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THROWING GOOD MONEY AFTER BAD?

Nuclear Power Plant Investment Decisions And The Relevance Of Sunk Costs*

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Experimental psychologists and decision theorists suggest that managers are overly reluctant to terminate economically unviable projects and that they fail to ignore sunk costs. This study serves two purposes. First, it shows that the framework of prospect theory allows us to reconcile the sunk cost effect with some older, well-established ideas in investment decision-making. Secondly, the study investigates the external validity of the sunk cost research in the context of the U.S. nuclear power program. The empirical analysis is based on share price movements in reaction to, among other events, all plant completions and cancellations (over $50 million) prior to March 1984. The results are mixed. However, prudency reviews ordered by Public Service Commissions around the nation point to evidence consistent with the sunk cost fallacy.

1. Introduction

In a recent issue, *Forbes* describes the failure of the U.S. nuclear power program as 'the largest managerial disaster in business history' (February 11, 1985). The cover story entitled, 'Nuclear Follies', argues that 'only the blind, or the biased, can now think that most of the money has been well spent'. A sample list of 35 nuclear power projects under construction (as of January 1, 1985) indicates that the plants, upon completion, will cost six to eight times the amount originally budgeted. Their average construction time will have doubled from six to twelve years. In addition, the in-service dates of many power units will need to be delayed due to the slowing growth in peak load

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electricity demand. As a consequence, 24 of the projects on the list are no longer competitive with coal nor, some of them, even with oil. However shocking, these findings do not come as a complete surprise. For more than a decade now, similar economic pressures have led to a wave of nuclear-power plant cancellations. Since 1972, the year of the first project terminations, 110 commercial power units have been abandoned. The cancellations, often at enormous cost, represent close to half the U.S. Nuclear Steam Supply System capacity previously ordered. They have brought several major utilities to the brink of financial collapse.

Regulatory commissions allocate the abandonment costs of the cancelled units among utility ratepayers, utility investors and U.S. taxpayers.[1] Only the costs which are 'prudently' incurred by management are eligible for recovery from the ratepayers. Past regulatory treatment of abandonment costs often reveals less controversy over the prudence of the decision to cancel any particular plant than over whether the plant should have been cancelled *sooner*. For example, in the case of *Allens Creek 1*, abandoned in August 1982, the Texas Public Utilities Commission concluded that Houston Lighting & Power failed to meet the management prudence criterion by not having cancelled the plant at least 2-1/2 years earlier. Accordingly, the Commission disallowed $166 million (out of $362 million total) the utility was seeking to recover.

On a surface level, the construction delays, the dramatic cost overruns and the charges that some cancellations 'were long overdue' all suggest that managers can become locked into a costly course of action. Once an investment project starts and, for whatever reason, suffers a serious setback, managers may be overly reluctant to terminate it. Instead, they may try to recoup their losses through a sustained commitment of resources to the same course of action, taking odds they would find otherwise unacceptable and, in effect, displaying risk-seeking behavior. Thus, the past experience of the U.S. nuclear program suggests that the managers of the electric utility industry had a tendency to 'throw good money after bad' and that they failed to ignore sunk costs.

Alternatively, one can argue that the previous interpretation of events is unduly loaded with hindsight bias. *Ex post*, we know that many nuclear power projects were economic failures, but were they also, at some point, *ex ante*? Possibly, utility management made appropriate decisions all along but a host of unexpected developments turned the projects sour. From 1966 to 1972, a period just prior to the flurry of new power plant orders, the common belief was that, for the forseeable future, annual growth rates in regional summer peak loads would remain at about seven percent or more.

[1] Abandonment costs incurred by a publicly owned utility, such as TVA, are borne by the ratepayers only. In the case of privately owned utilities, taxpayers become involved because utilities reduce their tax liability by writing off the cost of the plant against taxable income.

By 1982, these forecasts had been lowered to between 1.8 and 4.2 percent.[2] Design and construction costs grew far beyond early estimates due to unanticipated inflation, licensing delays, uncertainty about future regulatory standards and the obstructionist tactics of environmentalist groups. These unexpected problems, which had already become chronic by 1979, were only aggravated by the accident at Three Mile Island. Yet, with many observers the feeling remains that at least some of the problems were predictable and that, when they materialized, utility managers took too much time before drawing the logical conclusion.

In spite of its intuitive appeal and the attention it receives in the behavioral science literature, the 'sunk cost hypothesis' (also referred to as the 'escalation-of-commitment hypothesis') has stirred far less interest among economists and decision theorists. Generally, these researchers assume that normative and descriptive models of decision-making under risk coincide. With respect to capital budgeting decisions, the basic tenets of utility theory imply that only *incremental* costs and benefits should matter. Sunk costs ought to be irrelevant. On the other hand, there is considerable experimental evidence that the tendency to escalate commitment to a losing proposition is a robust judgment error [for a review, see Arkes and Blumer (1985)].

In light of these divergent viewpoints, the present paper serves two purposes. First, we reconsider and extend *theoretical* arguments by Thaler (1980) that the sunk cost effect fits into a wider pattern of common violations of expected utility theory, but that prospect theory – an alternative descriptive model of decision-making under risk, originally proposed by Kahneman and Tversky (1979) – can explain the anomaly. The framework of prospect theory allows us to discuss the link between the sunk cost effect and some older, established ideas in theories of investment decision-making, such as the concept of an aspiration level [Simon (1955)] or the definition of risk as 'the probability of not meeting a target return'. Next, we return to the failure of the U.S. nuclear power program and we investigate *empirically* whether the sunk cost hypothesis sheds new light on it. Special attention is given to the economic consequences of the regulatory environment in which the electric utilities operate. Some of the tests use event-study methodology that is standard in empirical finance. The data base includes all privately owned nuclear power plants, with investments over $50 million, that were ever ordered and terminated in the U.S. up to the Spring of 1984. We also investigate all plants which were completed over the same period.

The empirical evidence, based in part on the assumption of efficient security markets, does not provide uniform and clear support for a 'sunk cost effect'. Of course, any tests of such effect must allow for error-prone

[2]National Electric Reliability Council, *Electric Power Supply and Demand 1982–1991*, August 1982. Data from previous NERC reports summarized in Edison Electric Institute, *Electric Power Survey*, issues from April 1967 to April 1981.

managers, on occasion, to take action which rational (expected-utility maximizing) stockholders disagree with. Thus, implicitly, there is a presumption that mechanisms such as the threat of a hostile takeover [Jensen and Ruback (1985)], ex-post settling up in the labor market [Fama (1980)], or executive incentive contracts do not neutralize agency conflicts at all times. The opposite view, that agency problems are mitigated and that managers have little choice but to maximize the value of the firm, then presents itself as a logical alternative hypothesis. As it turns out, however, the evidence below presents just as many puzzles for the value maximization hypothesis as it does for the sunk cost effect.

2. The sunk cost hypothesis: Theory

Significant part of modern economic analysis of risky choice behavior is built upon a set of axiomatic principles which, some argue, all rational people would wish to obey and of which von Neumann and Morgenstern (1944) first showed the equivalence to choice by maximization of expected utility of final assets. Generally, it is further assumed that the decision-maker has a utility function that is uniformly concave, reflecting risk-aversion. However, it is well known that many people choose to violate the axioms. And, at least since Friedman and Savage (1948), there have been suggestions that risk preferences may be a mixture of risk aversion and risk seeking. As a result, several authors [e.g., Bell (1982), Loomes and Sugden (1982) and Machina (1982)] have proposed alternative descriptive models of decision-making under risk even though, for the most part, they hesitate to challenge the normative status of expected utility theory.

Following Thaler (1980), we explain the sunk cost effect within the framework of prospect theory [Kahneman and Tversky (1979)]. Define a prospect $(x_1, p_1; \ldots; x_n, p_n)$ as a gamble that yields outcome u_i with probability p_i (where $\sum_{i=1}^{n} p_i = 1$) and suppose that $u(\cdot)$ is a von Neumann–Morgenstern utility function. Then, in expected utility theory, various prospects can be ranked according to $u(x_1, p_1; \ldots; x_n, p_n) = \sum_{i=1}^{n} p_i u(x_i)$. At initial wealth position w, a prospect is acceptable if, and only if, $u(w+x_1, p_1; \ldots; w+x_n, p_n) \geqq u(w)$. Prospect theory modifies expected utility theory in several ways. For our present purposes, the replacements for the utility function u and the probabilities p_i are of special interest:

(i) Rather than over final asset positions, a value function is defined over gains and losses relative to a given aspiration level (see Fig. 1). The two-piece function (γ and λ) is concave for gains, reflecting risk-aversion, and convex for losses, reflecting risk-seeking. The function is steeper for losses than for gains – reflecting the fact that most people prefer the status quo over a symmetric prospect of the form $(x, 1/2; -x, 1/2)$.

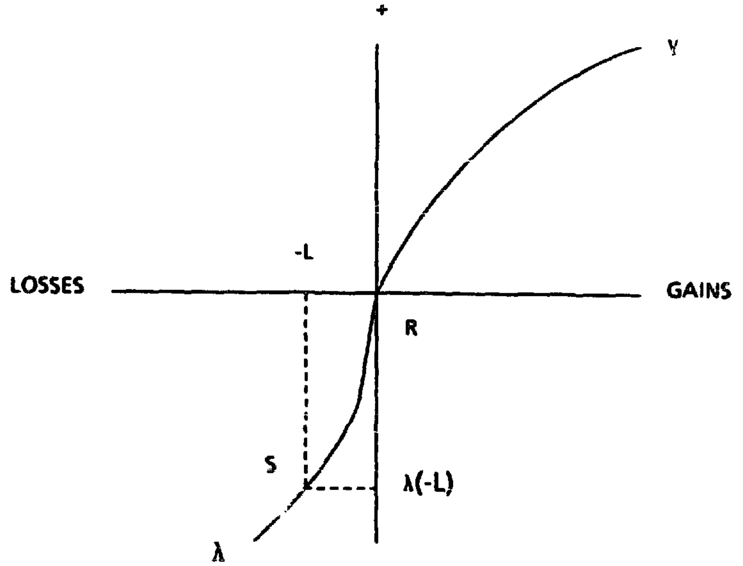

Fig. 1. The two-piece value function of prospect theory.

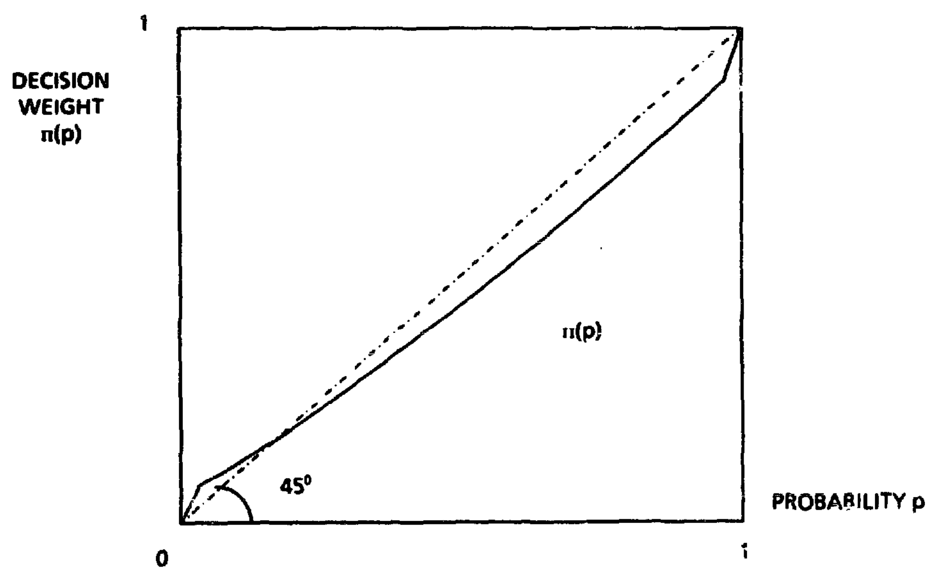

Fig. 2. The weighting function of prospect theory.

(ii) Rather than by a probability, the value of each outcome is multiplied by a subjective decision weight $\pi(p)$, an increasing function of p (see Fig. 2). We have $\pi(0)=0$ and $\pi(1)=1$. Generally, for small p, $\pi(p)>p$, and for $0<r<1, \pi(rp)>\pi(p)$. These properties reflect the relative overweighting of small probabilities and certainty (the 'certainty effect'). It follows that the sum of the decision weights associated with complementary events is less than the weight associated with certainty, i.e., $\pi(p)+\pi(1-p)<1$ ('subcertainty').

In prospect theory, prospects of the form $(x_1, p; x_2, -p)$, where $x_1 \geqq 0 \geqq x_2$, are ranked according to $V(x_1, p;\ x_2, 1-p) = \pi(p)\gamma(x_1) + \pi(1-p)\lambda(x_2)$. If $x_2 > x_1 > 0$, $V(\cdot) = \gamma(x_1) + \pi(1-p)[\gamma(x_2) - \gamma(x_1)]$. If $x_2 < x_1 < 0$, $V(\cdot) = \lambda(x_1) + \pi(1-p)[\lambda(x_2) - \lambda(x_1)]$. By assumption, the decision-maker acts so as to maximize V: all gambles with $V \geqq 0$ are acceptable. Choice behavior that follows prospect theory, as sketched here, leads to intransitivities, violations of dominance and other normatively undesirable consequences. However, prospect theory is consistent with the results of laboratory experiments and it explains such long-debated issues as the Allais-paradox or the coexistence of gambling and insurance [see, again, Kahneman and Tversky (1979)].

The theory also explains the sunk cost effect. Consider an investment project with two possible outcomes: the project either completely fails and the value of the firm decreases by I, the amount invested and now lost; or it succeeds (with probability p) and the value of the firm rises by E. Assume further that the company's management, intent on serving the shareholders' interest, feels indifferent about the project, so that

$$V(E, p;\ -I, 1-p) = \pi(p)\gamma(E) + \pi(1-p)\lambda(-I) = 0. \tag{1}$$

Prospect theory implies that, nevertheless, the project becomes attractive if, earlier, an amount L, funds that cannot be recovered, had been 'sunk' in it. Management faces a choice between two gambles: (1) the cancellation of the project, resulting in a certain loss $(-L)$, or (2) the project's continuation, resulting in a gamble $(E-L, p;\ -I-L, 1-p)$. It desires to escalate its commitment if, and only if,

$$V(E-L, p;\ -I-L, 1-p) > V(-L) = \lambda(-L). \tag{2}$$

If $E > L$, we have $V(E-L, p;\ -I-L, 1-p) = \pi(p)\gamma(E-L) + \pi(1-p)\lambda(-I-L)$. Because of the shape of the value function, (i) (risk-aversion for gains, risk-seeking for losses) $\gamma(E-L) > \gamma(E) - \gamma(L)$ and $\lambda(-I-L) > \lambda(-I) + \lambda(-L)$, and (ii) (losses loom larger than gains) $-\gamma(L) > \lambda(-L)$. Thus, $V(E-L,\ p;\ -I-L, 1-p) > \pi(p)\gamma(E) + \pi(1-p)\lambda(-I) + \pi(p)\lambda(-L) + \pi(1-p)\lambda(-L)$ where, by assumption (1), the first two terms on the RHS add up to zero. It immediately follows from the subcertainty-property of the decision-weights that expression (2) always must hold.

If, on the other hand, $E < L$, we have $V(E-L, p;\ -I-L, 1-p) = \lambda(E-L) + \pi(1-p)[\lambda(-I-L) - \lambda(E-L)]$. A sufficient (though not necessary) condition for expression (2) to hold is that $\lambda(E-L) \geqq \gamma(E) + \lambda(-L)$. This condition and the convexity of λ imply that $V(E-L, p; -I-L, 1-p) > \gamma(E)(1-\pi(1-p)) + \pi(1-p)\lambda(-I) + \lambda(-L)$. Since by assumption, $\gamma(E)\pi(p) + \pi(1-p)\lambda(-I) = 0$, and, because of subcertainty, $\gamma(E)(1-\pi(1-p)) > \gamma(E)\pi(p)$, the inequality in (2) follows once again.

The previous analysis can be extended in a straightforward manner. We already saw that the presence of sunk costs may cause a marginal project $V(E, p; -I, 1-p)=0$ to be perceived as worthwhile. Similarly, it may cause an uneconomic investment $V(E^*, p^*; -I^*, 1-p^*)<0$ to look attractive. Or, with capital rationing, it may change the ranking order of various projects. These are strong predictions and they lead us to reconsider the major underlying assumptions.

The two-piece shape of the value function of prospect theory captures the concept, long advocated by Herbert Simon (1955), of a reference point or aspiration level. A review article by Libby and Fishburn (1977) shows that the idea is very much part of management practice. For example, when the chief financial officers of *Fortune* 500 companies were asked to define a 'risky investment', the modal response was 'the probability of not achieving the target rate of return'. Payne, Laughhunn and Crum (1980) provide experimental evidence documenting aspiration level effects in risky choice behavior. They vary the relationship of pairs of gambles to an assumed reference point by changing all outcomes by a constant amount. Against the prediction of expected utility theory (with uniform risk aversion), the effect of such transitions is a reversal of choice within pairs of gambles.

The value function of prospect theory also suggests risk-seeking in the domain of losses. Laughhunn, Payne and Crum (1980) report on the risk preferences for below target returns of 224 managers from the U.S., Canada, West Germany and the Netherlands. When only non-ruinous losses were involved, about 70 percent of the managers were risk-seeking. The findings of Fishburn and Kochenberger (1979) and MacCrimmon and Wehrung (1986) similarly oppose uniform risk aversion.

Apart from prospect theory, the derivation of the sunk cost effect is also based on the assumption that decision-makers fail to easily adapt to their losses. Presumably, when the gamble $(E, p; -I, 1-p)$ is being considered, the reference point is the recent loss $(-L)$ (point S in fig. 1) rather than the investors' current asset position (point R). At point S, comparable gains are more 'valuable', and comparable losses less so, than at point R. Thus, the former representation incites more adventurous choices than the latter. At point S, in the choice between a certain loss and a long shot, the relative overweighting of both certain and improbable events has the same effect.

Thus, shifts of reference are critical for the relative worth of various gambles. Such shifts are not fully explained by prospect theory. The theory of mental accounting, proposed by Thaler (1985), argues that, before evaluation, decision-makers edit or 'frame' the different actions they can take by way of a series of 'mental accounts'. Each account deals with only *one* topic or context of interest and possible interaction between accounts is ignored. Suboptimal choices result because gains and losses are judged in *relative* rather than in *absolute* terms, e.g., most consumers are less willing to make a twenty-minute drive in order to save $10 on a $450 stereo system than to save the same amount on a $20 hairdryer. Mental accounting recognizes that the psychological value of a $10 saving depends on the context (the 'stereo account' or the 'hairdryer account') in which it is obtained even though, from an economic viewpoint, the only relevant question is whether a $10 saving is worth a twenty-minute drive.

Within mental accounting, the sunk cost effect can be interpreted as a strong aversion to closing a mental account at a loss. Whenever a manager starts a project, he 'opens a new account' and keeps a running score of the project's performance. Gains and losses are defined relative to, say, the status quo or the company's target return. When the project turns sour, the manager is slow to make peace with his losses (i.e., in fig. 1, the reference point shifts from R to S) and he tries to recoup them. The sunk cost effect thereby follows from an excessive desire to at least 'break-even' on a given mental account, even at the expense of a reduction in overall profits (i.e., when considering *other* mental accounts).

Several studies have tried to explain the psychological basis for this 'loss aversion'. Why are sunk costs not psychologically sunk also? Staw and his associates [Staw (1976); Staw and Ross (1978); Fox and Staw (1979)] believe that the tendency to escalate commitment is explained by self-justification or cognitive dissonance theory. At least since the forced compliance studies of the late 1950s, subjects – who are asked to perform an unpleasant act without adequate compensation – are known to bias their attitudes in a positive direction. People are thought in this way to protect their own self-images [Aronson (1976)]. Staw suggests that an individual who suffers a setback may go *beyond* the passive distortion of adverse consequences; by committing new resources, he may want to publicly demonstrate the ultimate rationality of his original course of action. The need to justify, especially in an organizational setting, thereby defines a concept of 'retrospective rationality' in contrast to the forward-looking 'prospective rationality' that underlies normative decision theory. In other words, decision-makers seek to appear rational and competent in *previous* as well as future actions.

Consistent with self-justification, experiments find subjects allocate more resources to a course of action when they, rather than somebody else, are responsible for the initial, unsuccessful decision [Staw (1976)]. At the outset, the subjects' choices are motivated by economic factors. As investments mount, however, their motives shift from the rational to the rationalizing [Staw (1979)]. This rationalizing effort is encouraged – and so are further investments – when information points to exogenous rather than endogenous causes of a particular setback. Unfortunately, Caldwell and O'Reilly (1982) also find that individuals may selectively filter information so as to maintain their commitment to a given policy. Bazerman et al. (1984) show that the sunk cost effect also occurs with group decision-making. High-responsibility groups and individuals are similarly concerned to rectify past losses and to convince themselves that their prior commitment was not a mistake.

Social norms for consistency in action may represent a second source of commitment. Many people share the image of effective leaders as steadfast to a course of action, suffering through some failures, only to succeed in the end [Staw and Ross (1980)]. To the desire to appear rational and consistent, Arkes and Blumer (1985) add the desire 'not to appear wasteful' as a third explanation for loss aversion. Note also that, in many cases, the same expenditure can be 'framed' either as a cost or as a loss. The importance of decision-context, framing influences on escalation has been studied recently by, among others, Bateman (1986), Davis and Bobko (1986), and Northcraft and Neale (1986). Consider the choice between a 25% chance to lose $200 and a sure loss of $50. Slovic, Fischhoff and Lichtenstein (1982) report that 80 percent of their subjects express a risk-seeking preference for the gamble. However, only 35 percent of them refuse to pay $50 for insurance against a 25% risk of losing $200. Even though the two problems are objectively identical, subjects apparently feel less comfortable losing $50 in a *gambling* context than giving up the same amount as a '*cost of protection*' against a greater loss. It is plausible that in commitment decisions, similarly, managers prefer to think that sunk costs may yet serve a useful investment purpose, and are not wasted, if only the project continues.

3. The sunk cost hypothesis: Empirical evidence

If the sunk cost hypothesis correctly describes the experience of the U.S. nuclear program, we may expect the hypothesis to manifest itself in three ways: [1] economically inviable power plants continue to be built, right now; [2] in the past, uneconomic plants were cancelled too late; [3] in the past, uneconomic plants were actually built to completion. None of these predictions are easily tested against the facts. Ideally, a test requires an independent review of the many investment analyses undertaken by dozens of utility managements around the nation a decade or more ago. It requires that such review be conditional on whatever information was available at the time, including information that may only be known by the constructing utility. While some regulatory commissions, concerned with rising electricity bills, have hired outside consultants to prepare just this type of retrospective inquiry, its complexity and data requirements are clearly impractical for empirical tests of the sunk cost hypothesis.

Our efforts are based instead on capital market research. We look for evidence of conflicting views and disagreement between, on the one hand, utility management and, on the other, regulatory authorities, bondholders and, most importantly, shareholders about the desirability of starting, continuing, completing or terminating a nuclear project. As long as the capital markets are strong form efficient in the sense of Fama (1970) and, therefore (at least, on average), 'always right', that assumption allows us to determine from asset price movements whether management was 'wrong' in a way suggested by the sunk cost hypothesis.

Suppose, for example, that the share price of a utility stock is observed to fall as management embarks upon the various stages of a power plant's construction, and to rise upon the news of cancellation. Then, in a rational stock market, the price gain may be interpreted as a sign of investor approval and relief that a value-decreasing project is dropped. The earlier negative price reactions suggest longtime conflict between the (rational) market view and management's opinion. Thus, the project abandonment arguably 'comes too late' and its timing is consistent with the sunk cost hypothesis. Or, as a second example, assume that management chooses to go ahead with a nuclear plant but is forced midway to halt construction because adequate financing cannot be found. At the same time, management claims it wants to continue. Again, these facts suggest obvious disagreement about the merits of the project.

The previous examples are not far-fetched. A 1983 study of the Energy Information Administration (U.S. Department of Energy) lists the reasons underlying 100 nuclear unit cancellations. The data are obtained either from written regulatory commission decisions or by directly contacting the constructing utility. For 39 out of 88 cancelled reactors built by investor-owned utilities, financial constraints were cited along with one or more other reasons. Five more nuclear units were cancelled *solely* because financing was not available on reasonable terms.[3] In work independent of our own, Statman and Sepe (1986) study the announcement effects of project termination decisions for industrial companies that, between 1975 and 1981, reported losses from discontinued operations in excess of twenty percent of operating income. They observe significant positive excess returns and conclude that rational investors bid up stock prices from a depressed level that reflects managers' disposition 'to throw good money after bad'.[4]

Analogous to the work of Statman and Sepe, our research design focuses on announcement effects and stock prices. However, we not only consider project terminations but also the decisions to start a nuclear project, or continue with its construction and, eventually, to complete it. Since all

[3]According to Christopher Young from the Wall Street firm of Donaldson, Lufkin & Jenrette: 'The markets tended to close... The only way you can fund [the nuclear project] yourself is to stop paying your common dividend – And once you cut the dividend, the market really closes. You can't sell common or preferred, and you can only marginally sell bonds. So now you can't fund the completion of the project, and you have to abandon it'. Quoted from *Forbes*, February 11, 1985, p. 96.

[4]Voluntary sell-off announcements are also known to have a positive effect on shareholder wealth. See Jain (1985) for references. However, these studies do not test various explanations of why the excess returns occur.

nuclear plants go through the same stages, it is possible to collect multiple comparable announcements and event dates, a difficult procedure for most other industrial projects. Two samples are studied. The first contains nuclear plant cancellations; the second, plant completions.

The *sunk cost hypothesis* argues that managers have a non-rational, vested interest to prolong economically inviable projects. If the market understands this 'agency' problem and prices stocks accordingly, the value of the firm (V) equals, at any time, an (appropriately discounted) probability-weighted average of the company's worth *with* the project (V_L) and its worth *without* the project (V_H) where $V_H > V > V_L$.[5] Abandonment decisions are 'good news' because they raise the firm's value from V to V_H. Continuation and completion decisions are 'bad news' because they lengthen the period management is expected to hang on to a losing project before terminating it or announcing a sell-off.

The alternative *market value maximization hypothesis* implies that the agency problem does not occur. We may consider two cases. In a strong-form efficient market, the value of the corporation varies strictly with its economic outlook and all managerial decisions, fully anticipated by the market, are immediately impounded in shares prices. Therefore, no announcement effects are expected. However, in a semi-strong form efficient market, news releases resolve some residual uncertainty since management, by assumption, has private information that investors do not have. Note that, in this case, the expected announcement effects go against the predictions of the sunk cost hypothesis. Project cancellation indicates 'bad news'; project continuation or completion, 'good news'.

The previous hypotheses represent polar opposites and they allow for a clean-cut interpretation of the results. Yet, a more complex scenario may occur when, say, the news of a plant cancellation is informative in *two* ways. First, investors – aware of how difficult it is to cut one's losses – feel relieved that rationality prevailed. Second, the news removes any remaining doubts that the project was indeed a money-loser.

Fortunately, these circumstances only cause a conservative bias *against* the sunk cost hypothesis. For a sample of project cancellations, we are in effect testing whether, *on balance*, the news of project termination leads to positive excess returns. The sunk cost hypothesis further predicts negative excess returns prior to cancellation. For a sample of project completions, we test whether, *on balance*, continuation and completion decisions lead to negative

[5]An 'agency' problem occurs because management ('the agent') does not serve the best interests of rational shareholders ('the principal') when its investment policy is partly based on non-economic considerations such as the psychological costs of cancelling a project. Yet, this 'agency' problem does not follow from a pure conflict of interest, as in Jensen and Meckling (1976). In fact, if the company's owners are subject to the sunk cost fallacy also, *both* parties may feel they are better off by continuing a project that would fail on economic grounds.

excess returns.[6] Thus, the tests tend to reject the sunk cost hypothesis too often.

In addition, note that, to whatever extent agency conflicts are mitigated for any of the utilities in the sample (e.g., through managerial stock ownership, compensation packages, or the threat of takeover), we may expect to observe considerable cross-sectional variation in the price reaction. Indeed, recent work with respect to unregulated industries concludes that changes in executive compensation are significantly related to stock price performance [Murphy (1985); Coughlan and Schmidt (1985)] and that the officers-directors of large corporations '...tend to own a sufficiently large amount of shares...to give them a considerable incentive to make decisions to increase the value of those shares...' with any other remuneration being '...not nearly as important as determinants of changes in their wealth' [Benston (1985), p. 82]. However, with respect to the managers of utilities, the importance of the link between changes in wealth and stock price performance is less clear. Based on a sample (largely overlapping with our own) of 54 utilities for the period 1975–1984, Agrawal, Makhija and Mandelker confirm a positive relationship between compensation and investor returns but further note, in a comparison with Benston, that, on average, '...the stockholdings of utility managers are less than 5 percent of those of industrial managers...' [(1987), p. 14].

3.1 Utility regulation and sunk costs

The empirical tests require careful interpretation for still other reasons, related to the regulatory environment in which electric utilities operate. For years, the industry was governed by the informal rule that, in return for utilities' investments in facilities to meet public need, public service (utility) commissions (PSCs; PUCs) allowed the companies a 'fair' return. With application to our tests, traditional valuation theory in finance predicts that the arrangement leaves utility stocks unaffected by unexpected changes in capital expenditures [see, e.g., McConnell and Muscarella (1985)]. More importantly, however, the implicit understanding suggests that for some time utility executives possibly did not face proper incentives for cost containment. State regulators insist that the rule was never meant to excuse mismanagement (see, e.g., the *Wall Street Journal*, October 2, 1986). While the PSCs limit shareholders' returns and, in return, shift some *but not all* business risk to the ratepayers, significant incentives for economic efficiency therefore remain.

[6]The sunk cost hypothesis does not make any prediction about likely share price reactions at the order dates in either sample. Still, it is interesting to know whether, even at this early stage, there is disagreement between management and utility investors about the economics of nuclear power.

The regulatory methods followed by the PSCs in deciding whether a plant (or a portion of it) is allowed to enter the rate base vary greatly. Usually, two principles are critical: the 'used and useful' test and the 'prudency' test. For cancelled plants, the PSCs adopt a liberal interpretation of the 'used and useful' principle in most states.[7] However, in some states, including Oregon, Ohio and Missouri, utilities by law cannot recover the cost of 'unused' properties under any circumstances. Still, for plant cancellations, most discussions about a 'fair' allocation of abandonment costs between utility investors, consumers and taxpayers center around the management prudence criterion.

In general, cost recovery has not been full. An analysis of the nuclear projects and regulatory jurisdictions for which a decision was reached prior to 1983 regarding abandonment costs exceeding $50 million (48 cases in total) reveals that, in a significant majority (29 cases), the allowed cost recovery was partial [Energy Information Administration (1983), pp. 33–57]. In eight cases, no cost recovery was allowed whatsoever. Only in eleven cases did the commissions grant full recovery. In their written decisions, several PSCs express concerns that are consistent with the belief that management does not ignore sunk costs. Some commissions note that 'ratepayers should not pay for management errors' (e.g., North Dakota PSC, with respect to *Tyrone 1*, owned by Northern States Power) and that 'the decision to cancel was not timely, causing excessive cost incurrence' (e.g., New York PSC, *Sterling 1*, Orange and Rockland). Accordingly, they deny full (e.g., *Tyrone 1*) or partial recovery (e.g., California PUC, *Sundesert 1 and 2*, San Diego Gas and Electric) of the investment from the ratepayers.[8]

For completed plants, both the 'used and useful' test and the 'prudency' test apply. For example, in 1984, the Pennsylvania PUC disallowed $287 million of the cost of Pennsylvania Power & Light's *Susquehanna 1* because it left the utility with a large power surplus. For identical reasons, the

[7] For example, the Washington Commission – while interpreting the 'used and useful' test such that only property is includable in the rate base which has the potential, if not the probability, of being in service in the future – has argued that 'It is simply one of the realities facing both investor and customer... that in order to provide for continuing generation needs, a utility must undertake massive investments, yet must maintain its financial integrity. Where necessary, this may involve a sharing of responsibilities and risks by both shareholder and ratepayer groups'. (*Washington Utilities and Transportation Commission* vs. *Pacific Power and Light Company*, Case No. U-82-12 and U-82-35 (2/1/83)).

[8] In an interesting paper, Zimmerman (1986) points out that the PSCs may have an incentive to behave opportunistically and to force cancellation if the expense of employing an alternative technology (say, a coal-fired power plant) plus the portion of the costs sunk into the abandoned nuclear project is less than what the ratepayers would have to pay if the nuclear plant is taken to completion. The implication is that, from the viewpoint of societal welfare, *too many* nuclear projects may have been cancelled, rather than too few. Also, utility investors get hurt and we would expect a negative stock price reaction at the time of cancellation. Again, this possibility causes a conservative bias against the prediction of a positive price reaction, which follows from the sunk cost hypothesis.

Montana PSC refused to let Montana Power charge its customers for nearly all ($344 million) of a new coal-fired power plant. In the summer of 1985, the New York PSC concluded that LILCO's management was seriously deficient and it disallowed $1.35 billion of the $4.2 billion cost of its new *Shoreham* nuclear plant on the grounds that the costs were imprudently incurred.

3.2. Data sources and sample design

The main data base consists of monthly stock returns for the utilities which are the principal owners of nuclear power plants ordered and subsequently cancelled with $50 million invested or more. Up to March 1984, 42 plants fall in this category. Their names and principal owners are listed in appendix 1. In two cases, the utility, in turn, is owned by another company listed on the NYSE.[9] We follow the listed parent company. It also happens that several power units are built simultaneously. If their pertinent dates are the same, these units represent a single observation in our sample. If the dates differ, they are considered separately. The return data are obtained from the *Center for Research on Security Prices* at the University of Chicago.

We study three different event dates in the life of a cancelled plant. The first date is the month that the utility places an order for a nuclear steam supply system (NSSS). Usually a public announcement of the utility's plans to build the plant has already occurred before that time but the decision can be easily reversed. In contrast, the ordering of a NSSS from a vendor legally obligates the utility to pay, at a minimum, cancellation fees stipulated in the contract. The second event date is when the utility reaches an important milestone in the plant's construction, e.g., the month in which the Nuclear Regulatory Commission (NRC) grants a construction permit. Some plants never reach this stage before they are cancelled. In those cases, we either use the docket date for application for a construction permit or the date on which the NRC issues a limited work authorization permit. For brevity, the construction milestones – docketing date, limited work authorization permit and construction permit dates – are referred to as 'construction progress' dates. The final set of dates contains the various months of public announcement of project termination.

The relevant dates are obtained from several sources: The *Historical Profile of U.S. Nuclear Power Development* (January 1, 1985), published by the Public Affairs and Information Program of the Atomic Industrial Forum; Report DOE/EIA-0392 (April 1983), *Nuclear Plant Cancellations: Causes, Costs, and Consequences*, prepared by the Energy Information Administration

[9]Central and South West Corp. wholly owns Public Service of Oklahoma. Jersey Power and Light is owned by General Public Utilities.

Table 1

Time distribution of event dates for samples of privately owned cancelled and completed nuclear power plants.[a]

	Cancellations			Completions		
Year	Orders placed	Construction progress	Project termination	Orders placed	Construction progress	Project completion
1956–1963				6	2	2
1964					3	
1965				7	1	
1966				15	5	
1967	1			24	12	2
1968				7	18	
1969	6			3	6	4
1970	1			7	7	3
1971	2			1	4	5
1972	6	3		1	4	6
1973	19	5			7	10
1974	4	12				11
1975	1	4				3
1976	4	2				6
1977	2	13	2			4
1978		7	4			2
1979		2	1			
1980			21			3
1981			6			1
1982			8			5
1983			2			2
1984			4			

[a]All entries are expressed in (number of) nuclear units. Because of certain data requirements, the numbers in the table do not perfectly match the final samples analyzed below.

within the U.S. Department of Energy; the *Wall Street Journal Index*, *Moody's* Public Utility Annual Report, and the annual reports of various utilities.

As mentioned earlier, we also collect data for all nuclear power projects which were completed by the Spring of 1984 (see appendix 2). There are 70 such investor-owned units. In each case, the construction progress date is the month in which the NRC grants a construction permit. The completion date is the month in which, after a critical early test, a low power operating license is issued.

Table 1 presents a time distribution of event dates for both samples. Note that most nuclear plant completions occur prior to 1977, the year of the first cancellations. The number of plant abandonments has risen sharply since the late 1970s. No new plants have been ordered since 1978.

3.3. Test procedures: Details

The relevant excess returns are measured as mean-adjusted returns. Thus, it is assumed that the ex ante expected return for a given stock j over period t equals a constant which can differ across securities: $E(\tilde{R}_{jt})=K_j$. We test whether the actual return during the test period, particularly in month '0', is statistically significantly different from the mean return in the estimation period. Formally, we have that $\tilde{\varepsilon}_{jt}=\tilde{R}_{jt}-K_j$.

Valid t-tests for abnormal performance assume that the residuals $\tilde{\varepsilon}_{jt}$ are independent across securities. There is some doubt that the securities in our sample fulfill this requirement: they are all in one industry and many experience events during approximately the same calendar time period. The t-statistics described below take into account any cross-sectional dependence in residual returns via a procedure Brown and Warner (1980) call 'Crude Dependence Adjustment'.

In order to achieve minimum overlap between the various estimation and testing periods for the three relevant sets of events, they are chosen as follows:

[1] the testing periods always run for seven months between month -6 and month 0, the 'event month';

[2] the timing and length (T) of the estimation periods depend on the event in question; for the order date, it runs between month -30 and -7 ($T=24$); for the construction progress date, between month $+1$ and $+24$ ($T=24$); for the cancellation and completion dates, between months -24 and -7 ($T=18$).

Note that, whenever a return is missing, all statistics described below are adjusted accordingly. The missing return as well as the return for the subsequent month are dropped from the calculations.

Let K_j be the mean return for security j over the estimation period, $K_j=(\sum_{t=1}^{T} R_{jt})/T$, and σ_j the standard deviation, $\sigma_j=[\sum_{t=1}^{T} (R_{jt}-K_j)^2/(T-1)]^{1/2}$. Then, with N firms in the sample the standardized portfolio abnormal returns during the test period ($t=-6, -5,\ldots,0$) equal,

$$AR_t=\frac{1}{N}\sum_{j=1}^{N}\frac{R_{jt}-K_j}{\sigma_j}.$$

The 'Crude Dependence Adjustment' procedure estimates the standard deviation of AR_t, $\sigma(AR)$, from its series of values for the estimation period. The average standardized portfolio abnormal return for the estimation period, AR^*, is equal to $(1/T)\sum_{t=1}^{T} AR_t$ and thus,

$$\sigma(AR)=\left[\sum_{t=1}^{T}(AR_t-AR^*)^2/(T-1)\right]^{1/2}.$$

Under the null hypothesis of no abnormal performance, the ratio of AR_t to $\sigma(AR)$ is distributed Student-t with $(T-1)$ degrees of freedom.

The t-statistic for abnormal performance over a cumulative interval of τ months into the test period is computed as the ratio of the cumulated standardized portfolio excess returns, $CAR_\tau=\sum_{t=-6}^{\tau} AR_t$, to $\sigma(AR)\sqrt{\tau}$. Again, the test statistic is distributed Student-t with $(T-1)$ degrees of freedom.

3.4. Empirical results and discussion

The empirical results are summarized in tables 2 and 3. In order to ease their interpretation, the average residual (ar_t) and cumulative average residual returns (car_τ) listed in columns 2 and 4 of both tables are not standardized. They are calculated as, respectively, $(1/N)\sum_{j=1}^{N}\varepsilon_{jt}$ and $\sum_{t=-6}^{\tau} ar_t$ where $\tau=-6,-5,\dots,0$. The findings appear to be robust. For example, we varied both the length (month-by-month, between 18 and 30 months) and the timing (before, after) of the mean return estimation period. In addition, we also worked with daily excess returns, using a variety of methods to compute them [see Brown and Warner (1985) for details]. These manipulations do not change any of the basic results and, consequently, they are not reported.[10]

Apparently, the stock market interprets both plant cancellations and completions as statistically significant 'bad news'. However, for neither sample, are significant announcement effects found around the order and construction progress dates. For plant cancellations, the cumulative residual adds up to *minus* 7.2 percent in a period of seven months, with most of it

[10]Monthly, rather than daily, excess returns are reported because there is considerable information 'leakage' prior to the actual event dates. For the sample of plant cancellations, we repeated all calculations using daily mean-adjusted, daily market-adjusted, as well as daily market model residual returns. The length of the estimation period was set at 100 trading days (days −120 through −21), with a test period 41 days long (days −20 through +20) and centered around the event date (day '0'). An equally-weighted average of the daily returns on all stocks listed on the NYSE and the AMEX served as the market return. For the mean-adjusted excess returns, the cumulative change on days −1 and 0 was an insignificant −1.5 percent. However, between days −20 and 0, the cumulative drop was −7.4 percent (t-statistic: −2.97) while, over the entire test period, it was −9.3 percent (t-statistic: −2.66). For the other methods, the findings were similar.

Table 2

Residual and cumulative residual returns for utilities owning cancelled nuclear power plants: Three event dates.[e]

Month	Average residual return (in %)	T-statistic	Cumulative average residual return (in %)	T-statistic
Order date ($N=25$)				
−3	0.3	0.26	0.9	0.16
−2	−1.4	−1.33	−0.5	−0.45
−1	−0.8	−0.85	−1.3	−0.76
0	−1.2	−1.01	−2.5	−1.09
Construction progress date ($N=25$)				
−3	−1.0	−0.19	−4.8	−0.03
−2	−0.7	−0.02	−5.4	−0.04
−1	−1.5	−0.55	−6.9	−0.26
0	−1.6	−0.46	−8.5	−0.42
Cancellation date ($N=26$)				
−6	−0.3	−0.48	−0.3	−0.48
−5	−1.5	−1.74[d]	−1.8	−1.57
−4	0.2	0.12	−1.5	−1.21
−3	−0.7	−1.00	−2.3	−1.55
−2	−0.4	−0.52	−2.7	−1.62
−1	−2.6	−3.36[a]	−5.2	−2.85[b]
0	−2.0	−2.48[c]	−7.2	−3.57[a]

[a]Significant at the 0.005 level.
[b]Significant at the 0.01 level.
[c]Significant at the 0.025 level.
[d]Significant at the 0.10 level.
[e]N represents the number of observations in the sample. The residual and cumulative residual returns in columns 2 and 4 are not standardized. The cumulative residuals for any month $\tau(\tau=-6;-5,\ldots,0)$ are found by adding the residuals from month −6 until month τ. The t-statistics are based on standardized residual returns. Given that there are no significant movements in excess returns for either the order or construction progress dates, we only report these excess returns between $\tau=-3$ and $\tau=0$.

(4.6%) happening during the last two. As explained before, this result is clearly in conflict with a 'powerful' sunk cost effect.[11]

On the other hand, for plant completions, the cumulative residual equals a significantly negative 4.5 percent. This is consistent with the relevance of sunk costs since the completion of a plant increases the probability of its commercial use. If the regulatory climate in a state is unfavorable and prohibits the utility from earning a 'fair' return, it may be preferable from the

[11]For a sample of plant cancellations partially overlapping with ours, Hearth and Melicher (1986) report a statistically significant cumulative average excess return of −2.99 percent over a period that starts five days before and that ends the day after the event date. They also find that the return varies inversely with the 'standardized' sunk cost of the abandoned project, i.e., its sunk cost as a percentage of the utility's book equity.

Table 3

Residual and cumulative residual returns for utilities owning completed nuclear power plants: Three event dates.[f]

Month	Average residual return (in %)	T-statistic	Cumulative Average residual return (in %)	T-statistic
Order date (N=48)				
−3	−0.4	−0.56	−0.6	−0.10
−2	−0.5	−0.46	−1.0	−0.29
−1	0.4	0.51	−0.6	−0.06
0	−0.3	−0.78	−0.9	−0.35
Construction permit date (N=46)				
−3	1.2	1.69[e]	1.8	0.98
−2	−0.1	−0.83	1.7	0.51
−1	0.9	1.22	2.6	0.96
0	−0.4	−0.27	2.2	0.79
Completion date (N=62)				
−6	−0.6	−1.49	−0.6	−1.49
−5	−0.2	−0.58	−0.8	−1.47
−4	−1.7	−2.56[d]	−2.5	−2.67[c]
−3	0.6	0.06	−1.9	−2.29[d]
−2	−1.6	−2.76[c]	−3.5	−3.28[b]
−1	−1.7	−3.07[b]	−5.2	−4.25[a]
0	0.7	0.45	−4.5	−3.76[a]

[a]Significant at the 0.001 level.
[b]Significant at the 0.005 level.
[c]Significant at the 0.01 level.
[d]Significant at the 0.025 level.
[e]Significant at the 0.10 level.
[f]See table 2.

shareholders' point of view, even at this stage, to cancel the project outright and to use whatever capital can be recuperated in projects that yield higher returns. Also, the commercial use of a nuclear facility is sure to increase the decommissioning costs of the plant after its useful life. Right now, these future costs are highly uncertain. An even worse scenario may develop if, upon completion, the new plant adds to a large surplus in generating capacity. Management's decision to obtain a low power operating license then says it wants to operate a plant that the PSC may not let into the rate base. In sum, there are plenty of reasons why plant completion may represent 'bad news' for investors. At the same time, the negative returns are not easy to reconcile with the market value maximization hypothesis.

In further agreement with the sunk cost hypothesis, utilities that own eventually cancelled plants lose on average as much as 8.5% of their value over the months that precede the date on which (for most of them) the NRC grants a construction permit. Yet, the result does not approach statistical significance. But it again suggests that for some nuclear plants investors looked very negatively upon managements' intention to start with their actual construction.

From the perspective of the sunk cost effect, the main anomalous result therefore concerns the negative excess returns for plant cancellation decisions. The returns are consistent with the market value maximization rule if investors did not anticipate that the nuclear projects were money-losers. Another interpretation, consistent with the relevance of sunk costs, suggests instead that the excess returns may be systematically less negative, or even positive, for those utilities where there is less of an alignment of managers' interests with those of stockholders.

We test this proposal by regressing cumulative daily (mean-adjusted, market-adjusted and market model) residual returns around the time of cancellation (computed between trading days -20 and $+20$, -20 and $+1$, and -2 and $+2$) on two measures of the relative number of shares held by management.[12] The data are collected from proxy-statements. The first measure is defined as the number of shares held (in the year of cancellation) by 'all directors and officers', divided by the total number of shares outstanding. Its sample average is 0.142 percent. Similarly, the second measure is the percentage of the shares held by 'the highest paid executive' (sample average is 0.015 percent). In total, we run 18 bivariate regressions (3 types of excess returns, $\times 3$ event periods, $\times 2$ definitions of the independent variable). Unfortunately, in no case does the relevant beta-coefficient carry a t-statistic larger than (absolute) 1.12. Almost all the regressions (16 out of 18) show an adjusted R-square of 0.0.

A second interpretation of the negative excess returns for cancellation decisions is based upon the changing attitudes of many Public Service Commissions in recent years. Some observers argue that, so long as the commissions were mere 'rubber stamps', investors priced utility stocks on the belief that, for failing projects, there existed (so-to-speak) 'an economic point of no return' beyond which the companies could recover a larger share of the cost of a plant by completing it than by outright cancellation. Completion meant that the commission became more likely to consider the plant 'used and useful'; cancellation, on the other hand, damaged the chances of substantial cost recovery.[13] Presumably, only the recent aggressiveness shown by the PSCs removed these 'perverse' incentives. Thus, changes in the

[12] The daily excess returns are computed as explained in footnote 10.

[13] This 'rubber stamp' hypothesis suggests that the utilities that operate in the toughest regulatory environment experience the largest price declines upon cancellation. However, Hearth and Melicher (1986), using a Kruskal–Wallis nonparametric test, find no statistical differences between the cumulative average excess returns around the cancellation date (trading days -5 through $+1$) for utilities that are grouped by a regulatory rating provided by the Duff and Phelps Company.

regulatory environment suggest that the stock price movements in response to the later (rather than earlier) completions and terminations are the more meaningful to evaluate the sunk cost hypothesis.

In order to test this view, we arbitrarily split both samples at the end of 1979. Our main focus of interest is whether the negative excess returns for the whole sample of project cancellations (on average, -7.2 percent) do primarily follow from the five observations prior to 1980. The early cancellations result in cumulative residual returns ($\tau=-6,\ldots,0$) of -16.3 percent (t-statistic: -2.95), a number that is indeed considerably smaller than the -5.2 percent for cancellations after 1979. However, the post-1979 returns remain negative, contradicting the sunk cost effect. The parallel findings for the samples of plant completions are equally damaging. After 1979 (eleven cases), these events lead to positive cumulative residual returns of 5.1 percent, with 3.7 percent occurring in month '0' (t-statistic: 6.62)!

Once changes in the regulatory environment are taken into account, the split sample findings therefore seem to favor the market value maximization hypothesis. However, they only deepen the puzzle in many other respects. For example, they fail to explain the large negative stock price movements in reaction to plant completions prior to 1980, which support the sunk cost hypothesis instead.

Confronted with these mixed and contradictory results, we conclude against our main hypothesis. The empirical analysis above simply does not offer a pattern of results that is uniformly consistent with the joint hypothesis of a rational stock market and a 'powerful' sunk cost effect. Our findings stand in contrast not only to the widespread public perception that numerous uneconomic power plants were cancelled too late but also to the written decisions of many PSCs. In addition, they go against what previous experimental research on the sunk costs fallacy would lead us to expect.

4. Conclusion

It is often claimed that managers are overly reluctant to terminate economically inviable projects and that they fail to ignore sunk costs. This study shows that the framework of prospect theory allows this type of behavior, however normatively unacceptable, to be reconciled with some older, well-established ideas in investment decision-making such as the concept of an 'aspiration level' or a 'target return'.

There is by now a considerable amount of academic work that documents the relevance of sunk costs in experimental contexts. As usual, the question of the external validity of this research and of its real-world implications needs to be considered. To our knowledge, this study represents one of the first few attempts to provide an answer [see also Statman and Sepe (1986)].

At least on a surface level, the past experience of the U.S. nuclear program seems to be wholly consistent with the intuitive notions underlying the sunk cost hypothesis. Given that it is impossible to reconstruct and to re-evaluate, ex post, the many investment analyses undertaken by dozens of utility managements over a period that spans three decades, the strategy of our paper is to look for evidence of 'disagreement' between management and a 'rational' stock market that is not subject to the sunk cost fallacy.

Nuclear power projects are especially well-suited for our purposes since they all go through the same stages, thereby allowing the collection of multiple sets of comparable event dates. On the other hand, some complications arise from the regulatory environment in which electric utilities operate. For example, investors (and management) may believe that the utility is better off by completing an economically inviable plant than by early cancellation if the mere fact of completion leads the PSC to look more favorably upon the project. Still, consumers have never provided full protection against downward risk in power generation, leaving strong incentives for economic efficiency.

Since any announcement resolves some residual uncertainty, our tests are (conservatively) biased against the sunk cost hypothesis. In agreement with the hypothesis, 'completion' announcements are associated with negative excess returns. However, against the relevance of sunk costs, 'cancellation' announcements are also associated with negative excess returns. Further empirical analysis only deepens the puzzle. Overall, the pattern of results is inconsistent with a 'powerful' sunk cost effect.

Of course, once one considers the methodological limitations of this study (in particular, the assumption of an 'efficient' stock market, populated by investors who are not themselves subject to the sunk cost fallacy), it may well be that sunk costs 'did matter' either on the average, or even more so, in any particular case. In any event, and contrary to our main findings, we also report systematic and anecdotal evidence that throughout the U.S. Public Service Commissions deny utilities full or partial recovery of nuclear construction costs for reasons of mismanagement consistent with the sunk cost fallacy. Recently, the Missouri Commission disallowed $384 million of the $2.98 billion cost of Union Electric Co.'s Callaway plant. The decision was based in part on a prudency review that unearthed internal notes from a senior company official, late in the project, that said 'we don't know where we are: we don't know how we're going to get this job done; we must find a way'. (Quoted from the *Wall Street Journal*, October 2, 1986.)

Appendix 1

List of investor-owned nuclear power plants cancelled before March 1984 with sunk costs above $50 million.[a]

Year of cancellation	Name of plant	Name of major participating utility (percent ownership)
1984	Marble Hill 1 and 2	Public Service of Indiana (100%)
	Zimmer 1	Cincinnati Gas and Electric (40%)
1983	Harris 2	Carolina Power and Light (100%)
	Cherokee 1	Duke Power (100%)
1982	Cherokee 2 and 3	Duke Power (100%)
	North Anna 3	Virginia Electric Power (100%)
	Pebble Springs 1 and 2	Portland General (47.1%)
	Allens Creek 1	Houston Lighting and Power (100%)
	Black Fox 1 and 2	Public Service of Oklahoma (60.9%)
	WPN 5	Pacific Power and Light (10%)
1981	Harris 3 and 4	Carolina Power and Light (100%)
	Hope Creek 2	Public Service Electric and Gas (95%)
	Callaway 2	Union Electric (100%)
	Pilgrim 2	Boston Edison (70%)
	Bailly Nuclear	Northern Indiana Public Service (100%)
1980	Forked River 1	Jersey Central Power and Light (100%)
	North Anna 4	Virginia Electric Power (100%)
	Jamesport 1 and 2	New York State Electric and Gas (50%)
	New Haven 1 and 2	Long Island Lighting (50%)
	Greenwood 2 and 3	Detroit Edison (100%)
	Sterling	Orange and Rockland (33%)
	Eric 1 and 2	Ohio Edison (46.1%)
	Davis-Besse 2 and 3	Ohio Edison (46.1%)
1979	Tyrone 1	Northern States Power (67.6%)
1978	Sundesert 1 and 2	San Diego Gas and Electric (100%)
	Atlantic 1 and 2	Public Service Electric and Gas (80%)
1977	Douglas Point 1 and 2	Potomac Electric Power (100%)
	Surry 3 and 4	Virginia Electric Power (100%)

[a]This list contains the plants that are part of our sample of cancelled nuclear projects. We count 42 nuclear units in 28 nuclear projects, 27 of which are owned by different utilities and cancelled at different dates.

Appendix 2

List of investor-owned nuclear power plants completed before March 1984.[a]

Year of Completion	Name of plant	Name of major participating utility
1983	William McGuire 2	Duke Power (NC)
	St. Lucie 2	Florida Power & Light
1982	LaSalle 1	Commonwealth Edison (IL)
	San Onofre 2	South California Edison
	San Onofre 3	South California Edison
	Summer 1	South Carolina Electric & Gas
	Susquehanna 1	Pennsylvania Power & Light
1981	William McGuire 1	Duke Power (NC)
1980	Joseph M. Farley 2	Alabama Power
	North Anna 2	Virginia Electric and Power
	Salem 2	Public Service Electric and Gas (NJ)
1978	Arkansas Nuclear One-2	Arkansas Power & Light
	Edwin I. Hatch 2	Georgia Power
1977	Donald C. Cook 2	Indiana & Michigan Electric (MI)
	Davis-Besse 1	Toledo Edison
	Joseph M. Farley 1	Alabama Power
	North Anna 1	Virginia Electric and Power
1976	Beaver Valley 1	Duquesne Light (PA)
	Brunswick 1	Carolina Power & Light (NC)
	Calvert Cliffs 2	Baltimore Gas & Electric
	Crystal River 3	Florida Power
	St. Lucie 1	Florida Power & Light
	Salem 1	Public Service Electric and Gas (NJ)
1975	Indian Point 3	Consolidated Edison
	Millstone 2	Northeast Utilities (CT)
	Tojan	Portland General Electric
1974	Arkansas Nuclear One-1	Arkansas Power & Light
	Brunswick 2	Carolina Power & Light (NC)
	Calvert Cliffs 1	Baltimore Gas & Electric
	Donald C. Cook 1	Indiana & Michigan Electric (MI)
	Duane Arnold	Iowa Electric Light and Power
	James A. Fitzpatrick	Consolidated Edison
	Edwin I. Hatch 1	Georgia Power
	Oconee 3	Duke Power (SC)
	Peach Bottom 3	Philadelphia Electric
	Prairie Island 2	Northern States Power (MN)
	Three Mile Island 1	Metropolitan Edison (PA)
1973	Fort St. Vrain	Public Service of Colorado
	Kewaunee	Wisconsin Public Service
	Oconee 1	Duke Power (SC)
	Oconee 2	Duke Power (SC)
	Peach Bottom 2	Philadelphia Electric
	Prairie Island 1	Northern States Power (MN)
	Surry 2	Virginia Electric and Power
	Turkey Point 4	Florida Power & Light
	Zion 1	Commonwealth Edison (IL)
	Zion 2	Commonwealth Edison (IL)
1972	Main Yankee	Maine Yankee Atomic Power
	Pilgrim 1	Boston Edison
	Quad Cities 2	Commonwealth Edison (IL)
	Surry 1	Virginia Electric and Power
	Turkey Point 3	Florida Power & Light
	Vermont Yankee	Vermont Yankee Nuclear Power

Year of Completion	Name of plant	Name of major participating utility
1971	Dresden 3	Commonwealth Edison (IL)
	Indian Point 2	Consolidated Edison of New York, Inc.
	Palisades	Consumers Power (MI)
	Point Beach 2	Wisconsin Electric Power (WI)
	Quad Cities 1	Commonwealth Edison (IL)
1970	Millstone 1	Northeast Utilities (CT)
	Monticello	Northern States Power (MN)
	Point Beach 1	Wisconsin Electric Power (WI)
	H.B. Robinson 2	Carolina Power & Light (SC)
1969	Dresden 2	Commonwealth Edison (IL)
	Robert E. Ginna	Rochester Gas and Electric
	Nine Mile Point 1	Niagara Mohawk Power
	Oyster Creek	Jersey Central Power & Light
1967	Haddam Neck	Connecticut Yankee Atomic Power
	San Onofre 1	Southern California Edison
1962	Big Rock Point	Consumers Power (MI)
1960	Yankee Rowe	Yankee Atomic Electric (MA)

[a]This list contains the plants that are part of our sample of completed nuclear projects. The 'completion date' is defined as the date on which a low power operating license is issued.

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