APPLIED SYSTEMS ANALYSIS

Engineering Planning and Technology Management

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CHAPTER 12

CHOICE OF DISCOUNT RATE

12.1 THE ISSUES

The choice of the discount rate is the single most critical element in any evaluation of benefits and cost over time. This is true for two reasons. The most obvious one is that the present values of future benefits and costs are intrinsically very sensitive to the discount rate, as Section 11.5 describes in detail. Relatively small changes in the discount rate can make a significant difference in whether a project appears desirable or not. The general rule is that higher discount rates make projects look less attractive. (Note, however, that exceptional counterexamples to this rule can be constructed, in which higher discount rates sometimes make a project more attractive. See Section 13.3 and especially Figure 13.2.)

The second reason the choice of the discount rate is often crucial is because it is a prime determinant of the choice of technology. Indeed, because higher discount rates minimize long-term benefits, they are therefore unfavorable to *capital intensive* projects—those investments such as steel mills, nuclear power plants, or concrete highways, whose large initial investment is repaid over many years. The choice of a lower discount rate is thus often a choice for such projects, as compared to their less capital-intensive alternatives—such as the manufacture of plastics, fossil fuel electricity, or asphalt highways.

The connection between the choice of discount rate and the choice of technology is quite subtle. Most designers are actually unaware of the phenomenon, and certainly few like to think that their expertise takes second place to a simple financial parameter. Yet it is so, as Section 12.2 discusses in detail.

The logic of what the discount rate should be is actually quite straightforward, as Section 12.3 indicates. In any textbook case, it is easy to determine the proper discount rate. The difficulty is that, in real situations, there is no method that clearly gives the right answer with good precision. As a practical matter, the choice of the discount rate is thus imprecise and rather arbitrary in the end.

The twin facts that the choice of the discount rate is a matter of judgment and can have rather enormous economic and technical implications make this selection highly controversial. Powerful political and economic interests will almost always be affected by the choice and ever ready to argue against it. Section 12.6 deals with their major counterarguments.

The final issues concern the ever-bothersome questions of how to treat risk and inflation. Sections 12.7 and 12.8 cover these questions, and Section 12.9 gives a variety of examples illustrating how one should think about the choice of discount rate.

12.2 A DETERMINANT OF TECHNOLOGY

Designers and managers are constantly having to face a fundamental kind of choice as they consider projects. Over and over the issue is: should they select the alternative which costs less initially but more to operate? or should they invest more at the beginning, to save money on operations and maintenance? On a personal level, for example, you may have to choose between regular tires and radials if you own a car. A builder might have to choose between a wood or a brick house, a city between paving its streets with asphalt or concrete, and a company between obtaining power from fossil fuels or by investing in hydroelectric or nuclear power. As these examples suggest, this choice between saving money now or later is, as a general rule, a choice between technologies.

This choice between technologies is often determined by the discount rate. As the parameter which establishes comparability between present and future sums of money, it settles the question of whether future savings justify extra expense at the beginning. Specifically, it determines if the net present value is positive or not.

Consider two technologies, A and B. Each implies some initial costs, C_{kA} and C_{kB}, and future recurring costs of operation and maintenance, C_{rA} and C_{rB}. The only interesting situation is if one technology has lower initial costs but higher operating costs, say:

$$C_{kA} < C_{kB}$$

$$C_{rA} > C_{rB}$$

(If one technology is always cheaper, the choice is trivial, of course.) The choice as to whether A is more economical than B is thus simply whether the extra initial cost of B, $C_{kB} - C_{kA}$, justifies the future savings it generates, $C_{rA} - C_{rB}$. This issue can be viewed as a distinct evaluation, with the time stream of costs shown in Figure 12.1.

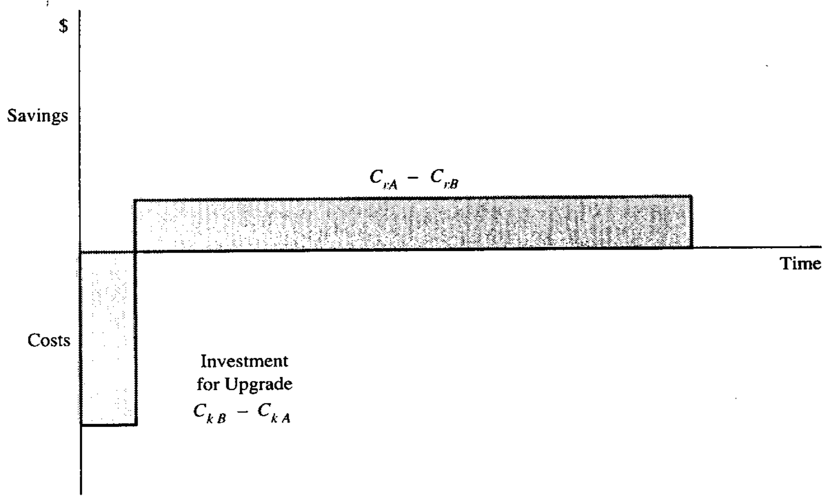


FIGURE 12.1
The cash flow of costs and savings associated with the choice between a "low capital–high recurring cost" technology (A) and "higher capital–lower recurring cost" technology (B).

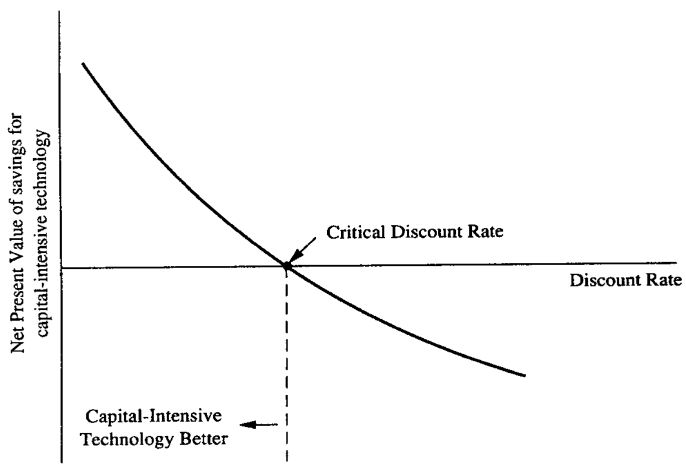


FIGURE 12.2
Lower discount rates make capital intensive technologies appear better in comparison to less capital intensive technologies.

The extent to which the discounted savings exceed the present costs depends directly on the discount rate. These net savings, the net present value of the savings minus the present costs, decrease with increases in the discount rate. The relationship is generally as in Figure 12.2. For discount rates below the *critical discount rate*, at which the net present value of the savings is zero, the technology that requires more initial capital is better; for higher discount rates, the less capital-intensive technology is more economical (see box).

The choice of the discount rate therefore can determine which technology appears best. The temptation to manipulate this selection for particular advantage can thus be great. Powerful economic and political interests allied with one technology or another will encourage this. When the U.S. Federal Highway

Dependence of Net Present Value on Discount Rate

Suppose your organization has the choice between two air conditioning systems, the regular and the "power-miser." The regular costs \$10,000 to install and \$3000 a year to operate. The "power-miser" has an initial cost of \$18,000 but uses only \$1800 of power a year. Both would last 10 years.

The choice between the two systems is a question of whether the benefits of the annual savings (3000 − 1800 = \$1200 a year) justify the additional initial cost of \$8000. Is the net present value of the upgrade to the more expensive system positive?

If the discount rate were zero, such that future benefits were not discounted, the upgrade is clearly worthwhile.

$$\text{NPV } (r = 0) = 1200(10 \text{ years}) - 8000 = \$4000$$

Conversely, if the discount rate were extremely large, future benefits would be discounted, totally in fact, for infinite r:

$$\text{NPV } (r = \infty) = 1200(0) - 8000 = \$ - 8000$$

The project is not worthwhile.

The variation of net present value with the discount rate can be obtained from Table 11.2. For example, for $r = 5\%$:

$$\text{NPV } (r = 5) = 1200(7.72) - 8000 = \$1264$$

The range of results is summarized as follows:

r%	:	0	5	10	15	infinity
NPV (\$)	:	4000	1264	−632	−1976	−8000

The critical discount rate, below which the more capital-intensive system is preferred, is around $8\frac{1}{2}\%$ by interpolation.

The overall dependence of net present value on discount rate for this evaluation of the upgrade plots is as in Figure 12.2.

Administration promulgated a regulation, some 20 years ago, that the discount rate for federally funded highways would be zero, this was widely interpreted as a victory for the cement industry over the asphalt interests. (Roads made of concrete cost significantly more than asphalt roads, but require less maintenance and less frequent replacement.)

Other financial arrangements can also influence the choice of technology, as is evident by how we can shift the curve of net savings in Figure 12.2. For example, the rules in the United States whereby the federal government pays the states up to 90% of the initial costs of highways, but none of the later operating and maintenance costs, systematically shifts the curve upward for the states, by the reduction in the differential initial costs. This shifts the critical discount rate to the right, and favors concrete as the more capital-intensive technology for building highways (see box). Similarly, the peculiarities of the tax system in the United States allow states and cities to obtain money at very low rates for public purposes, such as highways. This lowers their discount rates and also favors capital-intensive technologies such as concrete highways. Is there any wonder that the U.S. interstate highway system is almost entirely built of concrete? Yet other highways, built without federal funds—such as the Massachusetts Turnpike—are built of the less capital-intensive alternative, asphalt. This illustrates the potentially powerful effect of the choice of discount rate on the choice of technology.

Raising Critical Discount Rate by Capital Subsidies

You are reevaluating the alternative air conditioning systems: there now is a subsidy on the initial investment. (These arrangements are quite common: businesses may benefit from "investment tax credits" that lower the net cost of new investments; local governments may receive grants from the central government.) Specifically suppose that the subsidy amounts to 20% of the initial cost.

The initial cost of the upgrade to the more expensive system is correspondingly reduced by 20%. The cost of the upgrade is now

$$18,000(0.8) - 10,000(0.8) = \$6400$$

implying a 20% savings compared to the previous cost:

$$8000 - 6400 = \$1600$$

The net present value of the upgrade thus systematically increases by $1600 for all values of r, since the operating costs do not change. The new range of results is

r%	:	0	5	10	15	infinity
NPV ($)	:	5600	2864	968	–376	–6400

The new critical discount rate is $13\frac{1}{2}$% by interpolation. The 20% subsidy on capital costs has, in this case, raised the critical discount rate by 5% and made the capital-intensive technology far more attractive.

12.3 LOGICAL BASIS

The discount rate is the mathematical means for establishing whether a project is worthwhile, as indicated by a positive net present value. The discount rate must therefore be chosen so that the set of worthwhile projects it defines matches what is really acceptable to a person or organization.

Anybody's set of worthwhile projects consists of all those with the greatest returns on investment that fit into their budget. The other opportunities, which offer lower returns, are not worthwhile to a person: to include them within a budget, better projects would have to be dropped and the person would suffer a loss. The discount rate should thus be set so that all the best projects that fit within a budget are included, and all the rest excluded.

At any time, every individual or group has a wide range of investment opportunities. These will naturally never be the same at all times for all persons; opportunities arise and disappear. Acting rationally, the investor first places money in the most rewarding opportunity, then the one with next highest returns on investment and so on. The matter of investing sequentially into the projects with the greatest returns generates the kind of curve shown in Figure 12.3.

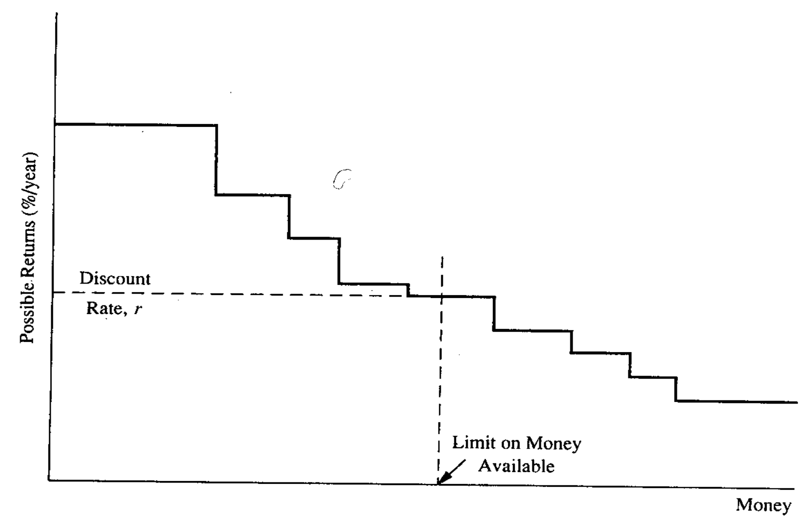


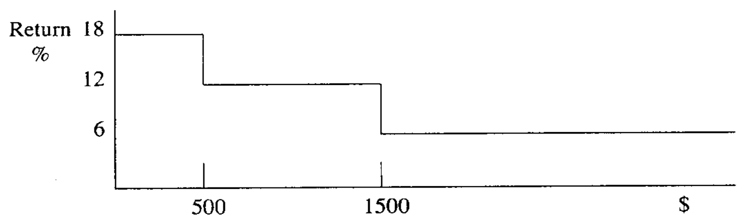
FIGURE 12.3
Representative pattern of possible returns on investment for a particular individual or company.

Ultimately it becomes asymptotic with the return available from the essentially unlimited opportunities to place money in banks or government bonds at their prevailing rate of interest. In practice, companies or individuals run out of capital well before these lowest opportunities. This limit on money available varies for each investor, of course; it depends on how much money one starts with, on how much banks might be willing to lend, and on legal limits that may exist on how much one can borrow. The intersection of this limit with the curve of returns on investment defines the discount rate for the investor (see box).

Pattern of Returns on Investment

Imagine yourself just after the holiday shopping. You have a $500 debt on your credit card on which you pay 18% annually, have borrowed $1000 from your local bank at 12%, and have a savings account paying 6%—with, unfortunately, no money in it.

Your pattern of returns on investment, if these are your only opportunities, is as follows. You presumably could put as much money in the bank as you wished.



Your discount rate depends on how much cash you have to spend on the investment—on the unspent total of what you received as holiday presents, for example. If this is between $500 and $1500, your discount rate should be 12%: only alternatives offering returns at least this high are worthwhile to you. If you have less that $500, your discount rate should be 18%.

Finally, if you were considering a project whose cost exceeds the steps of the graph, your discount rate would be a weighted average of the above rates. If the proposed project cost $750, say, and that was all the cash you had, your opportunity cost would be 18% on the $500 and 12% on $250, for an average of:

$$\frac{[18(500) + 12(250)]}{750} = 16\%$$

The discount rate should thus represent the productivity of the last increment of money available to a person, company, or government, the marginal productivity of capital to that agency. It simultaneously should be the

- lowest acceptable rate to any investor.
- highest rate among the remaining opportunities if more capital were available.

The beauty of the discount rate can now be explained. It provides an immediate indication of whether any project falls within the economic range of acceptability for an investor. Suppose the return on investment of a project, r_p, just equals the discount rate; $r_p = r$. Then the project has a net present value of zero, when discounted at the rate of r%. Similarly, a project that returns at a higher rate, $r_p > r$, has a positive net present value. Conversely, if the project returns at some lower rate, $r_p < r$, it has a negative net present value. In short, by using the proper discount rate, we can immediately tell if a project is economically acceptable simply by looking at the sign of its net present value.

The discount rate can also simply be viewed as the shadow price on the budget. It is indeed the increase in return an investor could obtain for each extra dollar available.

> **Semantic caution:** The discount rate is frequently in practice referred to as the *"opportunity cost" of capital*. This is confusing because, as indicated in the discussion of shadow prices and opportunity costs in Chapter 6, these concepts are quite different. The reason the discount rate is called the opportunity cost is because, if investors want to obtain money for a new project without borrowing more money, they have to give up the opportunity to do some other project. Acting rationally, this would be one with the lowest return on investment of all they have invested in, that is, one with a return equal to the discount rate.

The difference between the discount rate and the interest rate should now also come into focus. The discount rate for any investor acting rationally should be substantially above the interest rate on any loans. Investors borrow money because they see that by doing so they can make a profit, the difference between their discount rate and the interest they pay. Conversely, if the interest rate were higher than the discount rate, rational investors would pay off their loans. Finally, the discount rate generally exceeds the interest rate by a fair margin because bankers and other lenders like to see a comfortable cushion to protect their loans, and never seem to lend as much as the borrower might want.

12.4 RATE FOR PRIVATE SECTOR

The productivity of money in commerce and industry is typically well over 10% a year, and frequently closer to 15 or 20%. These numbers are difficult to pin down precisely, because they vary significantly between types of industry, individual companies, and with the general state of the economy.

In general, the rates of return are lower in industries regulated by the government than for companies that are not. The reason is that they are allowed less profit, in exchange for the lower risk associated with a regulated industry. Electric power companies in the United States commonly have rates of return on the order of 10%, and banks of about 12% or so. Manufacturing companies often appear to have returns of 15% or more.

Calculating the rate of return for any company requires a detailed, sophisticated analysis of its accounts, together with an understanding of the applicable tax laws. Individual companies rarely go through this kind of exercise. In practice they typically set a corporate standard, which they believe to approximate their reality. Sometimes they do this indirectly, as by setting a minimum criterion of acceptability, particularly of the payback period (see Section 13.3). The discount rates used in industry, either explicitly or implied, typically appear to be 15 or 20%.

In the United States, various investment banks and stock brokers attempt to calculate the rates of return of companies whose stock is traded publicly. They do this by statistical analysis of the past performance of any company in comparison to other similar companies. The results derived from these analyses have the appearance of being quite accurate, since they are given to several decimal points. But appearances are deceiving. These results depend crucially on dubious assumptions, most particularly that the future will be similar to the past 20 years or so, which is always a doubtful proposition. In any case the figures generated by these analyses are comparable to those given above.

12.5 RATE FOR PUBLIC SECTOR

Most of the controversy surrounding the choice of the discount rate concerns the rate the government should use. This is because governments are, generally, run by politicians more sensitive to political pressures than economic realities.

Despite the political controversy, the rational economic rule is simple: the discount rate for government and public sector projects ought to approximate the discount rate for business and industry. The reasoning is that

- the money the government raises comes from taxes on the private sector.
- the money thus taken from companies and individuals restricts their opportunities to invest in productive facilities or to pay off debts, as for mortgages.
- the private sector discount rate represents the loss of productivity to society, the opportunities foregone because of taxes.
- the government should, therefore, use this rate when evaluating its own projects to make sure that society as a whole is not a loser—as it would be if money were diverted from projects with higher productivity to ones with lower productivity.

The best economic minds are now agreed on this general reasoning.

In practice, the discount rate for government is often taken to be lower than the average rate of returns in private industry, somewhat closer to those

in regulated industries. The rationale is that government activities involve less risk. A 10% discount rate is now widely used: in the United States, this is the rate required by the federal Office of Management and Budget for the evaluation of national projects; the World Bank uses 10% in its feasibility studies; the British Airports Authority has been using 14%; and so on.

12.6 ALTERNATIVE ARGUMENTS

The alternative arguments concerning the selection of the discount rate are directed toward establishing a lower rate, closer to 3 or 5%. The proponents of these arguments are interested in justifying capital-intensive projects with long lives, the kind of project that is not favored by high discount rates. The arguments are particularly directed toward government, to justify massive public works such as highway or waterway construction in the United States, railroads in some countries, steel mills in others. They are not aimed at private enterprise, which simply could not survive economically if it adopted the arguments proposed.

Even though these arguments do not seem at all appropriate, it is important for any analyst to be aware of them and prepared to deal with them. This is the reason they are summarized here.

The first major argument is that the government's discount rate ought to equal the interest rate it pays on its bonds, particularly the long term bonds. This principle is not right. As pointed out in Section 12.3, nobody's discount rate should equal their interest rate, unless they have unlimited money available. In general, as Figure 12.3 illustrates, there is a wide gap between the two. As even governments have to operate eventually within the constraints of their budgets, their discount rate should certainly be above the rates they pay on their bonds.

This argument used to be popular in public works agencies in the United States some years ago. At that time, the average interest rate paid by the United States on its bonds—many of which had been issued during the Depression and World War II—was quite low, almost 3%. Now that the average interest rate paid by the United States on its bonds is closer to 8%, and that economic rationality has been imposed by the U.S. Office of Management and Budget, this "interest rate" argument is on the way to disappearing in the United States.

The second line of argument is emotional. It runs along the lines of "look at all the worthwhile projects we could not build if we evaluated them with a high discount rate." The key word here is "worthwhile." The argument presumes that certain people, such as government officials or technocrats, already know what is best, what is worthwhile, independent of any evaluation or careful analysis.

This argument often gets quite emotional, because the discussion over any one project quickly gets transformed into whether one is for or against some acknowledged social good. For example, controversy over a project to irrigate lands and create new farmland can get translated into an argument as to whether or not one is really against agriculture and poor farmers, when really—in this case—the issue is that reclaiming desert land at a cost many times the value of good farmland elsewhere is simply a waste of money that no rational person would contemplate, if it were not to be paid for by the government.

The use of reasonable discount rates, of about 10%, in no way prevents us from spending money on any social concerns a government and its people choose: health, education, welfare, or whatever. If the public values these services highly, and is willing to pay for them, they will be provided. Use of a high discount rate ensures that the government provide its goods and services rationally, with the right scale and the right technology. Use of a high discount rate does not prevent us from spending on highways, for example, but it does impel us to choose the type of construction that makes economic sense.

12.7 TREATMENT OF RISK

In the private market, projects that are riskier than others are forced to pay higher interest rates to attract capital. A speculative new company will have to pay the banks several percentage points more for its borrowings than established, prime customers. Private companies, which always run the risk of bankruptcy, have to pay more than the government. This extra amount of interest is known as the *risk premium*. The question is, should this amount somehow be included in the discount rate?

As a practical matter, the risk premium already is included in the discount rates described in the previous two sections. The speculative new company, borrowing at a rate several points above the prime rate of interest, should have a discount rate above this higher interest rate. The regulated electric utility, typically an established company whose continued existence is guaranteed by the government, will be able to borrow money more cheaply, will invest in projects whose marginal productivity is correspondingly lower, and should have a lower discount rate.

When a particular project is especially risky, the evaluation ought to account for risk directly. As the discussion on evaluation methods in Chapter 10 indicates, decision analysis (described in Chapters 16 and 17) is the preferred way to appraise projects with a high component of risk.

12.8 TREATMENT OF INFLATION

Inflation is the loss in value of money over time. It is the phenomenon represented by observations that money now does not buy what it used to. Inflation is typically measured by *price indexes*, which indicate how much money is required, at any time, to buy a standardized collection of items. The usual way to express inflation is in terms of percent per year, just as the discount rate.

The question always is: how should we deal with inflation in an evaluation? Should it be included in the discount rate? Should future benefits and costs be adjusted? Should it be ignored, or what?

The answer is that we should do what is necessary to establish comparability between money now and money later. This is the central idea of the evaluation of projects over time, and the role of the discount rate.

The general rule is that if future revenues and costs are measured in future dollars, the ones that are inflated, then we must include this effect in the evaluation. This can be done by either of two equivalent procedures:

- Deflating all future revenues and costs by the rate of inflation
- Increasing the discount rate by the rate of inflation

Both procedures lead to exactly the same result: money later is discounted for both the time value of money and for inflation (see box).

Conversely, if future revenues and costs are measured in *current dollars*, at prices unchanged due to future inflation, then there is no need to account for inflation in the evaluation. The next section provides examples of these situations.

To apply these rules we also need to know whether the inflation rate is already included in the discount rate, as may be the case for private companies. Indeed, to the extent that a company estimates its productivity by looking at

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Alternatives for Dealing with Inflation

Imagine that you are buying a house and can choose between two kinds of 20-year mortages offered by the bank. One requires you to pay $10,000 more now than the other, but saves you $2000 a year in payments.

Suppose that your personal discount rate is 10% in current dollars and that you estimate inflation to be 5% a year. Which mortgage is better for you?

Mathematically, the question is whether the extra $10,000 payment has a positive net present value. You can calculate this two ways.

Recognizing that the future payments will be in inflated money, you can increase the discount rate by the rate of inflation and proceed accordingly. Using Table 11.2, you then find

$$\begin{aligned} \text{NPV} &= 2000(\text{series present worth at } 15\%) - 10{,}000 \\ &= 20{,}000(6.26) - 10{,}000 = \$2520 \end{aligned}$$

Alternatively, you can first deflate the annual payments by the 5% inflation to obtain equivalent amounts in current dollars, and then discount these amounts using the corresponding 10% discount rate. The effect is most easily seen using the exponential form of the compound amount factor (see Section 11.4):

$$(1 + r)^N = e^{rN}$$

The annual savings expressed in current dollars are then $2000(e^{0.05N})$. The present value of each annual payment is then $[2000(e^{0.05N})]e^{0.10N}$. This is equivalent to $2000(e^{0.15N})$ which leads to the same result as before.

Which of the alternatives is easier to use depends on the situation. No general rule applies.

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its annual return on its investment, it incorporates the inflation rate. This is because its investment was years ago, and its returns are now, in inflated money. This situation makes the evaluation process as simple as possible: measure future revenues and costs in the amounts you expected to see, that is, inflated, and apply the standard discount rate for the company, which accounts for the inflation. For government, whose discount rate is approximated as a low round number, it is generally safe to assume that the discount rate does not include the effect of inflation.

What the future inflation rate may be is always a question. It is both quite variable and dependent on the situation. Recent experience in the United States well illustrates the potential variability over time: in the 1970s the annual rate of inflation routinely exceeded 10% per year, in the 1980s it fell to around 4 to 5%. As this indicates, the inflation rate can be controlled by government policy, and thus varies enormously between countries. Some, like Switzerland, seem consistently to have very low rates of inflation, a few percent or so; others, like Argentina, Brazil, and Israel, have suffered from chronic hyperinflation on the order of 100% a year.

The rate of inflation also depends on the industry. At any time, different sectors of the economy undergo changes and experience quite different rates of price changes. Recently in the United States, for example, the inflation in the costs of healthcare was two or more times the national rate. To track these different inflation rates, industrial associations and government agencies routinely publish specialized price indexes such as the Wholesale Price Index, the Consumer Price Index, and the Construction Price Index. Always in the spirit of establishing comparability in an evaluation, the rule is to use the inflation rate suitable to the situation.

12.9 EXAMPLES

This section provides a series of samples illustrating the principles of selecting a discount rate for a variety of situations.

Example 1: An individual has $200 to buy new tires. She has $1000 outstanding on her credit card, for which she is paying 18% a year, and unlimited opportunities to put money into a 6% savings account. Question: at what discount rate should she evaluate her two alternatives for buying tires, the long-lasting radials or the cheaper belted tires that will have to be replaced sooner? Answer: 18%. Any extra investment in tires should provide at least this return or she would be better off paying off some of her credit card bill. Note that this rate includes both inflation and replacement tires, since she pays for both with future money. Her discount rate free of inflation is (18% − inflation rate).

Example 2: The same person has to choose between an ordinary refrigerator and an energy-efficient model that is expected to save 500 kwh/yr. The electricity now costs $0.10 per kilowatt-hour. Question: Should she adjust for inflation in doing the evaluation? Answer: With this information, no. The savings are given in current dollars, unaffected by inflation, so they are directly comparable to current costs once the discount rate free of inflation has been applied.

Example 3: She now finds out that, as a result of a regulatory decision, the cost of electricity will increase by 15% a year over the lifetime of the refrigerator. Question: Now how should she deal with inflation in her evaluation? Answer: Since she is dealing with future costs, she should either deflate them by the expected rate of inflation, or evaluate them with the discount rate including inflation (in her case 18%).

Example 4: A city plans to expand a toll bridge to accommodate more cars. The toll is now $1.00 a trip. Question: Should this be adjusted for inflation in the evaluation? Answer: Almost certainly yes. This case differs from that of Example 2 in that prices for tolls tend to stay constant whereas other prices adjust for inflation. So here the current price can be assumed to be the future price, and should be adjusted downward to account for inflation.

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PROBLEMS

12.1. *Personal Discount Rates*

Some effort has been made to sell small cars and certain other goods on the basis of reduced energy and maintenance costs. However, most consumer purchases are based on the purchase price and performance. For appliances and machinery whose operating costs are large compared to the initial cash outlay, such naïve approaches may result in choices that are more expensive than necessary.

(*a*) Consider a refrigerator which costs $300, uses 1600 kwh of electricity per year, and requires an annual one-hour service call. If service costs $10/hr, electricity costs 3 cents/kilowatt-hour, the purchaser's discount rate is 10%, and the refrigerator lasts 10 years, what is the life cycle cost of the refrigerator (total discounted cost)? What is the equivalent annual cost? Which measure (life cycle or annual cost) would you find most useful in choosing a refrigerator?

(*b*) An improved refrigerator is introduced. Better insulated and more efficient than the standard, it costs $700, uses only 600 kwh per year, and is otherwise identical. Which refrigerator is the better choice for a purchaser in Plainville, where electricity is 3 cents/kwh and service $10/hr? In New York City, where electricity is 7.6 cents/kwh and service is $15/hr? Assume both buyers have a 10% discount rate.

(*c*) Consider two different New Yorkers. Connie Ross, a junior executive, lives in a posh Manhattan apartment building. She finds her salary barely adequate to maintain her lifestyle and has considered getting a loan from her credit union (at 12% interest). However, she still has $1500 in the bank, drawing 10% interest.

Ralph White works overtime as an electronics assembler to support his family. He has never been able to save more than a minimum down payment for any major purchase; eligible only for dealer financing and being in a high-risk category, he pays about 20% interest on the remainder of the purchase price.

Which refrigerator is a better investment for Connie? For Ralph?

12.2. *Student Finances*
You are a student with a monthly income of only $600, and in some difficulty.

- You owe the student store $200, on which you pay an 18%/yr interest rate, calculated monthly, on unpaid balances.
- Your bicycle was just stolen and you want to buy one that regularly sells for $220, but is selling for $200, this week only, for cash.
- Your room and board is prepaid and you need $100 in expense money for the month.
- You have a $100 Savings Bond that earns 5%/yr, and $200 in the local savings bank that earns 6%/yr.
- You have $300 in a checking account. This money earns no interest and requires a $1.50 service charge for any month in which the balance is less than $200.

(*a*) How should you change your investments, if at all?
(*b*) What is your opportunity cost of another $100 this month?
(*c*) If you buy the bike this week, rather than next month at $220, what is its true cost?
(*d*) What is your discount rate?

12.3. *Inheritance*
Assume you receive $5000 to invest for your future. Your available alternatives for this money are:

- Use up to $2500 of it to pay a tuition loan, on which you pay 12% interest on unpaid balances.
- Put as much as you want of the $5000 in a savings bank to earn 5% per year.
- Buy a discounted bond for $5000 (the smallest denomination), that is redeemable only after 3 years for $8500. You can then reinvest this money in more of the same type of bonds.

(*a*) What is the opportunity cost, in percent, of the $5000?
(*b*) What discount rate should you use for evaluating an investment opportunity for the entire $5000 in some other business? for only $2500 of the $5000?

12.4. *Money Store*
The Money Corporation is considering a new product line. Its present financial situation is as follows:

- It can borrow money at the prime interest rate of 9%.
- The average annual inflation rate is 5%.
- The interest on tax-free government bonds is 7%.
- Its marginal after-tax return on other investments is 10%.
- It pays corporate taxes at the rate of 40%.

What discount rate should the company use in evaluating its expansion proposals, given that its benefits and costs for these projects (but not for the other investments) are in terms of current dollars? For example, benefits accrued in 2000 are in terms of today's dollars. (What counts here is your explanation of the right answer.)

12.5. *DR Review*
(*a*) What is the meaning of the government's discount rate?
(*b*) When should it be used?
(*c*) How might it be determined?
(*d*) What might be an appropriate rate for the United States?

12.6. *Port Authority*
The Port Authority is evaluating alternatives to repair or replace its bulldozers. Some have high initial cost but lower future costs, while other alternatives defer costs to the future. What discount rate should be used under the following set of conditions? Why?

- Savings certificates from the local bank pay 5%.
- The lowest or prime rate available to local borrowers is 9%.
- Public Facilities construction bonds sold several years ago pay 8%; more could be sold at $8\frac{1}{2}$%.
- The funds for the repair of trucks must come from a reserve in the current operating budget. At the end of the year money left in the reserve can be carried forward to reduce the following year's operating budget or it can be used to retire bonds ahead of schedule.

12.7. *Park Hue*
Park commutes 10 miles by train and subway at a cost of $6/day. Having just received a promotion that entails a free parking space, Park is trying to decide whether to buy a second car (the first being used by the family) to drive directly to work. This would save 10 min.
(*a*) Define the time streams of the relevant costs and benefits. What do you estimate the opportunity costs of Park's time to be?
(*b*) Define and justify your choice of discount rate for the evaluation. Then calculate the net present values of the alternatives.
(*c*) How does your evaluation change if Park had no family and no first car?

12.8. *Snowbird High Again*
Refer to Problem 11.8. Suppose that all repair and replacement costs will have to be covered by a contingency fund that has a current balance of $80,000. Contingency fund money not committed by January 1 will revert to the city's general fund and be allocated in whatever manner the city council sees fit.

The current financial market is approximately as follows: an average annual inflation rate of 3% has driven the interest rate paid by local banks to 8%; high-grade corporation bonds pay 9%; and school board bonds which are tax exempt pay 7%.
(*a*) What solution makes the most sense if you are the superintendant?
(*b*) If you are the school board and have to raise money for the project?
(*c*) If you are a member of the city council, and anticipate a tax rebate to citizens?

12.9. *Hi-Tacky Corporation*
The Hi-Tacky Corporation is considering a new energy efficient heating system that will provide savings in current dollars of $5000/yr. Based on the following information:

- Taxes are paid at the rate of 50%.
- Inflation has an annual rate of 8%.
- The prime interest rate is 7%.
- After-tax return on other long-term investments is 12%.
- Savings certificates from the local bank pay 5%.

What discount rate should it use when evaluating the heating system?

12.10. *Start-Up*
Your friend the entrepreneur has just started a new business. Your advice is needed on the discount rate to be used to evaluate new opportunities. Looking through the financial records, you find that your friend could already

- insulate the building for $40,000, which would save 5600 gal/yr of fuel, currently valued at $1/gal.
- pay off $80,000 borrowed at a rate of 12% on the balance.
- pay $20,000 for an annuity paying $3200/yr for 30 years.
- lend to another entrepreneur who guarantees to double a $30,000 investment in 5 years.

Your friend has $60,000 in cash for investment. Estimating inflation at 4% a year, what is your friend's minimum discount rate for a $20,000 investment? a $60,000 investment?

12.11. *Government Procurement*
The local government has several options for its $200,000 project fund:
(i) Establish an in-house desk-top publishing office, to get annual savings estimated at $28,000 in today's money.
(ii) Exercise an option to buy the land under their parking area, on which they now have a 30-year lease at $38,000/yr.
(iii) Buy the computer equipment they now lease for $70,000/yr. This will have to be junked in 5 years.
Estimating inflation at 6% annually, rank the above projects.

CHAPTER 13

ECONOMIC EVALUATION

The purpose of an economic evaluation is to determine whether any project or investment is financially desirable. Specifically, an evaluation addresses two sorts of questions:

- Is any individual project worthwhile? That is, does it meet our minimum standards?
- Which is the best project in a list of possibilities? What is the ranking of projects on this list?

This chapter shows how both these questions should be answered.

Economic evaluations are difficult to do correctly in practice. This is in great part because this work is done by middle-level managers or staff who necessarily, by the fact that they see only part of their company's or agency's activities, cannot realistically take all the appropriate factors into account. The result is that most evaluations are done on the basis of assumptions often out-of-date or otherwise inaccurate for the situation at hand.

Conceptual difficulties are another source of error and confusion in economic evaluation. A number of the standard criteria for evaluation contain biases which make them inappropriate and even quite wrong for particular kinds of situations. This chapter focuses on these issues so that the practitioner will be able—to the extent possible within the requirements of employers or clients—to select the most suitable criteria of economic evaluation.

The core of this chapter is the presentation of the variety of possible criteria for evaluation, in Section 13.3. These include net present value, benefit-cost ratios, internal rate of return, cost-effectiveness ratio, and payback periods. Each