Independent Safety Controls with Moral Hazard

by

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We analyze the role of liability, insurance, and side payments for independent safety controls with unobservable care levels. By independent safety controls we mean that the accident probability depends on the care levels of two parties, and that the effects of the controls on the accident probability are stochastically independent. We show that efficiency can be reached for these kinds of double moral hazard through side payments if one agent detects that the other agent's security control has failed. This requires either an appropriate liability rule, or an arbitrarily chosen liability rule combined with fair insurance coverage. (JEL: C 72, D 82, G 22, K 12)

1 Introduction

1.1 Topic and Results

We analyze the role of liability, insurance, and side payments for independent safety controls with unobservable care levels. By independent safety controls we mean that the accident probability depends on the care levels of two parties (agents), and that the effects of the controls on the accident probability are stochastically independent. Neither effort is either observable or verifiable, so that a situation of double moral hazard arises.

There are many examples illustrating the importance of independent safety controls. Consider a plane crash that would not have occurred had the manufacturer not delivered a faulty part. The crash also would not have occurred if the service company had undertaken a proper checkup. At both stages, some control is undertaken, but the control is incomplete for reasons of surveillance costs. The example carries over to other situations of technological safety control, where the odds that a defect slips through all controls is determined by the cumulative probability that all of the various control stages fail simultaneously. Summing up, our model can be applied to all situations where the failure risks are stochastically independent.

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* We are grateful to Ralf Ewert, Uli Hege, Peter Jost, and two anonymous referees for helpful comments.

Journal of Institutional and Theoretical Economics
JITE 158 (2002), 408–419 © 2002 Mohr Siebeck – ISSN 0932-4569

Since HOLMSTRÖM [1982], it has been well known that the best budget-balanced contract can engender only a second best in the common double-moral-hazard problem. First, sharing rules cannot be made contingent on actions, since these are unobservable. Hence, negligence rules where the liability payment depends on the care levels actually chosen are not feasible. But efficient strict liability requires that each agent be made responsible for the total harm, so as to make each choose his or her efficient action (see FINSINGER AND PAULY [1990]). This violates the budget-balancedness constraint. In our context of liability rules, budget-balancedness means that punitive damages – that is, liability payments above total harm – are excluded.[1] It follows that no liability rule can restore efficiency as long as contracts between the two agents are ruled out.

In our paper, we allow for contracts between the two agents carrying out the independent safety controls. If there were no asymmetric information, then *any* arbitrarily chosen liability rules where the agents must pay for the total harm would be efficient. Since the agents have to pay for the total harm anyway, it is in their mutual self-interest to maximize social welfare, and they can do so by agreeing on a contract where the agent who deviates from the efficient care level pays for the total harm. This is a simple application of the Coase theorem, and means that the problem at hand would be trivial if the agents were able to observe each other's care levels. However, with double moral hazard, the agents cannot contract upon their care levels. Nevertheless, we show that a first best can be reached through side payments if one agent detects that the other agent's security control has failed with respect to a certain kind of harm. Observing that the other agent's security control has failed provides a stochastic signal on her behavior, and this signal can be exploited to improve the allocation.

The contribution of our paper is to demonstrate that efficient side payments exist only if one of the following two conditions is fulfilled: (i) the sharing rule that divides total harm between the two agents is chosen appropriately, or (ii) at least one agent has access to fair insurance coverage. Thereby, we provide a role for insurance that has nothing to do with risk aversion. Without insurance coverage, an efficient liability rule requires that the agents' shares depend on the efficient care levels.[2] More precisely, we prove that efficient side payments exist if and only if agent A's liability share *for each accident* equals agent B's *optimal* failure probability with respect to a specific accident.

However, such a sophisticated sharing rule seems questionable from a practitioner's point of view. First, the court may often have less information on the technology (and hence on the efficient actions) than the agents themselves. Second, the court would not only have to propose different sharing rules for different care costs, but also for different accidents. Finally, these divisions of harm could not depend on the unobservable care levels actually chosen, but on efficient care levels only. This

[1] Punitive damages are legally restricted to cases of reckless conduct like drunken driving. The economic problem of punitive damages is that, more often than would be efficient, potential injurers are discouraged from pursuing risky activities.

[2] Not, of course, on the actual care levels, since these are unobservable.

would probably lead to high uncertainty, serious distributional problems, and prohibitively high transaction costs. For these reasons, less sophisticated liability rules are required.

Here, insurance coverage enters the scene. We demonstrate that *any* arbitrarily chosen sharing rule leads to efficient behavior if at least one party has access to fair insurance coverage. For instance, if the court holds only one party strictly liable for the total harm, agents A and B will agree on contingent side payments and an insurance contract leading to optimal behavior. Insurance contracts thus help to simplify liability rules and to restore efficiency in cases where the parties involved are better informed on their mutual avoidance costs than the court is. This seems to be an interesting and hitherto unanalyzed role for insurance companies.

1.2 Relation to the Literature

To the best of our knowledge, the present paper is the first one addressing liability rules for independent safety controls under double moral hazard. More generally, our paper is related to the literature on double-moral-hazard problems. Since the fundamental nonexistence result derived by HOLMSTRÖM [1982], many papers have analyzed situations in which the results are more friendly. Specifically, it is demonstrated that the allocation can be improved if correlation across agents is permitted (GREEN AND STOKEY [1983], MA [1988], ROMANO [1994]), if one action can be observed in a sequential setting (DEMSKI AND SAPPINGTON [1991]), and if asymmetry among agents is taken into account (LEGROS AND MATSUSHIMA [1991], GUPTA AND ROMANO [1998]). STRAUSZ [1999] also analyzes double-moral-hazard problems in a sequential setting. The main difference between his analysis and ours is that he assumes nonverifiable, but observable actions. This means that agents can adjust their actions to their counterparts' behavior. By contrast, our result does not depend on the sequential character of independent safety controls – if both agents choose their efforts simultaneously, it is nevertheless possible to fix side payments for mistakes detected by exactly one agent.

Our side payments are comparable to situations where a principal is vicariously liable for an agent and can stochastically infer the agent's behavior through monitoring (DEMOUGIN AND FLUET [1999]). In these situations, side payments used to increase one agent's care level may set excessive monitoring incentives for the principal. FEESS AND HEGE [2002] analyze independent safety controls with observable actions, but with private information on avoidance costs. They show that a first best can be reached through a simplified version of a Bayesian mechanism.

Papers analyzing welfare-increasing roles of insurance companies that have nothing to do with risk aversion include LINDGREN AND SKOGH [1996] and JOST [1996].[3] Most closely related, FEESS AND HEGE [1999] demonstrate that insurance contracts can solve the double-moral-hazard problem if they serve as budgetbreakers. However, this requires that the court make the liability rule dependent on

[3] See SKOGH [1999] for an overview.

insurance contracts signed, and has nothing to do with our suggestion that insurance companies can offset the excessive incentives created by side contracting.

Section 2 presents the model. Section 3 derives the efficient sharing rule without insurance. Section 4 develops the structure of the efficient contracts if only one agent is held liable. We conclude in Section 5.

2 The Model

There are two risk-neutral agents $i = A, B$. Agent i selects an effort $a_i \in A_i$, which determines the probability $p_h^i(a_i)$ that agent i's care fails with respect to accident x_h. If it were for agent i alone, then accident x_h would actually occur with probability $p_h^i(a_i)$. We call $p_h^i(a_i)$ agent i's *failure risk* with respect to harm h. Although not necessary to derive our results, we assume $dp_h^i(a_i)/da_i < 0$, $d^2(p_h^i)/d(a_i)^2 > 0$, and $p_h^i(a_i) > 0 \ \forall a_i, \forall h$. The probability of accident x_h occurring if vector a is chosen is then the risk of both safety controls failing simultaneously, that is,

$$p_h(a) = \prod_i p_h^i(a_i). \tag{1}$$

For instance, this means that harm of type h does not occur if one of the agents detects the defect leading to h. For notational convenience, a_i denotes both the players' efforts and their costs, so that social costs can be defined as the sum of expected harm and the players' costs of care:

$$SC = \sum_h p_h(a)x_h + \sum_i a_i. \tag{2}$$

Efficient care levels are denoted a_i^f and are given by

$$\sum_h \frac{dp_h^i\left(a_i, a_{-i}^f\right)}{da_i} x_h = -1 \qquad \forall i. \tag{3}$$

The only regulation considered in our paper is a sharing rule that divides harm between the two agents. This sharing rule is a strict liability rule in the sense that the agents' liability payments do not depend on the care levels actually chosen by them. Note that negligence rules where the division of harm depends on the care levels cannot be applied, due to the assumption that care levels are unobservable. For the same reason, efficient compliance standards cannot be enforced. Hence, strict liability rules seem to be a natural solution.

To characterize a liability rule, we define α_h^i as i's liability share if accident h happens. We exclude punitive damages by assuming that the sum of liability payments adds up to the total harm: $\sum \alpha_h^i = 1 \ \forall h$. It follows that the cost function of player i is given by

$$C_i = \sum_h \alpha_h^i p_h(a)x_h + a_i. \tag{4}$$

In reality, the agents may voluntarily take part of the harm into account because of reputational effects, or simply because they are concerned about harm for reasons of humanity. As usual in the economic analysis of accident law, we neglect these desirable effects and assume that agents minimize their expected costs. Minimization of (4) leads to the first-order condition

$$(5) \qquad \sum_h \frac{\alpha_h^i \, dp_h\left(a_i, a_{-i}^f\right)}{da_i} x_h = -1 \qquad \forall i.$$

Comparing the privately optimal care levels (5) with the socially efficient care levels (3) shows that private incentives to take care are too low if $\alpha_h^i < 1$, that is, if a party's liability share is below the total harm. This implies that efficiency can never be reached with a common liability rule if punitive damages are excluded: indeed, $\alpha_h^i = 1 \ \forall i$ contradicts the restriction that $\sum \alpha_h^i = 1$. Keep in mind that reversal of the burden of proof could not solve the problem as long as care levels cannot be verified in court. Hence, the problem cannot be solved if contracts between the players are excluded.

An important point to note is that, with private contracts, every arbitrarily chosen sharing rule would be efficient if the agents could observe each other's behavior. In this case, without asymmetric information, we know from the Coase theorem that the parties would maximize their joint utilities. Since they are made responsible for the total harm, this means that they would minimize the total social costs regardless of the initial sharing rule. Also, in our setting, the parties have an interest in choosing the socially efficient care levels, since they have to pay for the total harm, and they will try to improve efficiency through smart private contracts. However, these contracts cannot be made dependent on the care levels, due to our assumption of double moral hazard. In the next two sections, we analyze under which circumstances private contracting nevertheless leads to a first-best allocation.

3 Sharing Rules Contingent on Efficient Behavior

In this section, we demonstrate that there is a *unique* sharing rule set by law or by court that allows for efficient side payments between the two agents involved. Suppose without loss of generality that agent A has full bargaining power when suggesting a contract to B.[4] The contract consists of a flat payment and a contingent sum A has to pay whenever A's safety technology has failed with respect to a specific accident but B detects the mistake and hence avoids the accident. The timing of the game is as follows:

(1) The sharing rule specifying $\alpha_h^i \ \forall h, i = A, B$, is set by the authority.

↓

(2) A suggests a private contract consisting of a flat payment c and a contingent side payment $z_h = \gamma_h \cdot x_h$ payable if B detects harm h overlooked by A.

↓

[4] In our auditing example, this could mean that auditing markets are competitive.

(3) B accepts or not.
↓
(4) Unobservable efforts a_i, $i = A, B$, are chosen.
↓
(5) An accident occurs if both safety controls fail with respect to a specific accident, and payments are made according to the sharing rule and the private contract.

We show that the only efficient sharing rule requires that A's liability share equal B's *efficient* failure probability. This given, it is in the self-interest of the two parties to agree on the same side payment, and first-best care levels are chosen. This is expressed in

Proposition 1: Efficiency requires that $\alpha_h^A = p_h^B(a_B^f)\ \forall h$. The two parties will then agree on $\gamma_h = p_h^B(a_B^f)\ \forall h$ and choose their efficient care levels.

Proof: See Appendix.

For an intuition, let us first consider agent B. For agent B, each contract where A's liability share α_h^A and the contingent payment γ_h are identical for all possible damages leads to efficient incentives. This is so because α_h^A weakens B's incentive by the same amount as γ_h improves it. It follows that all sharing rules can lead to efficient incentives for B, if it is supposed that the side payment is adjusted accordingly. However, only $\alpha_h^A = \gamma_h = p_h^B(a_B^f)$ simultaneously yields efficient incentives for agent A, because the liability payments (α_h^A) are weighted with $p_h^B(a_B^f)$, whereas the side payment is weighted with $1 - p_h^B(a_B^f)$ in equilibrium. This implies that the countervailing effects of a liability payment and a contingent payment do not necessarily cancel out for agent A. This is only the case if the liability payment and the contingent payment are both $p_h^B(a_B^f)$. Hence, player A's share needs to be player B's optimal failure probability. This result is intuitively plausible, because the accident risk depends solely on A's behavior if B fails. Hence, the higher B's optimal failure risk, the higher A's liability share required to set efficient incentives.

4 *Other Sharing Rules and Insurance Coverage*

Note that the efficient sharing rule does not refer to the (unobservable) actions itself, but only to the efficient actions. From a purely theoretical point of view, it seems to be natural to increase A's liability if there is an increase in the efficient probability that agent B does not detect a technical defect – the higher the probability that agent B fails, the greater is agent A's responsibility to avoid the accident. However, for the reasons explained in the introduction, there are many practical obstacles when dividing the damages according to the *optimal* failure risk of the agents for each specific accident. In this section, we consider the case in which the court does not want to (or is not able to) make the shares dependent on optimal failure probabilities.

In many cases, it is reasonable to assume that the court is less informed about the participants' technologies than agents are. Hence, we search for less sophisticated liability rules.

In reality, we often observe that firms are insured against liability risks coming from independent safety controls. We demonstrate that *any* arbitrarily chosen sharing rule leads to efficient behavior if the side payment is chosen accordingly, and if at least one party has access to fair insurance coverage. For simplicity and without loss of generality, we restrict our attention to the case where only party A insures herself. The time structure of the game considered is now as follows:

(1) The sharing rule specifying α_h^i $\forall h$, $i = A, B$, is set.

↓

(2) A suggests a private contract with B consisting of a flat payment c and a contingent side payment $z_h = \gamma_h \cdot x_h$ payable if B detects harm h overlooked by A.

↓

(3) A suggests a contract with an insurance company consisting of a premium π and a deductible d_h for harm h. Insurance markets are competitive.

↓

(4) B and the insurance company accept or not.

↓

(5) Unobservable efforts a_i, $i = A, B$, are chosen.

↓

(6) An accident occurs if both safety controls fail with respect to a specific accident, and payments are made according to the liability rule and the private contracts.

We claim that private contracting restores efficiency regardless of the sharing rule chosen by the court:

Proposition 2: Suppose the court chooses liability shares α_h^A, α_h^B with $0 \leq \alpha_h^A \leq 1$ $\forall h$. Then *(a)* Agent A suggests a contract to B consisting of a flat payment $c = a_B + \sum_h p_h(a^f)x_h - \sum_h p_h^A(a_A^f)\alpha_h^A x_h$, and a contingent payment $z_h = \alpha_h^A x_h$ $\forall h$. *(b)* Agent A suggests an insurance premium

$$\pi = \sum_h p_h(a^f)\left(\alpha_h^A x_h - \frac{p_h^B(a_B^f)x_h(1+\alpha_h^A) - \alpha_h^A x_h}{p_h^B(a_B^f)}\right)$$

and a deductible

$$d_h = \frac{p_h^B(a_B^f)x_h(1+\alpha_h^A) - \alpha_h^A x_h}{p_h^B(a_B^f)} \qquad \forall h.$$

(c) Agent B and the insurance company accept the contracts offered. *(d)* Both agents choose their efficient care levels, and the insurance company breaks even in expectation.

Proof: See Appendix.

For an intuition, let us first consider the special case where agent A is liable for the total harm ($\alpha_h^A = 1$). Since also agent B must take the total expected harm into account to act efficiently, $z_h = x_h \; \forall h$ is required so as to "duplicate" her liability exposure via a reward scheme. For agent B, it does not make a difference with respect to her incentive whether she calculates an expected liability payment, or whether she considers x_h as a potential reward.

Since agent A has to pay the total damages *and* a contingent side payment, her total expected payment when her safety control fails would be excessively high, so that she would exert too high an effort. This incentive is balanced through the fact that the insurance company pays part of the damages. The deductible paid by agent A,

$$d_h = \frac{2x_h p_B^h\left(a_B^f\right) - x_h}{p_B^h\left(a_B^f\right)} \qquad \forall h,$$

follows from the fact that the liability risk is weighted with p_h^B, and the contingent fee with $1 - p_h^B$.

If $\alpha_h^A < 1$ (and hence $\alpha_h^B > 0$), the contracts need to be modified as stated in Proposition 2. The side payment decreases from $z_h = x_h$ to $z_h = \alpha_h^A x_h$, since agent B takes $1 - \alpha_h^A$ already into consideration. Agent A's deductible increases accordingly, and the insurance premium is adjusted to ensure that the insurance company earns zero profits in expectation.

The special case where one agent is held liable for the total harm ($\alpha_h^A = 1$) is important for practical reasons. First, this is clearly the easiest liability rule one can imagine. Second, it might often be desirable to create efficient incentives for one agent through reward schemes alone, but not through liability payments. Consider hierarchical relationships where a principal (A) is held liable for harm caused in her firm. If agent B is an ordinary employee, she is *de facto* protected by limited liability, since she would not be able to pay for her share α_h^B. Hence, it would not be possible for A and B to duplicate the liability rule suggested in Proposition 1 via private contracting. Or think of A as a firm checking its environmental risk, and hiring expert B for additional environmental auditing. In these cases, it is current practice that the firm is strictly liable for the total harm, whereas the expert is only liable for accidents caused by gross negligence (which can hardly be proven if care levels are unobservable). Finally, in cases of financial auditing or in the process of loan origination, harm might occur years after the safety system failed, and the contractual relationship between A and B might long be over. In all these cases, there are good reasons to hold one participant liable for the total harm.

5 *Discussion*

We have demonstrated that the team production problem can be solved through liability rules without punitive damages for the special case of independent safety controls. The special feature of independent safety controls is that the players are trying to detect the same mistakes. As the detection probability is increasing in a party's effort, it follows that the fact that a partner does or does not detect a mistake provides a stochastic signal on her behavior. This signal can be used in side contracts to ensure efficient behavior. We have considered two mechanisms: a sharing rule contingent on the parties' efficient behavior, and an arbitrarily chosen sharing rule that, combined with insurance contracts, restores efficiency. Due to practical objections against the first liability rule, we consider the special role of insurance coverage as our paper's main contribution.

Two legal conclusions can be drawn from our model: first, strict liability without contributory negligence can efficiently be adopted for multiparty accidents if the setting fits our model. Second, side payments based on whether or not one party detects a mistake should be legally allowed in contractual relationships. This seems to be natural, but is not always true in reality. Interestingly, contingent fees for auditors checking the financial statements of firms are prohibited by the codes of professional ethics, to avoid collusion between the firm and the auditor. Auditing cases fit our model, since inefficient investments may arise if the firm's balance sheet is faulty *and* the auditor does not correct the mistake. Hence, standard liability rules without contingent payments cannot be efficient if the team production character of the auditing problem is taken seriously. We believe that side payments in cases where it is likely that the audited firm would have been exposed to liability payments if the mistakes had not been detected by the auditor are suited to mitigate the inefficiency problem. These cases could be specified in the auditing contract, and permission could be required for such contracts so as to prevent any kind of collusion.

We now turn to some possible objections to our analysis. First, one might question if our second mechanism is really different from the first one. Our second mechanism does not require that the court makes the liability shares dependent on the participants' efficient behavior, but private contracts are still contingent on efficient behavior. Hence, the second mechanism is only superior if the agents involved are better informed than the court. We believe that this assumption is reasonable for the cases at hand, since our suggestion is based on close contractual relationships anyway. In our auditing example, auditing firms and specialized insurance companies may well be better informed than courts, which would have to design sophisticated sharing rules for *all* firms on the market. Private contracts only have to consider the parties actually involved, and are therefore likely to be more accurate.

As a second objection, one might question why we do not consider a contracting arrangement between a principal (the court) and two agents, as in KOFFMANN AND LAWARREE [1993]. However, though such an arrangement is natural if a principal hires two agents, it is not in cases where a court designs general liability rules for accidents not known in advance.

With respect to our auditing case, one might finally wonder whether the collusion problem is not more important than the double-moral-hazard problem. In the auditing literature, collusion means that the auditor hides mistakes found in the balance sheet (truth-telling problem). However, strict liability as suggested in our paper automatically solves the truth-telling problem – since both agents take the total harm into account, neither can be better off by faking the results of the investigation.

Appendix

A.1 Proof of Proposition 1

With shares α_h^A and $\alpha_h^B = 1 - \alpha_h^A$, and given $z_h = \gamma_h \cdot x_h$ and c, agent A's *expected* cost function is

$$C_A = \sum_h \alpha_h^A p_h(a) x_h + \sum_h \gamma_h p_h^A(a_A) \left[1 - p_h^B(a_B)\right] x_h + c + a_A. \quad \text{(A1)}$$

The first term is her expected liability payment. The second term is the expected side payment, which occurs only if B detects the mistake. This happens with probability $1 - p_h^B(a_B)$, and agent A pays a part γ_h of the damage x_h. c is the flat payment, and a_A is the cost of effort.

Analogously, agent B's costs are

$$C_B = \sum_h \left(1 - \alpha_h^A\right) p_h(a) x_h - \sum_h \gamma_h p_h^A(a_A) \left[1 - p_h^B(a_B)\right] x_h - c + a_B. \quad \text{(A2)}$$

Given $\alpha_h^A = \gamma_h = p_h^B(a_B^f)$, the expected cost functions turn out to be

$$C_A = \sum_h p_h\big(a_A, a_B^f\big) x_h + a_A + c \quad \text{(A3)}$$

and

$$C_B = \sum_h p_h(a) x_h - \sum_h p_h\big(a_A, a_B^f\big) x_h + a_B - \dot{c}. \quad \text{(A4)}$$

Since A's privately optimal behavior is independently of B's effort given by the socially optimal first-order condition $\sum_h [dp_h^A(a_A, a_{-A}^f)/da_A] x_h = -1$, she clearly acts efficiently given the contract proposed in Proposition 1. This is the case whenever the private contract duplicates the liability rule, that is, if $\alpha_h^A = \gamma_h$. Given A's efficient effort choice (which is anticipated by B by definition of an equilibrium), B also acts efficiently, because the *variable* part of her expected cost is simply $\sum_h p_h(a) x_h + a_B$. B accepts if she gets at least her reservation level of utility in equilibrium, so that c is given by

$$\begin{aligned} c &= \sum_h \left(1 - \alpha_h^A\right) p_h(a) x_h - \gamma \sum_h \gamma_h p_h^A(a_A) \left[1 - p_h^B(a_B)\right] x_h + a_B \\ &= \sum_h p_h(a^f) x_h - \sum_h p_h(a^f) x_h + a_B^f = a_B^f. \end{aligned} \quad \text{(A5)}$$

Given that B gets only her reservation level of utility of zero, A's cost function is identical to the social cost function, so that she prefers to suggest the efficient contract. *Q.E.D.*

A.2 Proof of Proposition 2

With $0 \leq \alpha_h^A \leq 1$ and z_h, the *variable* parts of the players' *expected* cost functions are

(A6) $$C_A^V = \sum_h p_h(a)d_h + \sum_h p_h^A(a_A)\left[1 - p_h^B(a_B)\right] z_h + a_A,$$

(A7) $$\begin{aligned} C_B^V &= \sum_h p_h(a)\big(1-\alpha_h^A\big)x_h - \sum_h p_h^A(a_A)\left[1 - p_h^B(a_B)\right] z_h + a_B \\ &= \sum_h p_h(a)x_h - \sum_h p_h(a)\alpha_h^A x_h \\ &\quad - \sum_h p_h^A(a_A)z_h + \sum_h p_h(a)z_h + a_B. \end{aligned}$$

Suppose the contracts suggested in Proposition 2 have been accepted. Let us start with agent B. Given a_A^f in an efficient subgame-perfect equilibrium, agent B chooses a_B^f if and only if $z_h = \alpha_h^A x_h \ \forall h$. This is so because $-\sum_h p_h^A(a_A)z_h$ is independent of her behavior, and because $-\sum_h p_h(a)\alpha_h^A x_h + \sum_h p_h(a)z_h = 0$ in this case. $z_h = \alpha_h^A x_h \ \forall h$ means that her side payment received must be identical to the part of the damage not paid by her in case of an accident.

Substituting z_h into A's cost function yields

(A8) $$\begin{aligned} C_A^V &= \sum_h p_h(a)d_h + \sum_h p_h^A(a_A)\left[1 - p_h^B(a_B)\right]\alpha_h^A x_h + a_A \\ &= \sum_h p_h(a)d_h + \sum_h p_h^A(a_A)\alpha_h^A x_h - \sum_h p_h(a)\alpha_h^A x_h + a_A. \end{aligned}$$

Since the variable part influenced by A's behavior must be identical to $\sum_h p_h(a)x_h$ under the assumption that agent B acts efficiently, we need to have

(A9) $$\sum_h p_h(a)d_h = \sum_h p_h(a)x_h - \sum_h p_h^A(a_A)\alpha_h^A x_h + \sum_h p_h(a)\alpha_h^A x_h.$$

Taking into account that agent B chooses a_B^f in an efficient equilibrium, solving for the deductible yields

(A10) $$d_h = \frac{p_h^B\big(a_B^f\big)x_h\big(1+\alpha_h^A\big) - \alpha_h^A x_h}{p_h^B\big(a_B^f\big)},$$

as stated in Proposition 2. The flat payment c and the insurance premium x follow from the participation constraints on B and the insurance company, where the insurance company's profit is

(A11) $$R = x - \sum_h p_h(a^f)\big(\alpha_h^A x_h - d_h\big) = 0.$$

Since the contract leads to efficient care levels as proven above, and since agent A's expected costs are identical to the social costs, no other contract can be subgame-perfect. *Q.E.D.*

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