A European Nuclear Accident Pool*

Göran Skogh

Department of Management and Engineering, Linköping University, Linköping SE-581 83, Sweden.

E-mail: goran.skogh@liu.se

The compensation to victims of nuclear accidents is based on a Paris (OECD) and a Vienna (UN) convention. A problem with the system is that a strictly liable, but insolvent or uninsured plant owner leaves victims without compensation. In this paper, it is argued that a system could be better organised by, for example, the European Union (EU). A State that permits a nuclear reactor on its territory should be strictly liable. Benefits are: (i) States are able to compensate large damages; (ii) theory suggests that stepwise modified risk-sharing could be made beneficial for risk-averse States; (iii) the EU can enforce sharing agreements by Member States; (iv) a State can limit its financial burden by redressing some liability to the domestic nuclear industry. The incentive created hereby, as well as regulations on location and safety may prevent accidents. A European nuclear accident pool will have a collective interest in accident prevention.

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Introduction

New investments in nuclear energy production are planned around the world and supported by, for example, the European Union (EU). Yet the insolvency problem remains. In other words: Who compensates the victims, if there is a major nuclear accident? An answer to the question is that strict liability prevails according to the “Paris Convention” of 1960 by the OECD¹ and the “Vienna Convention” of the UN nuclear agency, IAEA.

However, the liability is “channelled” to the licensee of the energy producing plant. Thus, the accident damage shall be covered by the injurer (the plant owner) only. Since other firms in the nuclear electricity production chain, such as suppliers of uranium, are excluded from liability, and because the plant owners often are without necessary financial resources, industrial third-party liability is in practice more or less fictive.

To certify some compensation to victims of nuclear accidents, the Conventions include rules on minimum coverage for accidental damage. According to an Amendment to the Paris Convention of 2004, victims shall (with a start in 2008) be

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¹ The OECD Nuclear Energy Agency, NEA, www.nea.fr/

compensated up to €1.5 billion for an accident. This agreement is below named “the Amendment”. I assume for simplicity that the Amendment will be honoured, although it is still not ratified. The Amendment may be seen as a future (optimistic) minimum. The compensation today varies a lot among States, but it is considerably smaller.

The compensation in the Amendment is divided into three layers: (i) first, mandatory liability insurance and/or industrial guarantees cover damage up to €700 million; (ii) for larger damage, up to €1.2 billion, the State where the accident occurs contributes with €500 million;² (iii) on top of that, at damage larger than €1.2 billion, there shall be contributions of €300 million by States signatories to the Conventions. Moreover, the Amendment allows States to include unlimited liability of the nuclear plant owner.³

The compensation to victims remains small, although large financial resources are involved. The total compensation of €1.5 billion can be compared with the Chernobyl accident with an estimated damage in Belarus only of U.S. \$235 billion.⁴ It can be argued that a meltdown of that type is not possible any more. Nevertheless, there may be accidental damages in production, transport, storage and leakage that are considerably larger than €1.5 billion. An accident polluting land in a densely populated area can result in very large damage, including a financial crisis due to collaterals losing their value. Personal injuries and fatalities could be many.⁵ Examples from other areas are the 11th September 2001 terrorist attack with estimated insurance compensations of \$21 billion, the hurricane Karina, in August 2005, with insurance coverage of \$45 billion and the explosion of the AZF chemical plant in Toulouse, France, in September 2001, with estimated costs of €1.8 billion.⁶

Accidental damage above €1.5 billion is not covered by the Amendment. The compensation to victims for larger losses is unregulated and left to national laws and political *ad hoc* solutions. Individuals, firms and various institutions may thus be seriously harmed. Small accidents in this article are of such a kind that the injurer is able to compensate the victims, and this corresponds with the first layer above. Large accidents are of such a kind that the compensation according to the Amendment is not enough to cover the losses. The damage on third parties exceeds €1.5 billion. Very large accidents cannot be covered by the Member States without a social loss due to risk-aversion, that is, the State is willing to pay an increasing marginal risk-premium. A loss of, for example, 1 per cent of GNP could be at a level where a State is willing to pay a risk-premium to escape liability. The upper level of losses thought of in this article is in the rank of 5–10 per cent of GNP.⁷

How shall such foreseeable high-loss–low-probability accidents be regulated? The standard response by economists is to suggest a Pigouvian tax on nuclear energy. An environmentalist may add that the income of the tax should be funded or earmarked for environmental purposes. But who shall meter the tax and how large should

² A State can redress this duty to the nuclear operator making the plant owner liable for €1.2 billion.

³ In reality, unlimited liability is limited to the remaining assets of the plant owner, which may be small.

⁴ SOU (2006, p. 271).

⁵ I disregard the problem of measuring damage.

⁶ Friends of the Earth Europe (2007), <http://www.foeeurope.org>.

⁷ Unforeseeable low-probability apocalyptic catastrophes are not studied here.

it be? Law and economics scholars may argue that the industrial liability must be made effective by, first of all, an elimination of the channelling of liability to plant owners without financial resources; and that the whole nuclear power industry should be liable. They all base the suggestions on the Polluter-Pays-Principle (PPP).

In this paper, I argue that the Polluter-Pays doctrine is not what is needed, and suggest a system of State liability, combined with a sharing of large accidental damage. The system should be supervised by an international community of States. The EU is the practical example we have in mind. The purpose is to contribute with a concrete example to the principal discussion on a complicated matter.

The following section discusses which party ought to be liable for nuclear accidents. The parties considered are those included in the Amendment: the plant owner (polluter), the nuclear electrical power industry, the Signatory States and, finally, the State where the plant is located and an accident occurs.⁸

The damage from a nuclear accident may be very large. Fear of ruin and pooling of risk are, therefore, an issue. The next section applies a theory of risk-sharing based on the Restated Diversification Theorem (RDT).⁹ The analysis shows conditions at which sharing of losses is mutually beneficial. The model assumes identical agents, but the theory can be applied also when the parties differ in probability or potential loss. That is, strictly liable States can benefit by bilateral risk-sharing agreements.

The penultimate section discusses shortcomings in the present system, and how to implement a new one. The last section concludes.

Who should be liable?

The plant owner

Before discussing pooling by contracts, the property rights (here the right to compensation for infringements) have to be settled. Who should be liable for a nuclear accident: the producer (the polluting plant owner), the nuclear electrical power industry or the State hit by an accident? According to the Coase Theorem, it does not matter from an efficiency viewpoint who is liable (at zero transaction costs). In tort cases, like nuclear accidents, there are prohibitive transaction costs. Hence, liability rules matter. First of all, the liable party must be solvent and trusted. An insolvent firm that may escape liability is not a worthy player. Insolvency causes incomplete compensation leaving a burden on victims. Moreover, the incentive to take care is limited to damage below the bankruptcy level.

The PPP is a fundamental doctrine in environmental policy: polluting firms shall pay for their pollution. That is equivalent to strict liability in tort law: accidental damage shall be compensated by the injurer. The PPP may work efficiently in

⁸ An accident can, of course, be international. To simplify I disregard that possibility by assuming no international externalities. All damage is in the own country.

⁹ See Skogh and Wu (2005).

relatively small accidents with claims within the financial capacity of the injurer. On the other hand, a large potential damage and the small assets of the injurers – as in the nuclear power production – cause a problem of bankruptcy. Neither full compensation nor efficiency result, simply because the injurer cannot pay. Hence bankruptcy sets a limit on the PPP.¹⁰

Mandatory liability insurance can be used to certify some compensation to victims. Plant owner liability is covered by insurance in the Paris and Vienna Conventions. A problem of insurance is that the economic incentive to take care gets transferred from the nuclear firm to the insurer. If the insurer is poorly informed about the nuclear risks there is a problem of moral hazard and large administrative costs. To be effective, an insurer needs a large experience of risks and safety in the nuclear power production and of claims settlement.¹¹ The number of incidents and accidents is so far small in the industry, and the insurer's knowledge about the safety in production is limited, compared with, for example, fire insurance. Knowledge about fire insurance goes back centuries, while nuclear risks are development risks.

Development risks, including nuclear electricity production, are new risks due to technical or environmental change. Such risks are usually not insurable. Indeed, the nuclear atomic accident pools are separated from ordinary property and liability insurance.

It is sometimes argued that insurance of nuclear accidents and similar catastrophes are not available because the insurance market cannot diversify the potentially very large losses. Yet the international reinsurance markets, together with the international financial markets, are large enough to diversify huge losses. Thus, the statement does not seem to be fully correct. Rather, the problem is that the probability distribution cannot be calculated with sufficient confidence. Insurance is unavailable because of the limited information on the unexperienced risks. In the future with more information, it may be easier to trade "risk participation shares" on a large scale in the financial markets, as suggested by Tyran and Zweifel.¹²

Limited information on the risks and the insured, as well as monopolies in the national atomic pools, make the use of insurance questionable. Faure and Fiore¹³ argue that there are national monopolies in the nuclear insurance industry, which may explain very high insurance premiums. In sum, the PPP with or without mandatory insurance has serious limitations. We cannot expect the insurance industry to accept a larger amount than the present €700 million of liability cover. The PPP must be modified, and the liability moved to a party with large enough financial resources.

¹⁰ A small solvency margin in producing corporations may be a policy of financial organisation within the industry. That is, the owner of a dangerous industry runs the production with minimal equity to limit losses at failures. The channelling of liability to the nuclear plants supports this behaviour.

¹¹ The time to sue for compensation for personal injury has been prolonged to 30 years. The insurance industry complains and demands a maximum of 10 years. A reason is the problem of foreseeing claims in the future SOU (2006, 43, pp. 163–168).

¹² Tyran and Zweifel (1993). For a comparison of catastrophic bonds, see Radetzki and Radetzki (1999).

¹³ Faure and Fiore (2007).

Nuclear power industry

The liability of nuclear plants can be transferred to the nuclear power-producing industry by, for example, mandatory guarantees or pledges. An option is the vertical guarantee. That is, corporations in a chain of production cover the liability of other firms in the chain. It may work as follows: The public authorities require that a plant covers a certain minimum amount of damage at an accident. Since the assets of the firm are small the plant owner has to find some guarantor outside the plant (otherwise, the plant receives no permit to produce). The guarantor can be the “mother” in a “family” of electricity-producing corporations that covers insolvent “daughters”.¹⁴

Horizontal guarantees by plant owners in competing corporations may increase liability and diversify risks, especially if they are combined with vertical guarantees. Mutual risk-sharing could be an example of such a combination of guarantees. In Faure and Skogh,¹⁵ we give a hypothetical example where 100 plants in Western Europe each contribute to the coverage of the damage at a nuclear accident with \$1 billion as a maximum. That would make compensations up to \$100 billion.

The example demonstrates the potential for liable plant owners of sharing equally. There are implementation problems, however. How could many States with nuclear power production unify legislation and make each plant contribute \$1 billion for accidents in any of the 99 other plants of various nationality, size and type? Moreover, guarantees are costly to administer. Horizontal and vertical guarantees in total of \$100 billion reduce the credit capability of the industry. Cartelisation among the pool members could also be a problem.

A number UN and OECD countries have accepted the Paris and Vienna Conventions. Given the financial capacity of these countries and the large nuclear energy production by many of these States, one would perhaps expect more support to the victims. The last layer of €300 million, as described in the Amendment, is, in this light, not impressive. One reason why the contribution by the Signatory States remains small may be complicated multilateral negotiations. Another reason may be that the negotiations include redistribution in favour of some against the interests of others. Expected losers may block unfavourable agreements. A third reason may be that it is hard to efficiently enforce agreements worldwide.

Nevertheless, there are real examples of systems of mutual risk-sharing with large compensations compared to the Amendment. Of special interest is the U.S. system. The Price–Anderson Act of 1957 stipulates that each plant in the U.S. shall, for an accident in any of the U.S. plants, contribute to the coverage of the damage. Today the maximum payment by each contributing plant is \$98.5 million. Victims of a nuclear accident will in this system be compensated up to an amount of around \$10 billion. The national system in Germany with joint industrial liability is also of interest – it enables compensations up to €2.5 billion.

¹⁴ Such guarantees may undermine the channelling. An argument in favour of channelling is that the number of cases in court could be many, if claims could be raised against different parties in the chain of production. The restriction of liability seems, however, more serious from an efficiency point of view.

¹⁵ Faure and Skogh (1992).

Faure and Fiore¹⁶ suggest a sharing system in the EU similar to the American one. The U.S. example is of great interest, but a European copy may be complicated to reach. The United States has the legal and economic power to mandate liability in all nuclear power plants in the Federation. The Amendment is an indicator of the level of compensation that is politically feasible internationally. The EU has, with its jurisdiction, a position in between. Relatively independent Member States, and an influential nuclear industry lobby, make it hard to force the parties. Hence, it is important to find a European system that is acceptable to the involved parties.

The state hit by an accident

The Amendment specifies the liability of the State hit by an accident. It is agreed to be €500 million, in the layer between €700 million and €1.2 billion.¹⁷ The Signatory States layer comes thereafter. For an accidental damage above €1.5 billion, liability is left unspecified. The compensation to victims of larger accidents will thus depend on national laws and political *ad hoc* solutions. The relevant laws vary among countries, and the legal rights of victims can be arbitrary. Victims may be left uncompensated and social and political conflicts can emerge.

A State hit by a large accident has, in addition to economic liability, moral and political duties to compensate citizens, local communities, institutions, neighbouring countries, etc. The State, or its taxpayers, will thus have to carry a large burden. In fact, the Amendment layer of €500 million seems small. Indeed, the layer of €500 million appears to be a limitation of liability. One may ask, therefore, whether the liability of the States should be made explicit also for large nuclear accidents. Legal certainty reduces potential distributional conflicts, which is important, especially in a chaotic situation.¹⁸

Note that limitations of the liability of the State are also important to clarify. For instance, personal injuries can (perhaps) in welfare States be covered by social insurance and by first-party insurance.

There are several efficiency reasons why the State hit by an accident should be liable. First of all, the State is large enough to cover losses below “Very Large Accidents” of, say, 10 per cent of GNP. Second, the citizens and the government presumably fear accidents that ruin citizens and cause social disorder or international conflicts. This fear is, in the model discussed below, characterised as risk-aversion on state level. The fear may be reduced by risk-sharing among Member States, which will be discussed below.

An efficiency argument for making the Member State hit by an accident liable is that the State has considerable influence on the probability and size of a nuclear accident in its territory: (i) the State takes the decision to permit or reject nuclear

¹⁶ Faure and Fiore (2007).

¹⁷ The liability of the State can, as noted above, be shifted by the State to the domestic nuclear plants.

¹⁸ In Skogh and Stuart (1982), we show the social loss of anarchy. See also Faure and Skogh (2003, pp. 116–119).

production in the country; (ii) the location of a plant, which has to be accepted by the planning authority, is important for the potential accidental damage; (iii) public authorities regulate the nuclear production – safety is regulated in detail, nationally and internationally; (iv) the nuclear industry is for many nations owned, partly or completely, by the State. Hence, the ultimate control is for many plants already in the hands of the State; (v) the State benefits from the nuclear production by taxes and environmental improvements. The reduction of green house gases is an often-quoted public good of nuclear energy. In the calculus, both benefits and costs should be considered. If the State is liable for accident costs the economic consequences become explicit to the planner.

Note that making the State ultimately liable does not free the plant owners, or the nuclear industry, from liability. The State can redress liability, for example by increased use of industrial guarantees. Such a second-order transfer of liability can reduce the burden of the State, and it creates incentives to prevent accidents.

The current preventative regulation is extensive, nationally and internationally. The intervention in the production is motivated by the fact that the incentive to prevent accidents is strongly reduced due to the insolvency problem. Yet, there may be over-regulation in certain areas and under-regulation in others. Political demand of completely safe solutions may cause inefficient large protection, while other risks may remain neglected.¹⁹

Is it possible to establish and enforce liability of the State where the accident occurs? There are several reasons why international agreements on liability are hard to reach. First, worldwide negotiations are extremely complicated and time consuming. Hence, if a small number of negotiations in a community of States like the EU is possible, it may make this process easier. Second, the number of potential parties (Member States with nuclear power production) must remain relatively small. At the same time, the pool must not be too small to diversify risks effectively. Third, a jurisdiction with power to enforce its rules is needed. Here the U.S. experience is of special interest. One factor that made the American solution possible is the legal power of the Federal State. Similarly, the EU adds a legal level that may regulate and enforce accident liability of Member States. The Directive on Environmental liability is one example where the EU introduces liability rules to improve the environment. The European Solidarity Fund already compensates victims of natural disasters.²⁰ Hence, the EU can possibly establish a system of nuclear liability in its Member States.

A remaining problem is that State liability can become very costly to a State hit by an accident. Some form of sharing of losses should reduce the burden. But the Member States represent different nuclear risks; some produce no nuclear power, others produce a lot; some Member States are small and others are big; some plants are old, others are new, etc. Is it at all possible to make them accept Member State liability in combination with sharing of losses?

¹⁹ Viscusi (1998) gives many examples on inefficient risk policy.

²⁰ The European Union Solidarity Fund (2007), <http://europa.eu/scadplus/leg/en/lvb/g24217.htm>.

Theory of risk-sharing

A contractual approach

To motivate a European nuclear accident pool we need a theory on risk-sharing. Why do people share losses, or why does risk-sharing fail? We also need a normative base to judge whether a situation is good or bad. The normative stand in this study is contractual. Free contracting is assumed beneficial for the contractors and for society. Civil law should, therefore, among other things, reduce transaction costs via rules simplifying contracts. If transaction costs are prohibitive, as they are in third-party tort cases, there may be costs that need to be internalised into the economy. The purpose of the liability law is in that case to correct for the absence of contract and trade. Still, the underlying norm for legal regulation is a hypothetical agreement that the parties could have agreed upon in a world of costless contracts.²¹

Implementing political reforms requires that nobody is worse off.²² The parties shall not be forced into the system. Free Pareto agreements are improvements. If State A installs a nuclear power plant that may cause an accident damaging State B, then B should be fully compensated. That is, neither A nor B should be worse off.

Utilitarian cost-benefit analysis with no compensation of those harmed is not undertaken here. Instead we look for solutions that improve the situation for all parties. This requires that all Member States in the pool gain by the new system and/or are compensated so that none of the pool members is worse off. The parties may be the EU Member States producing nuclear energy.²³

The choice of this demanding norm is not only of theoretical interest. A functional agreement on sharing of accident costs must be accepted by all participating parties. States that expect to lose by the agreement must be free to leave the pool.

But how can costly strict liability possibly be accepted? May *ad hoc* political solutions be better? Recall that the liability rules are part of property rights. Property rights have two functions, first to avoid distributional conflicts, and, second, to facilitate contracts and trade. This is fundamental in a liberal society. A law of Member State liability certifies that victims have rights and duties. The national acceptance of strict liability also clarifies the duty of the State. Having no law or an arbitrary one may be worse.

Insurance and risk-sharing

Before studying risk-sharing, a distinction between insurance and risk-sharing is needed. Insurance and risk-sharing are, in the analysis below, distinct types of

²¹ Note the difference between the contractual approach in this article and the standard Pigouvian tax. The matter here is that the property rights are not honoured because of insolvencies and other transaction costs. A well functioning market requires that rights and duties are defined and exchangeable, which includes that liable parties are able to pay. By placing the liability on States (supervised by the Union) with financial capacity, the market opens and benefits and costs get internalised by contracts. Additional taxes disturb the efficiency.

²² Cooter and Ulen (2000).

²³ There is, of course, no guarantee that all citizens, in or outside the Union, are not harmed by a change of system.

contracts. Insurance is a contract where a premium is paid *ex ante*, with the promise to cover a certain future contingency. Risks are traded by insurance, from the insured to the insurer. The trade may diversify risk if the insurer has a mixed portfolio. If the portfolio contains correlated risks, insurance may, indeed, increase the risk disposal of the insurer. Reserves may be required to certify that the insurer is solvent and able to fulfil the obligations.

Risk-sharing is different; (risk-averse) parties facing similar losses share negative outcomes. In its simplest form, it is a bilateral agreement that includes no prepayment or funding. A characteristic of risk-sharing is that it does not require pricing *ex ante*. The shares at the time of an accident are, however, decided in advance. The monetary contributions to the pool are realised *ex post* when the claims are settled.

Prepayments and funding for risk-sharing can be motivated for various reasons. One is that the parties do not trust each other. The fund may guarantee that there are assets available after an accident. Another reason for savings and funds is the benefit of diversification over time. Stochastic accidents may be covered by a stream of regular payments to a fund. Funding will not be discussed below. We focus on sharing by States and assume that the assets of the State make specific funding for nuclear accidents unnecessary.

The terms risk-sharing and pooling are often mixed with insurance in the literature. Here pooling and risk-sharing are synonymous, but insurance is different. It may add to the confusion that insurance and risk-sharing, and various combinations thereof, are common in the insurance industry; sharing is typical of the mutual company, while the insurance dominates in the stock company. Reinsurance includes both sharing and insurance contracts. The layers of liability for nuclear accidents are examples of complicated mixes of insurance and sharing. Insurers may, as in France, insure the third-party liability of the nuclear plants, while international reinsurers share their risks in a common pool. The Signatory States contribute by shares within their layer of €300 million. The U.S. system is a risk-sharing solution.

The restated diversification theorem (RDT)

There is no established theory separating insurance and risk-sharing contracts – the traditional theory focuses on insurance. The dominating Expected Utility Theory assumes that probabilities of losses are estimated, or subjectively known. Risks can, in this theory, always be priced. This presumption does away with the difference between insurance and risk-sharing. We need a theory on pooling without known probabilities of losses.

The diversification theorem states: “If a risk-averse individual has a choice between two assets with identical but random returns, the individual prefers to invest half of the endowment in each asset”.²⁴ This theorem is basic in portfolio theory and in insurance economics; diversification is demanded by the policyholder and supplied by an insurer with a diversified portfolio.

²⁴ Rothschild and Stiglitz (1971, p. 83).

The diversification theorem needs to be somewhat modified to explain risk-sharing. The reason is that risks are not priced in sharing, as they are in insurance. We²⁵ have restated it into a theorem about two individuals sharing their losses.²⁶ The RDT says that two identical risk-averse individuals, each having an asset with identical but random returns, gain by sharing their losses equally.

Note that the RDT is true for any distribution of losses, as long as the risk is the same for both individuals. In other words, if both individuals are faced with an equal potential loss, V , and the loss occurs with a probability, p , which is the same for both, then both gain by sharing losses equally. The share of each is thus $\frac{1}{2}V$, if a loss occurs.

A second result is that the equal sharing rule, $\frac{1}{2}$, is Pareto optimal. The reason for the bilateral gain is that the variance in outcomes is reduced by pooling. Risk aversion guarantees that a movement away from equal sharing makes at least one worse off.

Third, since the RDT is true for all V and p , sharing partners must not know p – it suffices that they trust that the counter-party takes the same risk. Equals may thus gain by sharing without knowing the probability of loss.²⁷

Sharing among unequals

The assumption of identical individuals may seem to limit the applications of the model. Yet equality is not a necessary condition for beneficial bilateral sharing. Some differences in agents and risks do not change the application of the RDT. First, allowing agents with different attitudes to risk in the model will not change the results substantially. Risk-lovers and risk-neutral agents (States) prefer, of course, to stay outside the pool.²⁸ Risk-averse pooling agents gain by equal sharing, although the outcome must not be optimal. The outcome depends in the model on the strength of risk-aversion and bargaining power of the agents.

Second, diverging risks may be unified to make sharing feasible. If, for instance, some power plants are made out of graphite, and thus riskier than the others, restoration may be required to make the quality and risk the same. Thereafter, entering the pool may be accepted.

Third, so far we have assumed that the value (potential loss), V , is the same for the bargaining agents. What will happen if the values of their potential loss differ? The agent with a large potential loss will gain much compared to the agent with a small potential loss. The small agent gains little or loses by pooling. Both can be better off,

²⁵ Skogh and Wu (2005).

²⁶ Instead of one individual splitting the portfolio we have two individuals with each one independent asset.

²⁷ It is an interesting finding that there are methods to beneficial sharing without information on probabilities. It is contrary to Bayesian decision theory that assumes the assignment of subjective probability to all outcomes. For an experiment on decision without probabilities, see Ahmed and Skogh (2006). Sharing seems to be a straightforward solution when information on probabilities are lacking.

²⁸ Risk-lovers and risk-neutral agents may act as insurers of the risk-averse. As long as the marginal disutility of risk-taking varies among pool members there are potential gains by pooling, see Aase (2002) on the Karl Borch model on risk-sharing. However, Borch's model assumes side payments that are excluded in the Skogh and Wu (2005) model.

however, if the shares are modified according to the size of the agent's potential losses. A potential loss of double value thus motivates a double share in the accident damage.

Fourth, it is sufficient for the agents to accept a presumption of equal risk. That is, the probability of an accident may be assumed the same for both as long as nothing else is known. The understanding of their innocence must not bother the agents. Indeed, the absence of discriminating information makes mutually beneficial sharing feasible. However, as soon as information becomes available it may be used to modify shares and to introduce safety measures. There is no simple rule saying that more information is better. Indeed, information may split a pool.

The formation of a nuclear accident pool

Bilateral sharing

So far the model shows that bilateral sharing may benefit both parties. Economies of scale in diversification give an argument for including more members in the pool. Hence, there are stepwise bilateral agreements that are beneficial for all risk-averse agents.

Assume now that there is an international community like the EU. The Union Law regulates common matters. The Member States have their own national jurisdictions. The Member States trust the legal power of the Union and follow its decisions. Hence, enforcement problems are assumed away.

Some Member States produce nuclear energy and others want to invest in new plants. National laws of the Member States vary, but the Nuclear Accident Law is supposed to be a matter of the Union. Hence, the Member State where the accident occurs has the duty to compensate all victims. To simplify we assume further that all damage hits only one State. Hence, there is no externality in terms of damage outside the Union.

The Member State is free to redress liability to nuclear power plants or to the nuclear industry in its own territory. Mandatory insurance and industrial guarantees may be used as in the Amendment. On occasion, there could be a layer of, say, €700 million as in the Amendment. It would limit the burden of the State. The ultimate liability, if any of the guarantors fail to fulfil their obligations, is on the State. But the Amendment is not in use.

A risk-averse State is willing to pay a risk premium at a damage of, say, 1 per cent of GNP or more. The largest foreseeable accident is supposed to be around 10 per cent of GNP.²⁹ To avoid large-scale liability, sharing with other Member States facing the same problem becomes attractive. Assume, like the model above, that there are two nuclear power-producing Member States that are similar in all nuclear accident relevant aspects. They agree bilaterally to share costs for a nuclear accident in one of the two States. A pool is hereby established. The agreement with enforced by the Union. It is, as noted above, a Pareto-improving contract in accordance with the RDT.

²⁹ More than one accident is excluded by assumption.

Note that the diversification increases with more members in the pool. Hence, a third State may join the pool increasing the diversification, to the benefit of all three pool members. The shares may be modified according to, for example, production levels and location; large plants and plants close to densely populated areas may have to carry a larger share of accident costs. Some plants must be unified by renovations in order to be accepted in the pool. Note that such a modification of shares can be accepted, although the probability of an accident is unknown. Indeed, beneficial sharing may be possible also at genuine uncertainty, if a presumption of equality prevails. Consequently, most risk-averse States may freely join the pool. So far, we have limited the study to a pool of Member States of the Union. Nations outside the Union may join the pool as well.

Once the pool is established it will have a collective incentive to control and limit accidental losses. Safety regulations, location decisions and the norms for entry and exit will, therefore, presumably be supervised by a central authority in the Union.

Equality and equal sharing

The model presented above is based on free agreements among utility maximising agents (States). The sharing is motivated by pure self-interest. There is no charity or solidarity in favour of the victims or the poor. Such redistribution is not motivated in our contractual model. Yet the risk-sharing evens out the wealth among pool members; without the pool some would be victimised and others not.

The low Amendment compensation may cause social disorder and political conflicts, especially for very large accidents. Victims, including citizens, taxpayers, firms and institutions of various types, will have to carry the costs more or less randomly. The compensations from the State and others will in this case depend on moral standards and political pressures *ex post*. During very large accidents there may be many victims without any compensation. Gifts and charity may help the victims, but a mutually agreed right to compensation gives presumably larger legitimacy to a claim.

Note that the equality concept in the sharing model differs from the equality in the philosophy of distributive justice. In philosophy, equal sharing could be a moral imperative, a duty to help victims, for example, because all humans are of equal value. The victim without legal rights may try moral imperatives like “equal human value”, “solidarity”, etc. Moral imperatives seem often to be part of a rhetoric that is of little importance after an accident when losses are distributed. In fact, compensations to victims of, for example, natural disasters are usually limited to rescue support and first aid. Long-term support to victims of natural disasters and other large accidents is often missing.

An alternative interpretation of the (moral) duty to compensate victims of accidents is to claim that there is an implicit social contract on sharing. That is, regardless of the absence of a written agreement or law stipulating sharing rules, there is a commitment accepted by the citizens. A counter-argument is, of course, that if there were such a commitment it could have been written and incorporated in the law.

The Amendment regulates losses up to €1.5 billion. Our European system could possibly share losses of, say, €100 billion, if it were fully developed.³⁰ Above that level, the consequences are hard to foresee. The victims may have to rely on gifts. However, if such a catastrophe occurs, the sharing rules at regulated levels may still be applied with a “social contract” motivation.

Concluding remarks

The PPP does not work as intended in major nuclear accidents. Liability to third parties is strongly limited by potential insolvency, both in the nuclear power plants and in the insurance industry. Here it is argued that the shortcomings may be limited by liability on a state-level – instead of the present system with liability on plant-level. An international community like the EU could develop a system where a Member State that allows a nuclear power plant in its territory is strictly liable for damage to third parties.

Large claims can be covered by mutual risk-sharing by a pool of Member States. The analysis rests on the RDT that says that sharing is mutually beneficial to risk-averse parties. Stepwise bilateral sharing can improve for all due to the benefit of diversification. The model described shows conditions for mutually beneficial sharing in case the plants differ in, for example, quality, size and location. States in the Union are free to join or leave the pool, liability and risk-sharing included. States outside the Union may also be free to join the pool. It is up to the States with nuclear power production to decide.

Note that a pool contains a collective incentive to control the accident risk. The accident risk, as well as the burden of the pool of Member States, can be reduced by liability redressed to the nuclear industry. The Member States are also able to influence the nuclear production by restrictions in permits, zoning and by implementation of safety regulation.

Explanations of why the present international system works poorly are: (i) the doctrine of PPP does not fit in case the financial capacity of the polluter is smaller than the accidental damage; (ii) there is no worldwide legal system that can enforce the current agreements; (iii) large-scale negotiations are complicated; (iv) arguments on fairness and justice, instead of mutual sharing contracts, are used to support victims. Finally, bilateral Pareto contracts build the system from the bottom – nobody must be forced into the system.

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³⁰ There are 141 reactors in 13 countries within the EU, see Faure and Fiore (2007).

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About the Author

Göran Skogh is Professor of Economics in the Department of Management and Engineering at Linköping University in Sweden. His field of research is the economic analysis of law, uncertainty and insurance.