

Jörg Schiller

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¹ Jörg Schiller, Universität Hamburg, Institut für Versicherungsbetriebslehre, Von-Melle-Park 5, 20146 Hamburg, Tel.: +49 40 428386143, Fax: +49 40 428385505, Email: schiller@econ.uni-hamburg.de.

The Impact of Insurance Fraud Detection Systems*

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Abstract

The purpose of this paper is to characterize the impact of fraud detection systems on the auditing procedure and the equilibrium insurance contract, when a policyholder can report a loss that never occurred. Insurers can only detect fraudulent claims through a costly audit (costly state verification). With fraud detection system insurers can depend their audit on the signal of the system and auditing becomes more effective. This paper presents conditions under which insurance fraud and the resulting welfare losses can be reduced by the implementation of a costly fraud detection system that is supplied by an external third party.

Key words: insurance fraud, auditing, detection systems

JEL-Classification: D 82, G 22

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1 Introduction

Fraud is a well known phenomenon in insurance markets. Policyholders have the ability to use their informational advantage about the occurrence of an insured loss to report losses that never happened. Economists usually concentrate on an incentive compatible truth-telling mechanism that induces the agent to reveal his private information honestly. But in many situations that mechanism is not feasible, especially in the insurance fraud context, when the principal cannot commit ex ante to his audit strategy. Townsend [1979] introduced the costly state verification approach, which is used in many environments like credit markets (e.g. Gale/Hellwig [1985]) and taxation problems (e.g. Mookherjee/Png [1989]). The most important shortcoming of these earlier approaches is that insurance fraud never happens in equilibrium, because it is assumed that the principal can credibly commit ex ante to any desired audit probability. The crucial assumption of that commitment approach is that the principal decides before the agent takes his action. This kind of modelling is not very realistic in most auditing problems, because the principal would always revise his previous decision after the reception of the claims, if this is profitable. Commitment is a very powerful tool for principals, but the analysis of auditing problems should concentrate on so-called strategic commitment devices. If the principal cannot credibly commit himself ex ante to an audit strategy, policyholders will have an incentive to report some fraudulent claims as Picard [1996], Fag-gart/Picard [1999] and Boyer [2000] show. The only possible equilibrium is a Perfect Bayesian Nash equilibrium in mixed strategies, where policyholders defraud and insurance companies audit randomly. The special property of auditing procedures concerning insurance markets is that agents are assumed to be risk-averse.

Informative indirect information systems are very common in principal-agent models. Firstly, this paper concentrates on the impact of fraud detection systems on the auditing procedures and the overcompensation of the policyholder. Although some papers, like Belhadji/Dionne/Tarkhani [2000] and Artis/Ayuso/Guillén [2000], analyzed fraud detection models, to the best of our knowledge no paper concerning non-commitment auditing has taken information systems into account. This is surprising, because these systems are very popular and effective in existing insurance markets with considerable size, like the auto insurance market. Due to fraud detection systems, the insurer can concentrate his audits on suspicious claims and will obviously not audit all claims with the same probability and can therefore improve the effectiveness of his audits. Our approach is similar to that of Macho-Stadler/Pérez-Castrillo [2002], but they refer to tax audits with commitment and risk-neutral agents. We consider a fraud detection system, that provides indirect information about the true state of the world. The information of the system is observed privately by the insurer and is therefore

non-contractible. This information is modeled similar to Holmström [1979] as an additional signal that cannot be intentionally manipulated by the policyholder.¹ The quality of the fraud detection signal has a great impact on the fraud probability but not on the audit probability. *Ceteris paribus* fraud will happen less often in equilibrium, if the quality of the signal rises.

The insurer's inability to commit himself credibly causes an inevitable market inefficiency. Some proposed solutions for that non-commitment problem concentrate on the strategic commitment force of external third parties. For example, a common agency that takes wholly or partly charge of the insurer's audit costs and is financed *ex ante* by participating companies might help to decrease fraud as Picard [1996] shows. In contrast, Melumad/Mookherjee [1989] suggest that insurers can simply sign an incentive-compatible audit contract with an investigator and can therefore commit themselves credibly to any desired audit probability. Both approaches to overcome the non-commitment problem are not universally applicable. The *ex ante* collection of auditing expenditures by the common agency is impossible in non-regulated markets, where companies compete in premiums, because the transfer to the agency is sunk at the competition stage. The latter solution of Melumad/Mookherjee rests as well upon very critical assumptions. First of all, the underlying contract is not renegotiation-proof and the principal has incentives to renegotiate the delegation contract. Secondly, the authors abstract from the moral hazard problem between the principal and the external investigator. Since gathering information is costly, the development and implementation of an information system depends on the resulting costs and the expected market outcome. In this paper, we explore conditions under which a fraud detection system will be applied and give, in addition to Boyer [2000] and Picard [1996], a new motivation for the use of an external party like an Insurance Fraud Bureau (IFB). The important role of the IFB in our model is to transform the prevailing fix implementation costs of a fraud detection system, which can lead to a market breakdown, if firms compete in prices *a la* Bertrand.

The remainder of the paper is organized as follows. In section 2 we present the basic model and the optimal insurance contract without a fraud detection system. Section 3 concentrates on the effects of a fraud detection system on the equilibrium of the audit game and the underlying insurance contract. Furthermore, in section 4 we derive conditions under which a system will be implemented and show how the fraud detection should be organized. The conclusions follow in section 5.

¹The presented model is in that way not a signalling game, because the signal is an exogenous, statistical information generated from the fraud report, but the policyholder is unable to strategically influence the signal.

2 Equilibrium without fraud detection

2.1 The model and the sequence of play

We assume an insurance market with free entry, where $I \geq 2$ insurance companies compete through premium offers α . The insurers are risk-neutral, they face homogenous and independent risks of the policyholders, and therefore they have constant marginal costs. If insurers charge the same premium, they will share the market equally. In Bertrand equilibrium the premium offers correspond to the expected costs of a policyholder and all companies will charge the same premium. In absence of any fixed costs, what we will suppose until section 4, insurers make zero expected profits $\Pi(\cdot) = 0$ in equilibrium. The N risk-averse policyholders have the same attitude towards insurance fraud², the same initial income W_0 and the same twice differentiable von Neumann-Morgenstern utility function $U(W)$, with $U' > 0$ and $U'' < 0$. They maximize the expected utility of final wealth $EU(W)$. The traded contracts $C = (\alpha, \beta)$ consist of an insurance premium $\alpha \geq 0$ and an indemnity $\beta \geq 0$.

There are only two states of the world, "no accident" (ω_0) and "accident" (ω_1), with $\omega \in \{\omega_0, \omega_1\} = \Omega$. The probability of an accident is $\pi \in]0, 1]$ and the loss in the state of an accident is L . It is assumed that the loss is not higher than the policyholder's initial income $L < W_0$, and that insured consumers have private information about the state of world $\omega \in \Omega$. After the policyholder observes the move of nature ω he decides, whether to file a claim (m_1) or not (m_0), with $\{m_0, m_1\} = M$. Consequently, the insurance company has to decide, whether to audit a received claim (a_1) or not (a_0), with $\{a_0, a_1\} = A$. The audit is assumed to be perfect, thus after an audit the insurer can observe the state of world. The audit costs, which the insurer has to bear under any circumstances, are $c > 0$. Policyholders who are caught defrauding must pay a penalty k that is sunk and is not collected by the insurance company.³

²Boyer [1999] analyzes a situation with two different types of policyholders. One type never commits insurance fraud and always reports the state of the world honestly. The second type of policyholders is opportunistic and weighs up the costs and benefits of a fraudulent claim, if no accident occurred. In this paper we will concentrate on the second type of opportunistic policyholders.

³The penalty k is not part of the insurance contract, because it is usually determined by law and/or courts.

The sequence of play is:

- Stage 1: Insurance companies simultaneously offer insurance contracts C ;
- Stage 2: The nature chooses the state of the world. This move is private information of the policyholder;
- Stage 3: The policyholder decides whether or not to file a claim;
- Stage 4: The insurance company decides whether or not to audit a claim;
- Stage 5: The payoffs are paid and the game ends.

The Perfect Bayesian Nash equilibrium (PBNE) of the game consists of sequentially rational strategies given a belief system μ that is derived from the strategy profile through Bayes' rule whenever possible.

2.2 The claiming game

Policyholders can observe the state of the world. In equilibrium it is quite obvious, that every policyholder who suffered a loss will file a claim. The other way around it is trivial, that will never be a best response for the insurance company to audit, if no claim was made.⁴

Lemma 1 *The only PBNE in mixed strategies has the following properties:*

- *The insurance company has sequential consistent ex ante beliefs $\mu = \frac{c}{\beta}$, that a filed claim is fraudulent;*
- *Policyholders will always file a claim, if an insured loss occurred. Otherwise, if they have not suffered a loss, they will file a fraudulent claim with probability:*

$$\eta^* = \left(\frac{\pi}{1 - \pi} \right) \left(\frac{c}{\beta - c} \right); \quad (1)$$

- *Insurance companies audit all claims with the same probability*

$$\nu^* = \frac{U(W_0 - \alpha + \beta) - U(W_0 - \alpha)}{U(W_0 - \alpha + \beta) - U(W_0 - \alpha - k)}. \quad (2)$$

Proof. See Boyer [2000] ■

In equilibrium all claims are audited with the same probability and the policyholders who suffered a loss will always file a claim and get the indemnity, whether the insurer audits or not. But those, who have not suffered a loss, file a fraudulent claim with probability η^* .

⁴This result is just technical, because insurers are not able to audit a claim that was not made.

2.3 The equilibrium insurance contract

The insurer has to design a contract as a combination of coverage and premium that maximizes the policyholder's expected utility. Because of the non-existence of any fixed costs, the unique symmetric equilibrium premium offer of all I insurers corresponds to the constant marginal costs of a policy. Since the premium equals the marginal costs of a policy, insurers make an expected profit of zero. Until section 4, we will abstain from taking a closer look at the competition between insurers and therefore impose a zero expected profits constraint. The designed contract, in particular the indemnity β , alters the payoffs of the policyholder and influences the equilibrium randomization of the insurer and the policyholder. In the last section the equilibrium strategies for a given contract were specified. If insurance is sold at a fair premium, risk-averse consumers maximize their utility by full insurance, but, as a consequence of the audit game, in equilibrium there will always be some fraudulent claims which cause additional marginal costs per policyholder. Thus the premium offers of the companies will entail a proportional fraud loading $q > 1$.

Lemma 2 *In competitive insurance markets without fraud detection systems the utility maximizing contract $C^* = (\pi\beta^* \frac{\beta^*}{\beta^*-c}, \beta^*)$ entails overinsurance $\beta^* > L$ and a positive fraud loading $q > 1$.*

Proof. See Boyer [2000] ■

At first glance it seems quite surprising that the equilibrium contract entails overcompensation. There are two questions:

- Why should the insurer supply contracts that give the policyholder more incentives to commit insurance fraud?
- Why do risk-averse consumers maximize their utility by taking an income risk?

Firstly, the overcompensation does not only provide additional incentive for fraud, but it also gives the insurance companies an incentive to audit. The difference between the audit costs and the possible savings from detected fraudulent claims increases ceteris paribus with an increasing coverage. Therefore, the equilibrium fraud probability diminishes with an increase of coverage β as (3) shows:

$$\frac{\partial \eta^*}{\partial \beta} = - \left(\frac{\pi}{1-\pi} \right) \frac{c}{[\beta-c]^2} < 0. \quad (3)$$

Due to the properties of Nash equilibria in mixed strategies, in equilibrium the insurer is indifferent between his actions. With an increase of coverage, the policyholder has to change her equilibrium randomization in

order to make the insurance company indifferent between his actions. The insurance company is not able to commit himself *ex ante* to any other than the equilibrium audit strategy ν^* , because any other announcement will be identified as an incredible threat.

We can clarify the argument, if we take a closer look at the insurance premium $\alpha^* = \pi\beta^* \frac{\beta^*}{\beta^* - c}$. Insurance coverage is not supplied at a fair price, because the equilibrium premium entails a positive fraud loading q for any relevant parameter combination:

$$q = \frac{\beta}{\beta - c} > 1 \quad \text{for all } c \in]0, \beta[. \quad (4)$$

The fraud loading q decreases in coverage as shown by equation (5):

$$\frac{\partial q}{\partial \beta} = -\frac{c}{[\beta - c]^2} < 0 \quad \text{for all } c \in]0, \beta[. \quad (5)$$

Equation (5) confirms the earlier statement. The incentive for the insurance company to audit a filed claim increases *ceteris paribus* with an increase of the indemnity. The effects of overcompensation are similar to that of the unlimited liability discussion concerning principal-agent problems. The standard principal-agent problem has an approximate first-best solution without limited liability, if the penalty is set infinitely high, because that drastic penalty deters the agent from cheating. In our context the solution works the other way around. If the indemnity tends to infinity, insurance companies cannot allow that policyholders defraud, and therefore have to increase their audit probability which causes a decrease of the fraud probability. The indemnity cannot be increased infinitely, because the risk-averse policyholder has to bear an income risk for all indemnities $\beta \neq L$. The binding constraint is the utility maximization of the policyholder.

3 Equilibrium with a fraud detection system

3.1 Modifications

Let us assume that insurance companies are now able to implement a fraud detection system with a given technology that assigns an exogenous signal s to each reported loss. For the moment we desist from the costs of the fraud detection system and specify its properties. But later on, in section 4, we take a closer look at the consequences that the costs of the system might have.

The fraud detection system generates one of two possible signals $\{s_0, s_1\} \in S$, when a policyholder files a claim. The whole set of claims consists of two different types of reports:

- truthful claims with the probability $p(\omega_1, m_1) = \pi$ and
- fraudulent claims with the probability $p(\omega_0, m_1) = (1 - \pi)\eta$.

In addition to a filed claim, the insurance company receives a private signal from the fraud detection system. The properties of the fraud detection system are common knowledge. The conditional probabilities of the signal $s \in S$ given the state of world $\omega \in \Omega$ and the action $m \in M$ are:

	$p(s \mid \omega_1, m_1)$	$p(s \mid \omega_0, m_1)$
s_1	δ	ϕ
s_0	$(1 - \delta)$	$(1 - \phi)$

Table 1: Contingent Probabilities

The resulting probabilities of the signals are:

$$p(s_1) = \delta\pi + \phi(1 - \pi)\eta \quad (6)$$

and

$$p(s_0) = (1 - \delta)\pi + (1 - \phi)(1 - \pi)\eta \quad (7)$$

respectively.

We assume, that the insurance company will update their fraud beliefs $\mu(m)$ according to Bayes rule. Thus, the ex ante fraud beliefs $\mu(m, s)$ of the insurer after observing the signal s are:

$$p(\omega_0 \mid m_1, s_1) = \mu(m_1, s_1) = \frac{\phi(1 - \pi)\eta}{\delta\pi + \phi(1 - \pi)\eta} \quad (8)$$

and

$$p(\omega_0 \mid m_1, s_0) = \mu(m_1, s_0) = \frac{(1 - \phi)(1 - \pi)\eta}{(1 - \delta)\pi + (1 - \phi)(1 - \pi)\eta}. \quad (9)$$

3.2 Sequence of play

The earlier stated sequence of play must be modified with respect to the fraud detection systems. The insurer is now able to audit contingent on the signal. Consequently, the insurer has to decide whether to audit or to directly adjust the reported claim without any audit after he has observed the signal s .

The sequence of play is as follows:

- Stage 1: Insurance companies simultaneously offer insurance contracts C ;
- Stage 2: The nature chooses the state of the world. This move is private information of the policyholder;
- Stage 3: The policyholder decides whether or not to file a claim;
- Stage 4: When the policyholder files a claim, the insurance company receives a private signal $s \in S$. Otherwise the payoffs are paid and the game ends;
- Stage 5: The insurance company decides whether or not to audit a claim;
- Stage 6: The payoffs are paid and the game ends.

3.3 The claiming game

The signal of a fraud detection system should carry some relevant information about the probability that a particular claim is fraudulent. Therefore, we want to characterize in accordance with Holmström [1979] valuable or informative signals in the auditing context as follows:

Definition 1 *A signal is said to be informative, if $\mu(m_1) \neq \mu(m_1, s)$ holds, and non-informative otherwise.*

Next, we have to derive conditions that determine whether or not the insurance company should use the signal. Thus, we have to show how and to what extent the decisions of the players are influenced by the fraud detection system. The most critical point is the quality of the fraud detection system. With a higher quality the insurer can detect the same number of defrauders with fewer audits. The key feature of Nash equilibria in mixed strategies is that players randomize over their pure strategies in order to make the other players indifferent between their pure strategies. Using that property, we can easily state that the fraud detection system will only influence the randomization of the policyholder. The following Lemma shows under which conditions the fraud probability will decrease.

Lemma 3 *The fraud probability is always smaller with than without fraud detection, if a signal of the fraud detection system is informative.*

Proof. The proof is straightforward. We only have to compare the fraud probabilities with and without the system. For this reason we have to derive

the equilibrium fraud probability with fraud detection, which follows from the indifference condition of the insurer:

$$-\beta = \mu(m_1, s) [-c] + (1 - \mu(m_1, s)) [-\beta - c]. \quad (10)$$

Because of the two possible signals, we get two resulting probabilities. This seems surprising, but in equilibrium, as we will see during the proof, there can only be one. The resulting fraud probabilities are:

$$\eta_{s_1}^* = \left(\frac{\pi}{(1 - \pi)} \right) \left(\frac{\delta c}{\phi [\beta - c]} \right); \quad (11)$$

$$\eta_{s_0}^* = \left(\frac{\pi}{(1 - \pi)} \right) \left(\frac{(1 - \delta)c}{(1 - \phi) [\beta - c]} \right). \quad (12)$$

Obviously, both fraud probabilities are equal and as high as the fraud probability without detection, if $\phi = \delta$ holds. As a result, the fraud probability will decrease, if $\phi \neq \delta$, since the fraud beliefs of the insurer differ between s_1 and s_0 . Insurers will in equilibrium use the signal which leads to a lower fraud probability. ■

For the sake of simplification, we assume that the fraud beliefs of the insurer after the observation of s_1 are higher than after s_0 . This assumption does not cause any trouble, because, if the system is informative, we only have to denote the signal with the higher beliefs by s_1 . Another problem arises, if the signal s_1 leads to higher fraud beliefs, but the probability of the signal $p(s_1)$ is very low. From (6) and (11) we can derive the probability $p^*(s_1)$, which depends on the equilibrium fraud probability η^* .

$$p^*(s_1) = \delta\pi \frac{\beta}{\beta - c} \quad (13)$$

In such a case, the insurer cannot only concentrate on the filed claims with that signal. Therefore, the insurer would have to audit all claims with the signal s_1 and some claims with the signal s_0 . Consequently, in equilibrium the audit probability $\nu(s_0)$ is only zero, if $p^*(s_1)$ exceeds a critical value. To avoid that problem, we further assume that insurers audit claims with the signal s_1 without any exception.

The policyholders have to take the equilibrium audit strategy of the insurance company and the quality of the fraud detection system into account. Particularly, the probability $p^*(s_1)$ is very important, because it has a major influence on the exposure of fraudulent claims. As mentioned earlier, the fraud signal has an impact on the insurer's incentive to audit. However, after the implementation of the fraud detection system the structure of the game is unaffected.

Proposition 1 *If the insurer audits claims with the signal s_1 without any exception, the only PBNE for a given fraud detection system (δ, ϕ) will have the following properties:*

- *The insurance company has ex ante sequential consistent beliefs $\mu = \frac{\delta c}{\phi\beta - c[\phi - \delta]}$, that a filed claim is fraudulent;*
- *The equilibrium fraud probability is:*

$$\eta^* = \left(\frac{\pi}{(1 - \pi)} \right) \left(\frac{\delta c}{\phi[\beta - c]} \right); \quad (14)$$

- *The equilibrium audit probability $\nu^*(s_1)$ is:*

$$\nu^*(s_1) = \frac{1}{p^*(s_1)} \frac{U(W_0 - \alpha + \beta) - U(W_0 - \alpha)}{U(W_0 - \alpha + \beta) - U(W_0 - \alpha - k)}, \quad (15)$$

but the overall audit probability ν^ does not change, compared to the case without fraud detection.*

Proof. See Appendix ■

Not surprisingly, a perfect fraud detection system ($\delta = 0$) leads to a fraud probability of zero, because the insurance company would always receive the signal s_1 in the case of a fraudulent claim. But in equilibrium no fraudulent claims exist, because policyholders anticipate, that, if they cheat, the insurer will audit. Thus, in equilibrium the insurance company does not receive the signal s_1 and no audit is necessary. In the remainder of this section we compare the audit game with a fraud detection system with the results of the model without fraud detection. Especially we show the impact of a fraud detection system.

3.4 The equilibrium insurance contract

The signal is non-contractible, because it is private information of the insurer. For that reason, we can derive the optimal insurance contract \hat{C} in the same way as in section 2.3 and maximize the expected utility of the policyholder under the zero profit constraint of the insurance company.

$$\begin{aligned} \max_{\hat{\beta}} EU &= \pi U(W_0 - \alpha - L + \beta) + (1 - \pi)[(1 - \eta^*)U(W_0 - \alpha) \\ &\quad + \eta[[1 - \nu^*(s_1)p^*(s_1)]U(W_0 - \alpha + \beta) \\ &\quad + \nu^*(s_1)p^*(s_1)U(W_0 - \alpha - k)] \end{aligned} \quad (16)$$

s.t.

$$\alpha = \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]} = \pi\beta \left(1 + \frac{\delta c}{\phi[\beta - c]} \right) \quad (17)$$

Corollary 1 *In competitive insurance markets with an informative but imperfect fraud detection system ($\delta > 0$), the equilibrium contract \hat{C} entails overinsurance and $L < \hat{\beta} < \beta^*$ holds.*

Proof. See Appendix ■

The extended motivation of overcompensation as given in section 2.3 still holds, but the extent of overcompensation for an informative fraud detection system can be reduced, due to the decreased incentives of the policyholder to commit fraud. For that reason, overcompensation and fraud detection are substitutes, as both instruments help to mitigate insurance fraud. The informative detection system is welfare improving, because the fraud probability diminishes as was shown in Lemma 3, and more important, the expected marginal costs per contract decrease as Corollary 2 states.

Corollary 2 *After the implementation of an informative system, the marginal costs of a policy decrease.*

Proof. We have to compare the equilibrium marginal costs of a policy for any coverage β with and without the fraud detection system.

$$\pi\beta\frac{\beta}{\beta-c} > \pi\beta\frac{\phi\beta-c[\phi-\delta]}{\phi[\beta-c]} \quad (18)$$

Since the fraud detection system is informative and s_1 generates higher fraud beliefs than s_0 , the conditional probability of an insurance fraud after the observation of the signal s_1 is higher than after the signal s_0 , thus $\phi > \delta$ holds. Consequently, (18) holds for all relevant β . This is the reason why insurance companies - in absence of any costs - have to implement the informative fraud detection system in order to be competitive. ■

Fraud detection and overcompensation are two strategic devices that help to reduce insurance fraud. Our findings are in the spirit of Demougin/Fluet [2001]. Among other things, they analyze the impact of varying information gathering costs (like monitoring or auditing) on the optimal auditing-incentive-mix in a hidden action principal-agent relationship, where both parties are risk-neutral and the agent faces a limited liability constraint. In our model the agent is risk-averse and the exogenous penalty is an implicit limited liability constraint. Therefore, the insurer as the principal has to use other monetary incentives to reduce the costs of fraud. Another difference compared to our approach, is that the overcompensation is used as an indirect incentive for the principal to audit and not as an incentive for the agent to choose a higher effort level. The results are very similar, because if an informative signal is available, the principal will use more auditing and less monetary incentives to reduce the information rent of the agent. The meaning of "more auditing" is only valid in a wider sense here, because of the strategic auditing game. The better information of the insurer however leads to a reduction of overcompensation.

4 The organizational design of fraud detection

The effectiveness of the fraud combat is very sensitive to its organizational design. There are many approaches addressing whether or how an IFB can help mitigating the market inefficiency caused by the non-commitment problem of the principal. In Picard's view, the non-commitment problem can (partly) be solved by a common agency created for all insurance companies, that does not audit, but (partly) takes charge of the audit expenditures and is financed by of the whole market through partition fees. However, such a solution is only valid for regulated insurance markets. A different approach employed by Melumad/Mookherjee [1989] suggests for the case of a tax audit that the tax authority can delegate the auditing job to an independent investigation agency. But such delegation causes additional agency costs, because the investigator gets an incentive compatible audit contract. This solution is not really convincing for two reasons that the authors concede. Firstly, it is not renegotiation-proof, because the insurer has an incentive to privately renegotiate the contract with the audit agency after the audit contract is publicly signed. Secondly, Melumad/Mookherjee abstract from the moral hazard problem between the insurer and the agency. In light of this criticism, their results cannot really explain the existence of an IFB, as the non-commitment problem also arises in the proposed solutions. A further weighty shortcoming of both solutions is that they disregard the resulting costs and, more importantly, from the impact of the costs on the competitive market equilibrium. The final task of this paper is to examine the impact of the costs of a fraud detection system on the market equilibrium.

In addition to the information about the probability of a fraudulent claim, the fraud detection system will usually generate relevant information for the audit itself. Therefore, we could assume that the audit costs after the implementation of the systems would be lower than before. But the system will cause some costs of data input, because the relevant facts of the claim must be available for the system. Finally, we suppose that the two effects lead to the same audit costs c . More relevant than the per unit audit costs are the fixed costs of developing and implementing the system.⁵ For the remainder of the section we will concentrate on the arising problem of the fixed costs of fraud detection.

In the presence of fixed costs, the existence of a competitive market equilibrium is questionable, because the fixed costs are sunk for the premium competition stage. In the case where only one insurer can invent and implement the system at some fixed costs D , he will undercut all other companies and will force them to withdraw from the market, because of his reduced

⁵The implementation costs of an existing fraud detection system in New Jersey are 10 to 12 million USD. The per annum operating costs are more than twice of the implementation costs (see PANK, Ron [2001]: Making A Dent In Auto Insurance Fraud, *Best's Review*, October 2001).

marginal costs and charges $\alpha_M = \alpha - \varepsilon$. This market configuration is only feasible in the sense of Baumol/Panzar/Willig [1982], if the market has a considerable size and no capacity constraint is present. In equilibrium the monopoly insurer will make an expected profit:

$$\Pi = N [\hat{\alpha} - \alpha_M] - D \geq 0, \quad (19)$$

for some N .

For the remainder of the section, we will concentrate on the case, where an external supplier, e.g. an IFB, invents and implements an informative fraud detection system with a given technology. The supplier offers every insurer a participation contract $P = (F, f)$ that entails a fixed fee F and a variable fee f for every signal s . The sequence of play is as follows:

- Stage 1: The supplier offers the contract P to all insurers;
- Stage 2: The insurers decide simultaneously whether or not to accept the offered contract;
- Stage 3: Insurance companies simultaneously offer insurance contracts C ;
- Stage 4: The nature chooses the state of the world. This move is private information of the policyholder;
- Stage 5: The policyholder decides whether or not to file a claim;
- Stage 6: If the policyholder files a claim, the insurance companies that participated at stage 2, receive a private signal $s \in S$;
- Stage 7: The insurance companies decide whether or not to audit a claim;
- Stage 8: The payoffs are paid and the game ends.

We only analyze stages 1-3, because they determine whether the system can be implemented or not. There are only two possible types t_j , $j = 0, d$ of insurance companies that can offer insurance contracts, where 0 denotes companies without and d companies with a fraud detection system. Next, we exclude dominated participation contracts, that can never be a part of an equilibrium of the whole game of stages 1-3.

Lemma 4 *The optimal participation offer entails no fix participation fee F .*

Proof. See Appendix ■

Due to the Bertrand competition, there is no way that insurers can engage in activities that cause any fixed costs, because on the competition

stage such fixed costs are sunk. Consequently, the insurer can only offer insurance coverage at marginal costs and makes expected losses in the amount of the fixed costs. The only possibility to implement the system is to transform fixed costs into variable costs. Hence, the external supplier should implement the system centrally and charge insurers a fee f for each received signal. A market equilibrium with fraud detection can only be reached, if:

- i. The market configuration with fraud detection is feasible and sustainable, and consequently the marginal costs with fraud detection are lower than without.

$$\pi \frac{\phi [\beta - c] - \delta}{\phi [\beta - c]} [\beta + f] \leq \pi \beta \frac{\beta}{\beta - c} \quad (\text{C1})$$

- ii. The external supplier makes non-negative profits.

$$f \geq \frac{D}{N \pi \frac{\phi \beta - c [\phi - \delta]}{\phi [\beta - c]}} \quad (\text{C2})$$

Since Condition (C1) holds, there is no market configuration where an insurance company can make expected profits by not participating in the fraud detection system and undercutting the other companies. On the other hand, as can be seen from (C2), if the market size (number of policyholders) does not exceed a critical value, no fraud detection will be introduced.

Proposition 2 *A sustainable market equilibrium with fraud detection by all insurance companies is feasible, iff the market size N exceeds a critical value.*

Proof. In Bertrand equilibrium the premium offer corresponds to the marginal costs of the insurer with the lowest marginal costs. Due to Corollary 2 for some small f (C1) will hold. Therefore, if (C1) holds, no insurer, whether he participates or not, has an incentive to undercut the premium $\alpha^d = \pi \frac{\phi \beta - c [\phi - \delta]}{\phi [\beta - c]} [\beta + f]$, because he would make expected losses with such an offer. If (C1) holds, it is a dominant strategy for every insurance company to participate. The market size N is crucial, because f vanishes, if N tends to infinity. Ceteris paribus f declines with a rising market size, and therefore fraud detection is becoming more advantageous. ■

Although we disregarded the strategic problem of the external supplier and only considered a break even situation, Proposition 2 can explain the fact that fraud detection systems are only used in insurance market with a high number of policyholders. As a result, an enough informative and costly fraud detection system can only be supplied by an external party through a participation contract with a variable fee. Every insurer accepts the participation contract in order to be competitive.

5 Conclusions

One possible strategic commitment device to reduce fraud in the non-commitment context is overcompensation of the agent, because it commits the insurer to audit more often. In this paper, we have characterized the impact of a fraud detection system on the equilibrium of the audit game and the insurance contract. We show that informative fraud detection systems are another possible strategic commitment device to reduce the fraud probability in the economy, because insurers can condition their audits on the signal and no longer audit all claims with the same probability. Due to the properties of Nash equilibria in mixed strategies, the detection system affects only the randomization of the policyholders. Since the fraud probability and the overcompensation of the policyholder diminish in signal quality, the non-commitment problem of the insurer remains as long as the signal is incomplete.

The amount and structure of the costs of a detection system is very crucial in our context. Fraud detection systems base on computer programs that cause high implementation costs. Operating a system will only be remunerative, if the benefits from the declining fraud probability exceed the relative costs of the system related to an individual consumer. For that reason, the number of policyholders on the market is critical for the effectiveness of fraud detection. Thus, we can confirm the fact that fraud detection is only performed in insurance markets with a considerable size, such as the auto insurance and the workers compensation insurance market. Moreover, we deduce, that due to the fixed costs of the system and the Bertrand competition on the considered insurance market, the contract between insurers and the external supplier of the system can only consist of a variable transfer from the insurer to the supplier.

The analysis neglects two aspects. First of all, we do not consider any negotiations. As Macho-Stadler/Pérez-Castrillo [2001] show for the commitment audit case, a fraud detection system which generates an informative signal, gives the insurer incentives for renegotiations with the policyholder. After observing the signal, insurers have an incentive to settle with policyholders in order to save audit expenditures. The settlement is ex post efficient, but dilutes the deterrence effect of the fraud detection system. Future research should concentrate on the renegotiation incentives and their effects in a non-commitment environment. Another shortcoming of our approach is the binary signal of the system. More realistically, the model should be enlarged and should consider continuous signals and their impact on the audit game, even if such an extension will presumably not cause any structural changes of the equilibrium properties.

Appendix

Proof of Proposition 1. The equilibrium audit probabilities $\nu^*(s)$ of the insurance company will make the policyholder indifferent between his actions m_0 and m_1 , if no accident occurred. Thus $\nu^*(s)$ must solve:

$$\begin{aligned} U(W_0 - \alpha) &= p^*(s_1)[\nu^*(s_1)U(W_0 - \alpha - k) \\ &\quad + (1 - \nu^*(s_1))U(W_0 - \alpha + \beta)] \\ &\quad + p^*(s_0)[\nu^*(s_0)U(W_0 - \alpha - k) \\ &\quad + (1 - \nu^*(s_0))U(W_0 - \alpha + \beta)]. \end{aligned} \quad (20)$$

As we have assumed, the audit probability $\nu^*(s_0)$ is zero in equilibrium. Therefore, the audit probability $\nu^*(s_1)$ is:

$$\nu^*(s_1) = \frac{1}{p^*(s_1)} \frac{U(W_0 - \alpha + \beta) - U(W_0 - \alpha)}{U(W_0 - \alpha + \beta) - U(W_0 - \alpha - k)}. \quad (21)$$

The overall audit probability $v^* = p^*(s_0) \cdot \nu^*(s_0) + p^*(s_1) \cdot \nu^*(s_1)$ is unchanged in equilibrium, thus

$$v^* = \frac{U(W_0 - \alpha + \beta) - U(W_0 - \alpha)}{U(W_0 - \alpha + \beta) - U(W_0 - \alpha - k)} \quad (22)$$

still holds.

The fraud probability makes the insurer indifferent between his action a_0 and a_1 . Lemma 3 stated, that for an informative fraud detection system, the resulting beliefs are $\mu(m_1, s) \neq \mu(m_1)$. Since we denoted the signal with the higher fraud beliefs by s_1 , the posterior fraud belief of the insurer after observing a filed claim and the accompanied signal s_1 is:

$$\mu(m_1, s_1) = \frac{\phi(1 - \pi)\eta}{\delta\pi + \phi(1 - \pi)\eta}. \quad (23)$$

The belief of (23) must be higher than that resulting from s_0 , because the policyholder plays a "no-signalling-game" with the insurer. Due to the randomization of the policyholder, the insurer is indifferent between his pure actions a after observing the signal s_1 . Thus $\mu(m_1, s_1)$ solves the indifference condition:

$$-\beta = \mu(m_1, s_1) [-c] + (1 - \mu(m_1, s_1)) [-\beta - c]. \quad (24)$$

In equilibrium the insurer will have no incentive to audit after observing s_0 , because, if he is indifferent after s_1 between his actions, the fraud belief after observing s_0 are strictly lower. Using (23) the resulting fraud probability is:

$$\eta^* = \frac{\pi}{(1 - \pi)} \frac{\delta c}{\phi[\beta - c]}. \quad (25)$$

It is left to proof that the ex ante fraud belief of the insurer is a result of the equilibrium fraud probability. Hence, the belief must be confirmed in equilibrium. The ex ante fraud μ belief is:

$$\mu = \frac{(1 - \pi)\eta^*}{\pi + (1 - \pi)\eta^*} = \frac{\delta c}{\phi[\beta - c]}. \quad (26)$$

Since all elements of the PBNE have been found, the prove is done. ■

Proof of Corollary 1. The utility maximizing insurance premium can be derived by rearranging the zero profit condition of the insurance company.

$$\begin{aligned} \alpha = & \pi\beta + (1 - \pi)(1 - \nu^*)\beta \frac{\pi}{(1 - \pi)} \frac{\delta c}{\phi[\beta - c]} \\ & + \nu^*c \left[\delta\pi + \phi(1 - \pi) \frac{\pi}{(1 - \pi)} \frac{\delta c}{\phi[\beta - c]} \right] \end{aligned} \quad (27)$$

Simplifying (27) yields to:

$$\alpha = \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]}, \quad (28)$$

which is equivalent to:

$$\alpha = \pi\beta \left(1 + \frac{\delta c}{\phi[\beta - c]} \right). \quad (29)$$

After using (28), the simplified maximization problem is:

$$\max_{\beta} EU = \pi U \left(W_0 - \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]} - L + \beta \right) + (1 - \pi)U \left(W_0 - \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]} \right). \quad (30)$$

The first order condition for an interior solution is given by:

$$\begin{aligned} \frac{\partial EU}{\partial \beta} = & \pi U' \left(W_0 - \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]} - L + \beta \right) \left[1 - \pi \frac{\phi\beta^2 - 2\phi\beta c + c^2[\phi - \delta]}{\phi[\beta - c]^2} \right] \\ & - (1 - \pi)U' \left(W_0 - \pi\beta \frac{\phi\beta - c[\phi - \delta]}{\phi[\beta - c]} \right) \left[\pi\beta \frac{\phi\beta^2 - 2\phi\beta c + c^2[\phi - \delta]}{\phi[\beta - c]^2} \right] = 0. \end{aligned} \quad (31)$$

We can simply show that the marginal utility of the policyholder for full insurance is positive and if it is so, overinsurance will be optimal. Let us take a closer look at the marginal utility of the policyholder at the locus $\beta = L$.

$$\frac{\partial EU}{\partial \beta} \Big|_{\beta=L} = \pi U' \left(W_0 - \pi L \frac{\phi L - c[\phi - \delta]}{\phi[L - c]} \right) \left[1 - \frac{\phi L^2 - 2\phi L c + c^2[\phi - \delta]}{\phi[L - c]^2} \right] \quad (32)$$

Equation (32) is positive as long as the second bracket is positive and (33) holds.

$$\frac{\phi L^2 - 2\phi Lc + c^2[\phi - \delta]}{\phi[L - c]^2} < 1 \quad (33)$$

After some transformations of (33) we get condition (34):

$$\delta > 0. \quad (34)$$

Condition (34) is true, as long as the fraud detection system is not perfect, which implies that some suspicious claims with the signal s_1 are not fraudulent. In equilibrium the optimal coverage solves:

$$\begin{aligned} & \frac{U' \left(W_0 - \pi\beta^* \frac{\phi\beta^* - c[\phi - \delta]}{\phi[\beta^* - c]} - L + \beta^* \right)}{\pi \cdot U' \left(W_0 - \pi\beta^* \frac{\phi\beta^* - c[\phi - \delta]}{\phi[\beta^* - c]} - L + \beta^* \right) - (1 - \pi)U' \left(W_0 - \pi \cdot \beta^* \frac{\phi\beta^* - c[\phi - \delta]}{\phi[\beta^* - c]} \right)} \quad (35) \\ & = \frac{\phi(\beta^*)^2 - 2\phi\beta^*c + c^2[\phi - \delta]}{\phi[\beta^* - c]^2}. \end{aligned}$$

The optimal coverage β^* for $\delta > 0$ is strictly higher than L , because the marginal utility at the locus $\beta = L$ is always non-negative as we have shown. From (29), (33) or (35) we can easily deduce, that full insurance is only optimal, if the fraud detection system is perfect ($\delta = 0$). ■

Proof of Lemma 4. We distinguish the observable and unobservable contract choice of the insurers at stage 2. Firstly, we consider the case where the contract choice is observable. Using backwards induction argumentation, we can exclude any fixed fee F . If insurers accept the contract with a fixed fee, they will make an expected loss of $\Pi^d = -F$, because at the competition stage 3 they can only charge premiums equally to their marginal costs. The strategy to accept that contract is dominated by not accepting it and withdraw from the market, which leads to a expected profit of zero.

If the contract choice is unobservable, the relevant strategies of the insurers will consist of a participation contract choice and an insurance contract offer. The external supplier will only offer contracts at stage 1 that will earn non-negative expected profits at stages 2 and 3. Therefore, the supplier offers the contracts $P_v = (0, f)$, where the supplier only charges a positive variable fee $f \geq \frac{D}{N\pi \frac{\phi\beta - c[\phi - \sigma]}{\phi[\beta - c]}}$ and the contract $P_f = (F, 0)$, where the supplier only charges a positive fixed fee $F \geq \frac{D}{T}$. At the competition stage 3, the two types of insurers can only offer the usual Bertrand equilibrium contracts. This leads again to the result that the participation contract P_f with a fixed fee causes expected losses and no insurer will choose any contract with a fixed fee. ■

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For orders please contact / Kontaktadresse für Bestellungen:

Prof. Dr. Martin Nell
Geschäftsführender Direktor des
Instituts für Versicherungsbetriebslehre
Von-Melle-Park 5
D-20146 Hamburg

Tel.: +49-(0)40-42838-4014

Fax: +49-(0)40-42838-5505

E-mail: martin.nell@rrz.uni-hamburg.de

<http://www.rrz.uni-hamburg.de/IfVBL/wp.htm>

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