

Insurance Coverage of Accidental Damage to the Environment.

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1. Introduction

We do not know what will happen in the future. Nevertheless, we know that there will be large accidents. Catastrophes will create sudden huge transitional losses. Risks related to substances will harm a large number of people, and the environment. It is, of course, of great general interest to prevent such risks, and to find systems that distribute the costs so that random victimisation of the population is avoided. Here the insurance industry has a fundamental mission.

In this article I raise the question how accidental losses should be covered in the future. The focus is on negligence and no-fault legislation combined with first-party insurance versus strict liability combined with third-party insurance. I take a normative stand frequently used in Law and Economics.¹ That is, the goal of accident law is supposed to be the minimisation of the total cost of accidents, including costs of prevention, the damage at accidents, and administrative costs. A second goal is to spread the losses so that random victimisation of the population is avoided.

The economic model of accident law has been most efficient in structuring the study of tort law and third-party insurance. The analysis has also influenced legal practice, especially in the US where tort liability and its coverage by insurance is a most important matter. Also Europe has been influenced, e.g. in product liability and environmental law. Practical application has both its pros and cons. It is obvious that the economic model is a powerful analytical instrument which has contributed to a deeper understanding of the economic effects of liability law in relation to other safety measures. On the other hand, an uncritical

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¹ The research in Law and Economics starts in the early 1960s. The concept was introduced by Richard Posner and was used by Veljanovski (1982) as the title of a book *The New Law and Economics, a Research Review*. The first edition of Posner's famous *Economic Analysis of Law* was published in 1973. The European Association for Law and Economics was founded in 1984.

application of the most simplistic economic model of liability may contribute to a wider application of liability law than that motivated by analysis.

The purpose of this article is to investigate under what conditions liability (in combination with insurance) works properly, and where it does not. A second task is to suggest alternative solutions in cases where liability appears inefficient. Next, in Section 2, I present the basic economic model of liability. In the following sections, I investigate the applicability of liability rules and insurance in situations where the assumptions of the model do not fit reality. *Insurance* is here defined as a contract where a premium is paid *ex ante* for coverage of a certain contingency. Risk aversion and bankruptcy problems are discussed in Section 3. Section 4 treats new industrial hazards and development risks that cannot be predicted statistically. Section 5 examines the implementation of strict liability for unpredictable losses. First-party insurance is studied in Section 6. Mutual risk-sharing as a means of diversification of unpredictable losses is studied in Section 7. Section 8 treats cases where tort liability appears to work most efficiently. Section 9 examines situations where public compensation schemes appear favourable. Finally, Section 10 concludes the paper.

2. The basic economic model

A simple model is used to analyse the economics of various liability rules. The model considers only *primary costs*, i.e. costs of prevention and the damage of accidents. Thus it neglects costs of administering the system. The injurers and the victims are supposed to be risk neutral, profit maximising actors. Common knowledge of the law is assumed. The injurers and victims also know their ability to reduce accident risks by taking care. Consequently, the actors will, to the extent it is beneficial, adapt to the law by taking preventive measures.

Accidents may be reduced in various ways. One option is to limit the *activity level*. That is, reduced road traffic, limited transports of oil, or less dangerous industries would decrease the number of accidents. Similarly, a limited utilisation of a given capacity in an industry could reduce the number and/or the severity of accidents. The basic model assumes a given activity level. Thus, the accident risk may be reduced through precautions such as safety checks and repairs. Preventative measures reduce the probability of accidents, as well as the damage if an accident occurs.²

² For an extended analysis including the activity level, see Shavell [1987].

A further distinction in the model is made between *unilateral*, and *bilateral accidents*. In the bilateral case two parties, the injurer and the victim, both contribute to the probability of the accident and/or the size of the resulting damage. The economic analysis, therefore, considers the efficiency of the care taken by both parties. Unilateral influence prevails where the injurer alone causes an accident.

In the case of *negligence*, the court is assumed to decide on the precautionary and preventative measures that the injurer should have taken to absolve him from liability. Thereby, the court sets a standard of *due care*. If an accident occurs and the injurer has not taken due care, he will be liable for the damage. Potential injurers will, therefore, adapt accordingly to the level of due care to avoid accident costs. Hence, the injurer will bear the total cost, including prevention cost and accident costs, only if he takes precautionary measures below the due care standard. If, on the other hand, the injurer takes measures equivalent to, or higher than, the legal standard, the victim will need to bear the cost of the accident. That is, the injurer will minimise his own costs by following the court's due care standard. Consequently, injurers will avoid liability, and the victim will bear the cost of any accident. The total outcome will be optimal if the legal standard set by the court is efficient.

With a system based on strict liability, potential injurers will, on the contrary, pay for all damages. That is, with the strict liability rule in mind, liable parties participating in risky activities will minimise the costs and take precautionary and preventive measures. The firm will also adjust the activity level efficiently. In other words, strict liability leads in the unilateral case to efficiency because the party that undertakes precautions and invests in prevention also bears the cost of accidents.

Negligence is also efficient, provided that the level of precautionary measures (due care) chosen by the court is efficient. Note, however, that a fundamental disadvantage of the negligence rule is that the court must have access to information as to the efficient level of care. To the extent that information is available, it will most likely be in the possession of the injurer who controls the risk. This informational asymmetry offers the most important argument in favour of strict liability.

Another informational obstacle with respect to negligence is that it must be proven, and the burden of proof is normally on the victim. If only obvious carelessness is possible to prove, the potential injurers will adapt to this and an inefficient level of care will result.

In the unilateral case it is assumed that only the injurer's behaviour has an impact on the accident risk. Normally, however, also the victim has some ability to reduce the probability of accidents, or the damage when an accident occurs. The question arises, therefore, which liability rule is preferable, if one wishes to give both parties incentives to take care. Are there any liability rules that can provide incentives to both the injurer and victim to take optimal care?

Strict liability renders, for the above mentioned reasons, incentives to the injurer to take care. The victim, on the other hand, realises that she receives full compensation and, therefore, has no incentive to take care. Hence, a simple strict liability rule is suboptimal since it does not provide the victim with an efficient incentive.

Yet, victims can be given incentives for optimal care taking if the strict liability rule is conditional on careful behaviour by the victim. In other words, strict liability combined with a so-called *contributory negligence defence* may make both injurer and victim behave carefully. This rule means that the victim will not receive any compensation from the injurer if the victim does not follow the due care the law requires. A strict liability rule combined with such a contributory negligence defence will provide optimal incentives to both the injurer and the victim - again provided that the due care standard set by the court is optimal. The explanation is as follows; the victim will take due (optimal) care to avoid her having to bear her own loss. The injurer, knowing that the victim will take optimal care will also have an incentive to take optimal care under the strict liability rule to minimise his expected total accident costs.

In addition a negligence rule will provide the victim with an incentive for optimal care taking, if the legal due care standard is optimal. The reason is that injurers will normally take due care to avoid liability under negligence. Under such a rule, a victim in principle carries her own loss and has, therefore, optimal incentives to minimise her expected accident costs.

A difference between the two liability rules is that the judge has to settle the due care level of the injurer according to negligence, and due care of the victim according to strict liability, with the contributory negligence defence. Hence, the informative advantage of strict liability is no longer fully obvious. Nevertheless, with industrial accidents most of the prevention is related to circumstances known in the business, and not by the victim. Under such conditions strict liability would be preferable. Nonetheless, the behaviour of the victim must also be considered, which is achieved by a strict liability rule with the defence of contributory negligence. Indeed, strict liability completely unconditional on the behaviour of

the victim hardly exists. For instance, it is commonly required that the victim limits the damage, otherwise compensation will be reduced or withdrawn.

3. Insurance

The model above assumes risk neutral parties, which may be realistic for profit maximising firms, but hardly for individuals. In fact, individuals are usually assumed to be risk averse, hence the demand for insurance.

In the model it is also assumed that the risk neutral liable party is able to pay the damage. However, if the damage is larger than the assets of the firm the liability will *de facto* be limited to the assets collectible. Because the maximum collectible payment for an accident is limited the incentive to take care is also reduced. Indeed, there is no economic incentive to prevent losses above the limit set by the available assets. Available assets smaller than the damage also result in only partially compensated victims. Some type of guarantee that transfers risk to an external risk carrier may, therefore, be required. An insurance contract by which the insurer compensates losses in certain specified contingencies, e.g. accidental industrial pollution, is equivalent to a partial guarantee.³ Insurance is often a requirement for permission to run a business, transport goods, drive a car, employ personnel, etc. Insurance is here required as a guarantee on behalf of potential victims, including the public that may be harmed if the liable party does not pay. Mandatory insurance contributes to efficiency to the extent that the insurer compensates the victim and monitors the behaviour of the injurer.⁴

The liability demanded by the legal system is often traded to an insurer. Insurance reduces, however, the incentive to take care and causes a moral hazard. A method of mitigating the moral hazard is to use deductibles. Generally, the policy holders will insure the large loss and keep the small. In addition, insurance usually does not cover intangible losses like pain and suffering, and personal losses like the loss of a family album, etc.

Indeed, the property and liability insurance industry is expert in the risks they insure. The industry earns profits by calculating and pricing risks, as well as by identifying the impact of various precautions and preventative measures. The industry can, therefore, offer customers policies with various preventative requirements. For instance, an industry that

³ For an analysis of insurance as guarantee, see Skogh, G. (1991).

⁴ Note that this demand for insurance prevails independently of the risk attitude of the policy holder.

installs sprinklers may get a reduced premium. Similarly, a hazardous industry may obtain a premium reduction if it promises to undertake systematic safety checks, etc.

The fulfilment of the requirements and conditions of the insurance policy is mainly controlled in the claims settlement procedure. The compensation may be withheld or reduced if the policy holder does not follow the terms of the contract. Hence, the insurer has considerable control over the behaviour of the insured.

In a “perfect” world where the insurer can fully identify and control the injurer and modify premiums in relation to precautions and preventative measures, the care level will become efficient. In reality the insurer has limited information, however, which explains why there are both deductibles, and precautionary requirements, combined with inspections and claim settlement control.

How does the insurance influence the efficiency of tort law if a negligence rule prevails? In the unilateral case the injurer will avoid liability by taking the due care required by the courts. Hence, the victim will normally have to pay accident damages. If the victim is risk averse she will purchase first-party insurance. No increase in accident rates will occur in the unilateral case because the victim’s behaviour has no impact on the accident risk. The efficiency of the negligence rule thus depends, as before, on the standard of care set by the courts.

In the bilateral case both the victim and injurer have an impact on the accident risk. A negligence rule will give the injurer incentives to follow the law and take “due care”. The risk averse victim will, on the other hand, have an incentive to insure. Being insured, the victim has no incentive to take care. The insurer will, therefore, include safety measures in the policies, and offer deductibles and bonuses to the policy holder. The problem of checking on the victim is the same as for the injurer insured for strict liability.

If the prevailing rule is one on strict liability with the defence of contributory negligence the outcome is the mirror image of a negligence rule. That is, the victim will have an incentive to take due care in order to avoid liability and the injurer will carry the accident costs. The risk averse injurer will purchase liability insurance and the insurer will have to check the behaviour of the injurer.

A conclusion to be drawn from this is that the model of efficient liability rules fits reality fairly well even when the parties are risk averse and/or there is a bankruptcy problem, and the risk is passed to an insurer specialised in handling the risks in question. Note,

however, that the presumption here is that the insurer can predict the risk, as well as the impact of any safety measures.

4. Development risks

So far we have, according to the model, assumed that the liable party, or insurer, knows the probabilities of accidents, and how to influence the risk. Yet many activities contain a large degree of uncertainty. Accidents are caused by new systems, chemicals and products, or combinations thereof in a complex and largely unknown way. The economic effects of liability law and insurance in unpredictable accidents are thus crucial.

Below we define an *actuarial risk* as a contingency that can be estimated empirically or technically. The expected accident cost can be calculated, and the risk is possible to price *ex ante*. Actuarial risks are *old* risks in the sense that they have been experienced repeatedly before. Examples are risks of fire and water damage that may be covered by ordinary insurance policies. The information is *public* in the sense that insurers as well as policyholders may know the probability of occurrence, and how various safety measures and precautions reduce the risk.

Development risks, on the other hand, are *new* risks arising due to technological or social changes. Lack of experience makes it impossible to foresee such risks and make estimates regarding the probability of accidents. Any belief about the probability is, thus, arbitrary.⁵ Consequently, accident prevention cannot be based on information about marginal conditions.⁶ The only way to escape accidents is to avoid possibly dangerous activities.

One example is the production and use of asbestos before asbestosis was discovered. Asbestos used to be regarded as a most useful product, although everyone knew that there was a possibility that it might be harmful. Indeed, such knowledge had been available for hundreds of years. Nonetheless, as long as there was no specific information about the danger, no one considered stopping production. Accordingly, information was not available about how to

⁵Our use of the word "development risk" is close to the wording of the European Council Directive of 25 July 1985, 85/374/EEC, Art. 7 e, on product liability, which states "that the state of scientific and technical knowledge at the time the product was put into circulation was not such as to enable the existence of the defect to be discovered."

⁶In the standard model of tort liability -- where L is the constant potential loss, the probability of an accident is p depending on the control x , and the cost of control is w -- the total cost of accident that the party is supposed to minimise is $Lp(x) + xw$. The minimisation requires information about the marginal condition $Lp' = w$, that is, detailed information about the $p(x)$ function is assumed.

obtain reductions in the risk of incurring asbestosis. Other examples in a similar vein are risks of cancer or allergies from newly invented chemicals and new techniques. We know that a danger may exist, but the uncertainty about the size of potential losses and/or their probabilities is genuine.

There is, of course, a wide range between the two extremes of actuarial risk and development risk. On the scale in between, *unpredictable hazards* are observed dangers that are known to exist but are not possible to predict statistically. For instance, the probability of damage due to a new pesticide in agriculture may be unknown. Yet, it is known that similar substances are harmful. Precautionary measures in terms of the reduced use of the pesticide may, thus, be undertaken, although the risk is not quantifiable. After an accident or some other evidence attesting to the hazard, understanding increases about the adherent risk. However, the lack of repeated experience makes it complicated or impossible to make estimates with assurance on the probability of an accident. While the parties may have formed certain beliefs about the risks, the confidence in their beliefs is limited. Nevertheless, in the long run technical investigations and repeated experience might transfer the uncertainty into a statistically predictable actuarial risk.

Most insurers are unwilling to cover statistically unpredictable risks. It is by insuring a large number of similar risks that insurers obtain information on the actuarial relation between claims, safety devices, levels of deductibles, and costs of claim settlement. This specialisation creates an informative advantage that forms the base for profits in the industry.⁷ It also explains why statistical predictability is regarded as fundamental by the insurance industry.⁸ Risks that are unpredictable are very costly to insure, if they are traded at all on the market. Insurers are reluctant to provide coverage against events where the probability of its occurrence is ambiguous, either because of limited statistical data and/or the different views of experts regarding the underlying causality. Losses also need to be well defined, limited, and possible to estimate.

5. Strict liability for unpredictable losses

The main efficiency argument in favour of strict industrial liability is that the injuring firm controls the activity that may cause an accident. If the injurer knows that he must cover accident costs, there is an incentive to prevent accidents efficiently. This argument is based on

⁷ Skogh (1991).

the assumptions that the injuring firm has access to decentralised information, and that the manager of the firm is able to give and enforce orders. Mandatory liability insurance may have the same function for large losses. That is, the insurer compensates the victim and controls the policy holder by premiums, bonus systems, contractual constraints and in an investigating claims settlement procedure.

The assumptions about control and access to decentralised information in the firm are certainly realistic in many real world situations -- it is usually the manager of the firm who knows and controls the business. Public authorities or courts have inferior information about daily practice and the "due care" taken in a single firm. However, this is true for the most part for old actuarial risks.

New industrial hazards are different. A firm has no private specific information about pure development risks. It may have information about unpredictable hazards, but that information is typically of public interest. As soon as evidence appears that an activity, process, or substance is dangerous, it is of common interest to spread the information. A firm may, of course, have a vested interest to keep the information private, but there is usually a duty to disclose information about hazards. The duty may be enforced both through criminal and civil liability. Hence, information, if any, about unpredictable risks is usually public in nature.

The lack of private information about development risks and unpredictable hazards abolishes the argument for strict liability for such risks.

It may be argued, however, that strict liability for development risks is motivated anyway, because liability creates an incentive to collect information and undertake research. This may be true in a research intensive industry. However, the incentive will be at an optimal degree only if the firm controls the entire market. Otherwise, additional public research is motivated because the information pertains to the common interest. Private investigations aimed toward their own gain cause under-investments from a social point of view. Indeed, this is the standard argument for publicly financed research.

Nonetheless, there is some common knowledge about new and unforeseen accidents. We know that anything may be ultimately dangerous and that some activities appear to be more risky than others. A way to reduce risks is simply to avoid certain activities or substances. A dilemma, of course, is that the potential benefits will not actualise. Examples are gene techniques, which have many very beneficent applications, yet may also be extremely

⁸ Berliner (1982).

hazardous, although we may be uncertain about the areas in which the hazard may lie. Yet, the introduction of new techniques or products is often postponed until preliminary information on possible effects is obtained. For instance, experiments and tests are required before new drugs are released. However, experiments are costly and the delay may limit the use of products that are potentially valuable. Furthermore, experiments outside laboratories may be necessary in order to ensure newer and safer products. Other *ex ante* regulations, such as restrictions on loading, the production method, storage, pollution standard, licensing, etc., are also decided on uncertainty. The regulations have uncertain benefits in relation to the costs, but are, nevertheless, widely used.

For instance, what can a farmer using pesticides do in addition to what is publicly known? Not very much. However, everyone knows that pesticides should be handled, used, and stored with care, and precautions are described in safety regulations, e.g. by instructions printed on the bags. The reasonable due care to be taken by the farmer is to use permissible pesticides and follow instructions. This furnishes an argument in favour of negligence with development risks and unpredictable hazards. If a negligence rule prevails and the farmer is careless in not following issued instructions or by not disclosing information, he is negligent. To avoid damage, therefore, the farmer will normally undertake the required precautions.⁹ In other words, strict liability has no comparative advantage relative to negligence, as long as the understanding of what is reasonable due care is public.

All in all, strict liability is a dull preventive instrument for development risks and unpredictable hazards. Any prevention that can be achieved is based mainly on public safety regulation and less on private, decentralised information. The same is true for retroactive liability as in the case of asbestosis, and liability for "long tail" liability for soil polluted decades ago.

6. Compensation by tort law versus first-party insurance

Liability has both a preventative and a compensatory side. Here we turn to compensation. Note that the victim of an accident is primarily interested in compensation. Prevention concerns future accidents in which the present victim presumably will not be involved.

⁹For a discussion on the comparative advantages of decentralised liability and administrative regulation, see Skogh (1982) and Shavell (1987, ch 12).

Compensation is certainly also a public goal of tort law, but it is not very effective. In fact, tort law usually does not compensate victims. In the case of negligence the victim will normally not be able to prove negligence and will thus not be compensated. Strict liability will compensate the victim, in principle. There are, however, many circumstances under which the victim remains uncompensated. One is that the liable party cannot pay, or that the liability is uncovered by insurance. Another reason is that the injurer remains unidentified. A special problem is related to fatal accidents where compensation is paid only to survivors or relatives.¹⁰ Moreover, the victim may not claim for compensation. Indeed, most serious development risks of our time will not be coverage by liability.

In addition, the tort system is costly to administer. It is also slow -- it may take years before the liability is settled, and the victim compensated.

Nevertheless, many legal systems uses torts for compensation. A reason may be a distributive goal to favour poor victims at the expense the wealthy injurers. But if the legal system systematically uses the "deep pocket" and decides in favour of poor victims it will reduce the preventative effect, and it will merely increase the costs of insurance. Retroactive liability with the obvious goal to compensation may, in fact, more or less randomly compensate victims, and at the same time cause arbitrary costs for the third-party insurer.

Hence, there are reasons to search for alternatives. A major benefit of first-party insurance is that liability must not be settled. Hence it is relatively cheap to administer. Risk averse parties demand first-party insurance such as health, disability, pension, and life insurance. Health treatment and income losses due to cancer, allergies, and many other diseases caused by industrial accidents, new products and techniques are covered by such insurance. A reason why it is possible to insure such development risks by first-party insurance is the law of large numbers. That is, pension and life expectancy can be estimated well enough because the cause and variations of sickness, disability, and better health are not fully correlated.

First-party property insurance also protects victims when liability of the injurer is not in force. The victim's property insurance covers most accidental risks and industrial hazards, but may exclude potentially very large claims, such as nuclear accidents and natural disasters. On the other hand, such personal damage is, at least partly, covered by health, disability, and pension schemes.

¹⁰ Liability that compensates income losses to disable or survivors is insufficient for efficient prevention. The value of a "statistical life", which much exceeds the compensation of income losses, is more appropriate, see

A shortcoming of first-party insurance, of course, is the absence of the injurer's incentive to take care. Prevention must, therefore, be undertaken by *ex ante* regulations of safety as discussed above.

7. Mutual Risk-sharing

I have, so far, focused on the limitations of liability law and third-party insurance, especially in relation to development risks. New risks and industrial hazards are usually not insurable because the probability and loss due to accidents cannot be predicted. Does this mean that there is no way by which the insurance industry is able to handle new risks?

Insurance, as defined above, requires that the pricing is undertaken before the occurrence of the insured event. Thus pricing requires actuarial information. However, an agreement to mutually share each other's losses does not necessarily require any pre-payment.. For instance, a group of risk-averse individuals can benefit from sharing accident costs, *ex post*, also if the probability of an accident is statistically unpredictable. *Risk-sharing* requires thus less information than insurance does. Here there is a presumption, however, that the expected risk is regarded as the same for all.¹¹

The simplest form of risk-sharing is a mutual guarantee whereby the pool members promise to cover each other's losses. Risk-sharing requires, however, that the parties in the pool accept and trust the presumption that they are equal, that is, that all face the same risk (although they cannot estimate it statistically), and that moral hazard and adverse selection can be controlled.¹² Members in the same business may have some ability to control each other. They also have a common interest to obtain information, and to employ risk reduction measures.¹³ That is, the pool has a stronger incentive than the individual to undertake research and prevention.

Viscusi, 1998.

¹¹ See Skogh (1999). The logic is as follows: assume that there is a pool of N individuals faced with the same (but unknown) probability of losing the amount L . First, regard the case where only one accident occurs in the group. The probability that a certain individual is hit is, thus, $1/N$. Each risk-averse individual benefits from risk-sharing because she prefers a certain cost L/N to the probability of losing L with the probability $1/N$. The procedure can be repeated for two or more accidents, various probabilities, and sizes of the loss. The individuals gain from sharing equally, except for the cases where there is no accident or all are struck by an accident. Hence, equal sharing is preferred, independent of the probability and the size of the accident, see Skogh[1996].

¹² Knowledge of the relative risk appears to be sufficient. For instance, if sharing shippers estimate one ship to have the double cargo (loss) or double probability of becoming wrecked, the pool members may agree that the owner of that ship shall contribute with a double share in case of a loss.

¹³ These differences between mutual risk-sharing and insurance have been neglected in the theoretical literature, which usually makes no distinction between pooling and insurance.

A pool must also be large to efficiently diversify risks. Groups of equals tend to be small, however, and as soon as differences in the group are revealed, the mutual may be split. Groups of individuals that have long-term relationships, such as families, guilds, and other societies, may be able to exert control relatively easily, and thus trust one another. They also face similar risks. Taken together, this explains risk-sharing in such groups. Throughout history, there has been mutual aid for fire, death, disease, disability, and for the loss of cargo or ships. Today, we observe mutual risk-sharing in joint ventures and in the collective ownership of risky enterprises. Contemporary insurance companies often combine insurance and mutual pooling. Many insurance companies are mutuals.^{14 15}

Generally, mutual sharing appears to be prior to insurance that may develop at a later stage when actuarial information is available. A first step towards insurance may be the introduction of pre-payments in a mutual pool. Pre-payment may reduce distrust among pool members. Pre-payment also evens out costs over periods of time. If the pool is large enough to spread the risks, the fund large enough to even out payments over time, and actuarial information is available, the premium can be set close to the expected accident costs plus administrative costs. A modern, large mutual pool with diversified risks may charge premiums and offer no residual rights or place obligations on the policyholders. In practice, such firms are insurers according to our definition.

Note that a requirement of coverage may result in risk-sharing if there is not enough information available for insurance. Prerequisites for the risk-sharing of new industrial hazards are; *(i)* that there exists a group of firms in the industry with similar risks, *(ii)* that a common pool exists, or can be established at not too high a transaction cost, and *(iii)* that the pool is able to control moral hazard and adverse selection.¹⁶

8. When liability and third-party insurance works

Strict industrial liability, with the contributory negligence defence, was introduced in many countries already in the 19th century. An industry in focus was the railroad that caused fires

¹⁴ Stock companies selling insurance at a fixed premium developed during the industrial revolution hand in hand with actuarial science (Bucht, 1936).

¹⁵In the most advanced commercial centres insurers bet on unpredictable risks, such as the merchants did in Florence and Genoa during the Middle Ages and in Lloyd's coffee shop in London during the eighteenth century. Note that through experience these ancient marine insurers were well informed about the risks they covered.

¹⁶ The formation of such pools may, of course, be realised through the assistance of insurance companies.

along the tracks. Here the assumptions of the economic model appears reasonably fulfilled. There are identifiable injurers (railroads) and victims (landowners). Both parties may be risk-neutral or insured. The risk of fire, and the influence of precautions and safety measures, is predictable. As long as the negligence rule prevailed the landowners would normally have to pay themselves for the damage, because the railroad would take the care necessary to avoid liability. To be efficient the court would have to regulate the standard of care by the railroad correctly. However, information on rail road communication and technique is in the hands of the rail owners. Thus it seems less demanding for the courts to regulate the behaviour of the land owners, e.g. by restricting flammable storage along the tracks. Strict liability with the defence of contributory negligence, therefore, appears an economically motivated rule.

Many industrial accidents are such that the damage and the injurer are observable. The causality is relatively simple and the potential victims have little, or no, ability to prevent an accident. For instance, the only way inhabitants in a coastal region can escape the risk of oil pollution may be to leave the region. Disregarding this option, the accident is unilateral. Moreover, it is primarily the injurer who has knowledge about the impact of precautions that may prevent the accident. The injurer can also cover the loss by some form of guarantee or by risk-sharing. When these conditions are fulfilled there is a strong case for liability.

For instance, in 1967, a 120,000 ton oil spill polluted the English Channel after the Torrey Canyon accident. An oil spill of that size, polluting the sea and several nations, had never occurred before. Coastal nations agreed to apply strict tanker owner liability, and only accept oil tankers in their waters that were insured or guaranteed.¹⁷ It was possible to establish the convention because the states had a common interest in covering clean-up costs, and because the convention was enforceable due to the power to exclude tankers from harbours. The strict liability rule made the tanker owners responsible for a new risk that was similar in all overseas oil shipping. The threat of potential liability and of not being accepted in the harbours gave an incentive to the oil traders to search for guarantees. Insurance was not available. However, marine "Compensation and Indemnity Clubs" existed that shared the potential losses. Once a member of the pool, the jointly liable tanker owners became interested in regulating safety, an interest shared with the coastal states.

Another industry where mutual guarantees may be used more extensively is nuclear power. An international convention on the strict liability of nuclear power plant owners was

¹⁷The distinction between insurance and risk-sharing is usually not made in the literature. Many risk-sharing organisations are, thus, called "insurers".

signed in Paris in 1960. The liability was combined with mandatory insurance, risk-sharing, or financial guarantee. Atomic pools, set up by national insurers, insure and share property and liability. Damage to the power plants may be insured. Third-party liability may also be covered, but usually to a limit set by what is thought to be insurable. For instance, plants in Sweden are covered to around \$1.5 billion by property insurance, while the third-party liability is limited to around \$300 million. Risk-sharing agreements between the signatory states, and public coverage by the Swedish state, cover third-party losses up to \$500 million. The picture is the same in other signatory states. Hence, third-party liability is limited, although the nuclear industry is strictly liable.

One way to increase liability for very large accidents is to require risk-sharing within the nuclear industry. According to the Ferguson-Anderson Act of 1988, mandatory risk-sharing exists in the U.S., covering third-party liability up to \$9 billion. Faure and Skogh (1992) have outlined a hypothetical European risk-sharing agreement covering nuclear power third-party liability one hundred times larger than today that would make compensation possible also for very large accidents and would create a joint interest in the industry for mutual control. However, the solution requires agreements by states and by plant owners that are unequal in many respects. Thus, a more realistic possibility might be risk-sharing by plant owners in states with similar plants.

All in all, strict liability with requirements for sufficient means for coverage of damages, as a basis for free mutual agreements in the industry on guarantees (and insurance when available), seems to have important applications. For instance, the system could be applied to catastrophic breaches of water dams for hydroelectric schemes. Today the liability rules vary from country to country. If states decided to make the water power producers strictly liable, with the requirement of trustworthy guarantees for the licence to run the industry, the industry would search for appropriate funding systems, including international mutual sharing and insurance.

9. Public schemes for coverage of losses

The tort liability system appears to work relatively efficiently in the cases described above. That is, in cases where the liability model fits reality. Critical for the model, as well as in the real world, is that there must be identifiable damage, victims and injurers, and that the causality between care taken and the risk of accident is predictable.

In cases where these basic conditions are not fulfilled the liability system fails. For instance, many polluting and toxic substances cause allergies and diseases, although an injurer cannot be identified. If the causality is uncertain there may be no identified victim and thus no claim. First-party insurance is in such cases a way of reducing victimisation.

A shortcoming of private insurance is that everyone does not insure themselves-- there is a free-riding problem that relies on unprotected victims being taken care of anyway. This makes an argument for mandatory private first-party insurance or public compensation schemes.

In areas where private insurance is not feasible it is commonly argued that the public should cover major catastrophes and large unforeseen losses. There are several reasons why states administer mandatory risk-sharing, and citizens cover losses with taxes. The coercive power of the state, and the public organisation (or supervision) of the pool, may be necessary for its credibility.¹⁸ Another reason for public risk-sharing is that the national pool is large. The administrative costs of public no fault first-party insurance has been shown to be low.

Further, uncertainty about the risks may also be the reason for risk-sharing organised by public authorities. Indeed, hazards that are unpredictable, as well as completely unforeseen risks, may be beneficially shared collectively by all members of society. In other words, mankind can foresee that the unforeseeable will occur, although the uncertainty about what will happen is genuine. Agreements on the sharing of losses "no matter what happens" may thus be favourable. Such an agreement is open, however, to interpretations and conflicts *ex post* and, thus, may not be trusted. That may explain why agreements about mutual aid primarily exist within families, clans, and societies with strong internal control and trust. However, also on a national and international level there are explicit or implicit commitments to compensate the victims of unforeseen events. The interpretation of the commitment of aid and charity may be made *ex post* by a national parliament or by international organisations like the UN.

On the other hand, many welfare states have limited the public schemes by introducing private, or semi-private, insurance systems with a closer connection between premiums and benefits. A common argument put forth in favour of these reforms is public budget deficit. In addition, I may add the uncertainty argument: earlier, when actuarial information on individual risks was absent, public risk-sharing was a rational choice. Now, the presence of

¹⁸ Hägg (1994).

actuarial information makes a more extensive use of private insurance possible.^{19 20}

Meanwhile, new techniques and industrial hazards place new demands on the state because catastrophes due to industrial processes, chemicals, drugs, etc. will remain uncovered by insurance. Risk-sharing on a national or international level has advantages here, especially in relation to completely unforeseeable development risks.

A completely unforeseen development risk can possibly, to some minor extent, be reduced through general precautions. However, the absence of knowledge limits the ability to act -- whatever is undertaken may be inadequate. Because of the absence of efficient private prevention, development risks can only be covered by first-party insurance or by public compensation schemes. Precautions and preventive actions motivated under such uncertain circumstances may be accomplished through public safety regulation, enforced by a due care (negligence) standard, administrative sanctions, and/or criminal punishments.

10. Conclusions

The basic economic model of liability describes simple situations where strict liability may prevent accidents efficiently. Important assumptions are that: (i) the victim and injurer are identified, (ii) the causation is clear, (iii) the parties are risk-neutral and the liable party is able to pay the damage, and (iv) the risk is predictable and the impact of safety measures is known. When these conditions are met strict liability may be efficient and thus to be recommended.

If the parties are risk averse or the potential losses are so large that the liable party is unable to cover losses there is a demand for insurance. Insurance transfers the risk to the insurer. At the same time it reduces the policyholder's incentive to take care. On the other hand, the insurance industry establishes incentives to take care by deductibles, bonus systems and policy conditions. Hence, strict liability appears to work relatively efficiently also at risks covered by insurance and mutual risk-sharing. Oil pollution is an example. Risk-sharing may also be extended in areas like nuclear accidents and accidental dam breaches.

¹⁹ In fact, the evolution of fire-insurance followed a similar pattern: many European communities organised for centuries collective sharing of losses in the event of fire. Private fire mutuals, and later insurers, took over during the nineteenth century when actuarial information became available (Bucht, 1936).

²⁰ It is interesting to note that the fear of meltdowns in nuclear power plants has much in common with the fear of town fires several hundred years ago. Towns burned down with catastrophic consequences. The risks were not insured, but to some extent the losses were covered by risk-sharing agreements, and by charity. Later, the sharing developed, and as the actuarial science grew, property and personal losses could be insured. Similarly, at a meltdown some costs will be covered by private first-party insurance and through international compensation plans. The remaining, potentially very large losses will be left to random victimisation and charity. International risk-sharing may improve the situation. Later, when more information on the risks is available, insurance may be possible.

Development risks and new industrial hazards that are unpredictable are usually not insurable. The main argument for strict liability is that the injuring industry controls the accident risk, but that may not be possible with risks that are new and unpredictable, which strengthens the argument for negligence, in combination with victims' first-party insurance.

First-party insurance is also to be preferred in all situations where no liable party will cover the damage. Reasons for uncovered losses are that the cause, injurer, victim or harm is not identified. "Long tail risks" and complicated causation belong to the same category. The high administrative costs of implementing liability also renders an argument in favour of first-party insurance.

Retroactive liability will have no impact on prevention and is inferior as a means of compensation. Indeed, retroactive liability functions as random confiscation. First-party private or public coverage is thus to be preferred when unforeseen damage like asbestosis, gene defects, allergies with uncertain cause, etc. appears.

Risk-sharing on a national level has advantages, especially in relation to completely unforeseeable development risks. In other, well established public areas like health and pensions, many states tend to reduce their activities. Public budget deficits is one argument. Moreover, the risks are "old". Thus, actuarial information makes private insurance feasible.²¹
²² New techniques and industrial hazards place, on the other hand, new demands on the state.

A remaining problem is that completely unforeseen development risks can only, to some minor extent, be reduced through general precautions. The absence of knowledge limits the ability to act -- whatever is undertaken may be inadequate. Nevertheless, precautions and preventive actions motivated under such uncertain circumstances may be, to some extent, accomplished through public safety regulation, enforced by a due care (negligence) standard, administrative sanctions, and penal law.

²¹ In fact, the evolution of fire-insurance followed a similar pattern: many European communities organised for centuries collective sharing of losses in the event of fire. Private fire mutuals, and later insurers, took over during the nineteenth century when actuarial information became available (Bucht, 1936).

²² It is interesting to note that the fear of meltdowns in nuclear power plants has much in common with the fear of town fires several hundred years ago. Towns burned down with catastrophic consequences. The risks were not insured, but to some extent the losses were covered by risk-sharing agreements, and by charity. Later, the sharing developed, and as the actuarial science grew, property and personal losses could be insured. Similarly, at a meltdown some costs will be covered by private first-party insurance and through international compensation plans. The remaining, potentially very large losses will be left to random victimisation and charity. International risk-sharing may improve the situation. Later, when more information on the risks is available, insurance may be possible.

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