Environmental Assets & Liabilities:
Dealing with Catastrophic Risks

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Environmental Assets & Liabilities:
Dealing with Catastrophic Risks

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Abstract: We review the extent to which the Federal Government faces liabilities arising from its management of environmental risks, and argue that the degradation of natural capital can lead to social risks which ultimately will end up to some degree as the responsibility of the Federal Government. We then look in detail at the Price-Anderson Nuclear Industries Indemnity Act and try to assess the nature of the liability assumed by the Federal Government under this Act. This is clearly very large indeed, and we argue that this risk is not well-managed by current institutions and policies and suggest ways of improving the management of nuclear risks.

Introduction

In this paper we are aiming to review some of the possible environmental assets and liabilities of the Federal Government. Beginning with a general review of the economic value of environmental systems as natural capital, we consider the role of the Federal Government in managing such capital and subsequently focus on a specific set of liabilities, Federal liabilities under the Price-Anderson Nuclear Industries Indemnity Act of 1957. We begin with a general review of the nature of environmental assets and liabilities, as these are categories that are not widely known. We introduce natural capital as an asset of the nation and review its significance and some of the problems associated with valuation. This leads naturally to a general review of potential liabilities at the Federal level. There are several points that emerge from this review. The value of environmental assets is enormous, and in poor countries is often a large fraction of the total value of all assets. The values of these assets is often not well-measured, although progress is being made on this matter, and policy makers often do not incorporate into their policies their impacts on these assets. There are examples that suggest that an awareness of policy impacts on natural assets can contribute to more effective policies.

In the second part of the paper we focus on the Price-Anderson Act and the alternatives to this Act. We argue that the P-A Act imposes significant liabilities on the Federal Government, and ask whether this is appropriate and necessary. To gain insights into this,

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we review the programs by which catastrophic risks are managed in other areas by a combination of private sector and Federal insurance programs.

Natural Capital as an Asset

A nation's environmental assets are diverse and important. Environmental economists talk about natural capital, on a par with physical capital, human capital, intellectual capital and other forms of capital.[3] Environmental assets, like any other assets, provide a flow of services over time. Often they provide these services over very long periods of time, periods that are orders of magnitude greater than those relevant for most other forms of capital. If we value these assets at the present value of their services, then by applying conventional discount rates we lose most of the contributions that they make.

A good example is the New York City watershed, a collection of naturally-occurring ecosystems in the Catskills that cleanse and stabilize the flow of water to New York. This watershed has provided these services since the earliest days of New York and if not disturbed can continue to do so for centuries. Recently the City spent over $1 billion restoring the ecological integrity of this watershed, in order to restore the City's water to earlier levels of purity. We can see this as an investment in natural capital, with the benefit the flow of clean water and the avoidance of a complex and expensive filtration plant costing over $8 billion.[4] Although the Catskills watershed is an asset to New York City, which has invested extensively in it, the City does not own it. The watershed consists of land in the Catskills, most of which is privately owned either as farms or as homes. The City provides financial incentives for people living and working in the watershed area to behave in ways that are consistent with the continued operation of the watershed.

Forests are another topical example of natural capital. Forest can of course be cut for lumber, and have value in that role. Their growth gives a natural rate of return. In addition forests provide many services, one of which is carbon sequestration: in a world where greenhouse gases are threatening climate change and many companies are operating under carbon constraints, the ability to absorb carbon from the atmosphere is a benefit to society, even though it generally does not currently have a market value. But that is changing: the Clean Development Mechanism of the Kyoto Protocol provides a mechanism for monetizing the carbon services of forests, and the proposal of the Coalition for Rainforest Nations to generate avoided deforestation credits will take this further.[5] Forests are sometimes public property and sometimes private, and the carbon

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[3] For a discussion see Barbier and Heal, Valuing Ecosystem Services, The Economists' Voice, Berkeley Electronic Press, January 2006, www.bepress.com/ev and the references there.
[4] For more details see Geoffrey Heal, Nature and the Marketplace, Island Press, 2000 and National Research Council, Valuing Ecosystem Services: Toward Better Environmental Decision-Making, National Academies Press, 2004, available at http://www.nap.edu/books/030909318X/html/ For a detailed study of all aspects, economic and scientific, see also the National Research Council's book Watershed Management for Potable Water Supply: Assessing the NYC Strategy, National Academy Press, 2000.
[5] See www.rainforestcoalition.org for more information. Also relevant is "A Solution to Climate Change in the World's Rainforests," Geoffrey Heal and Kevin Conrad, Financial Times, November 5 2005, http://www2.gsb.columbia.edu/faculty/gheal/FT_Nov05.pdf

sequestration services that they provide are public goods. Forests provide other services as well – biodiversity support, for example, and recreational services – but carbon sequestration and lumber are their main sources of value. At the carbon prices that have ruled in the European Union's Emission Trading Scheme, the present value of the carbon services of a forest often exceeds its lumber value or the value of agricultural output that could be produced were the land to be cleared. For example, a moist tropical forest may have sequestered and stored from 50 to 200 tons of carbon per hectare. To emit this into the atmosphere in the European Union would cost anywhere from $4500 to four times this amount. So there is economic value to retaining this carbon and keeping it out of the atmosphere.

Natural resources such as oil, gas, coal and various other mineral deposits are also a form of natural capital, and the values of these are often reflected in the valuations of their owners, usually corporations. It is generally recognized that one of the main determinants of the stock market value of an oil company is the value of its oil reserves.[6] An interesting point is that if a corporation depletes its oil reserves, then under U.S. GAAP[7] and most equivalents, it must record this as depletion of assets in its financial statements. If however a nation depletes its reserves of oil or any other mineral resource, then the United Nations System of National Accounts does not require that it record a depletion charge against its income. If the national accounts of oil-producing countries were to record depletion charges, then their incomes would drop very significantly indeed.[8]

Soils are another important type of natural capital: a region with rich soils is agriculturally productive, and this is reflected in the value of land. Soils are complex ecosystems that evolve over time and can be damaged by overuse or by chemical pollution. A major cause of topsoil loss is soil being washed away by rainfall or blown away by heavy winds. Studies suggest that about one third of the world's arable land has been lost to erosion in the last half century, and that we continue to lose land at a rate of about ten million hectares each year.[9]

At a more abstract but perhaps also more important level the climate system is an asset. The Floridian climate goes a long way to explaining why people want to live there, and some of the economic value that it generates is reflected in land values. The same is true of the climate of the Caribbean, or of skiing resorts in the Rocky Mountains. Climate also plays an important role in determining agricultural productivity. The climate system is more than the temperature, though that is a central part of it: the humidity, precipitation and wind patterns all play an important role in determining the value of a climate system. The world's climate system is currently changing in a way that will make it less valuable to many. Florida also illustrates this point.

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[6] See for example Miller, Merton H & Upton, Charles W, 1985. "**A Test of the Hotelling Valuation Principle**," Journal of Political Economy, University of Chicago Press, vol. 93(1), pages 1-25, February.
[7] Generally Accepted Accounting Principles
[8] See Heal Accounting and the Resource Curse, in Escaping the Resource Curse, edited by Macartan Humphries, Jeffrey Sachs and Joseph Stiglitz, 2007 and references therein.
[9] See Pimentel et al, Environmental and Economic Costs of Soil Erosion and Conservation Benefits, Science, 24 February 1995 Vol. 267 No. 5201 1117-1123

The population of Florida has increased significantly over the past 50 years: 2.8 million inhabitants in 1950, 6.8 million in 1970, 13 million in 1990, and a projected 19.3 million population in 2010 (almost a 700% increase since 1950)[10]. The increase in the exposed property values in risk-prone areas due to a combination of pure inflation, speculation and rises in the standard of living increase the chance of significant insured losses from future natural disasters. If Hurricane Andrew had occurred in 2002 rather than 1992, it would have inflicted twice the economic losses, due principally to increasing development and rising asset values in Miami/Dade County and adjoining coastal areas in Florida affected by the storm.[11]

Compounding this increase in exposure is a trend for tropical storms/hurricanes and typhoons to become more intense over time due to global warming. Emanuel[12] introduces an index of potential destructiveness of hurricanes based on the total dissipation power over the lifetime of the storm. He shows a large increase in power dissipation over the past 30 years and concludes that this increase may be due to the fact that storms have become more intense, on average, and/or have survived longer at high intensity. His study also shows that the annual average storm peak wind speed over the North Atlantic and eastern and western North Pacific has increased by 50 percent over the past 30 years. Recent work by the International Panel on Climate Change (IPCC)[13] indicates that one of the impacts of a change in climate will be an increase in weather-extremes. We are likely to witness not only more intense storms, but also more intense heat-waves and drought, and more intense flooding episodes as well. The impacts are predicted to be more important in many low- and middle income countries (Africa, South America, Asia) than in the developed world.

Although all of these natural capital assets are important and in some general sense valuable, they are often hard to value precisely. In fact, valuing natural capital and the services that it produces has been an active area of environmental research in the last decade.[14] Sometimes a part of the value of natural capital is captured by markets, as for example the value of a forest as lumber. The owners of forested land in the Catskills watershed have traditionally valued it for the lumber that it produces. And more recently they have added to this the value of payments that they might receive from the City of New York for management of the land in a way conducive to the proper functioning of the watershed. But they get no payments for the carbon sequestered by their growing

[10] Kunrether, H. and Michel-Kerjan (2007) ".Climate Change, Insurability of Large-scale Disasters and the Emerging Liability Challenge" *University of Pennsylvania Law Review* 155(6):1795-1842.
[11] Andrew Dlugolecki, *Thoughts about the Impact of climate change on insurance claims*, in P. Höppe and R. Pielke (eds.), *Report of the Workshop on Climate Change and Disaster Losses, May 25-26*, (2006).
[12] See Emanuel, K., "Increasing destructiveness of tropical cyclones over the past 30 years." Nature 436(4): 686-688, August. 2005.
[13] See Intergovernmental Panel on Climate Change Fourth Assessment Report available at www.ipcc.ch
[14] This literature is reviewed in National Research Council, Valuing Ecosystem Services: Toward Better Environmental Decision-Making, National Academies Press, 2004, available at http://www.nap.edu/books/030909318X/html/

trees, which implies that they are providing a global public good without being compensated for it.

The World Bank has recently published the results of a major study of the values countries' environmental assets, along with the values of their other forms of capital. Their methodology is set out in full in their publication "Where is the Wealth of Nations?" available at http://siteresources.worldbank.org/INTEEI/214578-1110886258964/20748034/All.pdf. Not all values are estimated directly: some are calculated as residuals. Table 1 shows some of the conclusions that emerge from the Bank's studies. For low income countries, natural capital is an important and often the most important form of capital asset. It becomes a smaller part of the total picture as the level of development rises, falling from 29% of assets for low income countries to as low as 2% for high

Table 1 from *Where is the Wealth of Nations*, page xxiv

— $ per capita and percentage shares —

Income group	Natural capital	Produced capital	Intangible capital	Total wealth	Natural capital share	Produced capital share	Intangible capital share
Low-income countries	1,925	1,174	4,434	7,532	26%	16%	59%
Middle-income countries	3,496	5,347	18,773	27,616	13%	19%	68%
High-income OECD countries	9,531	76,193	353,339	439,063	2%	17%	80%
World	4,011	16,850	74,998	95,860	4%	18%	78%

Source: Authors.
Notes: All dollars at nominal exchange rates. Oil states are excluded. OECD: Organisation for Economic Co-operation and Development

income countries. Note that even 2% can be a high dollar value for these countries, and that many forms of natural capital are omitted from the calculations because of data limitations. It is also interesting to note that for high income countries the role of physical capital or produced capital, the traditional stereotype of a capital asset, is only 17% of total wealth. The most important component is intangible capital such as climate systems and biodiversity. As we mentioned before, the Caribbean's climate is probably its most important economic asset. For Costa Rica or Botswana with extensive ecotourism industries based on their exotic flora and fauna, biodiversity is also clearly an asset.

Environmental liabilities

What does this tell us about environmental liabilities? Certain categories are widely recognized such as those generated by the Superfund legislation, and liabilities associated

with past pollution activities. In the case of Superfund there are open questions as to who is liable because of the complexities of joint and several liability. But in general these are the responsibilities of the private sector not the federal government with the exception of Department of Defense sites, whose clean-up costs have been estimated at over $30 billion.[15]

A more prominent source of liabilities of the Federal Government arises from changes in the state of natural capital that lead to its ceasing to provide services, such as the loss of barrier islands in the Gulf of Mexico, which we discuss below. Much natural capital has the characteristics of public goods, so that to the extent that the government is normally responsible for maintaining it. A timely example is the gradual destruction of the barrier islands in the Gulf of Mexico offshore from New Orleans. Historically these islands protected New Orleans from storm surges, and their gradual disappearance contributed to the severity of the impact of Hurricane Katrina on that city.[16] This in turn created liabilities for the Federal Government through the designation of the region as a Presidentially-declared disaster area, with some estimates suggesting that Federal Government may spend as much as $150 billion in response to Hurricane Katrina . We can regard this as an environmental liability as it arose in part as a predictable consequence of the degradation of natural capital. Legally the 2007 Stafford Act probably makes the Federal Government liable for damages of this sort, and politically it surely is: the public expects the Federal Government to step in and offer restitution is situations such as Katrina.

Hurricane Katrina is illustrative of a class of situations where the Federal Government may incur liabilities as a result of its failure to manage environmental issues adequately. In this case a part of the cause of the disaster was undoubtedly the changes in the topography of the area around New Orleans as a result of dredging and canalization, and the removal of barrier islands, all of which can be considered degradation of natural capital or of environmental assets. The U.S. Army Corps of Engineers, a Federal Agency, was responsible for much of this. In addition some argue that climate change made a contribution to the severity of Katrina, and argue that the Federal Government by failing to act on this issue further contributed to the severity of the problem.[17] The general point here is that to the extent that degradation of natural capital leads to increased severity and frequency of natural disasters, there is an increase in Federal liability, though this is hard to quantify. The natural disasters associated with the mismanagement of natural capital could include storms, wildfires, floods and droughts, all of which can generate liabilities in the billions.

The bottom line on natural capital and the Federal Government's assets and liabilities is that this is a hugely important asset, its maintenance normally being a Federal responsibility, and that how well or badly it is maintained can have huge impacts on

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[15] See the CBO report at http://www.cbo.gov/showdoc.cfm?index=4764&sequence=0
[16] See Joel K. Bourse Jr. "Gone with the Water," National Geographic, http://magma.nationalgeographic.com/ngm/0410/feature5/
[17] See Emanuel, K., 2008: The Hurricane-Climate Connection. *Bull. Amer. Meteor. Soc.*, **89**, ES10-ES20.

Federal liabilities. These liabilities are hard to measure, but as the *de facto* insurer of last resort for catastrophes it will often inherit the check.

Nuclear Liabilities

The Federal Government has taken on the lion's share of the liability from a nuclear power plant catastrophe through the passage of the Price-Anderson (P-A) Act in 1957. Nuclear power stations have a rather unique environmental profile. If they operate as planned they produce little if any environmental damage. They emit neither gases nor pollutants of any kind. There is however a small chance of a very serious accident such as a core meltdown leading to damaging pollution as in 1986 at the Chernobyl nuclear reactor in the Ukraine. In this case, clouds of radioactive waste floated over much of the Ukraine, Belarus, Eastern and Western Europe and Scandinavia with fatalities estimate by international agencies to be about 9,000 individuals. Core meltdowns have also occurred twice in the U.S., once at the Enrico Fermi reactor in Newport, Michigan, in 1966 and again at Three Mile Island in Middletown, Pennsylvania in 1974. In it generally believed that little or no radiation was released in either of these cases.[18]

In addition to the risk of a core melt-down, nuclear power stations pose problems associated with the disposal of their radioactive wastes. Over its operating life a nuclear power station will produce many tons of highly radioactive long-lived waste, which poses a health hazard for many centuries. Since 9/11/2001 the wastes have been recognized as a possible ingredient for a dirty bomb used in a terrorist attack. The method for disposing of radioactive wastes from nuclear power stations is highly controversial, with no country having yet implemented a coherent long-term policy. In the U.S. the current policy is that waste be buried at the Yucca Mountain Repository in Nevada, but this has not been implemented. In the meantime many hundreds of tons of highly radioactive waste sit in containment tanks at the sites of commercial nuclear power stations, often poorly guarded. Were some of this to fall into the wrong hands, the costs could be immense and would be the responsibility of the Federal Government: there is a Federal liability here.

A core meltdown is generally agreed to be the most serious accident that can occur to a nuclear power station. What is the risk of this event, and what are the possible consequences? In the U.S., 104 commercial reactors have been built and operated. As noted two – Enrico Fermi and Three Mile Island – have experienced core meltdowns. In addition, according to data from the Nuclear Regulatory Commission (NRC), four have been closed in excess of one year for serious failures that if not corrected could have caused core meltdowns.[19] This means that 6 in 104 reactors have experienced meltdowns or near-meltdowns. Normally these data are not presented as X meltdowns or near-meltdowns in Y reactors. Rather they are presented as X meltdowns or near-meltdowns per Z reactor year, a much smaller risk. For example, if each of the 104 reactors had

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[18] See "Walking an Nuclear Tightrope: Unlearned Lessons of Year-Plus Reactor Outages," David Lochbaum, Union of Concerned Scientists, available at
http://www.ucsusa.org/clean_energy/nuclear_safety/walking-a-nuclear-tightrope.html
[19] Data from the U.S. Nuclear Regulatory Commission, available in Walking a Nuclear Tightrope," op. cit.

been operating for 25 years, as is the case for most of these power plants, then the figure would be 6 in 2080.

All the meltdowns and most of the near-meltdowns occurred in the 1960s and 1970s which suggests that the risks are highest early in the life cycle of a reactor design. This would be reasonable, and consistent with the idea of a learning curve associated with the management of something as complex as a nuclear power station. There are both reassuring and disturbing aspects to this observation. It is reassuring as far as the safety of existing reactors is concerned, but disturbing when one recognizes that the currently-proposed expansion of nuclear power would be through new and as-yet untried reactor designs that are focused on reducing the (very substantial) capital costs of nuclear power stations. The Federal Government has received or expects to receive applications to build 34 new nuclear reactors at 23 sites.[20] A new generation of reactors could take us back to the top of the learning curve and into an era of risk not experienced since the 1960s and 1970s.

What would be the costs of a core melt-down in which, as in the Chernobyl case, radiation was released from the containment vessel? There is no general theory for such an estimate, so we focus on a specific case, the case of Indian Point, a nuclear power station owned by Entergy Corporation and situated on the Hudson River 24 miles north of New York City. The huge population densities in the region make an accident here particularly threatening. Nuclear fallout from the plant could reach populated areas including New York City, northern New Jersey, and Fairfield County, Connecticut. A 1982 study by Sandia National Laboratories found that a core meltdown and radiological release at one of the two operating Indian Point reactors could cause 50,000 near-term deaths from acute radiation syndrome and 14,000 long-term deaths from cancer.[21] In addition to these horrifying health impacts, the release of a cloud of radioactivity over New York City could close the city down for business for a considerable period of time.

The financial costs of such an event are clearly stunning. 64,000 deaths valued at $6 million per person alone gives a cost of $384 billion. In the case of the 9/11/2001 attacks, insured business losses and business interruptions were valued at in the region of $35 billion. A disaster at Indian Point could possibly have a more disruptive effect on activity in the New York metropolitan area than the 9/11/2001 attacks, and for a much longer period of time. Business interruption losses in the range of $50-100 billion are possible, in addition to the costs associated with loss of life and damage to health. It is therefore reasonable to think that the direct and indirect costs of a nuclear accident could be in the hundreds of billions. Indeed a worst-case scenario could lead to the closure of New York City for years, as happened at Chernobyl, which is still closed over 22 years after the meltdown, leading to almost unthinkable costs.

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[20] Wald, M. "After 35-Year Lull, Nuclear Power May Be in Early Stages of Revival" *New York Times* October 24, 2008 p. B3.

[21] For more details see http://www.ucsusa.org/news/press_release/new-study-predicts-up-to-44000-prompt-fatalities-and-518000-longterm-deaths-from-indian-point-terror-attack.html

The Price-Anderson Act and Nuclear Accident Insurance[22]

The Price-Anderson Act, originally enacted by Congress in 1957, limits the liability of the nuclear industry in the event of a nuclear accident in the United States. The Act was passed in order to encourage the construction of nuclear power plants in the United States. At the same time, P-A provides a ready source of funds to compensate potential accident victims that would otherwise not be available. The Act covers large power reactors, small research and test reactors, fuel reprocessing plants and enrichment facilities for incidents that occur through plant operation as well as transportation and storage of nuclear fuel and radioactive wastes. The Act is seen as central to the commercial viability of nuclear power.

P-A sets up two tiers of insurance. Each utility is required to maintain the maximum amount of coverage available from the private insurance industry - currently $300 million per site. In the U.S., this coverage is written by the American Nuclear Insurers, a joint underwriting association or "pool" of insurance companies. If claims following an accident exceed that primary layer of insurance, all nuclear operators are obligated to pay up to $100.59 million for each reactor they operate, payable at the rate of $10 million per reactor, per year. As of February 2005, the U.S. public currently has more than $10 billion of insurance protection in the event of a nuclear reactor incident. More than $200 million has been paid in claims and costs of litigation since the Price-Anderson Act went into effect, all of it by the insurance pools. Of this amount, approximately $71 million has been paid in claims and costs of litigation related to the 1979 accident at Three Mile Island.

As part of the Energy Policy Act of 2005, signed into law by President Bush on August 8, 2005, Price Anderson was reauthorized for the next 20 years. This is the fifth time that Congress has reauthorized the Act since P-A was first passed in 1957 but it is the longest extension ever granted. High prices and dwindling supplies of fossil fuels have increased interest in nuclear energy and the long extension of P-A may increase the feasibility of investment in nuclear power plants. One should note, however, that since the Three Mile Island accident in 1978 not a single nuclear power plant has been built in the United States. As pointed out above there are a 34 applications for new reactors due to the concerns with global warming.

Are Nuclear Power Plant Accidents an Insurable Risk?

A principal reason for the passage of the P-A Act was to protect the utilities against the possibility of a catastrophic loss from a nuclear power plant accident. Private insurers were reluctant to provide this coverage because they were uncertain about the likelihood of a severe accident (e.g. a core meltdown) and the consequences of such a disaster. In other words, it was believed at the time that protection against nuclear accidents did not satisfy the conditions for insurability of a risk by the private sector. Is this in fact correct

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[22] For more details on nuclear accident insurance see Nuclear Energy Institute "Price-Anderson Act Provides Effective Nuclear Insurance at No Cost to the Public", February 2005.

– is it really necessary that the government should assume the liabilities associated with the P-A act, or could we, in fact, rely on the private sector to play this role?

The conditions for insurability in the context of environmental risks have been examined by Freeman and Kunreuther (1997).[23] Cummins (2006) and Litan (2006)[24] have recently examined this issue in the context of catastrophic risks. The discussion that follows uses concepts from these papers to focus on how an insurer decides whether or not to provide coverage against damage from an environmental risk

Law of large numbers

Insurers are likely to be concerned about the variability of profits from the risks they insure. The ideal risk is one where the potential loss from each insured is relatively small and independent of the losses from other policyholders. As the insurer increases the number of policies it issues in a year, the variance in its annual losses decreases. In other words, the law of large numbers makes it highly unlikely that the insurer will suffer an extremely large loss relative to the premiums collected.

Insurance against underground storage tank (UST) leaks is an example of an environmental risk that satisfies the law of large numbers since losses are normally independent of one another.   To illustrate the application of this law, suppose that an insurer wants to determine the estimated loss for a group of identical USTs   each of which has a 1/100 annual chance of leaking and causing damage of $100,000.   The expected annual loss for each UST would be $1000 (i.e. 1/100 x $100,000). As the number of UST policies n increases, then the variance of the expected annual loss decreases in proportion to n. Cummins (2006) considers the case where the insurer is willing to accept a low probability of insolvency ε arising out of a catastrophic loss when insuring a book of business. He shows that for risks which are independent and whose losses are characterized by the normal distribution, so that the central limit theorem applies, the equity capital per policy approaches zero as the number of insured policies becomes very large.

Conditions for Insurability

The application of the law of large numbers is predicated on the ability of insurers to estimate the likelihood and consequences of a risk and for the risks to be independent of each other. The risks associated with large-scale catastrophic disasters or accidents are unlikely to satisfy the law of large numbers. The following three conditions can then determine the degree to which such a risk is insurable:

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[23] Freeman, P. and Kunreuther, H. *Managing Environmental Risk Through Insurance,* Washington, DC: American Enterprise Institute and Boston: Kluwer Academic Publishers 1997.
[24] Litan, R, , 2006. "Sharing and Reducing the Financial Risks of Future Mega-Catastrophe," Issues in Economic Policy, No. 4 (Washington, D.C.: The Brookings Institution)

Condition 1 is the ability to identify and quantify the chances of the event occurring and the resulting losses under different levels of insurance coverage.

Condition 2 is the ability to set premiums for each potential customer or class of customers that reflect the risk.

Condition 3 is the ability to make a positive expected profit by providing coverage against the risk

We now examine each condition and raise some questions related to the ability of private insurers to provide coverage.

Condition 1: Identifying the Risk

To satisfy this condition, estimates must be made of the frequency at which specific events occur and the magnitude of the loss. The risk of a leaky UST is one with which the insurance industry is relatively comfortable because there is past data and scientific information that enables them to determine both the likelihood and consequences of such an event. Due to the infrequency of nuclear power plant accidents, it is much more difficult to estimate these parameters for insurance against this risk.

Condition 2: Setting Premiums that Reflect the Risk

Once the risk has been identified, insurers need to determine a premium that reflects the risk while not posing an unacceptably high chance of insolvency or severe loss of surplus due to a catastrophic loss. There are several factors that determine what premiums insurers would like to charge

Ambiguity of Risk A risk is ambiguous if we cannot assign a probability to it. Insurers, and indeed decision-makers in general, dislike ambiguity. The greater the ambiguity of a specific loss the higher the premium will be. In a mail survey of professional actuaries conducted by the Casualty Actuarial Society, 463 respondents indicated how much they would charge to cover losses against a defective product in two cases, one where the probabilities of a loss (*p*) was well specified at $p=.001$ and one where they experienced considerable uncertainty about the likelihood of a loss with the same mean likelihood. The median premium values were five times higher for the uncertain risk than for the well-specified probability when the losses from each insurance policy were independent. This ratio increased to ten times when the losses were perfectly correlated. (Hogarth and Kunreuther 1989).[25]

In another study a questionnaire was mailed to 190 randomly chosen insurance companies of different sizes asking underwriters to specify the prices which they would like to charge to insure a factory against property damage from a severe earthquake, to insure an underground storage tank and to provide coverage for a neutral situation (i.e. a

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[25] Hogarth, R. and Kunreuther, H. "Risk, Ambiguity, and Insurance", *Journal of Risk and Uncertainty,* April 1989

risk without any context). Probabilities and losses were varied. The probability of loss and the size of the claim were either well-specified or there was ambiguity regarding the likelihood of the loss and/or the claim size. The underwriters wanted to charge considerably more for the same amount of coverage when either the probability was ambiguous and/or the claim size was uncertain. (Kunreuther et al. 1995).[26]

Adverse Selection   If the insurer sets a premium based on the average probability of a loss, using the entire population as a basis for this estimate, those with the highest risk will be the most likely to purchase coverage for that hazard. In an extreme case, the poor risks will be the only purchasers of coverage, and the insurer will lose money on each policy sold. This situation, referred to as adverse selection, occurs when the insurer cannot distinguish between the probabilities of a loss for good- and poor-risk categories, but the insured can.

Moral Hazard   Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder. For example, providing insurance protection to a nuclear power plant may lead the utility to behave more carelessly than if it did not have coverage. One way to avoid the problem of moral hazard is to introduce deductibles and coinsurance as part of the insurance contract. A sufficiently large deductible can act as an incentive for the insureds to continue to behave carefully after purchasing coverage because they will be forced to cover a significant portion of their loss themselves. With coinsurance the insurer and the insured share the loss together. As with a deductible, this type of risk-sharing arrangement encourages safer behavior because those insured want to avoid having to pay for some of the losses.

Catastrophic Losses A nuclear power plant accident can produce catastrophic losses. Insurers who cover the risks from such disasters may have to pay potentially large claims to policyholders before they are able to collect sufficient premiums to cover their costs. This timing risk is an important element associated with catastrophic losses. [Litan (2006)].[27] Rating agencies may also play a role in influencing how many policies an insurer will want to write on risks with respect to catastrophic losses. A recent report by AM Best focuses on the importance of the ratio of annual insured catastrophic losses as percentage of policyholder surplus (PHS). In general, the report notes that the higher the level of loss relative to surplus, the greater has been the financial damage to the insurance industry (Williams and King 2006).

Condition 3 Earning a positive expected profit by marketing coverage

In theory insurers can offer protection against any risk that they can identify and for which they can obtain information to estimate the frequency and magnitude of potential losses as long as they have the freedom to set premiums at any level. However, due to

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[26] Kunreuther, H., J. Meszaros, R. Hogarth, and M. Spranca (1995), "Ambiguity and underwriter decision processes," *Journal of Economic Behaviour and Organization*, 26: 337-352.
[27] Litan, Robert E., 2006. "Sharing and Reducing the Financial Risks of Future Mega-Catastrophe," Issues in Economic Policy, No. 4 (Washington, D.C.: The Brookings Institution)

problems of ambiguity, adverse selection, moral hazard, and highly correlated losses, they may want to charge premiums that considerably exceed the expected loss. For some risks the desired premium may be so high that there would be very little demand for coverage at that rate. In such cases, even though an insurer determines that a particular risk meets the two insurability conditions discussed above, it will not invest the time and money to develop the product.

More specifically, the insurer must be convinced that there is sufficient demand to cover the development and marketing costs of the coverage through future premiums received. If there are regulatory restrictions that limit the price insurers can charge for certain types of coverage, then companies will not want to provide protection against these risks. In addition, if an insurer's portfolio leaves them vulnerable to the possibility of extremely large losses from a given disaster due to adverse selection, moral hazard, and/or high correlation of risks, then the insurer will want to reduce the number of policies in force for these hazards.

Conclusions on Insurability of Nuclear Reactors

The catastrophic risks associated with a meltdown of a reactor in a populated area, together with the release of radioactivity, are unlikely to be readily insurable. The risks are unique and massive, and not well understood. Problems of moral hazard and adverse selection may also be serious. If private insurers were to charge a premium that reflected their risk given the above features, it is likely to be considerably higher than if there was some public sector involvement. The Price Anderson Act was passed in this spirit but has not been evaluated with respect to how well it meets society's needs. We now address this question.

Evaluating Price-Anderson as an Insurance Program

Price-Anderson can provide as much as $10 billion of insurance to cover catastrophic losses. This is perhaps 10% of the likely cost of a meltdown associated with the release of radioactivity. The Act can provide adequate coverage should there be a severe nuclear accident. The gap between what is available under the Act and what would be needed would almost certainly be filled by the Federal Government. In other words, there is a potential liability by the public sector of $100 billion or possibly much more under the Price-Anderson Act. The probability that this liability will be incurred is small, so the expected value of the liability is perhaps in the range of billions rather than tens of billions.

Regulatory Capture

The risk that the government faces with respect to nuclear accidents is not entirely outside of its control. The government has to license nuclear power stations, and the NRC sets safety standards which if well enforced could cut the government's risk significantly.

There is a lot of evidence that the NRC suffers from regulatory capture and has performed poorly in its role of safety overseer.[28] The Federal Government can also reduce the risks associated with nuclear power by influencing the location of nuclear power points to more remote locations rather than major population centers so as to reduce potential liabilities.

Subsidies Associated with Price Anderson

As Heyes[29] points out, utilities are subsidized under the P-A Act because they are only responsible for damage up to about $10 billion. Canada has a similar cap on damages specified in the 1970 Nuclear Liability Act. The Canadian courts were forced to address the decreased incentive that this limited liability provides for investing in safety measures. In fact, Ralph Winter in a commentary on Ontario Hydro's behavior pointed out that the utility is looking for alternatives to investing in safety measures because of the high costs associated with them.

Another disincentive for utilities to invest in safety measures stems from the fact that insurance premiums do not reflect the performance and related risk associated with a nuclear power plant. Should there be an outage by a plant, the premiums are not adjusted upward to reflect the higher risk. By not having experience-rated premiums there is a type of interdependence that can be deleterious to all utilities in the industry. The financial vulnerability of one nuclear power plant depends not only on its own choice of security investments, but also on the actions of other agents. Inadequate investment elsewhere can raise a plant's premiums. This concept of *interdependent security* implies that outage in one plant could have financial impacts on all the other utilities operating nuclear power plants. As a result there may be suboptimal investment in the individual components (Kunreuther and Heal, 2003; Heal and Kunreuther, 2005)[30]. The existence of such interdependencies provides another challenge in determining the design of a nuclear power plant insurance program.

Modifying Price-Anderson

Learning from Other Federal and State Catastrophe Programs[31]

We now review the roles that the federal and state governments in the United States play in supplementing or replacing private insurance with respect to natural disasters and other catastrophic losses. In many respects the problems faced in these areas are similar to

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[28] "Walking a Nuclear Tightrope: Unlearned Lessons of Year-plus Reactor Outages." UCS, David Lochbaum.

[29] Anthony Heyes, The Price of Price-Anderson, Regulation, Winter 2002-2003. Available at http://www.cato.org/pubs/regulation/regv25n4/v25n4-8.pdf

[30] Kunreuther, H. and Heal, G. (2003), "Interdependent Security", *Journal of Risk and Uncertainty*. 26: 2/3, pp. 231-249; Heal, G. and Kunreuther, H. (2005), "IDS Models for Airline Security", *Journal of Conflict Resolution,* 49: 2, pp 201-217.

[31] The material in this subsection appears in Wharton Risk Center (2005) Chapter 2 in *TRIA and Beyond: Terrorism Risk Financing in the U.S.* August.

those associated with nuclear accidents: they involve low probability high cost risks for which the likelihoods of an accident are not well understood. Hence there are lessons to be learned from these other areas. We shall discuss insurance against floods, hurricanes and earthquakes as well terrorism insurance.

Flood Insurance

Insurers have experimented over the years with providing protection against water damage from floods, hurricanes and other storms. After the severe Mississippi Floods of 1927, they concluded that the risk was too great for them to provide coverage on their own and refused to do so again. As a result, Congress created the National Flood Insurance Program (NFIP) in 1968, whereby homeowners and businesses could purchase coverage for water damage. Private insurers market flood policies, and the premiums are deposited in a federally operated Flood Insurance Fund, which is then responsible for paying claims. The stipulation for this financial protection is that the local community makes a commitment to regulate the location and design of future floodplain construction to increase safety from flood hazards. The federal government established a series of building and development standards for floodplain construction to serve as minimum requirements for participation in the program. The creation of the Community Rating System in 1990 has linked mitigation measures with the price of insurance in a systematic way (Pasterick, 1998)[32].

Hurricane Insurance

The need for hurricane insurance is most pronounced in the state of Florida. Following Hurricane Andrew in 1992, nine property-casualty insurance companies became insolvent, forcing other insurers to cover these losses under Florida's State Guaranty Fund. Property insurance became more difficult to obtain as many insurers reduced their concentrations of insured property in coastal areas. During a special session of the Florida State Legislature in 1993 the Florida Hurricane Catastrophe Fund (FHCF) was created to relieve pressure on insurers to reduce their exposures to hurricane losses. The FHCF, a tax-exempt trust fund administered by the State of Florida, is financed by premiums paid by insurers that write policies on personal and commercial residential properties. The fund reimburses a portion of insurers' losses following major hurricanes (above the insurer's retention level) and enables insurers to remain solvent (Lecomte and Gahagan, 1998)[33]. The four hurricanes that hit Florida in the fall of 2004 (Charley, Frances, Ivan and Jeanne) caused an estimated $23 billion in insured losses, with only about $2.6 billion paid out by the Fund. Each hurricane was considered a distinct event, so that retention levels were applied to each storm before insurers could turn to the FHCF.

During a special session of the Florida State Legislature in January 2007, the capacity of the FHCF was expanded to $27.75 billion in insurance. However, there would have to be

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[32] Pasterick, E. (1998), "The National Flood Insurance Program," Chapter 6 in Kunreuther, H. and Roth, R., Sr. (eds.), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States.* Washington, D.C: J. Henry Press.

[33] Lecomte, E. and Gahagan, K. (1998), "Hurricane Insurance Protection in Florida" Chapter 5 in Kunreuther, H. and Roth, R., Sr. (eds.), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States.* Washington, D.C: J. Henry Press.

no damaging hurricanes until the year 2023 for the FHCF to pay all its claims from a hurricane with a 100 year return period. If such a disaster occurred before that date, the additional capacity to meet all the FHCF claims would have to be come from assessing all property and casualty lines of business excluding workers' compensation, accident and health, medical malpractice and flood insurance.[34]

Earthquake Insurance

The history of earthquake activity in California convinced legislators that this risk was too great to be left in the hands of private insurers alone. In 1985, a California law required insurers writing homeowners coverage on one to four unit residential buildings to also offer earthquake coverage. Since rates were regulated by the state, insurers felt they were forced to offer coverage against older structures in poor condition, with rates not necessarily reflecting the risk. Following the 1994 Northridge earthquake, huge insured property losses created a surge in demand for coverage. Insurers were concerned that if they satisfied the entire demand, as they were required to do by the 1985 law, they would face an unacceptable level of risk and become insolvent following the next major earthquake. Hence, many firms decided to stop offering coverage or restricted the sale of homeowners' policies in California.

In order to keep earthquake insurance alive in California, in 1996 the State legislature authorized the formation of the California Earthquake Authority (CEA), a state-run insurance company that provides earthquake coverage to homeowners. The innovative feature of this financing plan is the ability to pay for a large earthquake while committing relatively few dollars up front. There is an initial assessment of insurers of $1 billion to start the program and then contingent assessments to the insurance industry and reinsurers following a severe earthquake. Policyholders absorb the first portion of an earthquake through a 15 percent deductible on their policies (Roth, 1998).[35] However, twelve years after the creation of the CEA, the take-up rate for homeowners is about 15 percent, down from 30 percent when the California State Legislature created the CEA (Risk Management Solutions, 2004)[36]. It is questionable how effective this program will be in covering losses should a major earthquake occur in California.

Federal Aviation Administration 3rd Party Liability Insurance Program

Since the terrorist attacks of September 11, 2001, the U.S. commercial aviation industry can purchase insurance for third party liability arising out of aviation terrorism. The current mechanism operates as a pure government program, with premiums paid by airlines into the Aviation Insurance Revolving Fund managed by the Federal Aviation Administration (FAA).

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[34] Kunreuther, H. and Michel-Kerjan (eds.), *At War with the Weather* Cambridge, MA: MIT Press 2009

[35] Roth, R., Jr. (1998), "Earthquake Insurance Protection in California", Chapter 4 in Kunreuther, H. and Roth, R., Sr. (eds.), *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States.* Washington, D.C: J. Henry Press. .

[36] Risk Management Solutions (2004), "The Northridge, California Earthquake. A 10-Year Retrospective", May.

As the program carries a liability limit of only $100 million, losses paid by government sources in the event of an attack will almost surely exceed those available through the current insurance regime. In that case, either the government would need to appropriate additional disaster assistance funds as it did in the aftermath of September 11th, or victims would be forced to rely on traditional sources of assistance (Strauss, 2005).[37]

Terrorism Insurance

Insuring the risks from terrorist attacks has some similarity to insuring nuclear accidents – indeed one worst-case terrorist scenario involves terrorists causing a nuclear accident. In both cases the probability distribution over possible losses is largely a matter of guesswork, with no historical record to provide a benchmark. And in both cases, government policies can influence the risks. So it is worth spending some time reviewing the extensive recent discussion of how to manage terrorist risks.

Prior to September 11, 2001 terrorism exclusions in commercial property and casualty policies in the U.S. insurance market were extremely rare (outside of ocean marine) because losses from terrorism had historically been small and, to a large degree, uncorrelated. Attacks of a domestic origin were isolated, carried out by groups or individuals with disparate agendas. Thus the country did not face a concerted domestic terrorism threat, as did countries such as France, Israel, Spain and the UK.

In fact, insurance losses from terrorism were viewed as so improbable that the risk was not explicitly mentioned nor priced in any standard policy and it was never excluded from so-called "all-risk" policies with the exception of some marine cargo, aviation and political risk policies. Even the first attack on the World Trade Center (WTC) in 1993[38] and the Oklahoma City bombing of 1995[39] were not seen as being threatening enough for insurers to consider revising their view of terrorism as a peril worth considering when pricing a commercial insurance policy. Since insurers and reinsurers felt that the likelihood of a major terrorist loss was below their threshold level of concern, they did not pay close attention to their potential losses from terrorism in the United States (Kunreuther and Pauly, 2005)[40].

Terrorism presents a set of very specific problems regarding its insurability by the private market alone that have similar features to nuclear power. These include the potential for catastrophic losses, the existence of interdependencies and the dynamic uncertainty associated with the risk. All of these factors increase the amount of capital that insurers

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[37] Andrew Strauss (2005), "Terrorism Third Party Liability Insurance for Commercial Aviation, Federal Intervention in the Wake of September 11*", The Wharton School, Center for Risk Management and Decision Processes, June, Philadelphia.
[38]The 1993 bombing of the WTC killed 6 people and caused $725 million in insured damages. See Swiss Re (2002), *Focus Report: Terrorism—dealing with the new spectre.* Zurich: Swiss Re, February.
[39] Prior to Sept. 11th, the Oklahoma City bombing of 1995, which killed 168 people, had been the most damaging terrorist attack on domestic soil, but the largest losses were to federal property and employees and were covered by the government.
[40] Kunreuther, H. and Pauly, M. "Terrorism Losses and All-perils Insurance", *Journal of Insurance Regulation* (in press).

must hold to provide terrorism risk insurance coverage. The associated costs of holding that capital increases the premiums they would need to charge. The fact that government actions are likely to influence both the will and capacity of terrorist groups to attack (foreign policy, counter-terrorism) and on the level of potential losses poses additional challenges is closely related to the fact that the Nuclear Regulatory Commission influences the degree of acceptability of the risks facing nuclear power plants. The conclusion that emerges from experience with terrorist coverage since 9/11/2001 suggests that this risk is not well handled by the insurance market. This was recognized by the passage of TRIA, the Terrorist Risk Insurance Act, which established a role for the federal government similar to that assigned to it in the P-A Act.

To more fully understand the losses from 9/11 from an insurability perspective, one can compare this event with other types of extreme events that have affected the (re)insurance industry. Table 2 presents the 20 largest worldwide insurance losses due to natural catastrophes and man-made disasters from 1970 to 2007. Prior to 9/11 losses, the largest loss experienced by the insurance industry was Hurricane Andrew, which devastated the coasts of Florida in August 1992 and inflicted $21.5 billion in claims payments (indexed to 2004) (Swiss Re, 2005)[41]. When one adds the $6-7 billion in payments by U.S. Federal Victim Compensation Fund to victims of 9/11 and their families, the claims from the 9/11 terrorist attacks are almost twice those from Hurricane Andrew (Congressional Budget Office, 2005).[42] Claims from a major nuclear accident could be very much larger even that those associated with 9/11.

TABLE 2. THE 20 MOST COSTLY INSURED IN THE WORLD, 1970-2007 (INDEXED TO 2007 PRICES)

U.S.$ Billion (indexed to 2007)	Event	Victims (Dead or missing)	Year	Area of Primary Damage
46.3	Hurricane Katrina	1,836	2005	USA, Gulf of Mexico, et al.
35.5	9/11 Attacks	3,025	2001	USA
23.7	Hurricane Andrew	43	1992	USA, Bahamas
19.6	Northridge Earthquake	61	1994	USA
14.1	Hurricane Ivan	124	2004	USA, Caribbean, et al.
13.3	Hurricane Wilma	35	2005	USA, Gulf of Mexico, et al.
10.7	Hurricane Rita	34	2005	USA, Gulf of Mexico, et al.
8.8	Hurricane Charley	24	2004	USA, Caribbean, et al.
8.6	Typhoon Mireille	51	1991	Japan
7.6	Hurricane Hugo	71	1989	Puerto Rico, USA, et al.
7.4	Winterstorm Daria	95	1990	France, UK, et al.
7.2	Winterstorm Lothar	110	1999	France, Switzerland, et al.
6.1	Winterstorm Kyrill	54	2007	Germany, UK, NL, France
5.7	Storms and floods	22	1987	France, UK, et al.
5.6	Hurricane Frances	38	2004	USA, Bahamas
5.0	Winterstorm Vivian	64	1990	Western/Central Europe
5.0	Typhoon Bart	26	1999	Japan
4.5	Hurricane Georges	600	1998	USA, Caribbean
4.2	Tropical Storm Alison	41	2001	USA
4.2	Hurricane Jeanne	3,034	2004	USA, Caribbean, et al.

Sources: Wharton Risk Center with data from Swiss Re and Insurance Information Institute

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[41] Swiss Re (2005), "Natural catastrophes and man-made disaster in 2004: more than 300 000 fatalities, record insured losses", *Sigma* no 1/2005.

[42] CBO (2005), *Federal Terrorism Reinsurance: An Update*, Washington, DC: January.

Linking Insurance with Third Party Inspections Via Public-Private Partnerships[43]

The Price-Anderson Act needs to be modified by providing a more effective way of monitoring utilities and rewarding those that have undertaken risk reducing measures. Today there is inadequate inspection of nuclear plants due to limited personnel at the NRC and the lack of incentives by utilities to undertake these measures on their own. Lower inspection levels (or other effective methods for compliance evaluation) tend, not surprisingly, to lead to lower compliance rates. (Weil, 1996). They also reduce opportunities for government to find and require firms to correct the sorts of risky practices regulations seek to reduce.

Role of Third Party Inspections

One way to change the situation is to provide economic incentives for utilities to have their plants inspected so that can demonstrate that they are operating safely and be rewarded with a lower insurance premium. The combination of private inspection and insurance is a potentially powerful one for meeting and often exceeding environmental and safety regulations. If an inspection reveals ways that a company can reduce its safety and environmental risks and the costs of undertaking this activity can be recouped in the form of lower insurance premiums that justify the expenditure, then firms will want to adopt these measures.

Insurers have an economic incentive to conduct inspections that focus on risk reduction because they want to reduce the likelihood of paying a claim and the size of their payments. The insurer's economic survival depends on estimating the risk of future losses accurately, not on assuring compliance with government laws. To the extent that regulations are well-aligned with risk-reducing behaviors, insurers are likely to uncover non-compliance problems and encourage their correction. To the extent that they are not, insurers have little reason to inspect for regulatory compliance

How Inspections Aid Insurers

Insurance is likely to have greater risk-reducing potential if insurers include inspections, along with other forms of risk assessment, as part of the insurance-rating package. Private insurance inspections can play an important role for several reasons. At the most basic level, insured firms will be more aware of environmental and safety risks as well as regulatory obligations. This promises to be especially valuable in areas of health, safety and the environment that are plagued by low inspection levels.

Gathering Risk Information Inspections also enable the insurer to determine what the losses are likely to be as a function of the investments by firms in risk-reducing

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[43] This subsection is based on Kunreuther, Metzenbaum and Schmeidler (2006) "Private Inspections and Mandatory Insurance for Managing Safety and Environmental Risks" in Cary Coglianese and Jennifer Nash ed *Leveraging the Private Sector: Management-Based Strategies for Improving Environmental Performance* (Washington, DC: Resources for the Future

measures. Insurers can also provide guidance to the firm as to what types of actions would be most profitable for them to assure compliance with regulations and go beyond it. If insurers increase their inspections of a firm's safety practices prior to policy renewals, firms will have incentives to comply with the regulations, at least to the extent they suggest risk-reducing behaviors.

Use of Claims Data to Modify Existing Standards   Studying information about claims, incidents, and non-compliance may identify recurring events and high-cost problems needing new laws or standards. If an insurer has a large enough set of clients and can pool information so as not to reveal identities of firms, then it can provide valuable information to the public sector on the types of claims that have been made. This will enable the public sector agency to modify codes and standards in an appropriate fashion.

Rewarding Firms for Reducing Risks   Insurers always have the option of raising rates to reflect additional risks that they uncover. Insurers can also bestow reputation-enhancing rewards on firm operating at the highest level of compliance and taking risk-reducing actions beyond their formal obligations. Seals of approval or Gold Stars are valuable to the firm to the extent that customers, employees, or investors make decisions on the basis of safety and environmental records of different organizations. Some commercial partners will see the Gold Star as the designation of a quality operation and favor doing business with these firms. For example, Ford and GM require their suppliers to be ISO14001 certified.

The firm that earns the seal or Gold Star will have an incentive to reveal its third-party commendation to the public as well to the government. Regulatory agencies can utilize this information to target inspections to firms that have not had this official recognition. By reducing the universe of firms for possible inspection, there is a greater chance that those who have not complied with the regulation will be audited by a governmental agency. By raising the probability of a public inspection, more and more firms should adhere to regulations over time.

An insurance commendation is likely to have greater veracity than other sorts of third-party certifications because most third-party inspectors are paid a fee for their services by the inspected firm, and therefore feel a constant tug to keep their customer happy without a strong counter-balancing financial tug to identify risks that may require costly corrections. Insurers, in contrast, have a direct financial interest in reducing risk through their inspections.

Summary and Conclusions

On the general issue of environmental liabilities, it seems clear that the degradation of natural capital in systems as diverse as the climate system or the coastal barrier island systems can lead to significant social costs which are generally not well-covered by current insurance products. These end up as liabilities of the Federal Government by default, often as a part of the portfolio of the Federal Emergency Management Agency.

In the field of nuclear risks, the Price-Anderson Act transfers significant liabilities to the Federal Government. If there is an expansion of the use of nuclear power in the next decade, as appears to be the case, then these liabilities could increase further. Although it is clear that the contingent federal liabilities associated with P-A are large, it is hard to be precise about them. The probability of a major accident at a nuclear reactor (e.g. a core meltdown) and its costs are ambiguous.

There are, however, certain things that are clear. One is that the risk is to some degree under the control of the Federal Government, via the Nuclear Regulatory Commission if it enforces safety standards and influences the siting of nuclear reactors in remote areas. There is empirical evidence that the NRC does not aggressively pursue and penalize mismanagement of nuclear power stations, and that the Federal authorities are not sensitive to the increase in potential costs associated with siting near densely populated areas. There is scope for better management of this aspect of Federal financial risks, possibly by the use of third party safety auditors to supplement the NRC. In addition, the premiums charged to utilities under the P-A Act do not reflect their stations' safety risks: this would be another way of reducing the risk of a disaster. Currently there are few incentives for a utility to improve its safety record.

There do seem to be compelling reasons for thinking that Federal intervention is necessary if the risk of nuclear disaster is to be adequately insured. There are many characteristics of this risk that probably make it uninsurable. But that does not mean that the P-A Act is the best solution. We have reviewed the way in which catastrophic risks are managed in other areas, such as flood, hurricane, earthquake and terrorist risks. There has been considerably more constructive public debate about these risks than about nuclear risks. Typical of most of these areas is a first insurance layer covered by private insurance markets, with government coverage of losses in excess of the private risk cap. In the case of the P-A Act, the private coverage is just $300 million per incident, with a pool insurance vehicle covering the next $10 billion. There is no explicit statement of the government's role and liabilities. The figure of $300 million surely does not exhaust the private coverage available for nuclear disasters: for other areas the private sector provides coverage as high as ten billion or more. More of the nuclear risk could surely be met through the private sector, which would not only reduce the Federal liability but also provide increased incentives for risk management, sadly lacking under the current regime.