The Other Side of Nuclear Liability

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The draft nuclear liability bill indemnifies the supplier of a nuclear plant and caps the liability of the operator in the event of an accident. The indemnity for suppliers is meant to please multinational plant vendors who wish to be free of liability even for accidents that result from a design flaw. The cap on operator liability is far lower than the potential damage that a nuclear accident could cause. This clause is designed to facilitate the entry of domestic big business into the nuclear market by ensuring that domestic operators will not be held responsible in the eventuality of damage following an accident. Hence the bill transfers risks for a nuclear mishap onto the people at large. Furthermore, it offers almost no financial disincentive for unsafe behaviour on part of the operators and suppliers of nuclear plants.

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The withdrawal of the civil nuclear liability bill from active consideration in Parliament provides us with a short period to reflect on some of the larger questions that are often neglected in the arguments over the minutiae of the bill. Not that the latter are unimportant, but neglecting the larger questions is also unwise. To the extent that we discuss the bill itself, we focus on its two major features rather than the details.

The primary reason for the government to withdraw the bill was the strong opposition in Parliament and outside by various political parties and other formations. At the same time, there is also ample pressure, both foreign and domestic, to have some legislation passed so that various new players can enter the Indian nuclear energy market. Since the Manmohan Singh government is committed to a large expansion of nuclear power, it is expected that the bill will soon be revised and submitted for approval. What might the contours of such a revised bill be?

To understand this, we first broadly describe the expected landscape of new nuclear commerce in India. In this landscape, a supplier or vendor – a company like Westinghouse or General Electric (GE) or Areva – will "supply" a nuclear plant to an Indian operator. This operator will operate the plant to generate electricity and sell it to the grid. Under the current Atomic Energy Act, only the government, through the Nuclear Power Corporation of India Limited (NPCIL) can operate nuclear plants. Although private participation is currently disallowed, this might change in the future.

The nuclear liability bill focuses on the operating lifetime of the reactor and has two key clauses. First, in the event of an accident, it indemnifies the supplier from any kind of liability, regardless of what caused the accident, i e, even if the accident was the result of a design flaw. Second, it caps the liability of the operator at Rs 500 crore, with additional compensation, if required, coming from the government. These clauses are designed to please separate lobbies but are equally egregious.

The first clause is largely a result of pressure from United States (US) nuclear vendors. Before going any further, a clarification is necessary. The nuclear industry today is so multinational in nature that it may not be accurate to describe companies as American or French. An example is Westinghouse, which manufactures pressurised water reactors. Westinghouse was purchased by British Nuclear Fuels in 1998, which then sold it to Japan's Toshiba in 2006. In 2007, Toshiba sold 10% of the company to Kazatomprom, the national uranium company for the Republic of Kazakhstan. Besides these, the Shaw group, based in Louisiana, US, owns 20% of the company and the Japanese IHI Corporation a 3% share. Nevertheless, inasmuch as they continue to maintain strong links with the US government, we describe

companies like Westinghouse and GE as American. The US wants India to accede to a specific liability regime – the Convention on Supplementary Compensation (CSC) – and is the major source of political pressure on the government. However, other manufacturers like Areva (France) also expect that India will accede to some international liability regime.

All international liability regimes share the two features mentioned above: they channel liability to the operator and cap this liability, transferring final responsibility for compensation to governments. Both these provisions are in sharp contrast to standard tort law; former Attorney General Soli Sorabjee (2009) even suggested that these clauses would be struck down by the Supreme Court. Why does the nuclear industry operate within this special legislative framework?

Motivations for Liability Conventions

The answer to this is closely tied to the history of nuclear power development in the US and its efforts to export nuclear technology. The cap on total operator liability emerged in the first context whereas the requirement that the supplier should be indemnified from all legal liability came about in the second. There are deep parallels between this history and the forces that are at play in India today.

After the second world war, governments on both sides of the Atlantic were keen to promote nuclear power. In the US, however, for over a decade, electric utilities were reluctant to invest in nuclear power, primarily because it was economically unattractive. Government agencies offered "a series of incentives" that "included a raft of subsidies, the promise of immediate profits, sheltered investments, and the guarantee that unanticipated costs could be passed on to consumers through rate increases. Another potential advantage to private industry was the opportunity to develop a capital-intensive technology, thus decreasing dependence on labor" (Clarke 1985). These by themselves were insufficient to induce sufficient interest in nuclear power amongst utilities. It was ultimately the threat the government would enter the electricity generation market that catalysed the growth of the civilian nuclear industry in the US.[1] This was followed by a period when utilities adopted nuclear power with great enthusiasm, which lasted till around 1974.

Among the measures that the government undertook, was to set up a liability regime. This was needed because a nuclear accident could, as described later, cause immense loss of life and property. Of more concern to the industry was the fact that the claims for compensation that might be launched in the event of a major accident could easily bankrupt the operator and supplier of the plant.

One option was to obtain private insurance. But attempts to get insurance coverage ran into two problems. First, the hazard posed by nuclear power was entirely new, and there was no benefit to be had from "accumulated experience"; nor was there "the opportunity to employ the trial and error procedure which underlies so many segments of the insurance business" (Thomas 1958). The second more serious problem was that the cost of damage from a nuclear accident could be immense, well beyond the resources of any insurance company. And, the insurance companies believed in the axiom, "if you write catastrophe insurance you must expect to pay catastrophe losses" (ibid). It is to deal with this problem that the US Congress introduced the Price-Anderson Act. The act channelled all economic liability to the operator of the plant, and limited even that to a fixed amount, thereby making the government the ultimate insurer in the event of an accident.

The notion that the supplier should be indemnified from all legal liability came about when the US started to export nuclear plants to western Europe. Western European governments were keen to promote nuclear energy but, for various reasons, found themselves importing American light water reactors (LWRS).[2] American corporations were unwilling to bear liability for an accident in a plant designed by them. The US Atomic Industrial Forum conducted comprehensive studies examining how to protect American suppliers from liability claims originating in Europe. In an influential publication, called the "Harvard report", it recommended legislative intervention to make it *impossible* for anyone to file a liability claim against atomic suppliers! Soon afterwards, the first international liability regime – the "Convention on Third Party Liability in the Field of Nuclear Energy" (also called the Paris convention) – was adopted in accordance with these recommendations (Vanden Borre 2007).

Curiously, the US itself did not accede to the Paris convention (or even later treaties like the Vienna convention). Under American law it remains possible to sue the nuclear supplier although economic liability is channelled to the "omnibus insurance" provided by the Price-Anderson system. In fact, the US engineered the Convention on Supplementary Compensation for Nuclear Damage (CSC) in the late 1990s because of this and other incompatibilities between existing liability conventions and Price Anderson system. Although the CSC shares the two principles mentioned above, a "grandfather clause" allows the US to retain its own tort law without any changes.

These unusual legislative measures were justified by the Atomic Industrial Forum 50 years ago by appealing to the "undisputed fact that there is a vital national interest in the development of atomic power". A very similar argument is advanced by proponents of the liability bill and an analogous set of factors drive attempts to create a common international liability regime today. However, in the intervening 50 years we have seen the nuclear industry battling soaring costs, public antipathy that is in part a result of a catastrophic accident, and a persisting nuclear waste problem. It would seem to be in the national interest to turn away from nuclear power. But that possibility has not entered the debate over the liability bill in any serious fashion.

We now turn to a more detailed examination of these two key clauses in liability conventions.

Supplier Liability

Let us first turn to another arena to understand what is at stake in the notion of supplier liability. Speaking in February 2010 at a hearing in the US House of Representatives, Henry Waxman, the chairman of the Committee on Energy and Commerce, stated

> In preparation for this hearing, the Committee analysed over 1,00,000 pages of documents from Toyota and the National Highway Traffic

> Safety Administration (NHTSA). These documents show that both Toyota and NHTSA have received thousands of complaints of runaway Toyota vehicles...Our review indicates that Toyota received as many as 2,600 complaints of runaway vehicles through its telephone hotline alone. Over 700 of these incidents resulted in accidents. Toyota had three responses: First, blame the driver. Second, blame the floormat. Third, blame a sticky gas pedal. And NHTSA – without doing any meaningful independent review – accepted Toyota's explanations.[3]

The first response is likely be seen as unfair, especially now that Toyota's head himself has admitted that the problem lay with the company's quick pace of expansion. Yet, it is the equivalent of the first response that is being written into law through the nuclear liability bill.

The implicit assumption behind relieving nuclear suppliers from liability for accidents is that designs are perfectly safe. But can nuclear reactors reasonably claim to be completely immune from design errors leading to accidents? The historical evidence suggests otherwise.

After the 1978 Three Mile Island (TMI) accident in Pennsylvania, US President Jimmy Carter appointed a commission to investigate the accident. The commission was headed by a mathematician John Kemeny, and produced its report in 1979. Among other things, the report observed that

> several earlier warnings that operators needed clear instructions for dealing with events like those during the TMI accident had been disregarded by Babcock & Wilcox (B&W) [the supplier of the TMI reactor] and the Nuclear Regulatory Commission (NRC).

Important among these was the September 1977 incident at the Davis-Besse nuclear plant, again a B&W reactor, when a pilot-operated relief valve (PORV) stuck open and pressure fell, while the pressure level showed by the appropriate gauge kept increasing. The same was to occur in TMI and operators again assumed that the pressure within the reactor was rising and shut off water flow to the reactor core. The Davis-Besse incident was investigated by both B&W and the NRC, but no information calling attention to the correct operator actions was provided to utilities prior to the TMI accident.

The Kemeny Commission also concluded that the "control room was not adequately designed with the management of an accident in mind" noting in particular that

> over 100 alarms went off in the early stages of the accident with no way of suppressing the unimportant ones and identifying the important ones. The danger of having too many alarms was recognised by Burns and Roe (the architect-engineer) during the design stage, but the problem was never resolved...The arrangement of controls and indicators was not well thought out. Some key indicators relevant to the accident were on the back of the control panel (Kemeny et al 1979).

Of course, the same design errors are unlikely to be present in the reactors that were designed after TMI but there could be other design errors, some of which may not have been identified so far.

Indemnifying the supplier from liability has a serious consequence. Without liability, there is less incentive for the supplier to design safe plants. Nuclear reactor designers have multiple constraints. While they would obviously not want a reactor they designed to undergo an accident, they also have to make sure that the design is economical. Nuclear power, as is well known, is already very expensive (see for example, Deutch et al 2003; Ramana et al 2005; Ramana 2007 a and b). Thus, for example, one reason that recent reactor designs have adopted passive measures or components,[4] as compared to the more traditional active systems, is that "active safety systems are expensive to build and operate" (Forsberg and Weinberg 1990). To the extent that liability claims provide a signal, allowing potential lawsuits would make reactor designers err on the side of safety rather than economics.

There is a further concern. The ideological outlook that nuclear designers function under often makes them discount safety problems. For example, it has been long known that fast breeder reactors have special safety problems posed by core rearrangements (see Wirtz 1978; Waltar and Reynolds 1981). Nevertheless, the DAE has long pursued a breeder programme. While carrying out studies of safety of its reactor design (Singh and Harish 2002), it has also on occasion argued that safety concerns were completely misplaced in the first place. Thus, a DAE official argued that the fast reactor community "ought to assert themselves and destroy the sodium void phobia ...the necessity of a dome on the top of the reactor vessel and the core catchers needs to be challenged …after all, if the reactor can be designed to be inherently safe or if the probability of failure of the shutdown function can be brought down to 1e-8 [1 part in 100 million] per demand, why invest more funds for safety features" (Paranjpe 1992). This conviction that the reactor is inherently safe comes in the way of reliable safety studies, and indeed it has been shown that there are serious problems with these studies (Kumar and Ramana 2008). An example from a different technological arena of ideological predilections within an organisation leading to an accident is the January 1986 explosion of the *Challenger* space shuttle (see for example, Vaughan 1996).

If vendors are indemnified against potential claims of safety, their primary aim will then be to get the plant design approved by the regulatory authority that needs to certify the design as being safe. In terms of legal liability, then, the supplier's job is done once it has persuaded the regulatory agency, through whatever means, of the safety of the design. The indemnification also does not offer any inducements to the supplier to share new safety concerns that come to light at a later stage with the operator or improve the plant.

Moreover, this places a grave responsibility on the regulator which must, often in a short period because of political pressures, evaluate and approve a very complex design. The Indian regulatory system is ill-prepared to accept this responsibility.

The organisation responsible for the regulation of nuclear safety in India is the Atomic Energy Regulatory Board (AERB). There are two problems with the AERB: it has limited personnel and facilities, and it is not autonomous. The AERB reports to the Atomic Energy Commission (AEC) that is chaired by the head of the DAE; moreover, the AERB's budget comes through the DAE. The AERB's lack of technical staff and testing facilities has been commented on by Gopalakrishnan, a former chairman of the AERB (Gopalakrishnan 1999). We note also that, as described earlier, the Kemeny Commission also castigated the US NRC, which has greater resources than the AERB, for errors leading to the TMI accident.

Thus, the DAE is not only in charge of ensuring rapid nuclear growth, it is also the final arbiter in matters of safety. A few

months ago, the UK regulatory agency found flaws in the designs presented by Areva and Westinghouse for new nuclear plants and withheld safety clearance (*The Guardian* 2009). Can one imagine the AERB doing something similar? Not only would it face pressure from the manufacturers, but it would also have to contend with its parent organisation – the DAE – which would have an interest in expediting the regulatory process.

The lack of autonomy in nuclear regulation is indicative of a larger problem – the lack of independent sources of nuclear expertise. Between nuclear vendors who are anxious to sell their product, and a DAE, the sole official repository of all nuclear knowledge, that is desperate to import reactors in large numbers so as to increase nuclear power's contribution to electricity generation from a mere 3% to something more respectable, there is no official body that policymakers could turn to for advice on whether a reactor design is safe or not.

Cap on Operator Liability

We now turn to the issue of the liability cap on operators. As we mentioned above, the cap on operator liability came about because operators were unable to get the requisite insurance. One reason was that it was very hard to estimate the probability of a nuclear accident. More importantly, it was recognised that the consequences of a nuclear accident would require compensation that exceeded the capacity of the insurance market.

These two factors remain a problem to this date. From an actuarial perspective, the civilian nuclear industry has over 13,000 reactor years of experience, with one catastrophic accident that led to widespread radioactive contamination, i e, Chernobyl, and a number of less severe accidents, of which Three Mile Island is the best known example. This experiential basis is still too limited to be certain about the probability of a major nuclear accident.

Further, "many nuclear safety related events occur year after year, all over the world, in all types of nuclear plants and in all reactor designs and that there are very serious events that go either entirely unnoticed by the broader public or remain significantly under-evaluated when it comes to their potential risk" (Kastchiev et al 2007). Many of these accidents do not escalate into major ones purely because of chance or the intervention of human operators rather than any technical safety feature. From the viewpoint of an insurance company, or indeed of the public, such factors cannot be taken as assured.

The atomic energy establishment in India sometimes tries to suggest that the probability of an accident can be calculated precisely and is very low. For example, in November 2009, the officer in charge of the BARC safety council secretariat claimed at the India Disaster Management Congress that "the probability of occurrence of any major event is 10^{-6}" (1 part in a million) (Mishra 2009). This is disingenuous.

Theoretically, there are good reasons to be unsure about the probability of an accident. At a narrow level, the nuclear industry primarily analyses the safety of reactors using techniques called probabilistic safety analyses (PSA) or probabilistic risk assessment (PRA). The idea is to analyse an accident as resulting from a series of failures, for which probabilities are assigned. The first prominent application of PRA methodology to nuclear safety was in the 1975 reactor safety study in the US led by Norman Rasmussen (NRC 1975). Following widespread criticism of the study, and especially its executive summary, the NRC appointed an outside panel to examine the Rasmussen study, which eventually submitted its report in 1978 (Lewis et al 1978). The panel identified a major problem with PRA methodology: that it is "conceptually impossible to be complete in a mathematical sense the construction of event-trees and fault-trees" and this "inherent limitation means that any calculation using this methodology is always subject to revision and to doubt as to its completeness". This problem is practically inescapable.

A different, structural way of thinking about the same problem is to think about the nature of the technology. The different systems of a nuclear reactor interact in complex ways, making it possible that multiple failures could interact in unexpected ways. A second factor is the presence of tightly prescribed steps and unchangeable sequences in operation that must be adhered to. Therefore accidents can escalate quickly, with few alternate pathways to diffuse them (Perrow 1984). Safety interventions, whether by humans or automatic safety equipment must occur quickly, and be adequately planned for. Both these factors pose challenges to safety and its demonstration. They also make it more difficult to infer safe operation from past record; a system could have relatively minor accidents, but many such failures could combine unexpectedly in the future, leading to a much larger accident.

There is, thus, uncertainty about the probability of an accident. What of the magnitude of the damage? The Indian bill caps operator-liability at Rs 500 crore and this figure has drawn criticism. In defence, supporters of the liability have argued that other countries have similar figures. But this does not answer the criticism. Even some of the highest operator liabilities in other countries – in Japan, for example, plant operators must provide a "financial security amount" of $1.2 billion or about Rs 6,000 crore (*World Nuclear News* 2009) – are trifling compared to estimates of the potential damage from a nuclear accident. The CRAC II simulations conducted by the Sandia National Laboratory in 1982 examined the possible consequences of a worst-case accident under worst-case conditions (a so-called "class-9 accident").[5] For the Indian Point nuclear plant near New York, this study estimated a property damage of $274 to $314 billion (in 1982 dollars). These figures are debated by, for example, the US Nuclear Regulatory Commission. But the key point is that the magnitude is so much in excess of what is offered as liability.

Of course, these figures are specific to that reactor and to the location, i e, New York. But there is no corresponding study for the case of, say, Jaitapur or Kovvada. This represents a serious failure of process. Before the government even drafted such a bill, it should have launched a transparent and comprehensive evaluation of what the likely financial damage would be in the event of a catastrophic nuclear accident under Indian circumstances.

Such an evaluation should ideally be carried out by a panel that is independent of the nuclear establishment and involves not just engineers and scientists but also economists, public health professionals, doctors, psychologists, agricultural scientists, and

environmental restoration specialists. It should take into account the specificities of the country and proposed locations, including the largely rural population of India, the dependence on land and water resources for livelihoods, the state of public health, the capacity to deal with emergencies, and analysis of the effects of other industrial accidents in the country. And finally the inputs of the populations likely to be impacted should be taken into account, perhaps through offering a draft of the results for public comment. Without knowing whether the likely damages will be of the order of Rs 10 crore or Rs 1,00,000 crore, how can there be any discussion of where the liability limit should be placed?

However, contrary to common supposition, the liability cap is not designed to please the US. In fact, American companies do not really care how much the Indian operator needs to pay provided that they are not liable for anything. The low cap on liability is, very likely, the result of pressure from Indian big-business which wants to enter the lucrative nuclear power industry. For example, in his 23 September 2008 statement as Chairman of Reliance Power, Anil Ambani explicitly stated that they expect the government to "make at least 15 other policy changes to permit the entry of private players into the nuclear domain", including "enacting national legislations on civil liabilities" (http://www.reliancepower. co. in/ html/pdf/R_Power_ Chairmans_Speech%5B1%5D.pdf).

The present government is certainly responsive to such concerns. In a recent interview, Prithviraj Chavan insisted that "if we don't keep the caps reasonable, nobody will invest in India" (Phadnis and Chatterji 2010). He could not have been referring to foreign plant manufacturers (for whom the cap is zero!) so he must have been referring to private investment in the *operation* of nuclear plants.

Setting the cap at Rs 500 crore for private operators, again, sends the wrong signal. The cost of a nuclear plant itself could be as much as 60 times higher than this cap. For example, the reactor that Areva is constructing in Olkiluoto, Finland is anticipated to cost more than $6 billion or about Rs 30,000 crore. In a simplified scenario, consider a private company that is in the position of asking the supplier for a design modification that could lead to delays and a cost increase of 10% of the plant value. Would the company rather spend Rs 3,000 crore on this or take the risk of paying damages of Rs 500 crore sometime in the future?

The above example neglects the loss of revenue that the company would suffer in the event of an accident but including this does not change the essential conclusion. Assume that the plant has a small and constant probability of an accident every year r, and an anticipated lifetime L. Further, say that the cost of the plant is C and this is recovered over the time L (including a profit rate will not change the essential result here). The liability cap is

F. If the accident happens in the first year, the company entirely loses *C* and in addition must pay *F*. If the accident happens in the last year of operation, the company hardly loses any revenue but must still pay *F*. Neglecting the discount rate for simplicity, the expected loss of the company (for small *r*) is approximately (F + C/2) r L. A more detailed and general calculation is presented in the Appendix (p 54).

Let us understand this formula a little better. Say that a plant costs Rs 30,000 crore as above and the company finds that there is a problem in the plant that leads to an estimated 1% chance of an accident over its lifetime. This is, in fact, a very large and serious risk. With a liability cap of Rs 500 crore, the expected loss of the company is just Rs 155 crore. So, if it costs more than Rs 155 crore to correct this problem there is no financial incentive for the company to spend the money. In fact, even if the corrections do not cost anything in actual expenditure, but merely lead to a six month delay, at the beginning of the plant's life cycle, at a 3% discount rate, this would be equivalent to a loss of about Rs 450 crore which is more than the expected loss above.

Of course, this is not the whole story since the company would probably be concerned about several intangibles like the loss of reputation in the event of an accident. Moreover, the engineers and safety analysts involved might be careful about safety just out of professional integrity. However, the point illustrated above is robust: if the liability cap is very small compared to the typical sums of money that are spent on the plant, then the financial liability itself does not provide any disincentive for unsafe behaviour.

A Revised Bill

What might a revised bill look like? The political analysis above makes a few predictions. The US is very clear that its suppliers must be immunised from liability. And because the Manmohan Singh government is beholden to the US for having shepherded the waiver from the Nuclear Suppliers Group, it is very tough for it to stand up to American pressure. Although acquiescing to this demand will have serious safety implications as we described above, the government is likely to push the American case. So a revised bill will continue to channel liability to operators.

What about the issue of the cap on operator liability? The political pressures here are fewer. It is true that private companies – like the Tatas and Reliance – will not enter the nuclear market unless they are assured that they will not be required to pay compensation for all the damage that they may be responsible for. While the Manmohan Singh government would probably like to funnel profits from the nuclear industry into the private sector, this may not be a pressing priority.

Moreover, because the nuclear establishment in India is interested in maintaining some sort of monopoly over reactor operations, private companies are likely to be allowed to enter the nuclear sector only as partners of the NPCIL. This is the case, for example, with the joint venture between the National Thermal Power Corporation (NTPC) and NPCIL, where NTPC has only a 49% minority stake (*The Hindu* 2010). This tells us that to assuage political opposition, the government might well raise the liability cap on operators. However, this may be accompanied with some behind the scenes assurance that in any individual contract, the liability for a nuclear accident might be transferred to the NPCIL (which is a public sector company) freeing up the private partner from this responsibility.

It is worth noting though that a large increase in the liability cap would also help to ameliorate the lack of supplier liability in the bill. The draft bill explicitly allows the operator a "right of recourse" if the accident was caused by an act of "wilful or gross negligence on the part of the supplier". While this is no substitute for allowing the victims to sue the supplier it does mean that suppliers would be concerned that operators would try and transfer a large part of the liability onto them. This will induce them into taking greater care, especially if large sums of money are involved.

A note of caution is in order here. While the CSC explicitly allows the operator a right of recourse "if the nuclear incident results from an act ... done with intent to cause damage," the Indian bill extends this to cases of "gross negligence". It is quite likely that American companies will be unhappy with this clause. Omer Brown, a prominent legal analyst for the US nuclear industry complained that these terms are ill-defined and "the differences between negligence, gross negligence and wilful act are as clear as the differences between a fool, a damn fool and a goddam fool" (Varadarajan 2010). While it might be politically difficult for the government to delete this clause from a revised bill, individual contracts that the NPCIL signs with international suppliers might well explicitly renounce this right of recourse.

We should mention here that in recent times, senior government officials seem to be suggesting that the nuclear liability bill just sets the "strict liability" of the operator; i e, to claim the Rs 500 crore in compensation one does not need to demonstrate fault on part of the operator but that existing tort laws will continue to apply and that the liability of the operator (and perhaps even the supplier) here would be unlimited. As the *Hindustan Times* put it, "according to the government, the bill's intent is not to limit the compensation, but to ensure at least some immediate compensation" (*Hindustan Times* 2010).

This suggestion contradicts the explicit assurance in the bill that "no civil court shall have jurisdiction to entertain any suit or proceedings in respect of any matter which the Claims Commissioner...is empowered to adjudicate under this Act." As we described above, the cap on operator liability serves a purpose. It protects corporations from the bankruptcy that might result from a nuclear accident. And in order that this function is maintained, ordinary tort law cannot apply to nuclear accidents if this bill is passed; the government's claims to the contrary are misleading.

Concluding Thoughts

The nuclear liability bill is a result of two different sources of pressure: foreign countries, most prominently the US, and domestic big businesses which would like to come into the nuclear business because of the potentially large profits. But, as we have argued here, the two crucial clauses of the liability bill run counter to the principles of natural justice. The bill, in its current form, or in the modified forms that we think are likely, must be opposed.

At the heart of the debate over nuclear liability is a conflict of interest. On the one hand is the risk faced by nuclear suppliers and operators that they may, some day, be forced to pay large amounts

of compensation for catastrophic accidents that they can, through their actions, lower the chances of, but never eliminate. On the other hand, there are the risks faced by the inhabitants of the regions close to a nuclear reactor and the interests of the people at large who might be stuck with the burden of cleaning up the results of a catastrophic accident. Whose interests should the government protect? The Manmohan Singh government would like to intervene legislatively to immunise multinational corporations and limit the liability of domestic operators. A clearer indicator of the nature of the current Indian state cannot be found.

NOTES

1 In 1956, Senator Albert Gore (father of the former vice president of the United States, Al Gore) and Representative Chatfield introduced a bill that would direct the US Atomic Energy Commission to build nuclear power plants to provide electricity for its uranium enrichment and plutonium production activities, instead of buying electricity from nearby utilities. This cleared the Senate but Republican opposition did not allow it to pass in the House, proposing instead, "to give private industry more incentives to build the nuclear plants".

2 On the emergence of the light water reactor as the leading nuclear reactor type see Cowan (1990).

3 See http://energycommerce.house.gov/Press_111/20100223/waxman.statement.2.23.10.pdf. The background to this case was the numerous reports of incidents where cars manufactured by Toyota had experienced uncontrollable acceleration leading to accidents, some of which were fatal. Toyota later accepted that this was due to a deficiency in design and recalled millions of its cars.

4 A passive component operates without any external input, for example operators or equipment, to activate the function. See Anders Martensson (1992).

5 CRAC stands for Calculation of Reactor Accident Consequence.

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Appendix

Let us try and make the calculations for the financial disincentive provided by the liability cap a little more precise. We use the following notation: C – overnight cost of construction; α – discount rate; F – the total cap on liability; L – the total lifetime of the plant; r – the probability of having an accident per unit time; i – the net income (revenue – costs) of the plant per unit time. Here we consider the case of a catastrophic accident; the moment this accident happens, the plant shuts down, the operator pays the fine and loses all future revenue.

Let us start with the discrete time case and then pass to the continuous case. We divide time into units of δt. The probability that no accident happens for n units of time, and then happens is:

$$p(n)=(1-r\delta t)^n r\delta t. \quad (1)$$

The total income earned in this case is

$$\mathrm{I}(n)=-C-\frac{F}{(1+\alpha\delta t)^n}+\sum_{j=1}^{n}\frac{i\delta t}{(1+\alpha\delta t)^j}. \quad (2)$$

The probability that no accident happens in the lifetime of the plant and the income earned in that case is

$$p_o=(1-r\delta t)^{\frac{L}{\delta t}}, \quad I_o=-C+\sum_{j=1}^{\frac{L}{\delta t}}\frac{i\delta t}{(1+\alpha\delta t)^j}. \quad (3)$$

So, the expected income in L years ($\frac{L}{\delta t}$ units of time) is

$$\langle I_L\rangle = p_o I_o+\sum_{n=1}^{\frac{L}{\delta t}} I(n)p(n)$$

$$=p_o I_o+\sum_{n=1}^{\frac{L}{\delta t}}\left(-C-\frac{F}{(1+\alpha\delta t)^n}+\sum_{j=1}^{n}\frac{i\delta t}{(1+\alpha\delta t)^j}\right)(1-r\delta t)^n r\delta t$$

$$\to\left(-C+\int_o^L ie^{-x\alpha}dx\right)e^{-rL}+\int_o^L\left(-C-Fe^{-t\alpha}+\int_o^t ie^{-x\alpha}dx\right)e^{-rt}rdt$$

$$=\frac{e^{-L(\alpha+r)}\left((-1+e^{L(\alpha+r)})\,(i-Fr)-Ce^{L(\alpha+r)}\,(\alpha+r)\right)}{\alpha+r} \quad (4)$$

In our problem, r is small (since, typically $r\approx 10^{-4}$/yr or even smaller). So, we can expand to first order in r, which leads to

$$\langle I_L\rangle \approx -\frac{C\alpha+(-1+e^{-\alpha L})i}{\alpha}+\left[\frac{F}{\alpha}(e^{-\alpha L}-1)+\frac{i}{\alpha^2}(e^{-\alpha L}+L\alpha-1)\right]r. \quad (5)$$

The first term is the profit that would be made without accounting for accidents, while the second term tells us the disincentive from the revenue loss and fine. We get the answer used in the text when we set the discount rate $\alpha=0$ and also set the profit to zero, i e, $i=C/L$. In this limit, we see that

$$\lim_{\alpha\to 0}\langle I_L\rangle|_{i=\frac{C}{L}}\approx -(F+\frac{C}{2})Lr+\mathrm{O}(r^2L^2) \quad (6)$$

which matches with our previous answer.

If the discount rate is about 3% and the plant is operating over a lifetime of about 30 years, then we cannot use this formula but must instead use Eqn 5. The effect is to change a few factors but the important features of the result are unchanged.