}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPA_{2,\bullet}-SLA_{2,2}+IA_{2,\bullet}$ | $P_{1,\bullet}+L_{\bullet,1}-SPA_{1,\bullet}-SLA_{\bullet,1}+IA_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPA_{2,\bullet}-SLA_{\bullet,2}+IA_{2,\bullet}$ | $P_{1,\bullet}+L_{\bullet,1}-SPB_{1,\bullet}-SLB_{1,1}-SLA_{2,1}+IB_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPA_{2,\bullet}-SLB_{1,2}-SLA_{2,2}+IA_{2,\bullet}$ |
| B | $P_{1,\bullet}+L_{\bullet,1}-SLB_{2,1}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPB_{2,\bullet}-SLB_{2,2}+IB_{2,\bullet}$ | $P_{1,\bullet}+L_{\bullet,1}-SPA_{1,\bullet}-SLA_{1,1}-SLB_{2,1}+IA_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPB_{2,\bullet}-SLA_{2,1}-SLB_{2,2}+IB_{2,\bullet}$ | $P_{1,\bullet}+L_{\bullet,1}-SPB_{1,\bullet}-SLB_{\bullet,1}+IB_{1,\bullet}$<br>$P_{2,\bullet}+L_{\bullet,2}-SPB_{2,\bullet}-SLB_{\bullet,2}+IB_{2,\bullet}$ |

Table 3
Two Insurer Case
No Subrogation

| Nash Equilibrium | | |
|---|---|---|
| | Insurer 1 | Insurer 2 |
| (0, 0) | $IA_{1,\bullet} > SPA_{1,\bullet} + SLA_{1,1}$ | $IA_{2,\bullet} > SPA_{2,\bullet} + SLA_{2,2}$ |
| (A, A) | $IA_{1,\bullet} < SPA_{1,\bullet} + SLA_{1,1}$ | $IA_{2,\bullet} < SPA_{2,\bullet} + SLA_{2,2}$ |
| | $IB_{1,\bullet} - IA_{1,\bullet} > SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SLA_{1,1}$ | $IB_{2,\bullet} - IA_{2,\bullet} > SPB_{2,\bullet} - SPA_{2,\bullet} + SLB_{2,2} - SLA$ |
| (B, B) | $IB_{1,\bullet} - IA_{1,\bullet} < SPB_{1,\bullet} - SPA_{1,\bullet} + SLB_{1,1} - SLA_{1,1}$ | $IB_{2,\bullet} - IA_{2,\bullet} < SPB_{2,\bullet} - SPA_{2,\bullet} + SLB_{2,2} - SLA$ |

Table 4
Two Insurer Case
Net Cost of Claim and Investigations
Subrogation

| | | Insurer 1 Level of Claim Investigation | | |
|---|---|---|---|---|
| | | None (0) | PIP Based (A) | Total Claim Based (B) |
| Insurer 2 Level of Claim Investigation | 0 | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}$<br>$P_{2,0}+P_{1,2}+P_{2,2}+L_{1,2}+L_{2,2}$ | $P_{1,0}+P_{2,1}+P_{1,1}+L_{2,1}+L_{1,2}-SPA_{1,0}$<br>$-SPA_{1,1}-SLA_{1,1}+IA_{1,\bullet}$<br>$P_{2,0}+P_{2,2}+P_{1,2}$<br>$+L_{2,2}+L_{1,2}-SPA_{1,2}-SLA_{1,2}$ | $P_{1,0}+P_{2,1}+P_{1,1}+L_{2,1}+L_{1,1}-SPB_{1,0}$<br>$-SPB_{1,1}-SLB_{1,1}+IB_{1,\bullet}$<br>$P_{2,0}+P_{2,2}+P_{1,2}$<br>$+L_{2,2}+L_{1,2}-SPB_{1,2}-SLB_{1,2}$ |
| | A | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}$<br>$-SPA_{2,1}-SLA_{2,1}$<br>$P_{2,0}+P_{1,2}+P_{2,2}$<br>$+L_{1,2}+L_{2,2}-SPA_{2,0}$<br>$-SPA_{2,2}-SLA_{2,2}+IA_{2,\bullet}$ | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}-SPA_{1,0}-SPA_{1,1}$<br>$-SPA_{2,1}-SLA_{1,1}-SLA_{2,1}+IA_{1,\bullet}$<br>$P_{2,0}+P_{1,2}+P_{2,2}$<br>$+L_{1,2}+L_{2,2}-SPA_{2,0}-SPA_{1,2}$<br>$-SPA_{2,2}-SLA_{1,2}-SLA_{2,2}+IA_{2,\bullet}$ | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}-SPB_{1,0}-SPB_{1,1}$<br>$-SPA_{2,1}-SLB_{1,1}-SLA_{2,1}+IB_{1,\bullet}$<br>$P_{2,0}+P_{1,2}+P_{2,2}$<br>$+L_{1,2}+L_{2,2}-SPA_{2,0}-SPB_{1,2}$<br>$-SPA_{2,2}-SLB_{1,2}-SLA_{2,2}+IA_{2,\bullet}$ |
| | B | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}-SPB_{2,1}-SLB_{2,1}$<br>$P_{2,0}+P_{1,2}+P_{2,2}+L_{1,2}+L_{2,2}$<br>$-SPB_{2,0}-SPB_{2,2}-SLB_{2,2}+IB_{2,\bullet}$ | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}-SPA_{1,0}-SPA_{1,1}$<br>$-SPB_{2,1}-SLA_{1,1}-SLB_{2,1}+IA_{1,\bullet}$<br>$P_{2,0}+P_{1,2}+P_{2,2}$<br>$+L_{1,2}+L_{2,2}-SPB_{2,0}-SPA_{1,2}$<br>$-SPB_{2,2}-SLA_{1,2}-SLB_{2,2}+IB_{2,\bullet}$ | $P_{1,0}+P_{1,1}+P_{2,1}+L_{1,1}+L_{2,1}-SPB_{1,0}$<br>$-SPB_{\bullet,1}-SLB_{\bullet,1}+IB_{1,\bullet}$<br>$P_{2,0}+P_{1,2}+P_{2,2}+L_{1,2}+L_{2,2}$<br>$-SPB_{2,0}-SPB_{\bullet,2}-SLB_{\bullet,2}+IB_{2,\bullet}$ |

Table 5
Two Insurer Case
Subrogation

| | Nash Equilibrium | |
|---|---|---|
| | Insurer 1 | Insurer 2 |
| (0, 0) | $IA_{1,\bullet} > SPA_{1,0} + SPA_{1,1} + SLA_{1,1}$ | $IA_{2,\bullet} > SPA_{2,0} + SPA_{2,2} + SLA_{2,2}$ |
| (A, A) | $IA_{1,\bullet} < SPA_{1,0} + SPA_{1,1} + SLA_{1,1}$ | $IA_{2,\bullet} < SPA_{2,0} + SPA_{2,2} + SLA_{2,2}$ |
| | $IB_{1,\bullet} - IA_{1,\bullet} > SPB_{1,0} - SPA_{1,0} + SPB_{1,1} - SPA_{1,1} + SLB_{1,1} - SLA_{1,1}$ | $IB_{2,\bullet} - IA_{2,\bullet} > SPB_{2,0} - SPA_{2,0} + SPB_{2,2} - SPA_{2,2} + SLB_{2,2} - SLA_{2,2}$ |
| (B, B) | $IB_{1,\bullet} - IA_{1,\bullet} < SPB_{1,0} - SPA_{1,0} + SPB_{1,1} - SPA_{1,1} + SLB_{1,1} - SLA_{1,1}$ | $IB_{2,\bullet} - IA_{2,\bullet} < SPB_{2,0} - SPA_{2,0} + SPB_{2,2} - SPA_{2,2} + SLB_{2,2} - SLA_{2,2}$ |

Table 6
Multiple Insurer Case
Subrogation

| Nash Equilibrium | |
|---|---|
| | Insurer k |
| (0, 0) | $IA_{k,\bullet} > SPA_{k,0} + SPA_{k,k} + SLA_{k,k}$ |
| (A, A) | $IA_{k,\bullet} < SPA_{k,0} + SPA_{k,k} + SLA_{k,k}$ |
| | $IB_{k,\bullet} - IA_{k,\bullet} > SPB_{k,0} - SPA_{k,0} + SPB_{k,k} - SPA_{k,k} + SLB_{k,k} - SLA_{k,k}$ |
| (B, B) | $IB_{k,\bullet} - IA_{k,\bullet} < SPB_{k,0} - SPA_{k,0} + SPB_{k,k} - SPA_{k,k} + SLB_{k,k} - SLA_{k,k}$ |

When the number of insurers, n, increases:

The total investigation cost is $IA_{k,\bullet} = \sum_{j=1}^{n} IA_{k,j} + IA_{k,k} + IA_{k,0} (k \neq j)$. The share of efficient part ( $IA_{k,k} + IA_{k,0}$ ) in the investigation, which is spent on $SPA_{k,0} + SPA_{k,k} + SLA_{k,k}$, is $\frac{IA_{k,k} + IA_{k,0}}{IA_{k,\bullet}}$. When n→∞, $\frac{\sum_{j=1}^{n} IA_{k,j}}{IA_{k,\bullet}}$ →1, $\frac{IA_{k,k} + IA_{k,0}}{IA_{k,\bullet}}$ →0. That means that little of the investigation cost is spent to improve savings from $SPA_{k,0} + SPA_{k,k} + SLA_{k,k}$. Thus, no insurer would be likely to investigate claims for fraud. The Nash Equilibrium would tend to be (0, 0).