Limitation of Third Party Nuclear Liability: Causes, Implications and Future Possibilities

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1. Introduction

This paper deals with the third party liability of the nuclear power generation industry. It has several purposes. One is to clarify the distinctive features of nuclear liability as compared with traditional liability in tort (parts 2 and 3). The paper devotes particular interest to one such feature, namely the express liability limitation from which the nuclear power generation industry benefits. The causes and implications of this feature are discussed (part 4). One important implication of the current order is that the top risk[1] of the nuclear power generation industry is explicitly or implicitly transferred to governments. This risk transfer can be regarded as a subsidy to the nuclear power generation industry. Subsidisations counteract efficiency. Therefore, the possibilities of neutralising or abolishing the subsidy are explored (part 5).[2]

2. The liability of the nuclear power generation industry[3]

The issue of third party liability in the field of nuclear energy is regulated by a number of international conventions. The following sections provide brief summaries of the relevant articles of these conventions.

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1. i.e the top layer of damage compensation.

2. The deliberations in this part of the paper mainly concern the countries that were members of the OECD in the early 1990s.

3. All values presented in this part have been converted into US dollars.

2.1 Conventions on Third Party Liability

According to the Paris Convention on Third Party Liability for Nuclear Damage (1960), signed by 14 states, e.g. Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom, liability for damage to or loss of life and damage to or loss of all property (with few exceptions) caused by a nuclear accident is channelled to the operator of the nuclear plant in question (the operator).[4] The liability is strict, i.e. irrespective of fault,[5] and is limited to $ 22 million. This amount may be increased or decreased by each one of the states bound by the convention. In fixing the amount, the possibility of obtaining insurance coverage or other financial security is to be taken into consideration. The amount may never be lower than $7 million.[6] The liability is to be covered by insurance or other financial security held by the nuclear operator.[7]

The Paris Convention has been supplemented by the Brussels Convention Supplementary to the Paris Convention (1963), signed by a large majority of the states bound by the Paris Convention. Compared to the Paris Convention, the Brussels Convention is more specific about compensation payments. The states agree that compensation for nuclear accidents is to be provided in three steps. The first step consists of the liability of the operator under the terms of the Paris Convention, to be covered by insurance or financial guarantees. In the event that compensation is not sufficient, the liability of the installation state[8] is incurred up to $ 254 million (including the amount provided in the first step). If this amount is not sufficient to cover the damages, all states bound by the Brussels Convention are jointly liable, according to a particular formula, up to a grand total amount of $ 435 million. This is the third step of compensation under the terms of the Convention.[9]

Some 30 states around the world, several of which are states of former socialist Eastern Europe, have signed the Vienna Convention on Civil Liability for Nuclear Damage (1963), the basic principles of which are the same as those of the Paris Convention, i.e. (a) strict liability; (b) liability channelled to the operator; (c) limitations on the amount of liability; (d) compulsory insurance or financial security covering liability etc.[10] However, the Vienna Convention makes possible an even further limitation of liability than the Paris Convention. The operator's liability is to amount to at least $ 5 million.[11] Since 1988, Paris and Vienna Conventions are linked together by a Joint Protocol signed by most of the Vienna states.[12] According to the Protocol, the applicability of each convention is extended to states bound by the other convention.

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4. The liability of any other subject is thus excluded.

5. Article 3.

6. Article 7.

7. Article 10.

8. i.e. the state in which the nuclear plant is situated.

9. Article 3. See also Protocols (1982).

10. See de La Fayette (1992) p. 9; also Lopuski (1993) p. 189-210. The full titles are listed in the bibliography at the end of this article.

11. Higher amounts and even unlimited liability may be imposed by individual states.

12. Joint Protocol on the Application of the Vienna Convention and the Paris Convention (1988).

In September 1997, further steps were taken in order to improve the liability regime for nuclear damage. The Protocol to Amend the Vienna Convention (1997) was adopted, as well as the Convention on Supplementary Compensation (1997). According to the Protocol, the liability of the nuclear operator may be limited by the installation state, either to not less than $ 400 million; or to not less than $ 200 million provided that in excess of that amount and up to at least $ 400 million, public funds are made available by the installation state to compensate nuclear damage; or, for a maximum of 15 years, to a transitional amount of not less than $ 130 million. An amount lower than $ 130 million may however be established, provided that funds are made available by the installation state to compensate nuclear damage between that lesser amount and $ 130 million.[13] According to the Convention on Supplementary Compensation, which is an instrument to which all states may adhere regardless of whether they are parties to any existing nuclear liability convention, the installation state is to ensure the availability of at least $ 400 million for compensation in respect of nuclear damage. However, for a maximum of 10 years, a transitional amount of at least $ 200 million is accepted. In addition to and beyond the amount thus made available, the installation state shall make available public funds according to a particular formula specified by the Convention.[14] It remains to be seen, however, to what extent these new instruments will be signed.

2.2 National regulations

These conventions and protocols constitute a framework to which the regulations of each signatory state must conform. Within this framework, the national regulations differ substantially. To illustrate, the following paragraphs describe briefly the situation in Germany and Sweden. In addition, the situation in the USA, not bound by any international convention on nuclear third party liability, is described.

German nuclear operators bear third party liability that by far exceeds the requirements of the Paris and Brussels Conventions. The operator is strictly liable for the first $ 330 million. Up to $ 132 million, the liability is guaranteed by mandatory liability insurance. Damages between $ 132 million and $ 330 million are guaranteed by a mutual risk sharing agreement between German nuclear operators. The state guarantees compensation for damage between $ 330 million and $ 660 million. In addition, each operator has unlimited liability for damage within Germany over and above $ 660 million.[15]

Swedish nuclear operators are strictly liable for third party damage up to $ 254 million. The liability is guaranteed by mandatory insurance. For damages beyond this sum and up to $ 435 million, the state is liable jointly with other States Party to the Brussels Supplementary Convention. If these amounts are insufficient to fully cover the damages, the issue of further compensation from the state is to be determined by law. Hence, the sums of such compensation have not been determined.[16]

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13. Article 7.

14. Article 3.

15. See Danglemaier (1993) p. 427-430. It may be questioned whether the unlimited liability of the nuclear operator is in accordance with the Paris Convention which stipulates that the amount of such liability is to be restricted (Article 7).

16. See Atomskador (1996) p. 3-4.

US nuclear operators bear strict liability for damage up to $ 200 million. The liability is guaranteed by mandatory insurance. Damage beyond this amount is covered by a risk sharing pool in which all owners of nuclear reactors are members. In the early 1990s the maximum compensation provided by the pool was about $ 7.6 billion[17] (more recently, the total has been increased to close to $ 9 billion). For damages exceeding this amount plus the amount covered by insurance, Congress is committed to providing additional funds.[18]

3. The liability of the nuclear power generation industry compared with traditional liability in tort

Traditional tort liability is based on fault. Any subject may be liable. Liability is unlimited and liability insurance is voluntary. The above sections have illustrated that the liability of the nuclear power generation industry in most countries deviates from all these features. Nuclear liability is strict, channelled to the operator, limited and finally, liability insurance or equivalent financial security is mandatory. There is no doubt that these deviations affect victims as well as the nuclear power generation industry.

Traditional tort liability compensation presupposes not only that a certain act caused harm, but also that the harm is due to fault. The fault requirement limits the scope of liability. Strict liability irrespective of fault thus makes the liability regime more stringent. It strengthens the reparative function of the liability, i.e. the provision of compensation to victims[19] and thus imposes a burden on the subject liable, i.e. the nuclear power generation industry.

In traditional tort law there are no restrictions with regard to the identity of the subject liable. The channelling of liability to one particular subject thus reduces the possibilities of damage reparation. If, however, the channelling of liability to some specified subject is combined with the imposition of strict liability and compulsory insurance, as is most often the case, the negative effect on reparation will usually be small.[20] The channelling of nuclear liability has important implications for the nuclear power generation industry. Without such channelling, the suppliers of goods and services to that industry would be at risk of incurring liability for the potentially catastrophic harm caused by a defect in products or services delivered. Hence, if these suppliers were not exempted from liability, they too would have to insure against nuclear liability. Nuclear damage would then be doubly insured. Consequently, the costs of the nuclear power generation industry would be raised.[21]

In the case of unlimited liability, the victim is to be compensated in order to render him as well off as if the damage had not occurred. If the liability is limited, however, damage in excess of the limitation will not be compensated. It would thus seem that by limiting the liability, the reparative function of tort law is watered down. In many instances, however, this is not the case. In practice, unlimited liability does not exist. Liability is always limited to the amount of coverage provided by

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17. At this time, about 115 nuclear reactors were members of the pool. Thus, the maximum contribution by each member was $ 67 million.

18. See Marrone (1993) p. 376-377.

19. See Hellner (1995) p. 169.

20. See Dufwa (1993) p. 1810.

21. See Nordenson (1968) p. 34-35.

existing liability insurance plus the net worth of the subject liable. The two together will often prove severely inadequate for full compensation of catastrophic damage. In practice, therefore, liability will be limited in such cases. It follows that a formal limitation of liability at a level above the sum total of liability insurance and the net worth of the liable subject will have no impact on the actual compensation payments. The nuclear liability limitation, which is set at a level acceptable to insurers, is however below this level. In principle, it thus imposes a constraint on the reparative function of the liability. In practice, this effect is moderated by the fact that the governments have explicitly or implicitly assumed liability for nuclear damage above the liability limitation. There is no doubt that the liability limitation benefits the nuclear industry.[22] Without the limitation, the nuclear operator would face a risk of bankruptcy in the event of a severe accident. The limited liability removes that risk (provided that insurance is available and obtained), and thus reduces the cost of raising capital.

Whether or not liability insurance is compulsory does not influence tort liability as such. However, since liability insurance increases the capacity of the nuclear operator to actually fulfil his obligation, compulsory liability insurance promotes the reparative function of the liability. At the same time, it clearly limits the freedom of action of each nuclear operator.[23] Thereby, the duty to insure against liability or to provide equivalent financial security, clearly imposes a burden on the nuclear power generation industry as a whole.

4. The limited liability of the nuclear power generation industry

4.1 Causes

The most distinctive controversial feature of nuclear liability is the liability limitation.[24] The motive for this feature originates in the fact that the nuclear power generation industry under the current regime has a duty to insure or to provide some equivalent financial security for its third party liability.

The nuclear power generation industry involves small risks for very large (catastrophic) damage. A catastrophic event can be defined as a core meltdown followed by lethal radioactive releases, leading to several mortalities. The statistical probability for such an event taking place within the OECD area, where about 350 reactors are operating, has been assessed with the help of systematic probabilistic safety assessments (PSA) as one in between 350 and 6000 calendar years, with potential damage costs from below $ 1 billion up to tens of billions of dollars, reaching $ 100 billion in very exceptional cases (one in more than a million years).[25]

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22. See Westerlund (1994) p. 691 and Wetterstein (1990) p. 105.

23. More specifically, it is the operator's freedom to choose whether or not to engage in particular contractual relations that is reduced.

24. The liability limitation has been the target of much criticism in the literature, e.g. by Faure & Van den Bergh (1990) p. 241-254; Westerlund (1994) 685-707 and Wetterstein (1990) p. 96-106.

25. These numbers represent a summary of the state of the art, as reflected in concurrent literature. See Radetzki & Radetzki (1997) p. 367-370.

The insured amounts for industrial catastrophes seldom exceed the $ 500 million level, and in the rare cases that they do, the marginal insurance premium rises at an accelerating rate, to a level far above any reasonable assessment of the expected damage cost that the insurers would have to cover.[26] In order to explain the unwillingness to insure industrial catastrophe risks the insurance industry refers to the fact that insurance presupposes an unequivocal ability of insurers to cover insurance claims. An extensive legislative regulation with the aim of assuring that the capital reserve of insurers is adequate for covering the claims that may arise has been established in most industrialised countries. It is held that this regulation causes a capacity constraint, on each insurer individually, and on the insurance industry as a whole.[27] Two arguments are said to justify this attitude: first, that large industrial catastrophes constitute non-actuarial risks, not well suited for the insurance industry; and second, that the insurance industry lacks the capital needed to cover claims over and above the sums currently insured.

4.1.1 Nuclear liability represents a non-actuarial risk

Traditional insurance involves a transfer of risk at a price fixed ex ante[28] and thus presupposes that a premium corresponding to the risk taken can be calculated. This requires that two conditions are met. It must be possible to calculate the expected loss, i.e. the probability of insured damage multiplied by the estimated size of damage. These probabilities are best obtained from empirical experience. When no such experience is available, insurers must rely on assessments. However, such assessments are deemed to be more or less unreliable resulting in a greater degree of uncertainty.[29] In addition, the law of large numbers must be applicable. Hence, the similar but not correlated risks covered must be manifold. The larger the number of such risks, the closer the real damage cost will approach the underlying probability.

The insurance industry repeatedly claims that capacity constraints often emerge because one or both of the conditions are not met. If the expected loss cannot be determined with confidence, there is a situation of uncertainty, and the risk is non-actuarial. Examples are risks related to new products or processes.[30] If the number of similar risks is too low, the law of large numbers is not applicable. Such risks, too, are not actuarial. Examples are risks connected with heavily concentrated activity. In none of these cases can the capital that needs to be reserved for each risk be fully determined. Hence, the risks cannot be priced with confidence. The insurers normally resolve this dilemma by behaving in a risk-averse manner, venturing only a small sum of money on the uncalculable risk.[31]

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26. See Bohman (1979) p. 188. An example is the insurance of the first jetliners. Because of uncertainty about the accidents to which these vehicles might be prone, insurers initially charged a premium eight times higher than that which with hindsight proved sufficient. See Skogh (1996) p. 6-7.

27. See Skogh (1995) p. 329.

28. However, a two-step premium charge in the context of environmental liability insurance has been suggested by Abraham (1988) p. 981-982.

29. See Faure & Van den Bergh (1990) p. 247; Tyran & Zweifel (1993) p. 433 and Wetterstein (1990) p. 121.

30. See Skogh (1996) p. 5.

31. Se Abraham (1988) p. 947; Hogarth & Kunreuther (1992) p. 36; Kunreuther (1989) p. 319; Tyran & Zweifel (1993) p. 433.

4.1.2 The capital resources available to the insurance industry are inadequate for the insurance of nuclear catastrophes

Another main argument for the unwillingness to assume nuclear catastrophe risks is that the insurance industry lacks the capital needed for such undertakings. In 1995, the market value of capital and surplus held by the insurers and reinsurers of property and casualty in the US was assessed at some $ 230 billion.[32] The amount could be twice as large for the OECD area as a whole. This capital supports all property-casualty lines, of which only a fraction relates to losses from catastrophe-related claims. Assessments for the US suggest that an event leading to insured losses of $5 billion or more would lead to several insolvencies in the insurance industry,[33] while a disaster costing $20 billion and above would risk the impairment of the entire insurance system.[34] Similar consequences are likely to hold valid for the OECD area as a whole.

However, the capital resources of the insurance industry do not constitute a capacity constraint in an absolute sense. The legislative regulation of the insurance industry has been structured to assure the ability of the insurers to pay the claims that may arise. So long as the payment of claims is assured by a sufficient capital base, it is ordinarily free to insure in whatever way it likes. Hence, provided that additional capital is procured, the insurance industry is at liberty to venture into more sizeable risks, for which there is an insurance demand. The equity capital and reserves of insurers and reinsurers constitute the ultimate buffer for excessive unanticipated losses. However, a guiding principle in the insurance industry is that the premium income from each insurance class should suffice for the coverage of claims in all normal circumstances. Difficulties emerge when this principle is put against the theoretical insurance needs of the nuclear industry. Let us assume, hypothetically, that there is an established actuarial likelihood of 0.3% per year of a catastrophe occurring in one of the 350 reactors in the OECD area, with damage costs of $20 billion that the nuclear industry would like to cover by insurance. The annual net actuarial premium works out at $ 60 million, i.e. 0.3% of $ 20 billion. But since the catastrophe could occur the following year, the insurers would immediately need a $20 billion reserve on standby in order to meet the legislative requirements for solvency. Adherence to the standard principle that the premium from each insurance class provide the necessary reserves, would imply raising the initial annual insurance premium 300-fold, which is not practicable.[35] With this background, the unwillingness of the insurance industry to insure third party liability related to nuclear accidents in excess of a few hundred million dollars is understandable, although unsatisfactory.

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32. See Lewis (1996) p. 13.

33. Cutler & Zeckhauser (1996) p. 2.

34. See Lewis (1996) p. 5. This may be an exaggeration. Hurricane Andrew in 1992 carried an insurance loss of $ 18 billion, but did not impair the functioning of the insurance system as a whole.

35. Some difficulty in establishing an adequate capital buffer exclusively from premium income will always be there. In our example, this difficulty is exacerbated by the extremely low likelihood of catastrophe, and by the huge potential damage size. With potential damage of moderate size, it would be more practicable to shift resources from other insurance classes to cover claims, without seriously impairing the capital structure of the insurance firm as a whole.

4.1.3 Conclusion

Due to the fact that nuclear liability constitutes a non actuarial risk and that insurers lack the capital needed to insure nuclear catastrophes, there is an obvious discrepancy between the social need for, and the availability of insurance for nuclear catastrophes. Given that the nuclear power generation industry under prevailing regulatory regimes has a duty to insure for its third party liability, it is quite clear that it would not be able to operate if its liability was not limited. Hence, the failure of the insurance market to provide sufficient risk coverage would seem to constitute a valid motive for the limitation of nuclear liability.[36] However, this motive alone appears to be weak indeed. Nothing exists to prevent a combination of unlimited liability and a limited duty to insure.[37] In these circumstances, an additional reason behind the liability limitation from which the nuclear power generation industry benefits, appears to be an implicit political concord that this industry is desirable for society at large and therefore should be supported.[38]

4.2 Implications

It has been made clear that the liability of the nuclear power generation industry for third party damage is limited by international conventions as well as national legislation to a level below the sum of existing liability insurance and the net worth of the subject liable. Excessive liability is explicitly or implicitly covered by governments. The possibility of accidents causing third party damage in excess of the limits cannot be excluded. In effect, there is a transfer of the top risk from the nuclear industry, either to governments who have assumed liability in excess of stipulated limitations or to the potentially uncompensated victims, in the event that the authorities refuse to face responsibility for catastrophe indemnification.[39] This transfer of risk can be regarded a subsidy to the nuclear power industry.

Proponents of market solutions might object, in principle, to such public support of private activities. More specifically, the subsidisation of the nuclear power generation industry distorts market competition. In addition it reduces the incentives for the nuclear power generation industry to undertake precautionary measures to avoid risk.[40] In both cases, the subsidy could be said to counter-act efficiency. In these circumstances, the possibilities of neutralising or abolishing the subsidy ought to be explored.

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36. In this respect, it would seem as if limited liability constitutes a price that victims have to pay for mandatory insurance, see Faure & Van den Bergh (1990) p. 245.

37. See Wetterstein (1990) p. 103. In Germany such a combination of unlimited liability and a limited duty to insure or to provide equivalent financial security prevails (see above). In Sweden such an order has been suggested (see Atomansvarighetslagen (1997) p. 5-6).

38. See *Atomansvarighet* (1962) p. 26; Westerlund (1994) p. 691 and Wetterstein (1990) p. 105.

39. Theoretically all industries benefit from such a top risk transfer since, as mentioned above, liability is always limited to the amount of existing liability insurance plus the net worth of the subject liable. In the nuclear field, however, the express liability limitation at a level below this amount makes this risk transfer far more significant than it would be without legislative interference.

40. See Radetzki (1996) p. 245.

5. Other possibilities

5.1 Taxes or fees

One way to reduce the negative effects of the public subsidy given to the nuclear power generation industry is to allow governments impose special taxes or fees on the nuclear industry, corresponding to the cost that the government assumes.[41] One major disadvantage with this solution is, however, that there is no market to determine the size of the tax or fee in question. In spite of the PSA results referred to above[42] there is a possibility that the nuclear power generation industry would be over-or under-charged for the top risk transfer. If so, efficiency would still not be achieved.

5.2 Shifting the top risk to the nuclear power generation industry itself

A more radical approach to promoting efficiency would be the establishment of new institutions permitting a shift of the top risk of the nuclear power generation industry to that industry itself. The industry would then be obliged to carry full responsibility for the third party damage that it might cause. The liability of nuclear operators would thus be unlimited while governments would be released from any responsibility in this field. In order not to compromise the situation of victims, liability insurance or some other financial guarantee would need to be mandatory up to an amount large enough to cover the full cost of any plausible nuclear catastrophe, say $ 100 billion.[43] The following subsections aim at exploring the prospects of such private solutions under which the nuclear industry itself assumes a very large liability for catastrophe damage compensation. First, it will be investigated whether, and if so, under what conditions, the insurance industry could possibly be expected to assume a much greater responsibility in the future (5.2.1). Second, the possibilities for the nuclear industry to pool the large risks, and thus to extend the coverage for accident damage above the level provided by insurance, will be investigated (5.2.2). Third, some new financial instruments required for a fully-fledged private solution will be described (5.2.3). A concluding discussion on these private alternatives to cover nuclear catastrophe liability follows in (5.2.4).

5.2.1 Can the insurance industry be expected to assume top nuclear risks in the future?

As mentioned, the requirement that insurers maintain an unequivocal ability to cover claims does not imply an absolute limit to insurance capacity. The economic constraint on insurance capacity is directly related to the size of capital that needs to be reserved for claims payments. It is true that the cost of raising the capital needed by the insurer, whether in the form of equity or accumulated premium income, is bound to rise as the total is increased. The cost of capital will also depend on the prudence of the insurer. It could be that traditional insurers, assuming only calculable risks, will be able to obtain the capital needed for their operations at a lower cost than insurers who venture large amounts on non-actuarial risks. But so long as the insurer is not constrained by regulation of prices, he can always

41. All economic activities, including the nuclear power generation industry, pay taxes. The tax income from the nuclear power generation industry probably exceeds many times the risk cost transferred. However, taxes are not normally bound to cover particular purposes, which would be the case with the fee now suggested.

42. See Radetzki & Radetzki (1997) p. 367-370.

43. As known, unlimited financial guarantees do not exist.

compensate his rising capital costs by charging more for the coverage he offers. At a sufficiently high price, any risk should appear to be attractive to the insurer, wiping out, in practice, the dividing line between insurance and gambling.[44] Hence, in the absence of price regulation, there is no absolute *economic* constraint on the capacity to insure. Therefore, in a strict sense, the term "limited insurance capacity" is a misnomer.

It is quite clear, however, that traditional insurance is not well suited to assume the full risks of nuclear catastrophes. Insurers are specialists in spreading actuarial risks, the outcomes of which can be predicted with reasonable certainty. In addition, the potential damage costs of industrial catastrophes are truly enormous, both in absolute amounts, and in relation to the insurance industry's overall capital base. The insurers' standard procedure of building up adequate reserves from current premium income for calamitous outcomes in each insurance class, is not practicable for large industrial catastrophe risks because the probability of such events is extremely low. Given this, the insurance industry may find it hard to raise the capital needed to provide coverage for the top nuclear risks, even if it would be interested in doing so.

In conclusion, if insurance capacity is to be increased, business can no longer be limited to actuarial risks, and alternative methods of obtaining risk capital must be considered. Such changes to the traditional principles and attitudes of insurance business are quite unlikely in the near future. Hence, even though there is no absolute constraint on insurance capacity, the nuclear industry has to look elsewhere for coverage of catastrophe liabilities over and above a few hundred million dollars.

5.2.2 Can the top risks of the nuclear power generation industry be covered by risk pools?

As an alternative to insurance, non actuarial risks could be shared by those exposed to such risks. In contrast to insurance, such an arrangement does not presuppose ex ante pricing. If two or more parties agree about an ex post sharing of the cost of accidents caused by their activities, they simply have to pay the actual cost in the event of damage, with no fear of being overcharged. However, for a risk pool to be possible, each party to the agreement must consider the risks of the others as similar to the risk he is facing himself.[45] In cases of uncertainty, the extent of risks cannot be estimated with confidence. However, as long as there is no evidence that one party's risk is greater than another, the diversification of risks created by the risk pool has a potential to attract every risk averse risk bearer.[46] With time, the particular features of the risks created by each pool member might become clear. This does not imply the end of the pool, but merely that the terms of the risk-sharing agreement should be renegotiated.[47]

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44. See Pfenningstorf (1988) p. 22.

45. For mutual risk sharing to be successful, several other conditions must be met as well. These are not dealt with here, but see for example Skogh (1996) p. 7-11.

46. See Skogh (1995) p. 331.

47. See Skogh (1996) p. 9-10. All this indicates that risk pooling, in the same manner as insurance, presupposes that risks are estimated ex ante. Risk pooling is based on an agreement to share risks that are considered similar. The issue whether or not to accept risk pooling, and if so, on what conditions, thus presupposes that the risks are compared ex ante. Note, however, that contrary to an insurance contract, a risk sharing agreement does not presuppose that each risk is determined and priced exactly. What is required is only that the relative size of each risk, compared to the other risks in the pool, can be estimated.

In these circumstances it is by no means surprising that risk pooling has a long parentage, and that it is applied as a method for increasing the potential compensation provided in the event of nuclear accidents. As mentioned above, the US Price-Anderson Act (1957) requires the licensees of each of the 115 operating nuclear reactors to participate in a mutual risk pool. If the damage from a nuclear accident exceeds $ 200 million, which is covered by regular mandatory insurance, each participant to the agreement is obliged to provide a pro-rata share of indemnity up to $ 67 million per reactor. Thus, by way of mutual risk sharing, the financial compensation of third party damage in case of a nuclear accident is increased from $200 million to $ 7.6 billion[48] (the amounts have been raised recently to provide for a total close to $ 9 billion).

Coverage of the non-actuarial risks posed by nuclear catastrophes requires the commitment of very large sums of money and may indeed be considered as a highly speculative business. This is why the insurance industry can resolve our problem only a small part of the way. Risk pooling by the risky industries themselves provides a substantial further step. However, given the net worth of these industries, risk pooling too is inadequate. The nuclear liability arrangements in the US give a realistic picture of the maximum that insurance and risk pooling combined can reasonably accomplish. In conclusion, the nuclear industry has once again to seek elsewhere in order to achieve full coverage of its potential catastrophe liability.

5.2.3 Can top nuclear risks be transferred to financial markets?

The following paragraphs explore the possibilities for setting aside sufficient resources for coverage of nuclear catastrophe damage by reliance on new financial instruments, to be placed in the international financial markets. The approach involves a transfer of the top risks to hedge funds, pension funds, and other institutions which manage diversified capital portfolios on a large scale. It is asserted that these institutions would be better able and therefore more willing than insurers to handle the very large extent of potential damage liabilities attached to the nuclear industry. This assertion is based on the observation that these institutions handle capital on an incomparably greater scale than insurers, and therefore are better able to absorb the risks. It has been noted above that the capital and surplus of insurers and reinsurers of property and casualty in the US recently have been assessed at some $230 billion. Similar assessments suggest that the US capital market is 60-80 times larger,

48. See Marrone (1993) p. 376-377. In Europe, German nuclear operators spread risk between themselves through a risk pool (see above). However, this co-operation is by no means as extensive as that in the US. Far more extensive is the risk pooling arrangement suggested by Faure & Skogh (1992) p. 508-510. The authors discuss the possibility for establishing a European convention that stipulates strict liability of nuclear plant owners far above the existing arrangements for guaranteed compensation. The scheme would limit the liability to $ 100 billion. Each of the approximately 100 nuclear plants in OECD Europe would be obliged to join a mutual risk pooling agreement with a maximum liability of $ 1 billion per plant. A critical issue is how the nuclear power operators could assure such a high level of liability obligation. It is suggested by the authors that a small part of the liability might be obtained by pushing the insurance industry to make further engagements beyond those currently in force. However, the major part of the liability envisaged in the scheme would have to be reinsured by the national governments of each plant owner. Hence, since a large part of the compensation would still be guaranteed by states, presumably without charge, the nuclear power generation industry would be favoured by a state subsidy just as under the currently prevailing arrangements.

representing a total value in a range of US $15 000 – 20 000 billion.[49] The numbers for the OECD area as a whole have not been assessed, but one may surmise that they are about twice as large.

The issue at hand is how to manage a permanent need to keep $ 100 billion on standby in the OECD area for the compensation of damage from nuclear disasters without government interference. The amount corresponds to more than 20% of the current total capital of the insurance industry. Hence, setting aside such a sum would involve a substantial strain on this industry. On the capital market, however, where such a reserve would absorb only about 0.3% of total assets, there would be hardly any strain at all.

The institutional arrangements could take a variety of forms. One of many possibilities would be a nuclear catastrophe bond,[50] whose principal would be forfeited to the extent needed for damage compensation, in the event of a nuclear catastrophe with costs in excess of $ 9 billion.[51] The bond holders' risk of capital loss would need to be compensated through a coupon above the rates on risk-free bonds issued by the treasuries of major countries. The interest markup on the nuclear catastrophe bonds, above that carried by risk-free long-term papers, would have to be determined by a market assessment of the risk. If the extremely low probabilities of a large nuclear catastrophe derived from PSA analyses are to be believed, the markup for the nuclear catastrophe bonds in question would amount to a small fraction of one percent.[52] In the end, however, the market would set the rate differential, and the need to do that would stimulate further efforts to determine the underlying risk.[53] In addition, in contrast to most other capital portfolio assets, nuclear catastrophe bonds would not fluctuate in line with shares and bonds, the main assets in most capital portfolios. Hence, a marginal addition of catastrophe bonds to the assets of a portfolio would enhance diversification and reduce its value fluctuations over the business cycle, a clearly desirable feature.

The issuer of nuclear catastrophe bonds could be a group of insurers of nuclear operations, desirous to expand their business into an unexploited but potentially remunerative area. The bonds could alternatively be launched by a pool of nuclear operators, or by an intergovernmental institution set up for the purpose.[54] The money received for the catastrophe bond issue could be placed in government

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49. See Lewis (1996) p. 13-14 and CBOT Review (1996) p. 1.

50. Detailed proposals for how a natural catastrophe bond scheme could operate in the US have been made by Litzenberg, Beaglehole & Reynolds (1996) p. 76-86.

51. i.e. above the level that insurance and risk pooling arrangements could reasonably provide for.

52. In Radetzki & Radetzki (1997) p. 369, the third party cost of *all* nuclear accidents has been assessed in a range between a "realistic" level of US cents 0.01 per kWh, and a very cautious upper ceiling of US cents 0.1 per kWh. The average annual total for all OECD nuclear reactors works out at between US$ 170 million and US$ 1700 million. Only a small fraction of this total pertains to the very rare accidents with costs above US$ 9 billion. If this fraction is one tenth, then the cost of the risk carried by the bondholders would amount to US$ 17-170 million ($ 0.05-0.5 million per reactor), equal to a 0.017-0.17% markup on the envisaged US$ 100 billion bond issue.

53. In a private communication, Tomas Kåberger has suggested that the bond issue could be divided into tranches, with the first US$ 10 billion tranche employed to cover damage costs in the range of US$ 9-19 billion, the second in the $ 19-29 billion, and so on. The interest markup above risk-free bonds would decline for the consecutive tranches, given that the need to use them for damage compensation would become increasingly rare.

54. Tyran & Zweifel (1993) p. 436-438 have formulated a complex proposal for the institutional arrangements of such a scheme.

bonds, with the annual difference between interest paid and received charged to the nuclear industry. With the capital safely invested in risk-free assets, the only risk carried by the catastrophe bond holder would be the damage claims after a sizeable nuclear disaster.

5.2.4 Concluding discussion on private alternatives to cover nuclear catastrophe liability

Through a combination of (a) insurance, covering the damage costs of smaller, actuarially calculable accidents; (b) sharing of risks for medium sized catastrophes through nuclear operator pools; and (c) the assurance of damage payments for the very large catastrophes through the issue of nuclear catastrophe bonds, it would, at least in theory, be possible to envisage private arrangements in which the nuclear power generation industry is adequately assured of the funds needed for even colossal (up to $ 100 billion) catastrophe third party damage. Hence, it would indeed be possible to shift the third party liability of the nuclear power generation industry up to $100 billion from governments to the industry itself without compromising the situation of victims. To avoid threats to the survival of the nuclear industry, however, such a shift must of course be introduced in a gradual manner, together with the expansion of risk pool arrangements and the launch of nuclear catastrophe bonds.

Substantial efforts would be needed to develop markets in which the new instruments could be traded. Attempts have been made, mainly in the US, to launch catastrophe bonds to provide security against natural disasters. So far, the success in marketing these instruments has been mixed, and illiquidity prevails in the markets where they are traded.[55] This may be a natural state of affairs at the present stage. Markets usually take time to develop.[56] To make the new instruments attractive, it is essential to clarify unambiguously the liability that the holders of the nuclear catastrophe bonds would have to cover. This is an important but complicated issue, since third party compensation claims after a nuclear catastrophe are bound to take a long time to settle and will undoubtedly involve many uncertain choices and value judgements.[57]

A regime forcing the nuclear power generation industry to provide guarantees for compensation payments up to, say, $ 100 billion, and the simultaneous development of liquid catastrophe bond markets would help setting an objective price for the top risks of this industry, and so settle a contentious debate, that has been raging for decades, on what these costs are.[58] Transfer of the top risk to the nuclear power generation industry would furthermore involve an internalisation of a cost that has so far been external. Those who object to the political decision that the state should handle the top risks of the nuclear power generation industry, ought to find full satisfaction in the proposed regime. The cost of the top risk (i.e. the spread between the risk-free interest rate and the interest rate paid to the catastrophe bond holders) would be dependent upon the valuation of the risk connected with the activity of particular nuclear plants. Incentives to undertake precautionary measures to reduce the cost, would thus be strengthened. If the transfer of the top risk to the nuclear power generation industry through the suggested arrangements were to involve costs making the industry non-viable, then that

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55. See Cutler & Zeckhauser (1996) p. 27.

56. See CBOT Review (1996) p. 2 and Radetzki (1980) p. 76.

57. i.e. issues concerning causality between a nuclear accident and later events, e.g. diseases. See Skogh (1995) p. 322 and Ståhlberg (1994) p. 22-29.

58. See Tyran & Zweifel (1993) p. 438.

would be an important signal that the markets do not find the activity worthwhile. All this means that efficiency would be promoted, which is the important advantage of the proposed privatisation.

One major problem with this scheme, however, is that, the nuclear power generation industry is not alone in its potential of causing damage of colossal proportions. Several other industries suffer from a similar potential.[59] In theory, the third party liability of these industries is most often unlimited. However, with but few exceptions, there is no duty to insure. Hence, the liability of these industries is limited to the amount of liability insurance coverage, where such exists, plus the net worth of the subject liable. Damage over and above these sums would have to be compensated by governments or be left uncompensated. In effect, these industries, just as the nuclear power generation industry, benefit from a subsidy arising from a transfer of their top risks to governments or to victims. Consequently, if the nuclear power generation industry is forced to carry the full responsibility of third party damage up to, say $ 100 billion, it would be disadvantaged in comparison with at least a handful of other risky industries. Hence, in order to provide a level playing field, all risky industries would have to be obliged to provide private guarantees for the third party damage they might cause.

But even if such steps were to be taken, the private solution sketched here would be far from completely private. In at least two respects market forces would have to yield to political considerations. The first issue concerns the identification of the risky industries which would be required to provide far-reaching financial guarantees for damage coverage. Basically, all human activities carry a potential risk of causing damage of catastrophical proportions. All should therefore, in principle, be required to assure large financial means for damage compensation. In practice, such requirements on all activities are not feasible. Inclusion in the risky group would constitute a substantial disadvantage to an industry, given that no corresponding financial guarantee obligations are imposed on other industries. Classification of industries in this way therefore presupposes political decision making, and involves a deviation from a pure market solution. The second issue concerns the maximum financial guarantee to be assured by each risky industry. Since unlimited guarantees are not practicable, government involvement would be necessary to determine the maximum amount to be guaranteed, and to differentiate it across the risky industries. Finally, as mentioned, the $ 100 billion total discussed in this paper, should be adequate for covering virtually all nuclear catastrophe costs. Nevertheless, catastrophe damage above that level cannot be entirely precluded. The cost of such damage would continue to rest with the government or victims and constitute a subsidy, albeit a far smaller one than under existing arrangements.

In conclusion, the privatisation of the top risk management outlined here has both advantages and drawbacks. These have been spelled out above. The introduction of the proposed scheme would require an extended period of time and involve a considerable effort. Without having tried it out in practice, it is not possible to make an unambiguous claim that it is superior to an arrangement where the government assumes the top risk and avoids subsidisation by compensating itself through fees or taxes.

6. A summary of findings

Compared to traditional tort liability, the third party liability of the nuclear power generation industry bears four distinctive features. It is strict, i.e. not conditional on fault. It is channelled to the

59. Examples are the hydropower, chemical, airline and oil transportation industries. See Radetzki & Radetzki (1997) p. 370-372.

operator. Hence, no other subject can be liable. A maximum amount of the liability is stipulated expressly. Liability insurance or some equivalent financial guarantee of the liability is mandatory.

The present paper has focused on the most controversial of these distinctive features, i.e. the express liability limitation, which implies a transfer of the top risk of this industry to either governments or to the damaged but potentially under-compensated third parties. This risk transfer can be regarded a subsidy to the nuclear power generation industry. Such a subsidy involves at least two undesirable consequences: it distorts competition; it also reduces the incentives to undertake precautionary measures to avoid risk.

One way to reduce the negative effects of the public subsidy given to the nuclear power generation industry would be to let governments impose special taxes or fees on the nuclear industry, corresponding to the external cost that catastrophes might involve. A more radical measure would be to shift the top risk to the industry itself. The liability of nuclear operators would then be unlimited while governments would be released from any responsibility in this field. In order to avoid a deterioration in the situation of victims, liability insurance or some equivalent financial guarantee would then need to be mandatory up to an amount large enough to cover the full cost of any plausible nuclear catastrophe, say $ 100 billion. It has been shown that, in theory, it would be possible to envisage private arrangements in which the nuclear power generation industry is adequately assured of the funds needed for even colossal catastrophe third party damage. This could be accomplished through a combination of (a) insurance, covering the damage costs of smaller, actuarially calculable accidents; (b) sharing of risks for medium sized catastrophes through nuclear operator pools; and (c) the assurance of damage payments for the very large catastrophes through the issue of nuclear catastrophe bonds.

A requirement that the nuclear industry itself provide guarantees for compensation payments up to, say, $ 100 billion, and the simultaneous development of liquid nuclear catastrophe bond markets would help setting an objective price for the top risks, and so settle a contentious debate that has been raging for decades, on what these costs are. Transfer of the top risk to the nuclear power generation industry would, furthermore, involve an internalisation of a cost that has so far been external. Incentives to undertake precautionary measures to reduce the cost, would thus be strengthened. All this means that efficiency would be promoted, which is the important advantage of the outlined scheme.

The proposed privatisation of the top risk handling raises a set of other problems, however. A significant effort, involving considerable outlays, will be required to establish the new institutions and to test their operations in practice. Several complications are likely to arise in the process. A major problem with far reaching implications is that, beside the nuclear power generation industry, several other industries have the potential to cause damage of colossal size. Just as the nuclear power generation industry, these industries currently benefit from a subsidy consisting in that their top risks, too, are implicitly transferred to governments or to victims. Hence, if the nuclear power industry would have to carry the full responsibility of third party damage, this industry would be disadvantaged in comparison with at least a handful of other risky industries. Therefore, to provide a level playing field, all risky industries would have to be obliged to provide private guarantees for the third party damage they might cause. But even if such steps are taken, the solution sketched here would be far from completely private. Public authorities would have to single out the risky industries, and decide on the financial guarantee amounts required from each. Political distortions could easily creep into these decision processes.

The private solution would have to be tested in practice to determine whether its advantages outweigh its complications and the considerable launching effort. Until it has been tried out, it is hard to say whether it offers a solution to the liability problems that is superior to the one currently in force, supplemented with special fees to compensate the government for the cost of the transfer of top risk.

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