15. The Time Factor: Discounting

Often, people face decisions about present activities that will have effects well into the future For instance, energy conservation often requires a major immediate purchase (of insulation or more expensive light bulbs) that will reduce energy costs (of heating or electricity) in the future. How do we decide whether to undertake those purchases? As a general principle, how do we view benefits and costs that occur at different times than the present? This chapter highlights how economists model people's decision-making for future events. In particular, you will learn about

- The relationship between money in the present and money in the future: interest rates
- The way that interest rates affect the values of goods in the future
- Why there are many different interest rates in the economy
- The appropriate discount rate for analyzing public projects involving the future.

Investing in Energy Conservation

How do people decide how much to invest in energy conservation? Energy conservation is a very environmentally favorable activity: any energy conserved is energy that does not have to be produced, and energy production (from coal-burning plants, with their air pollutants, nuclear plants with radioactive waste, and dams that bury rivers under lakes) causes a great deal of environmental damage. If people invest too little in conserving energy, then society will invest too much in producing energy. Every attic insulation and every thermally efficient window replacement serves as a substitute for burning fossil fuels or producing nuclear power.

The “Home Energy Saver” website (http://hes.lbl.gov/) allows you to calculate ways of conserving energy in your own home. Some very simple actions could both save you money and reduce production of greenhouse gases and other pollutants.

A programmable thermostat (that reduces the temperature in the house when people are out or in bed) costs about $70. Buying one and using it saves about $45 per year in Ann Arbor, Michigan.   Is this a good deal?

Major home renovations are an excellent opportunity for making investments in energy efficiency. Energy efficient replacement decisions for items such as the thermostat, energy efficient windows, wall insulation, and efficient appliances (such as the refrigerator and clothes dryer) might cost an additional $4,047. In exchange, utility bills would drop about $744 per year, and releases of carbon dioxide (a major greenhouse gas) would be about 11,803 pounds lower every year. Is this a good deal?

Determining whether spending money now to save money in the future involves comparing values in the present and values in the future. Economists model this process using **discounting**, the subject of this chapter.

The Time Value of Money

How do we decide whether to invest in energy efficiency when there are large up-front costs and benefits only over time in the future? If we gain the benefits from burning fossil fuels now but must face the costs due to warming of the planet in the future, how do we balance current benefits with the future costs? Answering that question requires examining our opportunity costs.

What else might someone do instead of investing $4047 in energy efficiency measures? One possibility that would also earn a person money is to invest it in the bank.

The bank pays consumers for lending them their money, in the form of **interest**. An **interest payment** is the cost of borrowing, or the benefit of investing (saving). Saving involves depositing money (the **principle**) in the bank. The bank will put the money to use, by lending it to people who want to borrow (and are willing to pay money--interest payments--in order to do so). In exchange, the bank offers the investor an interest payment, as an incentive to keep the investment in the bank. The **interest rate**, often abbreviated r, is the interest payment divided by the principle (usually multiplied by 100, to make it a percentage).

Let's look at how interest works on investments. An interest rate of 5%, for instance, implies that an investment of $100 yields $105 a year from now. The **future value** (FV) of an investment at a defined future time is the value that the present amount (the principle) will produce when invested. It is the sum of the principle ($100) plus the accumulated interest payments. If the interest rate is the interest payment divided by the principle, then the interest payment is r multiplied times the principle, which (for reasons we will explain soon) we'll call a **present value**, PV. In mathematical terms, the future value FV after one year equals the principle, PV, plus the interest payment, r*PV, or FV = (1+r)PV. With the initial investment of $100 and an interest rate of 5%, FV = (1.05)*100 = $105.

Let's call the value in year 1 FV_1 and the value in year 2 FV_2. If the investment is left to earn an additional 5% for another year, then the value in year 2, FV_2, is $(1+r)*FV_1$, or $FV_2 = (1+r)*(1+r)*PV$, or $FV_2 = (1+r)^2*PV$. In the example, $FV = (1.05)^2*100 =$ $110.25. If the investment continues to earn 5% until year t, then it is easy to continue this logic to find that $FV_t = (1+r)^t*PV$. In other words, the **future value** is the equivalent of $100 today invested at 5%.

Discounting reverses this logic to tell us the amount in the present that, when invested, produces the future value. In other words, the **present value** of a future amount is the value in the present that, when invested at the specified interest rate, produces the future value. (The interest rate used for discounting is sometimes called the **discount rate**. There is no practical difference between an interest rate and a discount rate.) In the previous example, the present value of $105 next year is $100 today; the present value of $110.25 in two years is $100. More generally, if $FV_t = (1+r)^t*PV$, then

$$PV = FV_t/(1+r)^t.$$

Discounting converts an amount in the future into its present value.

For instance, suppose that it costs $1000 to plant a forest that can be harvested in 30 years; at that time, it will produce FV_{30} = $5000 worth of wood. Is this investment a good idea? The present value of that $5000 is PV = $\$5000/(1.05)^{30}$ = $1157. The present value of the forest in 30 years exceeds the cost of planting that forest in the present; investing in trees produces more money than investing in the bank. The **present net value** (PNV, or sometimes **net present value**, NPV) of this investment is the present value of the benefits, less the present value of the costs. Here, the present net value is PNV = PV(Benefits) – PV(Costs) = $1157 - $1000 = $157.

This formula is based on the situation where there is a value at only one time in the future. If, instead, there are amounts V_1 through V_t in years 1 through t, then the present value of these payments is the sum of the present value of each of the payments:

$$PV = V_0 + V_1/(1+r)^1 + V_2/(1+r)^2 + \ldots + V_t/(1+r)^t$$

For instance, perhaps there would be a thinning of the forest in year 15 that would produce \$1000 of value, though it would reduce the value of the future harvest to \$4000. The present value here is PV = $\$1000/(1.05)^{15} + \$4000/(1.05)^{30}$ = \$1407. Conducting the thinning increases profits, by allowing some revenue closer to the present.

There are a couple more very useful formulas for present values. First, suppose that the same payment is made every year for t years, so that $V_1 = V_2 = \ldots = V_t$. This amount is often called an annual value, AV. For instance, a lottery winner who gets \$2 million often in fact gets offered \$100,000 per year for 20 years. Is this amount in fact worth \$2 million? The formula for the present value of t payments starting next year is:

$$\text{PV} = \frac{(1+r)^t - 1}{r(1+r)^t} * AV\ .$$

(Box 16.1 presents the derivations of these formulas.) In the case of the lottery earnings, at a 5% interest rate, the present value is PV = $100{,}000*[(1.05)^{20}-1]/[(0.05)(1.05)^{20}]$ = \$1,246,221– the amount that, if invested in the bank at 5% for 20 years, would allow a person to withdraw \$100,000 every year for 20 years before the account ran out. Clearly, this amount is much less than the \$2 million advertised.

If the annual value extends from now until infinity, this formula becomes

PV = AV/r.

Annuities, which pay a fixed amount forever, can be purchased for a present value based on this formula. For instance, a payment of \$100,00 a year forever at 5% is worth PV = \$100,000/0.05 = \$2 million: it is necessary to get the lottery payment, not for 20 years, but forever, to get the equivalent of \$2 million at 5% interest.

Note that the present value of \$100,000 for 20 years is \$1,246,221, while the present value of \$100,000 forever is \$2 million. The difference between these two values gives the present value of $100,000 per year forever, but not starting for 20 years. This difference, $753,779, is very much less than the simple sum of $100,000 forever; it is also worth much less than having that infinite stream of money starting now. Values in the future are worth less than values today, because having them today allows us the opportunity to invest and earn interest.

The purpose of all these formulas is to estimate what people consider the present equivalent of something in the future. In each of these cases, a person has the choice of investing the money in the bank, or investing it in the alternative activity (growing trees or getting lottery earnings over time). The present value of future money signals the opportunity cost associated with investing in a project: it could always be invested in a bank instead. If the alternative activity produces a higher present value, then the alternative activity produces more value than money invested in the bank and thus is more valuable; if the present value of the alternative is less than the initial investment, money in the bank provides greater earnings.

In our energy efficiency example, a homeowner could invest $4047 today in home improvements and earn $744 per year (starting next year when the construction is done) in reduced electricity bills for as long as the house is standing. If we can approximate this time frame by infinity, then the annual savings are equivalent to PV = AV/r = $744/0.05 = $14,880, and the present net value is $14,880 - $4047 = $10,833: it is definitely more profitable to invest in energy efficiency than in the bank. On the other hand, if the homeowner only expects to live in the house another 5 years before moving, the present value is PV = $744 * $[(1.05)^5 - 1]/[(0.05)(1.05)^5]$ = $3221, for a PNV = -$826; she won't be in the house long enough to make the investment worthwhile to her.

Would higher energy efficiency increase the value of the house when it is sold? If it did, by even $1000, then the investment would be worthwhile. A new homeowner should be willing to pay that amount if he expected to stay in the house for at least 2 years, since the energy savings ($PV = \$744/1.05 + 744/1.05^2 = \$1383$) exceed the additional cost. If the investment costs can be included in the house value, the investment in energy efficiency is worthwhile over time.

For thousands of years, people have been willing to pay interest in order to get something now rather than wait until they had the money in hand. Since people are willing to pay a bonus to have something in the present rather than in the future, the otherwise identical good in the future is obviously worth less than the good right now. Discounting future values estimates the present-value worth of that future good.

Why Interest Rates Exists – An Aside

Interest rates have existed for thousands of years; they are discussion topics in the Old and New Testaments of the Bible as well as the Qur'an, generally viewed with disfavor. Why do interest rates exist?

There are two factors that lead to interest rates: (1) People prefer things now to later; and (2) People can invest in capital goods, like factories, that return more money in the future than they use today.

The first effect, known as the **personal discount factor**, exists because people are impatient. For instance, if people are offered the choice between having $100 today and $100 in one year, almost everyone chooses the $100 today. Why? Having $100 today gives the recipient several choices. She can use the money right now for any number of activities (paying rent, buying books, having a party) instead of having to wait a year; she can hold onto the money; or, she can put the money in the bank and earn interest on it. In contrast, if she waits until next year for the money, she gives up the options of using the money now or putting it in the bank. She is no better off than if she took the money in the first year; indeed, she is worse off, since she could have earned interest at the bank. (The few people who prefer to get the money next year may believe that they will make poor use of the money now; they want their choices to be limited.) This preference toward the present is very common, though people differ in how present-oriented they are.

The second effect, known as the **rate of return** or **return on investment**, arises because capital goods (either consumer durables like cars and refrigerators, or industrial goods like power plants) provide a stream of services in the future in exchange for a cost today. For instance, power plants are built because the present value of selling the power (less the operating costs) is greater than the cost of building the plant. Investing creates a greater present value than leaving the money in a mattress or safe deposit box, where it is not put to use.

The first effect means that people are willing to pay a premium (interest payments) to borrow money (to have more in the present). The second effect means that there will be greater wealth in the future, so that the people who borrow can in fact pay back the loan.

We will return to this topic in Chapter **20**.

In sum,

- Whenever there is a comparison between goods at different times, the ability to invest the value of the goods (money) and to earn interest provides an opportunity cost. If the interest payments provide more benefit than the good over time, then the bank is a better investment; if, on the other hand, the goods produce more value over time, then investing in the goods is more worthwhile.

- Compounding interest payments over time provides estimates of the future value of an investment in the present. A present value reverses this process to produce the amount in the present equivalent to values spread over time, when the opportunity cost (investing the money in the bank) is incorporated into the value. The process of calculating present values is known as discounting.
- The present net value (PNV, sometimes called the net present value, NPV) is the present value of benefits minus the present value of costs for an activity with benefits and costs over time. If the PNV is positive, then the activity will produce more net benefits than if the money for the project were invested in the bank; if the PNV is negative, the bank is a better investment opportunity.
- Interest rates exist in part because people are impatient, and in part because investing leads to economic growth. The first effect means that people are willing to pay interest to borrow money, and the second means that the economy will expand enough for people to pay back the borrowed money.

The Effects of Different Interest Rates

The interest rate used in discounting can have a significant effect on the present value of an amount. For instance, let's consider the energy efficiency investment for 7 years, which is the average amount of time that a person lives in one place in the U.S. At a 5% interest rate, the benefits over 7 years are PV = $\$744 * [1.05^7 - 1]/[0.05(1.05)^7] =$ $4305, more than the cost of $4047. Suppose that the homeowner, instead of facing a 5%

interest rate, must borrow at a 10% interest rate. Over the 7 years she intends to stay in the house, the present value of $744 per year is PV = $[(1.1)^7-1]/[(0.1)(1.1)^7] * 744 =$ $3622. Now, the homeowner is better off putting the money in the bank than spending it on energy efficiency.

Why does a higher interest rate change the results of the investment decision? The market interest rate reflects the opportunity cost of the investment, which is putting money in the bank. If the opportunity cost is relatively high, such as 10%, then people are getting a strong signal to put their money in a bank, rather than in energy efficiency. Investments that yield a lower return, such as energy efficiency here, are not worth doing, even though they will provide returns for years to come. A market interest rate measures how present-oriented people are in general. A high interest rate signals a greater societal preference for things in the present than does a low interest rate. As a result, when the interest rate is high, activities (such as investing in energy efficiency) that provide benefits in the future appear less worthwhile, because the immediate cost ($4047) seems more important than the $744 per year that will only arrive over time.

A low interest rate, in contrast, signals a relatively forward-looking society. If people discount at 2%, for instance, the present value of 7 years of energy efficiency is PV = $744 * $[(1.02)^7 – 1]/[(0.02)(1.02)^7]$ = $4815: the advantage of energy efficiency over the bank increases. It is worthwhile to wait for the energy improvements over time.

Two extreme interest rates demonstrate this effect. An interest rate of 0% represents no discounting of the future at all: people are indifferent between the present and the future. The present value of energy savings in this case is PV = $744*$[1/(1+r) + 1/(1+r)^2 + . . . + 1/(1+r)^7]$ = $744*(1 + 1 + 1 + 1 + 1 + 1 + 1) = $744 * 7 = $5208. It makes no difference to the homeowner whether energy savings come immediately or come in 7 years; the present value is the simple sum of the benefits each year. An interest rate of 0% implies that \$1 per year forever is worth more than \$1 million in the present, since, after 1 million years, the \$1 per year forever will be worth more. Very few people do not discount the future at all; almost all people, if given the choice between \$1 per year forever and \$1 million now, will choose the \$1 million now.

At the other extreme, an interest rate of infinity means that anything after today is worthless. With an infinitely high interest rate, $1/(1+r)$ is effectively zero, and any amount in the future is unimportant. Infinite discounting is equivalent to "Eat, drink, and be merry, for tomorrow we die." While very few people discount the future infinitely, some people do borrow on credit cards at high interest rates, or from lenders of last resort (such as pawnshops), when money in the present is truly important to them.

Figure 16.1 shows the effects of different interest rates on the present value of the energy savings. The value is highest when the interest rate is zero, and it falls off steadily as the interest rate increases. The present value of savings exceeds the cost of the investment, \$4047, as long as the interest rate is less than 6.73%. The interest rate that makes the present value of benefits equal to the present value of costs is called the **rate of return**. If a consumer knows the rate of return on an investment, she can compare that value to the rate of return on other investments and easily see which are more profitable.

The time period over which discounting occurs has a huge effect on the present value of an amount. Figure 16.2 shows the present value of \$1000 for periods up to 100 years, for 2%, 5%, and 8% interest rates. The present values fall off more quickly with a high interest rate than with a low interest rate, but all of them drop rapidly over time: the present value is less than half the original value after less than 10 years using an 8% discount rate, but that same reduction in value takes 35 years with a 2% discount rate. Almost regardless of the interest rate, values in the very distant future become very small when they are discounted: at a 2% discount rate, $1000 in 100 years is worth only $138, and it is worth $0.45 with an 8% discount rate. In other words, benefits and costs in the distant future that are discounted to a present value are relatively unimportant to benefit-cost comparisons. Whether the distant future deserves so little value in our decisions is a very important, and unresolved, policy and ethical question.

In sum,

- Higher interest rates lead to present values of future goods being lower than if lower interest rates are used. Higher rates imply that people "discount" the future more: the opportunity costs of investing in a project are relatively high and discourage investment.
- Discounting makes values in the very distant future worth little in present value. Whether effects in the very distant future should receive so little weight in our present decisions is an important policy and ethical question.
- The rate of return is the interest rate that leads the present value of benefits to equal the present value of costs. The rate of return provides an easy way to compare the net benefits of activities. If the rate of return on a project exceeds that of an alternative investment, the project provides greater net benefits.

Different Market Interest Rates

Any look at the advertising for a bank shows that there are, in fact, many market interest rates. Interest rates differ by whether the rates are real or nominal, whether a person is investing or borrowing, the time commitment of the investment or loan, and the riskiness of the investment.

Inflation

Let's start with real and nominal interest rates. The difference between these is inflation, an overall increase in the prices of goods and services. For instance, suppose that all the goods and services in the economy, and all wages, increase by 5% in a year. Inflation is 5% in this case. If all prices and wages increase at the same rate, though, purchasing ability has not changed at all; though the amount that a dollar can buy is smaller than it was, everyone has enough more dollars to compensate for the higher prices. For this reason, inflation is not considered a "real" phenomenon—that is, a phenomenon that leads to changes in behavior. (In practice, though, even when the overall price level increases, not all prices and wages increase at the same rate. People whose income is a specified unchanging amount—a fixed income—suffer especially from inflation.)

Most market interest rates are **nominal**, meaning that they include inflation. Suppose that inflation is 5% per year and that a bank account pays 7% interest. An investment of $1000 would provide $1070 to spend in a year. What would it buy, though? Since prices went up by 5%, the amount that $1070 would buy will go down by 5%, or purchasing power will be $1000 * (1.07/1.05) = 1.019. If i is the rate of inflation and r is the interest rate, then the **real interest rate**, the interest rate when inflation is taken out, is (1+ r)/(1+ i) - 1, 1.9% in this example. (A good approximation for the real interest rate when the percentages are small is the nominal interest rate minus the inflation rate, r - i.) At the end of a year, after accounting for interest and inflation, the purchasing power of the proceeds of the bank account is as much as the purchasing power of $1019 at the beginning of the year.

Should present value analysis be done using nominal or real interest rates? The answer is, it doesn't matter, as long as all values are consistently either nominal or real. One way to value the $1000 saved, for instance, is to use the real interest rate and say that it would earn $19 real. Another way is to use the nominal interest rate, find the nominal payoff of $70, and then divide that by the increase in the price level to get $19 real again. In other words, the real return is the same whether it is calculated using a nominal or a real interest rate, once inflation is taken out. In our energy efficiency analysis, it is likely that the $744 in savings every year is a real value: if energy prices increase over time at the same rate as inflation, the efficiency savings will be worth more in nominal terms, but the real savings are the same every year. In this case, the present value analysis should use only the real interest rate, since the energy savings are also in real terms. Because it is often at least as difficult to predict inflation as it is to predict energy savings or other future values, conducting analyses in real terms is often more practical than conducting them in nominal terms.

Borrowing vs. Saving

At a macroeconomic level, the interest rate is the "price" that leads to equilibrium between the amount that people save and the amount that people borrow. In that simple model, the interest rate should be the same for both borrowers and sellers. In fact, though, a person seeking to borrow money from a bank will face a higher interest rate than someone saving at the bank. The difference is due to the costs that the bank faces in bringing together the loan and the savings. The bank evaluates borrowers, keeps cash available for people cashing checks, collects payments from borrowers, keeps track of all the accounts, and ensures that interest payments get to the investors. These transactions costs provide a gap between the interest rates for borrowing and saving.

Duration

For examining the effect of the duration of an investment, let's consider a bond, a form of borrowing. When a company or a government issues a bond, it takes the purchase price (the amount of the loan) in exchange for paying back the principle with interest over a fixed period of time. Some bonds are for short periods of time, such as 3 months; others may be for 10 or 20 years. The interest rate for a bond tends to increase as the term (the duration of the bond) increases. Most bonds commit the borrower to pay the same nominal interest rate for a fixed period of time. (The exception is inflation-adjusted bonds.) If inflation is constant over time, then a constant nominal interest rate will cover this effect. If, however, there is some concern that inflation may increase before the term of the bond is over, then a higher rate for a longer-term bond provides a way to incorporate this effect. More generally, there is likely to be more risk associated with investments over longer periods of time, since more unexpected things can happen in a longer period, and greater risk (as we are about to see) leads to higher interest rates.

Risk

The United States government borrows money by issuing Treasury bonds. Because the U.S. government is expected always to meet its obligations, these bonds are considered the safest form of investment. An individual seeking to borrow money to buy a car, on the other hand, may not always pay the required amount on time. If a bank were deciding to whom to lend money, with both the U.S. government and the car owner offering the same interest rate, it is hard to imagine that the bank would lend money to the car owner. How, then, can the car owner borrow money? By offering a higher interest rate.

A risky investment is one where there is some likelihood that the loan may not be repaid, because the person who borrowed the money does not earn enough to keep up with payments. Investors demand a **risk premium**, an extra payment to compensate for the possibility that the loan will not be repaid, if they lend money to a borrower undertaking a risky investment. The risk premium is the interest rate on the risky investment less the rate on a safe asset, such as a Treasury bond. The higher interest rate for riskier investments acts to discourage people from undertaking risky activities and to discourage investors from lending money for those activities. If investors manage their portfolios carefully, the extra compensation from those who do repay the loans will exceed the losses from those who default on their loans.

Risk can come into play in another way, through the relationship of the return on one investment to the return on another. For instance, the savings from energy efficiency of $744 per year is an estimate based on current prices; if the price of energy increases unexpectedly, though, these savings will increase, and the investment will be even more profitable than originally predicted. On the other hand, the benefits of owning other energy-intensive goods, such as a car, will go down when the price of energy increases. Of course, the reverse happens when energy prices drop. Because the energy savings from efficiency increase when the benefits of a car decrease (and vice versa), the consumer’s net energy benefits will be more stable over time, and the risk associated with energy expenditures will be smaller, with both of these goods than if the consumer had only one of these goods.

If the benefits associated with two goods tend to move in the same direction in response to unforeseen events, then having both of them increases the risk associated with the two goods. On the other hand, if the benefits associated with the two goods move in opposite directions, as with energy efficiency and a car, then the having both of them reduces risk. If one good responds differently than most other goods to unexpected events, even if it is risky, it may be an especially desirable good when owned in combination with those other goods. Holding assets whose benefits respond differently to unforeseen events as a way to reduce risk is called **diversification**. Diversification is a highly recommended financial strategy.

In sum,

- There are many different market interest rates in the economy, due to consideration of inflation, transactions costs for banks, the duration of the investment, and risk.
- Inflation refers to a general change in the level of prices in an economy. If all prices and wages change by the same proportion, then nobody's purchasing power changes, but the nominal amount to conduct a transaction changes. Nominal prices and interest rates include inflation; real prices and interest rates remove inflation. Present value analyses can be done with either form of interest rate, as long as nominal prices are associated with nominal interest rates, and real interest rates are used with real prices.
- Interest rates for borrowing exceed those for saving so that the intermediary (typically a bank) gets paid for its role in the transaction.

- Rates of return on investments often vary with the duration of the investment. Usually investments over a long period of time involve higher returns than those over a shorter period of time, due to expectations about inflation and higher uncertainty about the future.
- When one investment is riskier than another investment, the riskier investment must offer a higher return in order to attract investors. Investors must decide whether they are willing to accept a greater risk of not getting paid back in exchange for more money if they are paid back.
- Investors can reduce their risk by diversifying their investments to include goods that respond differently to unexpected events. If an unexpected event, such as an energy price shock, occurs, then having one investment that increases in value from that event along with an investment that decreases in value because of the shock will reduce the investor's total risk.

Interest Rates for Public Projects

Present value calculations are so common that they are designated buttons on many business calculators. Businesses use them any time that they are deciding whether to make investments in new facilities. Governments also often compare the benefits and costs over time of their activities. For instance, in deciding what air quality standard to set for a place, the U.S. Environmental Protection Agency may compare the benefits of cleaner air over time with the costs of the technologies and other disruptions necessary to meet those standards. What interest rates should be used in these calculations?

For private investment decisions, the choice of an interest rate for calculating a present value is simple: it is the market interest rate at which the borrower can take out a loan. For instance, a homeowner evaluating whether to borrow $4047 to invest in energy efficiency would estimate the present value of the energy savings using the interest rate on the loan. Similarly, a business that is deciding whether to build a new factory will compare the present value of the profits from that factory with the costs of building it, using the interest rate at which it borrows the money.

Businesses, if they are to stay in operation, must recover their costs of operation, including their loan costs; as a result, the present value of their net benefits cannot fall below zero. Governments, on the other hand, have the ability to raise money through taxation. They are not obligated to earn profits; indeed, as we have seen, many government activities, such as providing parks or national defense, provide huge benefits but not necessarily profits. For these situations, the estimated values of nonmarketed benefits should be included in the benefits and costs over time. The question remains, though, what rate should the government use for its present value calculations?

One rule holds that interest rates ought to be the same for public investments that produce the same kinds of goods that the private sector produces. For instance, if a government agency is building a power plant, it should use the same interest rate as a private utility that is building a power plant. If the two power plants are identical and are providing the same benefits, they should produce the same present net value of benefits. Using a different interest rate for one sector would lead to one sector having a different present net value than the other, a result that could lead to one sector having a decided advantage in building power plants.

Are there projects for which the public sector should use a different interest rate than the private sector? Least controversially, investments that have low risk should have lower required rates of return, in either the private sector or the public sector. The public sector may have a lower interest rate for borrowing when it is perceived as financially reliable, as in the case of U.S. Treasury bonds. In other cases, though, such as when a city, state, or even national government develops large deficits and shows signs of financial mismanagement, the public sector may face very high interest rates.

Some argue that, in some cases, the public sector should use a **social discount rate** lower than the private interest rate. A lower interest rate would lead the public sector to put relatively more money into investments that produce benefits in the future (such as parks, roads, or other infrastructure) than into activities that produce benefits in the present (such as welfare programs). The argument for this rate is that there may be a market failure in people's borrowing and saving decisions that determine the market interest rates in the economy: in our daily interactions, we focus too much on the present, and we want our public sector not to make this error. A lower, social discount rate, combined with the government's ability to raise money by taxation, would, in essence, take money from the present and give it to the future. If people want their government to behave this way, then a social discount rate is appropriate to use.

For what projects is the social discount rate appropriate? As argued above, it makes sense to use the market rate for any government activity that provides the same service as a private activity, since the present net value of a project should not depend on whether the project comes from the public or private sector. The remaining activities are those the private sector is unlikely to conduct, primarily those involving correcting market failures, such as providing public goods. For these goods, a debate remains. Some argue that the only rate to use is the appropriate market interest rate, since it reflects the opportunity cost of an investment: the public sector agency could pay down any debt that it owes at the market rate, invest the money (if it is running a surplus), or even reduce taxes, which would give consumers the opportunity to invest the money (or pay down debt) at market rates. Others argue that, if asked, people would like their public representatives to put more weight on the future than they do as individuals.

The practical result of these debates is that different government agencies use different interest rates. The U.S. Office of Management and Budget, which reviews the proposed activities of government agencies for the President, recommends using a 7% discount rate as the approximate rate of return on private investment. The Congressional Budget Office recommends 2% as representing the real cost of borrowing for the federal government.[1] The U.S. Forest Service has used 4%, and the U. S. Environmental Protection Agency has used 3% and 7%. The U.K. Stern Review on the Economics of Climate Change argues that "it is hard to see any ethical justification" for putting less value on the welfare of future generations than on present ones.[2]

What is the correct rate to use for public activities? Since there is wide disagreement, one practical approach is to use a range of discount rates, as the U.S. Environmental Protection Agency has done, to see if the results of the analysis are sensitive to the interest rate used. If the present net value stays positive (or negative) over a reasonable range of interest rates, then the basic result—whether the benefits outweigh the costs—is not dependent on the choice of interest rate. In our energy efficiency example, any interest rate below 6.73% justifies the investments in energy

[1] See http://www.cbo.gov/showdoc.cfm?index=601&sequence=0, Box 2, for a discussion of some of these debates.
[2] http://www.hm-treasury.gov.uk/media/986/CC/sternreview_report_part1.pdf, p. 31.

savings over 7 years; with a longer time span for receiving benefits, the interest rate at which the investment is worthwhile (the rate of return) would increase.

In sum,

- The private sector, when it conducts present value analyses, uses the interest rate that is the most direct reflection of its opportunity costs—either the rate at which it would borrow money, or the rate at which it would invest the money in an alternative. Using a rate that reflects the return on the next best alternative provides the sector with information on which activity is most profitable.
- The public sector is not obligated to make profit. Indeed, its reason for existence (from an economic perspective) is to correct for market failures, such as providing for goods that markets will not provide adequately. As a result, it is less obligated than the private sector to use the market interest rate.
- For public sector activities that provide the same functions as private sector activities, the public sector should use the same interest rate as the private sector. Otherwise, two projects with otherwise identical characteristics, except the interest rate, will end up with different present net values.
- Some argue that the public sector should always use a market interest rate in its present value analyses, since the market rate reflects the opportunity cost to the agency of the activity (paying down debt or reducing taxes). Others argue that the public sector should use a lower social discount rate in its analyses, because the public sector should put more emphasis on the future than the private sector does. This fundamentally philosophical issue—how much weight should the present give to

the well-being of the future when making decisions involving both the present and the future—is critical for many current issues, but it is unresolved.

How Do People Value Energy Conserving Investments in Practice?

In our example, if the present value of energy efficiency benefits outweighs the present value of costs, then the investment is worth undertaking, and we would expect people to undertake these investments. When economists have studied whether people do actually make these purchases, though, it turns out that people often ignore energy efficiency savings that are financially worthwhile.[3]

For instance, an energy efficient refrigerator requires a higher initial expenditure but lower electricity bills for the life of the machine, about 10 years. People who discount the future a great deal will feel that the present value of the savings in electricity is less than the additional cost of the more efficient refrigerator and will buy the less efficient one. People with low discount rates will care more about the electricity savings and will buy the more efficient one. Observing how many efficient refrigerators are bought, and how many inefficient ones, permits us to estimate what interest rate consumers used in the present value calculation. Four different studies came up with lower bounds on the interest rate of 61, 45, 40, and 53 percent. These are very high interest rates indeed, even higher than the interest rates on credit cards. Other energy measures, such as those to increase the thermal integrity of a house, suggest somewhat more normal interest rates of 10 percent to 30 percent. It is still a research topic to explain the size of these interest rates. Possible answers include: the buyer doesn't

[3] See the very readable survey by Ken Train, "Discount Rates in Consumer's Energy Related Decisions: A Review of the Literature," Energy Vol. 10 no. 12 (1985), pp 1243-53.

believe the energy savings claims; the buyer doesn't intend to keep the appliance for very long; or the energy efficient appliance has other undesirable effects (they may not be as attractive, for instance, or they may be less convenient).

These high apparent discount rates mean that new energy-saving technologies often do not get adopted, even when they will save consumers money. Should governments require minimum energy efficiency standards, to impose these requirements on people against their own inclinations? Economists typically assume that consumers are the best judges of what is best for them, but they also argue that market failures, such as prices of electricity that do not include the full cost of the damages associated with electricity, need to be corrected.

In sum,

- Even when energy efficiency produces positive present net benefits with any plausible interest rate, people often do not buy energy efficient products. Some possible reasons for this financially inefficient behavior is that consumers are skeptical of the benefits, or do not plan on owning the appliances long enough to earn back the benefits, or the appliances may have other undesirable characteristics.

Chapter Summary

The key lessons from this chapter are:

- Whenever a decision involves benefits and costs over time, future benefits and costs must be discounted to a present value before they can be compared. Any value in the future has the opportunity cost of an investment in an interest-bearing account, such as a savings account. Discounting future values, the inverse of compounding interest on an investment, is a way to take into account that opportunity cost.

- Interest rates reflect the fact that people generally prefer things now to later, as well as the fact that investments now can lead to future benefits that are higher over time. People are willing to pay a premium (interest payments) in order to borrow money and have it now, and people must be paid a premium (again, interest payments) to save their money and make it available for investment. The investments, by providing more in the future in exchange for present investment, lead to growth that allows borrowers to pay off interest.
- Higher interest rates reflect greater overall impatience; things in the future are worth less than things now. At the extreme, a zero interest rate means that a value many years in the future is worth the same as that value now; an infinite discount rate means that anything after this moment is worthless.
- There are many market interest rates in the economy, reflecting inflation, banking costs, the duration of investments, and the risk associated with investments.
- When the private sector conducts present value analyses, profit maximization requires that it use the market interest rate that reflects the interest rate at which it would either borrow or invest the money.
- The public sector does not need to maximize profits. It makes sense for the public sector to use the same rate as the private sector when it makes investments like those in the private sector. Some argue that it should always use market interest rates, which reflect the government's opportunity cost in borrowing (or not reducing taxes). Others argue that the public sector should use a lower discount rate because it should put more weight on the future than the private sector does. This debate continues.

Figure 16.1. The Effect of Different Interest Rates on Present Value. This chart shows the present value of energy savings ($744 per year) for seven years at different interest rates. As the interest rate increases, the present value decreases. If the homeowner borrows the $4047 necessary to make the investment at an interest rate higher than 6.73%, the present value of the energy savings is less than the cost of the investment.

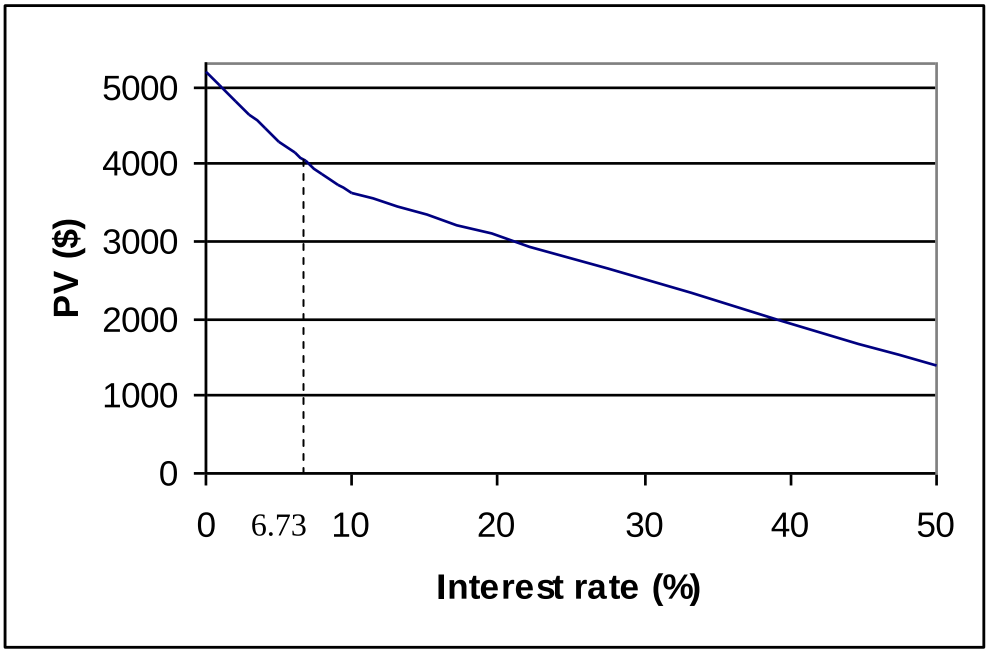
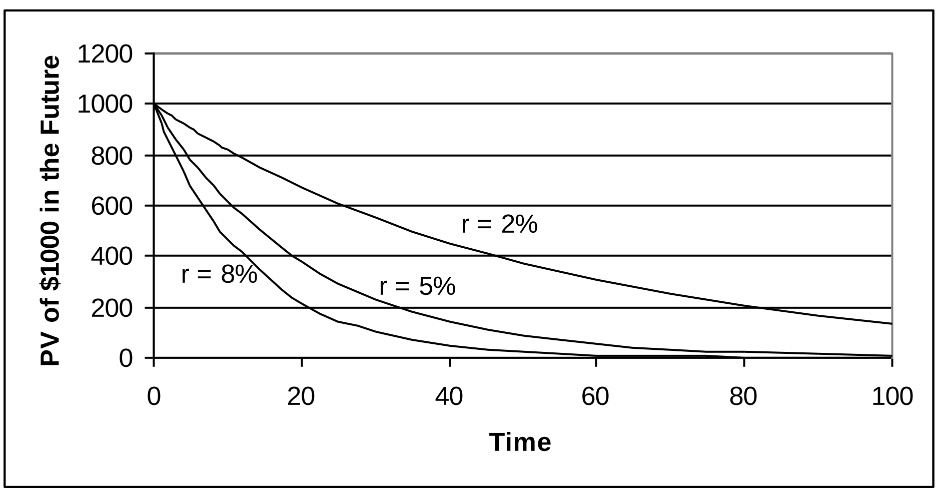


Figure 16.2. The Effect of Time on $1000 in Future Value. This chart shows the effect of time on $1000 in future value using three different interest rates. In all three cases the value falls rapidly; it falls much more rapidly with higher interest rates. Values in the very distant future are worth little in present value terms.



Box 16.1 The Math of Present Value Formulas

When an activity leads to benefits and costs over time, the present value associated with that activity is the sum of the values at different times, discounted to the present:

$$PV = V_0 + V_1/ (1+r)^1 + V_2/(1+r)^2 + \ldots + V_t/ (1+r)^t.$$

In a number of cases—including loan payments, lottery winnings, and estimated benefits from environmental improvements—the value that is being discounted is the same each period—that is, $V_1 = V_2 = . . . =$ Annual Value, AV. In those cases, it is possible to simplify the calculations down to some simple formulas with a little math.

Let's start with the value of a stream of payments starting in year 1 (that is, there is no payment in the present) and ending in year t, which is:

$$PV = AV/(1+r)^1 + AV/(1+r)^2 + \ldots + AV/(1+r)^t.$$

The trick to simplifying this formula is to find a way to reduce the number of terms, which we'll do with some manipulation of the equation. First, we'll multiply the equation by (1+r) to get

$$(1+r)*PV = AV + AV/(1+r)^1 + AV/(1+r)^2 + \ldots + AV/(1+r)^{t-1}.$$

Subtracting the first equation from the second gives:

$$(1+r)*PV – PV = AV – AV/(1+r)^t,$$

since the intermediate terms cancel out. We now want to solve for PV. Simplification yields

$$r*PV = AV[(1+r)^t – 1]/(1+r)^t.$$

Dividing through by r gives

$$PV = \frac{(1+r)^t - 1}{r(1+r)^t}.$$

If, on the other hand, the t payments start in the immediate (undiscounted) present and end at t-1, as is likely in the case of the lottery payment, we can adjust this formula by making it go only to t-1 and adding an undiscounted AV to it:

PV = AV + AV[$(1+r)^{t-1} - 1$]/[r*$(1+r)^{t-1}$], which becomes

$$PV = AV* \frac{r(1+r)^{t-1} + (1+r)^{t-1} - 1}{r(1+r)^{t-1}} = \frac{(1+r)^t - 1}{r(1+r)^{t-1}}$$

For an infinite stream of payments starting in a year, the formula, PV = AV/r, comes from finding the sum of an infinite series,

$$PV = \frac{AV}{1+r} + \frac{AV}{(1+r)^2} + \ldots + \frac{AV}{(1+r)^t} + \ldots$$

Multiplying both sides of the PV equation by 1+r gives

$$(1+r)PV = AV + \frac{AV}{1+r} + \frac{AV}{(1+r)^2} + \ldots + \frac{AV}{(1+r)^t} + \ldots$$

Notice that the terms starting with AV/(1+r) are exactly PV! We can substitute PV for these terms, which produces

(1+r) PV = AV + PV, which simplifies to

PV = AV/r.

If the value of payments starts immediately (that is, the first AV is not discounted) and goes forever, we need to add AV to this:

PV = AV/r + AV, or

PV = (1+r)AV/r