

Discounting 101

How does discounting help decisionmakers understand the costs and benefits of choices and policies—and how does it apply to climate change?

Explainer by **Brian Prest** — January 16, 2020

Discounting is the process of converting a value received in a future time period (e.g., 1, 10, or even 100 years from now) to an equivalent value received immediately. For example, a dollar received 50 years from now may be valued less than a dollar received today—discounting measures this relative value. The discounting process is a way to convert units of value across time horizons, translating future dollars into today's dollars. Discounting is used by decisionmakers to fully understand the costs and benefits of policies that have future impacts. This explainer will review the rationale behind discounting, how the discount rate is calculated, and why discounting matters for climate policies.

Why Discount?

Discounting is used to measure the difference between present values and future values. There are a few reasons why this difference exists:

- People tend to display impatient behavior, preferring their immediate well-being to future well-being. This means that people often value benefits received sooner more than they value the same benefits received later.
- People may reasonably expect to grow wealthier in the future, because income and wealth **have been increasing** on average in the United States and **globally**. If individuals expect to have more income in the future, then having an extra dollar today (when they are relatively less wealthy) is more valuable than having a dollar in the future (when they are relatively more wealthy, and hence consuming more).

- Money received today can be saved or invested to earn a positive rate of return, such as by putting the money into the bank, or by purchasing stocks or bonds. Therefore, the value of a dollar received today is greater than the value of a dollar received in the future, because it can be invested and earn a return in the interim.

The difference between present and future values makes it difficult to compare costs and benefits over time, and it can affect the outcome of policy analysis. Policymakers can use discounting to adjust for this difference and ensure that the costs and benefits of a policy are compared consistently.

Setting the Discount Rate

The **discount rate** represents how much value is assigned to benefits received today rather than in the future. The effect of different discount rates can be illustrated with the example of a homeowner considering replacing their standard washing machine with a new, energy-efficient, water-saving one. The homeowner has to decide how much they value the future benefits of replacing the appliance (the money they will save on their water and electricity bills, and however much they value the environmental benefits of saving water and energy), relative to the immediate costs they will incur today to purchase the new appliances. This can be represented by different discount rates:

- **Discount rate of zero: Present benefits and future benefits are valued equally—there is no preference between receiving a benefit today or in the future.** If a homeowner values each

dollar saved in the future from replacing the washer equally to each dollar in immediate costs of replacing it, this could be represented by a discount rate of zero. With a discount rate of zero, the homeowner would choose to buy the energy efficient appliance if the total undiscounted cost savings are at least as large as the replacement cost.

- **Low discount rate: Present benefits are only slightly more valuable than future benefits.**

If a homeowner values each dollar of future cost savings from the new washer slightly less than they value each dollar in immediate costs of replacing it, this could be represented by a low discount rate. With a low discount rate, the total undiscounted cost savings must exceed the replacement costs by a modest amount to convince the homeowner to purchase the new appliance.

- **High discount rate: Present benefits are much more valuable than future benefits.** If a homeowner values each dollar of future cost savings from the new washer far less than they value each dollar in immediate costs of replacing it, this could be represented by a high discount rate. With a high discount rate, the total undiscounted cost savings must exceed the replacement costs by a large amount to convince the homeowner to purchase the appliance.

For policy analysis, the discount rate is chosen to reflect the rate at which society is willing to trade off immediate and future values. Further, a number of specific questions and issues arise when determining the appropriate discount rate to use when valuing the benefits of reducing greenhouse gas (GHG) emissions. Some of these questions are described below.

In the Weeds: A Discounting Calculation Example

Suppose you can earn a guaranteed return of 3% by putting \$1 in a bank account. That \$1 will grow to be worth \$1.03 in one year ($\$1 \times (1+3\%) = \1.03). If we divide both sides of this equation by $(1+3\%)$, we have $\$1 = \$1.03 / (1+3\%)$, which relates the **present value** (\$1) to the **future value** (\$1.03) and the discount rate (3%). Then we say that, using a discount rate of 3%, the **present value** of \$1.03 received in one year is \$1 today.

If the \$1 is in the bank for more than one year, the investment yields **compound interest** (the interest on the interest). For a two-year investment, the value would be \$1.0609 ($\$1 \times (1+3\%) \times (1+3\%) = \$1 \times (1+3\%)^2 = \$1.0609$). As before, using a discount rate of 3%, the present value of \$1.0609 received in 2 years is \$1.

Compound interest accounts for why the investment grows by 6.09 cents rather than just 6.0 cents (3 cents per year for two years). Over long time periods, compounding of interest can have significant effects on the calculation results.

Leaving the bank account example behind, the general relationship between the present value (PV), the future value (FV), the discount rate (r), and the duration of the investment (t) is described by the following formula:

$$PV = FV / (1+r)^t$$

Because t , which represents the number of years in the future until the payment is received, appears in an exponential form, small changes in the discount rate can have large effects on present values. For example, consider a payment of \$1,000 received in 200 years. Using a 3% discount rate, the present value can be calculated as follows:

$$\$1,000 / (1+3\%)^{200} = \$2.71.$$

At a slightly higher discount rate of 4%, the present value is calculated to be only \$0.39, which is about 7 times smaller.

Who should be considered when setting the discount rate?

There are two different approaches to choosing the discount rate: the **prescriptive (or normative)** approach (how should society trade off current and future consumption based on ethical arguments), or the **descriptive (or positive)** approach (how do individuals and markets trade off current and future consumption based on observed behavior). The value of each approach for use in policy analysis is a contentious issue, with different analysts having differing opinions about which is best. Even within these broad approaches, there are many different ways to apply them.

The prescriptive approach emphasizes philosophical and ethical considerations. This approach requires making ethical judgments about how much we should value peoples' well-being at different points in time and the degree to which the incremental value of a dollar diminishes as wealth increases (which determines the relative value placed on impacts on future wealthier versus current less-wealthy individuals). The prescriptive approach for discounting requires making judgments based on a priori moral reasoning (described by [Stanford Encyclopedia of Philosophy](#) as reasoning “without drawing on observations of human beings and their behavior”).

By contrast, the descriptive approach bases discount rates on observable, realized outcomes in society (typically market interest rates). This approach requires determining which market interest rate is the most appropriate to use (e.g., should the discount rate be the same as the rate of return on bonds, or should it equal the return on capital investments?) and then estimating that rate using empirical data.

Discounting and Climate Change

Discounting is particularly significant for understanding the present value of mitigating climate change. This is because climate change has long-lasting effects: the warming effects of greenhouse gas (GHG) emissions

released today remain for hundreds of years or more. Discounting allows policymakers to measure the present value of the long-term benefits that come from reducing these greenhouse gas emissions.

While the benefits of decreasing emissions are spread over hundreds of years, the costs typically occur in the short run. This means that the costs will be minimally affected by discounting, while the benefits—which are spread across many years in the future—may be significantly affected by discounting. This disparity between the timing of the costs and benefits means that discounting can greatly impact the benefit-cost analysis of any policy or investment that affects GHG emissions.

For example, building a renewable wind farm requires capital investments (short-term costs). Once built, this wind farm will reduce emissions over the course of its lifetime and the benefits will extend even further into the future, since avoided warming effects last for hundreds of years (long-term benefits). The present value of the benefits from this wind farm will vary depending on which discount rate is used, while the present value of the cost will not be significantly affected by the discount rate.

The example below only considers benefits occurring 200 years from now. But, in reality, reducing emissions today has impacts that occur gradually over time, not just in 200 years but next year, the year after, and so on. Each ton of greenhouse gas emitted into the atmosphere has some impact each year into the future. The costs of these annual impacts are discounted (converted to the present value) and added up, and the resulting sum is called the social cost of carbon (SCC). Since these costs are discounted over time, the discount rate is a significant determinant of the SCC.

The Social Cost of Carbon (SCC)

As with climate change policy analysis in general, the discount rate plays a substantial role in calculating the **SCC**, which is “an estimate, in dollars, of the economic damages that would result from emitting one additional ton of greenhouse gases into the atmosphere.”

Doing the Math: What Role Does the Discount Rate Play in Climate Policy?

Suppose you invest \$1 in a wind farm in order to mitigate climate change, and the resulting reduction in emissions generates a future benefit of \$1,000 in 200 years. This future value can be converted into a present value, so that it can be compared with present-day costs and incorporated into policy analysis. To find the present value of this future benefit, we can use the formula from the bank account example above. The net benefit of this \$1 investment, in today's dollars, is the present value of the future benefit, $\$1,000 / (1+r)^{200}$, minus the \$1 spent today:

$$\text{Net Benefit} = \$1000 / (1+r)^{200} - \$1$$

For a discount rate of 3%, the net benefit of this investment is positive, which means that this investment passes a benefit-cost test:

$$\$1000 / (1+3\%)^{200} - \$1 = \$2.71 - \$1 = \$1.71$$

By contrast, for a slightly higher discount rate of 4%, the net benefit of the wind-farm investment is negative, which means that this investment does not pass a benefit-cost test:

$$\$1000 / (1+4\%)^{200} - \$1 = \$0.39 - \$1 = -\$0.61$$

This example demonstrates that small changes in the discount rate can have significant effects on the calculation of an investment's benefit (or, in other cases, a policy's benefit). Decisions regarding which discount rate to use can determine whether investments and policies that mitigate climate change will pass a benefit-cost test. (Of course, it is important to note that benefit-cost analysis is also only one ingredient in policy decisions, although it is an important one).

Small changes in the discount rate can have significant effects on the SCC. For example, when the Trump administration **released its estimates** of the SCC using discount rates of 3% and 7%, the SCC was reduced by 90% when using a 7% discount rate compared to when using a 3% discount rate (\$5 per ton of CO₂ versus \$44 per ton of CO₂ for a reduction occurring in 2020).

Since the SCC is often used to guide the desired stringency of regulations, this difference can be significant. A regulation reducing emissions at a cost of \$20 per ton would appear favorable using the \$44-per-ton estimate of the benefit (based on the 3% rate), but would not be deemed worthwhile using the \$5-per-ton estimate (based on the 7% rate). The cost of many potential GHG-reducing actions could fall within this range—investments that would be deemed worthwhile at the higher SCC value (calculated with a lower discount rate) but not the lower one (calculated with a higher discount rate).

Climate Change and the Discount Rate

Certain features of climate change suggest using a lower discount rate. Here are a few related considerations:

Does the discount rate take into account the values of the next generation?

Individuals may value their future personal well-being less than their current well-being, but does this imply that it is appropriate to place a lower value on benefits that will be received by future generations simply because they were born later? This question raises ethical issues that have been explored by **economists** and **philosophers** alike, some of whom argue for using lower discount rates to avoid unfairly penalizing people for being born at different times. For example, **Ramsey** (1928) argued that discounting future generations simply because they occur later in time is “ethically

indefensible and arises merely from the weakness of the imagination.” In contrast, others argue that society does have the means to pass on increased wealth to future generations and has tended to do so historically.

How does uncertainty affect which discount rate we choose?

Choosing a discount rate generally involves dealing with uncertainty. One **approach** to dealing with uncertainty is to use a discount rate that declines over time, rather than using a single fixed rate for all time periods. This approach implies that, when discounting the distant future amid uncertainty about the right discount rate to use, we should use a discount rate on the low end of the range of possible rates.

For example, suppose there is a 50/50 chance that the right discount rate over 200 years is either 1% or 7%. Which discount rate should be chosen? An intuitively appealing approach may be to use the average of the two discount rates, which is 4%— but this would be

incorrect. The correct approach is to discount the future value separately with discount rates of 1% and 7% and then take the average of the two discounted values. If you had to use a single discount rate that would get the same result as this correct (but more complicated) approach, you could calculate the single discount rate that gives the same result. In this example, the calculated* discount rate that produces the correct result is 1.35% (not 4%), which is much closer to the lower rate. The longer the time horizon, the **lower the discount rate** that should be used when taking into account this uncertainty.

There is also an **additional consideration** if there is a strong correlation between the future value of reducing GHG emissions (i.e., the value of avoiding the consequences of climate change) and the discount rate. In this case, we must also add a **risk premium** (that is, use a higher discount rate to reflect the risk associated with the benefit of GHG reductions) to the discount rate that depends on the strength of that correlation.

$$*1/(1+1.35\%)^{200} = 50\%1/(1+1\%)^{200} + 50\%1/(1+7\%)^{200}$$

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