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PREPARING FOR THE IMPROBABLE: SAFETY INCENTIVES AND THE PRICE-ANDERSON ACT

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ABSTRACT

The Price-Anderson Act requires commercial nuclear power plants to maintain (approximately) $660 million in off-site accident coverage through two forms of insurance: market-provided private insurance and self-insurance in the form of retrospective assessments of reactor owners. We examine how changes in retrospective assessments influence the safety incentives of nuclear reactor owners. As one would expect, increases in self-insurance premiums increase the incentive to install safety systems more quickly. However, a more important conclusion is that self-insurance premiums as a function of reactor riskiness, rather than equal payments by reactor owners, yield a higher level of safety than under the current law.

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The partial melt down at Three Mile Island showed that losses to the public from nuclear accidents could be less than those sustained by the electric utility owning the reactor. But the accident at Chernobyl impressed the world with the enormity of its off-site damages. During the week of the accident, subcommittees in both the U.S. Senate and House of Representatives were debating the renewal of the Price-Anderson Act (PAA). The Act codifies insurance for nuclear reactors by providing for two levels of coverage: private market-provided insurance and industry self-insurance. However, the coverage for new facilities,including Department of Energy contractors, will expire on August 1, 1987.

In considering the renewal of the PAA, policy makers should realize that the electric utility's behavior regarding safety is not independent of insurance premiums and coverage. The size of insurance premiums affects the firm's expected income and, hence, the incentive to engage in accident-avoidance behavior to protect this income. Attempts to design socially optimal legislation should not exclude the consideration of utility reaction to changes in the PAA.

A more comprehensive approach to examining the effects of amendments to the Act is to consider how they alter investment in reactor safety systems. The marginal benefit to the firm of responding quickly to new opportunities for enhanced safety is the increase in the probability of enjoying income without an accident. But the cost of a safety system generally decreases with time as other firms push a new technology down its learning curve. Insurance complicates these opposing tendencies. As we demonstrate, installation times decrease with increases in industry self-insurance premiums and with the positive correlation of these premiums with reactor safety.

Insuring Nuclear Power Plants

The Price-Anderson Act has the dual purpose of "protect(ing) the public and . . . encourage(ing) the development of the atomic energy industry" (42 U.S.C. 2012i). It protects the public by providing compensation for personal injury and property damage to roughly $660 million.

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It encourages the development of the industry by indemnifying plant operators and their suppliers for off-site damages above $660 million. In exchange for indemnity, operators assume strict liability for their actions after an "extraordinary nuclear occurrence," implying both a substantial discharge of radiation and substantial damages to persons or property.[1] For lesser damages the rules of state tort law apply.[2]

To compensate these losses, the PAA defines two levels of insurance.[3] The first is $160 million in private insurance provided by American Nuclear Insurers (ANI). Premiums for commercial plants are adjusted to reflect size, location (population density and property values), and, after the completion of two years of operation, the reactor's probability of having an accident, measured by an "Engineering Rating Factor." The factor is based on plant characteristics including radiation exposure, regulatory performance, significant events, and containment integrity. Currently, the annual average private insurance premium for operating reactors is about $800,000.[4] The premium can be reduced by up to 20%, or increased by up to 30%, based on the safety performance of the reactor.

Second, there is a layer of industry self-insurance. After an accident, reactor operators would be assessed. I equally not more than $5 million apiece, i.e., the firm owning the disabled reactor would pay the same amount for off-site damages as all other firms. Assuming 100 reactors, the second layer provides $500 million in coverage. The Federal District Court in the district where the accident occurs would distribute these funds. If damages exceed the limit, the Court would apply bankruptcy principles by distributing funds to individuals in proportion to total damages. Above $660 million, the nuclear power plant owner, the builders, and the parts suppliers are relieved of financial responsibility for damages to the public.

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1. An extraordinary nuclear occurrence is the death or hospitalization, within 30 days of the event, of five or more people, or $2,500,000 or more of damage off-site to one person, $5 million or more such damage in the aggregate, or $5,000 or more of damage off-site to fifty or more persons (Subpart E, 10 C.F.R. 140).
2. See, for example, Silkwood V. Kerr-McGee Corp., 485 F. Sup. 566 (D. C. Oklahoma, 1979) affirmed in part, reversed in part on other grounds, 667F.2d 908 (1981), reversed on other grounds, 104S.Ct 615 (1984).
3. Other forms of nuclear power plant insurance include (1) property coverage (to $1 billion) available from American Nuclear Insurers or from a consortium of utilities, Nuclear Mutual Ltd., and (2) replacement power coverage from Nuclear Electric Insurance Ltd. The latter involves a six-month deductible, i.e., it will not cover the first 26 weeks after the accident, and will provide payments for only two years. The most important remaining uncovered cost is the principal and interest payments on debt and dividends to equity. See John Graham, "Three Mile Island Status Report," presented at the Atomic Industrial Forum's Nuclear Insurance Issues Conference, February 14, 1983.
4. A portion of the premium is subject to refund following a ten-year loss experience period in the industry. According to ANI, refunds have been made in all years since 1967, the first year of eligibility under the refund plan. For example, in 1983 ANI refunded 37% of the total premiums paid in 1973. Even with the high administrative costs implied by this refund, the average premium of $800,000 implies a probability of an extraordinary nuclear occurrence that is at least thirty times greater than that estimated for the average plant by the NRC (see discussion in text below). For example, the ANI's premium schedule implies an expected loss of approximately $35 million conditional on an extraordinary nuclear occurrence. If administrative costs accounted for 60% of premiums, the implied probability of an occurrence is approximately 0.9% (=0.4 x $0.8 million/$35 million). Either the private-market insurance is extremely expensive to administer or private insurers perceive a much higher risk of reactor accidents than nuclear plant regulators, or both.

The 99th Congress was unsuccessful in renewing the Price-Anderson Act. On the first day of the session (January 3, 1985) two bills were introduced: HR 51 by Price (D-Illinois) would have increased the maximum *ex post* assessment per plant from $5 million to $10 million, whereas HR 445 by Seiberling (D-Ohio) called for compensation of all damages. These two bills, plus HR 2665 by Weiss (D-New York), were consolidated for mark-up in the Energy Subcommittee of the House Insular and Interior Affairs Committee. On the second day of discussion, Udall (D-Arizona), chairman of both the committee and subcommittee, introduced HR 3653. As shown in Table 1, the bill increased the first layer of insurance to $200 million (from $160 million) and raised the maximum payment by each reactor operator to $100 million (from $5 million), increasing total coverage to $10.2 billion. Although the subcommittee reduced the upper limit to $2.5 billion and the committee raised it to $8.2 billion, a compromise of $6.5 billion was reached before the bill was sent on. Both the House Energy and Commerce Committee and the Science and Technology Committee approved the $6.5 billion limit. But the bill did not come to the House floor.

In the Senate, S 1225, introduced by Simpson (R-Wyoming) and McClure (R-Idaho), won approval with amendments from the Senate Committee on Energy and Natural Resources and the Subcommittee on Energy Research and Development (Table 2). Although S1225 would have increased total coverage to only $2.6 billion, it would have done so by allowing different *ex post* assessments for individual reactor operators: "The (Nuclear Regulatory) Commission may establish amounts less than the standard premium for individual facilities taking into account such factors as the facility's size, location, and other factors pertaining to the hazards" (p. 5). The bill was referred to the Senate Environment and Public Works committee where it was considered with S 445 by Hart (D-Colorado), S 1761 by Stafford (R-Vermont), and S 2072 by Metzenbaum (D-Ohio). The Environment Committee approved a $6.5 billion limit, as in the House, but there was no reconciliation among Senators before the end of the last session.[5]

Investment In Safety Systems

Although many issues have been debated in Congress (e.g., whether members of the self-insurance pool could recover payments from the operator of the damaged reactor, see "Subrogation" in Tables 1 and 2, or whether coverage should be adjusted for inflation), primary attention has been focused on the maximum coverage of the first and second layers of insurance.[6] But an issue of perhaps greater significance is the influence of these changes in coverage on the incentives to install safety systems. For example, a number of safety systems were prescribed in "Clarification of Three

5. As of April 1987, HR 1414, co-sponsored by Udall and Philip Sharp (D-Indiana)had been reported out of Subcommittee on Energy and the Environment to the House Committee on Interior and Insular Affairs. It is similar to the amended version of HR 3653 at the end of the 99th Congress. In the Senate, the Energy Committee has considered S 748, a bill that does not address liability limits for commercial nuclear power plants, limiting itself to Department of Energy contractors. Given that three committees in the House and two in the Senate have jurisdiction, it is likely that a short-term extension will be required before resolving the issues that stopped Price-Anderson renewal in 1986.

6. On other aspects of the attempt to renew the PAA, see "Price-Anderson Legislation Dies in Final Days of 99th Congress," *Public Utilities Fortnightly* (November 13, 1986), p. 38-39.

Mile Island Action Plan Requirements: Requirements for Emergency Response Capability" (NUREG-0737). These include the Safety Parameter Display System (SPDS), Upgraded Emergency Operating Procedures (EOPs), and Emergency Response Facilities (ERFs). The SPDS provides computer-generated video displays of important safety-related information to plant operators.[7] EOPs describe appropriate operator response to abnormal conditions without the need to diagnose specific events. The ERFs are on- and off-site resource centers where utility and regulatory personnel can monitor reactor operation during emergency situations. While the Nuclear Regulatory Commission (NRC) made installation of these systems mandatory, no deadlines were set for installing them: "... the Commission has adopted a plan to establish realistic plant-specific schedules that take into account the unique aspects of the work at each plant" (NUREG-0737, Supp. 1, p. 2, July 1982).

Here, we examine how changes in self-insurance coverage would influence the response time to the implementation of NUREG-0737 requirements. We assume that utilities attempt to maximize the present value of their investment in reactor safety systems by choosing optimal dates of installation.[8] The evaluation of investment alternatives takes account of net cash flows under various scenarios: (1) no accident at the firm's plant and no accident in the industry, (2) no accident at the firm's plant, but an accident in the industry, and (3) an accident at the firm's plant. The present value of the safety system is equal to the sum of the discounted probability of receiving normal income over time plus the net return on investment in the safety system.[9] The optimal installation date depends on the size of the insurance premiums, the interest rate, the cost of the safety system, the percentage of system cost recovery, the change in cost as other firms engage in research and development, the amount of unrecoverable expenses after an accident, and the probability of an accident before and after the installation of the safety system.

What are the probabilities of these outcomes? Assessments of the probability of reactor accidents are hampered by the lack of experience with nuclear power technologies. One alternative is a detailed analysis of the probability of failure for reactor sub-systems, known as a probabilistic risk analysis (PRA). The most extensive PRA was conducted for the Atomic Energy Commission and the Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants* (October 1975). The report concluded that the best estimate of the probability of a core melt down per reactor year was 0.005%, i.e., with 100 operating reactors, there would be a 0.5% chance of melt down in the industry each year. More recent studies of particular plants place the probability of a core melt down between 0.1% and 0.0002% per reactor year.[10] Also, the NRC has updated its estimate to 0.03%, leading to a *New York Times*' headline claiming "By 2005, Nuclear Unit Sees 50-50 Chance of Meltdown," (April 17, 1985; p. A16).

7. See Joseph P. Joyce and George W. Lapinsky, "A History and Overview of the Safety Parameter Display System Concept," *IEEE Transactions on Nuclear Sciences* NS-30, 1 (February 1983).

8. An article by Peter Huber and Donnamarie McCarthy, "The Role of the Price-Anderson Act in the Contemporary Tort System," *Public Utilities Fortnightly* (May 1, 1986), pp. 22-28, claims "It is impossible for engineers and financial analysts to make fine (marginal safety) calculations" (p. 27). We believe, however, that utility executives behave rationally and that we can model their behavior, whether or not these decision makers can articulate the reasons for their actions.

9. For a technical development of the investment model, see Jeffrey Dubin and Geoffrey Rothwell, "Insurance for Nuclear Plant Accidents and the Adoption of Reactor Safety Systems," (California Institute of Technology, December 1986).

10. See V. Joksimovich, "A Review of Plant Specific PRAs," *Risk Analysis* 4,4 (1984), pp. 255-66.

To evaluate changes in the retrospective assessment policy, we assume that the probability of an accident without the safety system is equal to 0.03% and that the new safety system reduces the probability of an accident at an "average" plant by one-tenth, i.e., to 0.027%. While it is difficult to determine the *ex ante* effectiveness of any safety system, the NUREG-0737 requirements should reduce operator error in the interpretation of abnormal events through the verification and validation of conflicting signals, the rationalization of operating procedures in times of crisis, and the integration of personnel. For example, since the mid-1970s, operator error has lead to over 700 forced shutdowns of nuclear reactors, resulting in more than 23,000 hours of downtime, not including operator error at Three Mile Island, Unit 2. (See the NRC's *Licensed Operating Reactors*, NUREG-0200, volumes 1-10.) Of course, as the effectiveness increases, the value of these systems to the firm increases, decreasing the optimal waiting time of system installation.

The cost of responding to NUREG-0737 is several million dollars, but is expected to fall with time as more utilities install the safety systems.[11] A utility can recover a portion of its investment through the allowed rate of return on its rate base, with the portion of recovery differing among utilities owing to differences in the policies of state regulatory commissions. These differences, as well as the variables discussed above, produce a sequencing of optimal adoption dates among utilities: utilities adopting first in states that allow all or most of the cost of the safety system to be included immediately in the rate base, holding other variables constant.

Further, for purposes of illustrating the influence of retrospective assessments based on reactor riskiness, we assume that the first utilities to respond to NUREG-0737 would have to spend $17 million, $8.5 million of which would decline by 10% per year. Also, while firms are usually able to pass their private insurance premiums to their customers as a cost of producing electricity, to examine the full influence of changes in insurance premiums on firm behavior, we assume that the utility's customers are not charged for retrospective assessments. Finally, we assume that state regulators would allow 90% of the safety system investment to be included in the utility's rate base.[12]

In Table 3 we consider the influence of retrospective insurance premiums on optimal safety system installation times.[13] We allow (1) the maximum *ex post* assessment to vary between $5 and $105 million and (2) a decrease of the assessment based on the implementation of the safety system of 0 to 30%.[14] In our base case of the status quo, the optimal installation date for an "average" plant

11. The cost of the SPDS alone ranges from less than $1 million, using small dedicated computers, to a $20 million system meeting military specifications. See papers presented at the Electric Power Research Institute conference on SPDS implementation, May 6-8, 1986.

12. The 10% excluded from the rate base arises from regulatory lag. Some state commissions allow the inclusion of Research and Development expenses in the rate base, others do not. Almost all permit the inclusion of Materials and Supplies. See National Association of Regulatory Utility Commissioners, Part III, Section C, "Rate Base," *Annual Report*.

13. We choose the following additional values for our analysis: a real discount rate of 3% and annual purchase-power costs of $510 million (equal to a price of 7 cents per kilowatthour of electricity with a 70% capacity factor at a 850 megawatt power plant). A recovery rate of 80% from the state regulators yields an annual cost to the firm of approximately $100 million. We believe, based on the experience of General Public Utilities, that $100 million per year is a reasonable expected cost to the firm sustaining a reactor accident. Also, while the expected value of the *ex post* assessment depends on the probability distribution over the magnitude of losses, we assume that in the event of an extraordinary nuclear occurrence, firms pay the full assessment.

14. Reductions to a single firm would require increases to other firms. Of course, in the implementation of a differential retrospective assessments program, premiums would be based on overall safety performance, not simply the installation of a

is 3.81 years after the safety system was mandated (see the upper, left-hand corner of Table 3). As the *ex post* assessment increases, firms install more quickly. While differential retrospective assessments induce little change with expected premiums of only $5 million (i.e., a decrease of approximately two months), at assessments of $65 million, a 30% reduction induces firms to install twice as quickly (i.e., a decrease from 3.58 to 1.65 years).

Aggregate benefits of such reductions depend on the distribution of losses to society after a nuclear accident. However, given that optimal installation dates occur when private costs to the firm, including expected retrospective assessments, equal private benefits, reduction in the installation times improve social welfare with little increase in social cost. Policy makers must determine whether the benefits of greater safety outweigh the administrative costs of instituting differential retrospective assessments.[15]

While insurance premiums are our primary concern, federal regulation is not alone in influencing electric utility behavior. State regulatory commissions determine the portion of accident-related costs that can be charged to customers and the level of recovery on safety-system investment. As firms are more able to charge customers for the accident, the incentive to avoid reactor accidents decreases. As the regulatory commission allows the firm to recover a greater percentage of the investment in safety systems, the influence of declines in technology costs diminishes, so the firm installs more quickly. Hence, Congress should not ignore state utility commission policies regarding investment and expense accounting.

For example, after the accident at Three Mile Island (TMI), General Public Utilities (GPU) and its operating companies (Metropolitan Edison Co., Pennsylvania Electric Co., and Jersey Central Power and Light) faced regulators in Pennsylvania and New Jersey. To replace power from TMI, GPU arranged a revolving credit agreement (RCA) of $412 million in June 1979.[16] It was not until May 1980 that the Pennsylvania Public Utilities Commission and the New Jersey Board of Public Utilities allowed rate increases to cover replacement power. However, no allowance was made for interest on debt borrowed through the RCA. Further, because TMI was no longer "used and useful," it was removed from GPU's rate base. Thus, no funds could be raised through revenues to cover interest on debt or dividends to equity. Only after the restart of TMI-Unit 1 in October 1985 did regulators allow earnings on GPU's investment in TMI-1. State regulators did not require GPU customers to contribute to the cleanup of TMI-2, estimated at $1 billion, until after the restart of TMI-1. While insurance programs instituted since March 1979 should ease cash-flow problems after a reactor accident, state regulators will be decisive in determining the financial viability of a utility

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series of safety systems. Thus, reductions in *ex post* assessments to owners of safer plants (measured, for example, by the Engineering Rating Factor) would require increases in assessments from the owners of riskier reactors. The model presented here should generalize to other forms of safety behavior at nuclear reactors.

15. The utility's optimal installation date may differ from the socially optimal date because of the difference between the *ex post* insurance assessment and off-site damages from an accident. It is beyond our scope to define a socially optimal insurance and regulatory program. For discussions of the social optimality of Price-Anderson, see Linda Cohen, "Chapter 2: Optimal Compensation Systems: The Case of the Price-Anderson Act," in "Essays on the Economics of Licensing Nuclear Power Plants," Ph.D. dissertation, California Institute of Technology (September 1978) and John M. Marshall and Louis I. Lieb, "Liability and Safety in Nuclear Power Plants," UCLA-ENG-7724 (February 1977).

16. See "Statement of the Honorable Allen E. Ertel," in *Financial Fallout From Three Mile Island*, Hearings before the House Subcommittee on Energy Conservation and Power, May 1, 1981.

sustaining an extraordinary nuclear occurrence.

Of course, our results depend on our model and on the numerical assumptions underlying our calculations. For example, as cost declines more rapidly over time, firms have a greater incentive to wait for cheaper systems. And as the discount rate increases, the present value of waiting for a cheaper system decreases, leading to longer waiting times. Similarly, as research and development costs increase, the firm has a greater incentive to wait until costs fall. (This supports the existence of early cooperative research and development among utilities through organizations such as the Electric Power Research Institute.) Increases in the size of the reactor encourage quicker installation, because of the increase in the opportunity cost of losing the reactor's power. Finally, as the probability of an accident increases, firms install sooner.[17]

Conclusions

The current debate over Price-Anderson should consider the Act's influence on the timely adoption of safety equipment. If higher levels of coverage are required, Congress could assign a larger maximum *ex post* assessment to the owners of riskier reactors. This proposal is consistent with the original version of Simpson and McClure's Senate Bill 1225, which allowed for differential assessments. For example, after an accident, firms might be required to pay the same proportion of industry self-insurance coverage as they now pay for market-based private insurance. This procedure places the incentive of accident avoidance on the owner of a risky plant, as the insurance market does. It was unfortunate that the liability limits of S 1225 prompted its rejection without the retention of the differential assessments provision. While providing the same level of coverage, differential retrospective assessments induce firms to install safety systems sooner than the amendments to the Price-Anderson Act considered at the end of the previous Congress.

17. Dubin and Rothwell (1986) empirically examine the installation of the SPDS. We find that firms owning plants with greater numbers of equipment failures and operational errors, resulting in plant shutdowns of more than 72 hours, installed the SPDS sooner than other firms. We interpret this finding as support for our contention that as the probability of an accident increases, firms install safety systems sooner.

TABLE 1: U.S. HOUSE BILLS OF THE 99TH CONGRESS COMPARED

BILL NUMBER:	STATUS QUO	H51	H445	H2665	H3653
PRIMARY SPONSOR:		PRICE	SEIBER-LING	WEISS	UDALL
WOULD EXTEND PAA TO	1987	1997	NA	2007	1997
MAXIMUM COVERAGE ($MILLIONS)	660	1160	TOTAL	TOTAL	10200
INDEMNITY?	YES	YES	YES	NO	YES
INFLATION ADJUSTMENT?	NO	NO	NO	YES	YES
FIRST LAYER:					
MINIMUM COVERAGE AMOUNT	160	160	160	160	200
SECOND LAYER:					
TOTAL MAXIMUM AMOUNT	5	10	5	TOTAL	100
ANNUAL MAXIMUM AMOUNT	5	10	5	TOTAL	10
DIFFERENTIAL PAYMENTS?	NO	NO	NO	YES	NO
SUBROGATION: WHO CAN SUE WHOM?					
VICTIM VS VENDOR	NO	NO	NO	NO	NO
UTILITY VS UTILITY	NO	NO	NO	YES	YES
FEDERAL VS UTILITY	NO	NO	NO	YES	YES
TYPES OF INCIDENTS:					
EXTRAORDINARY EVENTS	YES	YES	NO	NO	NO
NON-EXTRAORDINARY EVENTS	TORT	TORT	STRICT	STRICT	STRICT
PERSONAL INJURY LIMITATIONS:					
YEARS AFTER DISCOVERY	3	3	3	3	3
YEARS UNTIL DISCOVERY	20	20	NONE	20	30

TABLE 2: U.S. SENATE BILLS OF THE 99TH CONGRESS COMPARED

BILL NUMBER:	STATUS QUO	S445	S1225	S1761	S2072
PRIMARY SPONSOR:		HART	SIMP-SON	STAF-FORD	METZEN-BAUM
WOULD EXTEND PAA TO	1987	NA	2012	2002	NA
MAXIMUM COVERAGE ($MILLIONS)	660	TOTAL	2160	TOTAL	TOTAL
INDEMNITY?	YES	YES	YES	YES	YES
INFLATION ADJUSTMENT?	NO	NO	NO	NO	NO
FIRST LAYER:					
MINIMUM COVERAGE AMOUNT	160	160	160	160	160
SECOND LAYER:					
TOTAL MAXIMUM AMOUNT	5	TOTAL	15	15	5
ANNUAL MAXIMUM AMOUNT	5	TOTAL	15	15	5
DIFFERENTIAL PAYMENTS?	NO	NO	YES	YES	NO
SUBROGATION: WHO CAN SUE WHOM?					
VICTIM VS VENDOR	NO	NO	NO	NO	NO
UTILITY VS UTILITY	NO	NO	NO	NO	NO
FEDERAL VS UTILITY	NO	NO	NO	NO	NO
TYPES OF INCIDENTS:					
EXTRAORDINARY EVENTS	YES	NO	YES	YES	NO
NON-EXTRAORDINARY EVENTS	TORT	STRICT	TORT	TORT	STRICT
PERSONAL INJURY LIMITATIONS:					
YEARS AFTER DISCOVERY	3	3	3	3	5
YEARS UNTIL DISCOVERY	20	NONE	NONE	30	NONE

*TABLE 3: CHANGE IN INSTALLATION TIMES AND INSURANCE PREMIUMS**

	SAFETY DISCOUNT			
SELF-INSURANCE PREMIUMS	-0%	-10%	-20%	-30%
5	3.81	3.75	3.69	3.64
25	3.73	3.45	3.18	2.92
45	3.65	3.16	2.70	2.26
65	3.58	2.88	2.24	1.65
85	3.50	2.61	1.81	1.08
105	3.43	2.35	1.40	0.54

*Premiums are in millions of dollars. Optimal waiting times are expressed in years.