Capital Budgeting: Some Exceptions to the Net Present Value Rule

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ABSTRACT: Textbooks tend to emphasize the net present value (NPV) rule, often arguing that it is theoretically superior to other methods. Yet other methods, many of which do not involve discounting, are also used in practice. Hence, one of two conclusions can be drawn: (1) firms are making suboptimal decisions or (2) the assumptions underlying the NPV rule are not always met in practice. The purpose of this paper is to present simple numerical examples wherein applying the NPV rule leads to erroneous decisions. The examples highlight the assumptions underlying the NPV rule.

INTRODUCTION

Capital budgeting is a vital activity. It is the process by which organizations make long-term investment decisions. Textbooks in accounting and finance discuss numerous evaluation criteria, including payback period, accounting rate of return, internal rate of return, and Net Present Value (NPV). These criteria can lead to differing conclusions.

The NPV rule of "accepting a project if and only if its NPV is positive" is based on the intuitive premise that money today is worth more than the same amount of money in the future. Textbooks tend to emphasize the NPV rule, often arguing that it is theoretically superior to other methods (see, for example, Kaplan and Atkinson 1989, 474-475; Zimmerman 1995, 119). Yet other methods, many of which do not involve discounting, are also used in practice. For example, in a survey referred to in Horngren et al. (1997, 794), more firms reported using the payback method either as a primary or secondary criterion to evaluate projects than any other method.

Since companies use these other methods, one of two conclusions can be drawn: (1) firms are making suboptimal decisions or (2) the assumptions underlying the NPV rule are not

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1 See, for example, Horngren et al. (1997), Kaplan and Atkinson (1989), Ross et al. (1995) and Zimmerman (1995).

2 Another survey reported that the payback method is commonly used as a secondary criterion, but not as a primary criterion (see Ross et al. 1995, 219).

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always met in practice. The purpose of this paper is to present numerical examples wherein applying the NPV rule leads to erroneous decisions. The examples highlight the assumptions underlying the NPV rule.

Although the simplest version of the NPV rule deals with the case in which cash flows are known with certainty, uncertainty in cash flows can be incorporated by taking expectations over cash flows and discounting using a risk-adjusted interest rate. However, uncertainty is related to two assumptions underlying the NPV rule that are not so easily dealt with. The NPV rule assumes that (1) the project approval decision is a "now-or-never" decision (if a project is turned down now it cannot be undertaken in the future) and (2) decisions are made either in a single-person firm or in a multi-person firm in which there are no information asymmetries among individuals. Our examples deal with cases in which these assumptions do not hold.

The examples are intentionally simple. They are intended to provide the reader with an appreciation for management’s use of a variety of criteria and an understanding of some of the underlying considerations. In practice, uncertainty, information asymmetry problems, and multiperiod, multi-project considerations greatly complicate capital budgeting, beyond the focus of this paper.

When the NPV rule’s assumptions are violated, the use of multiple criteria is a way of evaluating the project from different perspectives. If many of the criteria suggest the project should be taken, the chance is greater that the project is desirable. As Demski (1994, 385) writes, there is "ambiguity in the present value frame itself…. In this case, we then acknowledge an ambiguous framing exercise coupled with a portfolio of approaches to the framing task." Ross et al. (1995, 218–219) present a similar view: "[b]ecause the true NPV is unknown, the astute financial manager seeks clues to assess whether the estimated NPV is reliable. For this reason, firms would typically use multiple criteria for evaluating a project…. [f] different indicators seem to agree [then] it’s ‘all systems go.’"

The remainder of the paper is organized into three sections. The second section relaxes the now-or-never assumption in order to study the option value of waiting. The third section relaxes the “no information asymmetries” assumption and, in particular, studies decentralized information. The fourth section studies the effect of reducing information asymmetries.

**OPTION VALUE OF WAITING**

Textbooks suggest an exception to the NPV rule: If two mutually exclusive projects are being considered, then only the project with the higher NPV is to be accepted, even if both projects have positive NPVs (see, for example, Brealey and Myers 1996, 97–100). Two projects are mutually exclusive if undertaking one precludes undertaking the other. For example, if a firm owns a tract of land and has a choice of building either a warehouse or a plant on the land, then these two projects are mutually exclusive. The issue of mutually exclusive projects is traditionally discussed in the context of multiple projects. More

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3 For analyses in which the first assumption is relaxed, see, for example, Balakrishnan and Bhattacharya (1997), Dixit and Pindyck (1994), Ross (1995) and Trigeorgis (1998). For analyses in which the second assumption is relaxed, see, for example, Antle and Eppen (1985) and Harris et al. (1982).
recently, the evaluation of mutually exclusive projects has been extended to the case of one project—a project may be in competition with itself taken at a later date. Often, by turning a project down today, the firm preserves the option to invest in the project at a later date. By investing today, this option is lost. When is keeping the investment option alive better than investing in the project today?4

The Resolution of Uncertainty
One advantage of waiting to invest in a project is that the firm may receive better information about the project’s cash flows, i.e., uncertainty may be reduced over time. Consider the following example. If a project is undertaken, the required cash outflow (investment/cost) today is 100. The project generates a cash inflow of 120 or 90, each equally likely, in one year from now. For simplicity, assume the discount rate is 0 throughout the paper. Alternatively, one can view the cash flow numbers as being in today’s dollars (they are already discounted). The project’s expected NPV is \(0.5(120 - 100) + 0.5(90 - 100) = 5\), and the NPV rule would lead the firm to accept the project.

Suppose that by rejecting the project this year and waiting until next year to make a final investment decision, the firm learns exactly what the project’s cash inflow will be. If the firm waits, it will invest in the project if and only if it learns the cash inflow is going to be 120. The project’s expected NPV is \(0.5(120 - 100) + 0.5(0) = 10\). Because of the reduction in uncertainty, it is better to wait to make the investment decision.

The Luck of the Draw
Even if uncertainty is not reduced, it may be worthwhile to wait to accept a project. By waiting, it is possible the project will be undertaken under more favorable circumstances (e.g., interest rates may decline). Consider the following example. If a project is undertaken, it generates a cash inflow of 100. The cost is 60 or 90, each equally likely. When the project is undertaken, the project’s exact cost is known. Whether the cost is 60 or 90, the NPV rule dictates the project be accepted, since its NPV is either 40 or 10.

If the project approval decision is delayed, the cost depends on the prevailing economic conditions. Suppose the cost in the second period is again equally likely to be 60 or 90, and costs are uncorrelated across periods. Returning to the initial project approval decision, it is optimal to reject the project if the cost is 90; by waiting, the environment either stays the same or improves. If the cost is 90, the expected NPV of accepting the project today is \(100 - 90 = 10\) but by waiting is \(0.5(100 - 60) + 0.5(100 - 90) = 25\). Waiting enables the firm to obtain a new, potentially more favorable environment in which to undertake the project.

Why does the NPV rule not yield the correct answer in the above examples? The NPV rule implicitly assumes the project choice is a now-or-never decision. In both examples, we assumed the firm’s opportunity to invest in a project is not lost if the investment decision is delayed, i.e., the project choice is a “now-or-later” decision.

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4 Our discussion of the option value perspective to capital budgeting is based on Dixit and Pindyck (1994) and Ross (1995).
DECENTRALIZED INFORMATION AND CONTROL

Up to this point, we have had a simple picture of a firm in mind. The firm is owned and operated by a single individual. In this environment, capital budgeting can be modeled as a decision problem. In a multi-person firm, capital budgeting is perhaps better modeled as a control problem. In order to control managers’ behavior (e.g., limit “budget padding”), a budget center may find it optimal to commit to project approval/rejection decisions that would not be optimal in the single-person world of decision theory. Key ingredients of control problems are conflicts of interest and information asymmetries among firm participants.5

We next study capital budgeting as a control problem.6 Consider a firm whose participants consist of a center responsible for a project approval decision and a division manager who implements any approved project. The cash inflow from the project is 100, and the cost is either 60 or 90, each equally likely. The project is a now-or-never project. Since the project’s NPV is always positive, the NPV rule dictates the project be accepted. However, as we will show, this is not the correct rule to apply in the presence of a control problem.

Because of his proximity to operations, the division manager learns the exact cost of the project before the project approval decision is made. The center knows only the distribution over costs. Hence, there is an information asymmetry. In particular, information is decentralized in that the manager has an informational advantage over the budget center. Divisions submit detailed cost budgets to the center prior to approval. We refer to the amount of report-contingent resources provided by the center to the manager as the project’s funding. If the division manager always reports truthfully, it is optimal to approve the project and provide funding as requested by the manager. The project’s expected NPV is .5(100 – 60) + .5(100 – 90) = 25.

However, one problem with decentralized information is that division managers often show a marked tendency to pad their budgets. Slack in the budgets makes life more pleasant in the divisions. If a divisional budget is successfully padded, divisional personnel need not work as hard or as efficiently. Also, they may be able to consume corporate prerequisites. The center, on the other hand, would like to minimize the amount of slack in budgets (other things being equal).

The center supplies all funds for capital expenditures and receives the cash inflow (if the project is undertaken). The division manager bears the cost of production and consumes any slack. If the center supplies the funds requested by the manager, the manager will always report the cost of the project is 90 (even when it is 60). The center's expected profit is 100 – 90 = 10, and the manager's expected slack is .5(90-60) + .5(90 – 90) = 15.

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5 Accounting and control problems are closely linked. Accounting is based fundamentally on stewardship relationships, whereby resources are entrusted to individuals who have to account for the use of those resources. It seems unlikely the incentives of the accountor (steward) would completely coincide with those of the accountee (Ijiri 1975, 35).

6 The discussion of capital budgeting as a control problem is based on Antle and Eppen (1985).
Can the center earn higher expected profits? Consider the following contract, which we refer to as the "Slack Contract." The center commits to accepting the project and providing funding of 90, irrespective of the manager's cost report. Under this contract, the manager is indifferent between reporting truthfully and padding his budget. When indifferent, we assume the manager will report truthfully. The Slack Contract is equivalent to funding all projects at the level requested by the manager in the sense that, under both contracts, the same outcomes occur—the project is always accepted and funding of 90 is provided. The equivalence of these two contracts is a special case of what is referred to as the "Revelation Principle."

The Revelation Principle states that any equilibrium outcome of any mechanism can be replicated as a truth-telling equilibrium of a revelation mechanism. Two words deserve clarification. By an "equilibrium," we mean the manager's reporting strategy is a best response to the contract. By a "revelation mechanism," we mean a mechanism under which the manager is asked to report his private information. The Revelation Principle is a useful tool in economics because it greatly simplifies the task of finding an optimal mechanism. It justifies restricting attention to mechanisms under which the manager's own best interest is to truthfully reveal his private information.

There is another contract that induces truthful revelation of information—the center accepts the project if and only if the manager reports the project's cost is 60. We refer to this contract as the "Rationing Contract," since the center commits to rejecting a project when the cost is 90, even though it is guaranteed to generate a cash inflow of 100. Under this contract, when the cost is 60, the manager's slack is 0 whether or not he pads his budget; hence, the manager reports truthfully. The center's expected profit is \(0.5(100 - 60) = 20\), and the manager's expected slack is 0. Since the Slack and Rationing Contracts are the only ones that induce truthful revelation of information (other than always rejecting the project) and the Revelation Principle holds, we can conclude that the Rationing Contract is optimal in our example. As an optimal response to the manager's desire to pad his budget, the center commits to rejecting some positive NPV projects. Rationing disciplines the manager's reporting.

The benefit of the Rationing Contract relative to the Slack Contract is that when the cost is 60, the center ends up paying 60 instead of 90. The saving in managerial slack is \(0.5(90 - 60) = 15\). The cost of the Rationing Contract relative to the Slack Contract is that when the cost is 90, a positive NPV project is forgone. The cost of forgone production is \(0.5(100 - 90) = 5\). The benefit exceeds the cost by \(15 - 5 = 10\); recall that this is the difference between the center's expected profit under the Rationing Contract and under the Slack Contract \((20 - 10 = 10)\).

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7 The manager is not a pathological liar; he lies only if it increases his slack.
8 We have considered a simple accept/reject decision—the project is either accepted and fully funded or rejected. Even if it is possible to accept some fraction of the entire project and the cost and revenue functions are linear, either the Slack or the Rationing Contract continues to be optimal. We formulate this problem as a linear program and present its solution in the appendix.
9 If the probability of the low cost is .25, the benefit of rationing is \(.25(90 - 60) = 7.5\) and the cost of rationing is \(.75(100 - 90) = 7.5\). If the probability is even lower, the Slack Contract is strictly preferred to the Rationing Contract.
The glue that holds these contracts (and the Revelation Principle in general) together is commitment. The center commits to less aggressive use of information in order to elicit that information. Under the Slack Contract, it is important the manager believes funding of 90 will be provided even when he budgets 60. Under the Rationing Contract, it is important the manager believes that if he budgets a cost of 90, the center will reject the project. The role of commitment is particularly important under the Rationing Contract since, when the manager reports the cost is 90, both parties would be willing to tear up the contract and write a new one under which the 90 cost project is accepted. Doing so makes both parties better off (when the cost is 90). However, if the manager anticipates the contract will be renegotiated when a cost report of 90 is submitted, he will pad his budget when the cost is 60, making the center worse off. Hence, it is valuable for the center to build a reputation as someone who sticks to her agreements.

The Slack and Rationing Contracts are hurdle rate contracts. The center commits to accepting the project if its cost is equal to or below some cutoff and rejecting the project if its cost is above that cutoff. If the project is accepted, the funding provided to the manager is the cutoff cost. The optimal contract is also a hurdle rate contract when there are more than two costs.

REDUCING THE INFORMATION ASYMMETRY
Nonstrategic Information Sources
Suppose the center can acquire information about the cost of the project, which reduces the information asymmetry between the center and the manager.\(^\text{10}\) The source of the information is unmodeled; for now, treat it as a black box. How much is the center willing to pay for this information? Return to the example presented in the previous section. If perfect information can be acquired by the center, the project is always accepted and the funding is equal to the cost; the center's expected profit is 25. (Note that in this setting the NPV rule applies.) In the absence of the information system, the optimal contract is the Rationing Contract, which provides the center with an expected profit of 20. Hence, the value of perfect information is 5.

In the example, there is rationing in the presence of an information asymmetry and no rationing in its absence. This might lead one to conjecture that a reduction in information asymmetry is always accompanied by a reduction in rationing. We next show that when the center installs an information system that reduces the information asymmetry, she sometimes optimally increases the amount of rationing. In other words, reducing the information asymmetry does not necessarily move us closer to the NPV rule.

Suppose there are now four possible costs, 60, 70, 80 and 90, and the probability of each cost is .2, .05, .05 and .7, respectively. As before, the cash inflow is 100. First, suppose the center knows only the above probabilities, while the manager knows the cost. In order to identify the optimal contract, there are four hurdle rate contracts to compare. The optimal contract is to accept the project

\(^{10}\) Our discussion of the value of nonstrategic information is based on Antle and Fellingham (1995).
no matter what cost the manager reports and to provide funding of 90. The center's expected profit is 10, and the manager's expected slack is 7.5.

Now, suppose the center can install an information system that reveals whether costs are low (60 or 70) or high (80 or 90). The problem can be decomposed into two binary cost problems and each can be solved as in the previous section of the paper. The center uses Bayes Rule to update her beliefs when she observes the cost is low or high. For example, if she observes the cost is low, she assigns probability \( \frac{.2}{(.2 + .05)} = .8 \) to the cost being 60 and \( \frac{.05}{(.2 + .05)} = .2 \) to the cost being 70. The optimal contract is the Rationing Contract if the cost is low and the Slack Contract if the cost is high. The center's expected profit is 15.5, and the manager's expected slack is .5. Hence, installing an information system that reduces the information asymmetry is beneficial to the center. Perhaps surprisingly, it also results in more rationing.

Intuitively, the cost is very likely to be 90. Hence, rationing in this state is very expensive. Without the information system, the center has to give up production when the cost is 90 if she wants to do any rationing at all. This is so expensive that she optimally chooses not to ration at all. With the information system, when the center observes the cost is low, she can ration without the fear of giving up production when the cost is 90. As a result, the center finds it optimal to ration when the cost is low.

In the examples considered so far, the center always prefers to decrease the manager's informational advantage and the manager always prefers to increase his informational advantage. The first conclusion is true as long as the center has full powers of commitment, since she can always commit to ignoring the information. However, the second conclusion is not always true.

Continue with the previous example, except the probabilities of the cost being 60 and being 90 are switched. That is, the costs are 60, 70, 80 and 90, and the probability of each cost is .7, .05, .05 and .2, respectively. Without the information system, the optimal contract is to accept the project and provide funding of 60 if the reported cost is 60; otherwise, the project is rejected. The center's expected profit is 28, and the manager's expected slack is 0. With the information system, the optimal contract is the Rationing Contract when the cost is low and the Slack Contract when the cost is high. The center's expected profit is 30.5, and the manager's expected slack is .5. Hence, the manager is actually better off when his informational advantage is reduced.

One way to think about the above results is that the parties to a contract are affected not only by the size of the pie (expected production less the cost of production), but also by how the pie is split. The way in which the pie is split depends on the size of the pie; production and distribution problems do not decompose. The center optimally chooses the size to maximize the expected cash inflow less funding. With less of an information asymmetry, it is possible the center will choose to make the pie bigger and, hence, both parties will be better off. In such situations, the manager has incentives not to sabotage (and, in fact, to help support) an information system that reduces his informational advantage.
Strategic Information Sources

Suppose the information obtained by the center is provided by a strategic source, i.e., an individual who acts in his own self interest.\textsuperscript{11} Continue with the last example, except there are now two managers, A and B, each proposing his own project. The center can accept one or both projects. Costs in each division are correlated in that if manager i's cost is low (high), then manager j's cost is also low (high), i, j = A,B; j \neq i. The center obtains information about manager i from both manager i's report and manager j's report.

The optimal contract depends on the behavioral assumptions that are appropriate in predicting the way the managers will play in the budgeting game. One common behavioral assumption is due to John Nash. The Nash equilibrium concept assumes managers will play best responses to each other's strategies. That is, given manager j's strategy, manager i chooses a strategy that maximizes his expected slack. If the center designs a contract that ensures only that truthful reporting is a Nash equilibrium, the optimal contract is as shown in figure 1.

The optimal contract is a relative performance evaluation contract. The center will not accept a high budget from manager i unless manager j's budget is also high. The center's expected profit is \( 2[.7(100 - 60) + .05(0) + .05(100 - 90)] + 2(100 - 90) = 61. \) This is exactly twice the center's profit under the nonstrategic information system.

Since the center's expected profit (per project) is the same under strategic information supply as it is under nonstrategic information supply, it is tempting to conclude that the source of the information is not important. However, an additional control problem is introduced with strategic information. In our setting, as often occurs with relative performance schemes, the optimal two-manager contract gives rise to an implicit collusion problem. Although both managers reporting truthfully is a Nash equilibrium in the budgeting game, so is each manager always reporting his cost is 90. That is, there exists an equilibrium under which each manager pads his budget to the maximum extent possible. Moreover, the padding equilibrium increases each manager's expected slack to 22.5 (compared to .5 under the truth-telling equilibrium). This comes at the center's expense; her expected profit is reduced to 20 under the padding equilibrium. As Krep\( \text{s} (1990, 702) \) points out, "if a mechanism admits several Nash equilibria, some of which are worse for the designer (and, more importantly, better for the participants) than is the equilibrium that is desired, then one

\textsuperscript{11} The discussion presented in this section is based on Arya et al. (1996).

\begin{table}[h]
\centering
\caption{The Optimal Contract}
\begin{tabular}{|c|c|c|c|}
\hline
Manager j Reports & Manager i Reports & i's Project is & i's Funding \\
\hline
60 or 70 & 60 & Accepted & 60 \\
70, 80 or 90 & 60 & Rejected & 0 \\
80 or 90 & 60, 70, 80 or 90 & Accepted & 90 \\
\hline
\end{tabular}
\end{table}
worries that the participants will find their way to the wrong equilibrium."^12

The point of this example is twofold. First, extracting information from strategic sources can be a delicate exercise. Second, as additional control problems are introduced, capital budgeting decisions look less and less like a direct application of the NPV rule.

This paper emphasizes that viewing the NPV rule as governing all capital budgeting decisions may not be appropriate. The NPV rule applies in limited settings in which there are no control problems and in which the projects disappear if not undertaken immediately. The NPV rule is not wrong; given its underlying assumptions, it is correct. The challenge is to learn how to make budgeting decisions in settings wherein the assumptions do not hold. In such settings, there is potentially a useful role for other capital budgeting techniques such as evaluations based on the payback period, the internal rate of return, and the accounting rate of return.

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**APPENDIX**

Denote the cash inflow of the project by \( i \) \((0 \leq i \leq 1)\) and the cost of producing \( i \) by \( c_i \) \((c = c_L, c_H, c_L < c_H < 1)\). The probability of \( c \) being \( c_L \) is \( p_L \) and of \( c \) being \( c_H \) is \( p_H \). (Since marginal cost is less than marginal revenue, the project always has a positive NPV.) Let \( f \) denote the funding provided to the manager.

The contract the center offers the manager specifies cash inflow and funding amounts as a function of the manager's cost report. The center maximizes the expected cash inflow less funding, subject to the constraints that, under the contract: the manager has incentives to report truthfully \( T \), all funding comes from the center \( F \), and the cash inflow is between 0 and 1. The linear program that identifies the optimal contract is presented below.

\[
\begin{align*}
\text{Max } p_L \left[ i(c_L) - f(c_L) \right] + p_H \left[ i(c_H) - f(c_H) \right] \\
\text{subject to} \\
& f(c_L) - c_L i(c_L) \geq f(c_H) - c_L i(c_H) \quad (T_L) \\
& f(c_L) - c_L i(c_L) \geq f(c_L) - c_L i(c_L) \quad (T_H) \\
& f(c_L) - c_L i(c_L) \geq 0 \quad (F_L) \\
& f(c_H) - c_H i(c_H) \geq 0 \quad (F_H) \\
& 0 \leq i \leq 1 \\
\end{align*}
\]

The solution to this program is:

\[
\begin{array}{c|c|c|c}
 & \text{\( p_L \leq \frac{1-c_H}{1-c_L} \)} & \text{\( p_L > \frac{1-c_H}{1-c_L} \)} \\
\hline
i(c_L) = I & i(c_L) = I & i(c_L) = I \\
f(c_L) = c_H I & f(c_L) = c_L I & f(c_L) = I \\
i(c_H) = I & i(c_H) = I & i(c_H) = I \\
f(c_H) = c_H I & f(c_H) = c_H I & f(c_H) = 0 \\
\end{array}
\]
In the table on the prior page, the contract in the left column is the Slack Contract and in the right column is the Rationing Contract.

REFERENCES


