Chapter 6 - Discounting Future Benefits and Costs

Discounting allows for economically consistent comparisons of benefits and costs that occur in different time periods. In practice, it is accomplished by multiplying changes in future consumption (including market and non-market goods and services) by a discount factor. Discounting reflects that (1) people prefer consumption today over consumption in the future, and (2) invested capital is productive and provides greater consumption in the future. Properly applied, discounting can tell us how much future benefits and costs are worth today.

Social discounting is the main type of discounting discussed in this chapter. This is discounting from the broad society-as-a-whole point of view embodied in benefit-cost analysis (BCA). *Private discounting*, on the other hand, is discounting from the specific, limited perspective of private individuals or firms. This distinction is important to maintain.

This chapter addresses discounting over the relatively near term, called *intragenerational discounting,* as well as discounting over much longer time horizons, or *intergenerational* discounting. Intragenerational (a.k.a., *conventional*) discounting applies to contexts that may have decades-long time frames, but where the timeframe of analysis is within the lifetime of current generations. Intergenerational discounting addresses very long time horizons in which the discounted effects will impact generations to come.

This chapter focuses on the most important discounting issues for applied policy analysis, beginning with practical, basic mechanics and methods for discounting. It then turns to the theory and foundational logic for discounting and the different approaches to estimating discount rates. The presentation of the results should include the full stream of the benefits and costs over the time horizon of analysis both without discounting and appropriately discounted. Analysts should present results using both a consumption rate of interest and, if appropriate, a sensitivity analysis reflecting the shadow price of capital approach.[1]

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1 This chapter summarizes some key aspects of the core literature on social discounting, but it is not a detailed review of the vast and varied social discounting literature. Excellent sources for additional information are: Lind

6.1 Mechanics and Methods for Discounting

The most common methods for discounting involve estimating either net present values or annualized values.[2] An alternative method is to estimate a net future value. Net present value, annualization, and net future value are different ways to express and compare the costs and benefits of a policy in a consistent manner. These three methods will be discussed below.

6.1.1 Net Present Value (NPV)

The net present value (NPV) of a stream of benefits and costs in the future is the value that those benefits and costs provide to society today. The NPV at time 0 (the year to which values are discounted) of a projected stream of current and future benefits and costs is calculated by multiplying the benefits and costs in each year by a time-dependent weight, or discount factor, *d*, and aggregating all of the weighted values. This can be done by discounting the benefits and subtracting the discounted costs, which is equivalent to discounting the net benefits over all *n* years, (*n* is the number of years in the future until the last year of the time horizon of the analysis) as shown in the following equation:

$$\begin{aligned} NPV &= B0 + d1B1 + ... + dn{-}1Bn{-}1 + dnBn \\ &\quad - C0 - d1C1 - ... - dn{-}1Cn{-}1 - dnCn \\ &= NB0 + d1NB1 + d2NB2 + \\ &\quad ... + dn{-}1NBn{-}1 + dnNBn \qquad (1) \end{aligned}$$

where

B_t are the benefits in year t,

C_t are the costs in year t, and

NB_t are net benefits, the net difference between benefits and costs (B_t - C_t) in year t.

Alternatively, NPV can be calculated by estimating the present value (PV) of costs and the PV of benefits separately and then subtract the PV of costs from the PV of benefits:

$$NPV = (B_0 + \sum_{t=1}^{n} d_t B_t) - (C_0 + \sum_{t=1}^{n} d_t C_t)\,. \qquad (2)$$

In either case, the discounting weights, d_t, are given by:

$$d_t = \frac{1}{(1+r)^t} \qquad (3)$$

where r is the discount rate and t is the year.

As shown in equation (1), the benefits and costs should be discounted to the same year to appropriately calculate net benefits. This is because both future benefits and costs should be

(1982a, b; 1990; 1994), Lyon (1990, 1994), Pearce and Turner (1990), Pearce and Ulph (1994), Arrow et al. (1996), Portney and Weyant (1999), Frederick et al. (2002), Moore et al. (2004), Spackman (2004), Groom et al. (2005), Cairns (2006), Burgess and Zerbe (2011a), Moore et al. (2013a), Harberger and Jenkins (2015), Li and Pizer (2021), and Newell et al. (2022, 2024)

2 Note that discounting is distinct from inflation, although observed nominal market rates of return reflect expected inflation. While most of the discussion in this chapter focuses on real discount rates and values, benefits and costs should also be adjusted for inflation when relevant.

evaluated from the perspective of the same year to provide them equal consideration.[3] Also, as discussed in Section 6.1.6.1, the same rate should be used to discount benefits and costs in a given year. However, in some analyses with very long time horizons there may be reasons to use different discount rates in different future years, as discussed in Section 6.3.

6.1.1.1 Beginning-of-Year versus End-of-Year Discounting

In the NPV equation, B_0, C_0, and NB_0 are the benefits, costs, and net benefits incurred immediately (when t=0), so they are not multiplied by a discount factor. This makes sense when time is continuous, but what is "immediate" becomes less clear when time, t, is an entire year. For example, if a rule is finalized at the beginning of a year and costs and benefits will be realized throughout that year, are these values "immediate" or should they be discounted one period? If costs and benefits incurred throughout the year are considered immediate, then they would be B_0 and C_0 in equation (1) above. This is known as beginning-of-year discounting because all intra-annual effects in the current year are treated as if they occur at the beginning of the year, when t=0. The alternative is to treat all intra-year effects in the current year as if they occur at the end of the year, when t=1, and discount them back one period. Effects in the next year would then be discounted back two periods. This is known as end-of-year discounting. The choice between beginning- or end-of-year discounting does not generally have a large quantitative effect on the analysis. Whichever approach is adopted should be explicitly stated and applied to both benefits and costs so that the analysis is internally consistent.[4]

6.1.1.2 Time Periods of Less than One Year

When estimating the NPV, it is important to explicitly state how time periods are designated and when costs and benefits accrue within each time period. Typically, time periods are in years, but alternative time periods can be justified if costs or benefits accrue at irregular or non-annual intervals. To correctly discount intra-year effects, the annual discount rate, r, must be adjusted to an "effective rate," $\tilde{r}$, which produces the same result as the annual discount rate if compounded for one year. The effective discount rate for any non-annual period is:

$$\tilde{r}_t = (1 + r)^{1/(\#\ of\ periods)} - 1 \qquad (4)$$

For example, if the annual discount rate is 7% and costs are incurred on a quarterly basis (i.e., there are four periods in a year), then the effective quarterly discount rate, $\tilde{r}$, is approximately 1.7%. The formula for discounting weights, d_t, given above, can be used with this effective rate, but t is measured in quarters rather than years.

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3 As discussed in Section 5.2, the analysis should identify the year to which benefits and costs are discounted and the dollar year used to report them. It is important to identify and distinguish the reporting and dollar years of the analysis when they differ.

4 Three common Excel functions used for discouning -- PMT and PV, and NPV -- use end-of-year discounting by default. The PMT and PV functions include a 0/1 "type" argument indicating if the discounting is done at the end or the beginning of the year. The default is 0, and therefore needs to be changed to 1 to do beginning-of-year discounting. The NPV function implicitly assumes end-of-year discounting. To use the NPV function to calculate the net present value using beginning-of-year discounting, the solution to the NPV calculation must be multiplied by the expression (1+r), where r is the discount rate. Analyses that use the PMT, PV or NPV functions without making these adjustments are implicitly assuming end-of-year discounting.

While the discounting formula can be adjusted to account for intra-annual discounting periods, it may not be necessary unless exact values are required. The NPV generated by an intra-annual effective discount rate, $\tilde{r}$, will be between the NPV using beginning-of-the-year discounting and the NPV using end-of-the-year discounting using the annual discount rate, *r*. These NPVs don't usually differ by much in a typical economic analysis.

6.1.1.3 Continuous Discounting

Costs and benefits may also be discounted on a continual basis during the year. In this case, benefits or costs occurring at the end of a future year (or period), *t,* are discounted by the weight:

$$d_t = e^{-\tilde{r}t} \qquad (5)$$

Where *e* is Euler's number, or 2.718, when rounded to three decimal places, and is the base of the natural logarithm. This is a commonly used expression in economics and finance. Furthermore, continuous discounting provides a convenient way to represent a discount weight for some theoretical economic concepts related to discounting. Note equation (5) uses a discount rate appropriate for continuous discounting, $\tilde{r}$. As with intra-annual discounting discussed above, the effective discount rate, $\tilde{r}$, should produce the same result as the annual discount rate. The effective discount rate for continuous discounting is:

$$\tilde{r} = \ln(1 + r) \qquad (6)$$

In this case, t=1 represents one year, but the discounting weight is assumed to be applied to every moment, continuously throughout the year.

6.1.2 Annualized Values

An annualized value is an illustrative cost or benefit that, if incurred every year over the entire time horizon of the analysis, would produce the same net present value (NPV) as the original time-varying stream of costs, benefits, or net benefits. In some cases, annualized values are easier to understand than NPV.

Because the annualized value is constructed to generate the same net present value as the actual stream of values, comparing annualized values is equivalent to comparing net present values. That is, one can use either the NPV or the annualized values to determine whether benefits exceed costs or which option produces the highest net benefits. As with NPV, benefits and costs may be annualized separately and compared, or the stream of net benefits can be annualized.

The formulas below illustrate the estimation of annualized costs; the formulas are identical for benefits.[5] The exact equation for annualizing depends on whether there are any immediate costs (i.e., any costs at time zero, t=0).

Annualized costs when there is no cost at $t=0$ (e.g., no C_0 in equation (1)) are estimated using the equation:

$$Annualized\ Cost = PVC * \frac{r*(1+r)^n}{(1+r)^{(n+1)}-1} \qquad (7)$$

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5 Variants of these formulas may be common in specific contexts. See, for example, the Equivalent Uniform Annual Cost approach in the EPA's Air Pollution Control Cost Manual (U.S. EPA 2017).

where

> *Annualized Cost* = annualized cost accrued at the end of each of n years,
>
> *PVC* = present value of costs (calculated as in equation (1), above),
>
> r = the discount rate per year, and
>
> n = the length of the time horizon over which costs are annualized.

Annualized costs when there is initial cost at $t=0$ are estimated using a slightly different equation:

$$Annualized\ Cost = PVC * \frac{r*(1+r)^n}{(1+r)^n - 1} \qquad (8)$$

The annualization approach in equation (7) is generally consistent with end-of-year discounting because the first cost value, C_1, is discounted one period. Equation (8) is more consistent with beginning-of-year discounting because there is a value, C_0, which is not discounted one period.[6] Note that the numerator expression is the same in both equations, although the PVC is calculated differently depending upon whether there are costs at $t=0$. The only difference is the "n+1" and "n" terms in the denominator of (7) and (8).

Some important caveats are associated with the use of annualized values. First, they are generally illustrative; the annualized value is not the actual value that will manifest every year. Second, the annualized value changes with the timeframe of the annualization. This means that the annualized value will be *different* for each value of n, even for the same discount rate, r. The longer the timeframe assumed for the annualization, the lower the annualized value. Third, annualization formulas assume that the timeframe of n periods begins immediately. If the actual stream of costs being annualized does not occur immediately, the timeframe for the annualized value and the actual stream will not be the same.

One special case of equation (7), the annualization formula when there is no cost at t=0, is when $n=\infty$. In this case, the annualized cost is simply:

$$Annualized\ Cost = PVC * r \qquad (9)$$

For example, suppose an action permanently eliminates the use of an environmental amenity (e.g., a wetland), and the estimated present value of that amenity is $1 million at a discount rate of 2%. The cost of this policy is the lost value of the amenity in perpetuity -- the period of the analysis is effectively infinity. The annualized cost of that policy - that is, the cost that if lost every year, *forever*, would be equivalent to $1 million in present value today - is $1 million ∗ 2% = $20,000 per year.

The corollary to equation (9) is:

$$PVC = \frac{Annualized\ Cost}{r} \qquad (10)$$

Thus, if an environmental amenity is estimated to be worth $20,000 per year, its present value using a %2 discount rate is $1 million, assuming that it provides benefits into perpetuity.

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6 The default PMT function in Excel (with "type" equal to 0) will produce the same answer as equation (7). Setting the "type" variable to 1 will produce the result from equation (8).

6.1.3 Net Future Value (NFV)

Instead of discounting all future values to the present using the NPV, it is possible to estimate the stream of values from the perspective of some future year, for example, at the end of the last year of the policy's effects, n. This would be the net future value (NFV). This might be particularly useful when conducting a retrospective analysis.

The net future value for net benefits (NB_t) is estimated using the following equation:

$$NFV = a_0 NB_0 + a_1 NB_1 + a_2 NB_2 + \ldots + a_{n-1} NB_{n-1} + NB_n \tag{11}$$

Where, as before, NB_t are net benefits, (B_t - C_t), in year t. This formula can also be used for either benefits or costs alone.

In the NFV equation, the *accumulation* weights, a_t, are different from the discounting weights in equation (3) used for NPV, and are given by:

$$a_t = (1 + r)^{(n-t)} \tag{12}$$

where r is again the annual discount rate. The net future value for year n can be expressed in relation to the net present value for t=0, as follows:

$$NPV = \frac{NFV}{(1+r)^n} \tag{13}$$

The NFV can be modified for intra-annual values using an effective discount rate described in the NPV section above. It can also be calculated assuming continuous accumulation using the effective discount rate in equation (6) and accumulation weights:

$$a_t = e^{\tilde{r}t} \tag{14}$$

The only difference between equation (14) and equation (5) is the use of $\tilde{r}$ rather than -$\tilde{r}$ in the exponent.

6.1.4 Comparing the Methods

NPV represents the value of a stream of costs and benefits from some point in time (often the present moment) going forward. NFV represents the value of the stream of costs and benefits at some future time. Annualization is the calculation of a constant, annual value for costs and benefits that would produce the same NPV as the actual stream of costs and benefits.

Depending on the circumstances or application of the analysis, one method might have certain advantages over the others. Discounting to the present to get an NPV is likely to be the most informative for the standard economic analysis of a policy that will generate future benefits and costs. NFV may be more appropriate for evaluating the cumulative impacts of regulation or when conducting a retrospective analysis. The difference between the two is simply the choice of the reporting or perspective year for the analysis. Annualized values may be used in conjunction with the NPV to communicate the result or compare options when the costs or benefits are highly variable over time. It is important to remember, however, that annualized values assume that the annualization period begins immediately and that the results are sensitive to the annualization period – the annualized value will be lower the longer the annualization period -- so analysts should be aware of potentially different annualization periods when comparing annualized values from one analysis to those from another.

The choice of discount rate affects the values generated by these discounting methods. For a given stream of net benefits, the NPV will be lower with higher discount rates, the NFV will be higher with higher discount rates, and the annualized value may be either higher or lower depending on the time at which impacts occur and the length of time over which the values are annualized. However, the ranking of monetized net-benefits among regulatory alternatives is unchanged across these three methods for any discount rate.

6.1.5 Sensitivity of Net Present Value Estimates to the Discount Rate

Both the size and sign of NPV can be sensitive to the choice of discount rate when there is a significant difference in the timing of costs and benefits. This is the case for policies that require large initial outlays or have long delays before benefits are realized, as do many EPA policies. Text Box 6.1 illustrates how discount rates affect NPV.

In other cases, the discount rate is not likely to affect the sign of the NPV estimate. Specifically, the NPV will not be affected by the discount rate when:

- All effects occur in the same period. In this case, discounting may be unnecessary or superfluous because net benefits are positive or negative regardless of the discount rate used.
- Costs and benefits of a policy occur consistently over the period of the analysis, or their relative values do not change over time.

In these cases, whether the NPV is positive does not depend on the discount rate, but the discount rate can still affect how the present value compares to another policy.

6.1.6 Issues in Discounting Applications

Several important analytic components need to be considered when discounting costs and benefits.

6.1.6.1 Consistent Use of the Discount Rate

The same discount rate must be used for both benefits and costs occuring in a given year, as the discount rate reflects society's intertemporal preferences for trading off consumption over time independent of the sign of the change in consumption. This is necessary for a consistent comparison of net-benefits across policy alternatives and helps prevent discounting from being used to justify a particular policy. A high discount rate reduces the weight given to costs and benefits in the future and minimizes their impact on the NPV, whereas a low discount rate weights future impacts more heavily and increases their impact on the NPV. Therefore, almost any policy can be arbitrarily justified by using separate discount rates for benefits and costs.

Text Box 6.1 - Potential Effects of Discounting

To illustrate how different discount rates affect net present value, consider an example where the benefits of a given program occur 30 years in the future and are valued (in real terms) at $5 billion at that time. The rate at which the $5 billion future benefits is discounted can dramatically alter the economic assessment of the policy: $5 billion 30 years in the future discounted at 1% is worth $3.71 billion in the present, at 3% it is worth $2.06 billion, at 7% it is worth $657 million and at 10% it is worth only $287 million. In this case, changing the discount rate from 1% to 10% generates more than an order of magnitude of difference in the present value of benefits. Longer time horizons will produce even more dramatic effects of discounting on a policy's NPV. After 100 years, the present value of $5 billion is $260 million at 3% and only $5.8 million at 7% (see Section 6.3 on intergenerational discounting). Particularly in the case where costs are incurred in the present and therefore are not affected by the discount rate, it is easy to see that the choice of the discount rate can determine whether a policy has positive or negative net benefits.

6.1.6.2 Future Value of Environmental Effects and Uncertainty

There are two issues that are sometimes confounded with social discounting and the choice of social discount rate, but should be treated separately: how the value of environmental impacts change over time, and when future benefits and costs may be uncertain. While these issues are important, particularly in an intergenerational context, they both should be addressed separately in the economic analysis rather than adjusting the discount rate to account for them.[7]

First, the future value of environmental effects (i.e., their "current price" in future years) depends on many factors, including the availability of substitutes and the level of wealth in the future. For example, the relative price of environmental goods in the future will rise if those environmental goods become scarcer over time. These changes in relative prices should be applied to future effects and the associated values discounted, but the discount rate should not be adjusted to incorporate a change in relative prices.

Second, uncertainty or risk in future benefits and costs resulting from the policy should not be incorporated into the social discount rate. While it is technically possible to adjust the discount rate to account for uncertainty, doing so may hide important assumptions and information about the relative effects of discounting and uncertainty from decision-makers. Uncertainty about future values should be treated separately when discounting. However, uncertainty about the discount rate itself is different from uncertainty about future benefits and costs and can affect discounting as discussed in Section 6.3.3.

6.1.6.3 Placing Effects in Time

Placing effects properly in time is essential for all calculations involving discounting. As discussed in Section 5.4, analyses should account for implementation schedules and the resulting changes in emissions or environmental quality, including possible changes in behavior that occur between the announcement of policy and compliance deadlines. Additionally, a lag may occur between changes

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7 See, for example, Moore et al. 2017.

in environmental quality and the corresponding change in welfare. It is the change in welfare which defines economic value, and not the change in environmental quality itself. The EPA's Science Advisory Board addressed this issue (U.S. EPA 2001a) for the 2001 Arsenic Rule (U.S. EPA 2001b). If exposure to arsenic in drinking water is reduced, the number of cancer cases is expected to decline over time to a lower, steady-state level. How fast this reduction in risk occurs depends on the "cessation-lag" following reduction in exposure. Whenever values are estimated for future periods, the analysis should also report those values discounted to the present to allow for a proper comparison across periods and avoid a potential misunderstanding regarding the magnitude of a future period's benefits and/or costs relative to those in the current period, all else equal.

6.1.6.4 Period of the Analysis

As described in Section 5.4, the guiding principle is that the time horizon should be sufficient to capture all of the welfare effects from policy alternatives, subject to available resources. This principle is based on the requirement that BCAs reflect the welfare outcomes of those affected by the policy. A complete BCA accounts for all welfare changes over the entire time period that an action is expected to yield benefits and costs.

Analysts should avoid presenting the net benefits or effects of a regulation for a single snapshot period (e.g., a year), as it is likely incomplete and, therefore, cannot be used to draw clear conclusions about the overall impact of the regulation. For example, consider the case where a regulation requires capital expenditures in the first year and has no subsequent costs, but benefits are realized over many years following the initial investment. Presenting the benefits and costs of the rule in only the first year or only one of the subsequent years would misrepresent the regulation's expected net benefits.

Previously, n was defined as the final period in which the policy is expected to have impacts. While a complete BCA should account for impacts expected to occur in *all* future years, it may be impractical to do so. One solution is to analyze a time horizon that ends in $T<n$, such that:

$$\sum_{t=T}^{n}(B_t - C_t)\frac{1}{(1+r)^t} \leq \varepsilon, \qquad (15)$$

where ε is an acceptable estimation tolerance for the NPV of the policy's net benefits. That is, the time horizon should be long enough that the net benefits for all future years beyond T are expected to be negligible when discounted to the present. In practice, however, it is not always obvious when this will occur. For instance, it is not necessarily possible to anticipate whether or when the policy will become obsolete or “non-binding” due, say, to exogenous technological changes or how long the capital investments or displacements caused by the policy may persist.

A symmetric approach may be used to identify the appropriate starting point of the time horizon of the analysis. For example, the time horizon of analysis may begin in year τ, rather than in the year the regulation is promulgated, 0, if in the years from 0 to τ-1 the net benefits are zero or sufficiently small. Note that this guidance should be used cautiously. Even if the net benefits are expected to be negligible in early or later periods, if the benefits or costs are large during those periods relative to total benefits or costs, then the analysis should account for them to be clear about the impacts over time.

As a practical matter, other than identifying points in time before and after which benefits or costs are negligible, a reasonable time horizon of the analysis may, for example, be informed by:

- The expected life of capital investments required by, or expected from, the policy (e.g., when the emissions of flow pollutants are affected);

- Statutory or other requirements for the policy or the analysis; or
- The extent to which benefits and costs are allocated to future generations.

Section 5.4 elaborates on how these first two bullets may influence the time horizon of analysis, while Section 6.3 elaborates on the third.[8]

The choice of time horizon for the analysis should be clearly explained and well-documented, and the analysis should highlight the extent to which the sign of net benefits, or the relative rankings of policy alternatives, are sensitive to the choice of time horizon. If annualized values are reported — then both annualized benefits and costs should be be reported and the time horizon over which benefits and costs are annualized should be the same and clearly documented. Furthermore, an annual value of benefits (or costs) should not be compared to an annualized value of costs (or benefits) because, as discussed in Section 6.1.2, annual and annualized values represent different time scales of analysis.

6.1.6.5 Discounting Non-Monetized Effects

A common criticism of discounting for environmental policies is that health impacts such as "lives saved" or physical impacts such as "improved water quality" are not like money flows. They cannot be deposited in a bank and withdrawn after earning interest. This criticism does not appreciate that the valuation approaches are designed to estimate the amount of money that is as valuable to individuals as the environmental or health effects being examined. If all environmental and health impacts have been appropriately valued (monetized), then those money-equivalent flows can be discounted like real money flows over time.

However, some effects cannot always be monetized. In this case, the undiscounted stream of the non-monetized effects should be presented as they occur over time. As a general matter, these non-monetized effects should still be discounted in benefit-cost analysis and cost-effectiveness analysis if they are aggregated over time. This is because they are assumed to hold some value, albeit unspecified, and discounting assumes that individuals prefer the benefit of that value today over the future. This is the usual practice in cost-effectiveness analysis (Section 7.5.2.1), where monetized costs and non-monetized effectiveness measures are both discounted. OMB Circular A-4 (2023) recommends discounting non-monetized health effects.

For some effects, however, the (unknown) marginal value of a change in the non-monetized effect might be dependent upon the level and timing of that change. That is, marginal values are not constant over time. For example, suppose there are annual emissions thresholds below which environmental effects are negligible, but above which lead to major environmental damages. The economic value of emissions depends upon whether those emissions are above or below this threshold, and discounting these economic values would be appropriate. If we lack these values, however, and discount the effects themselves, we are treating all changes as if they had the same value. Here, it would be preferable to display the undiscounted stream of non-monetized effects with an appropriate justification and explanation.

6.2 Background and Rationales for Social Discounting

8 Section 8.2.3.1 provides additional guidance on the appropriate time horizon of analysis specific to accounting for costs of compliance.

The goal of social discounting is to compare benefits and costs that occur at different times based on the rate at which society is willing to make such trade-offs. The analytical and ethical foundation of the social discounting literature rests on the traditional test of a *potential* Pareto improvement in social welfare, whereby those who, on net, benefit from a policy could potentially compensate those who, on net, experience costs, such that everyone is at least as well off as they were before (see Chapter 1 and Appendix A). This framework casts the consequences of government policies in terms of individuals contemplating changes in their own consumption over time.[9] In this context, trade-offs (benefits vs. costs) reflect the preferences of those affected by the policy, and the time dimension of those trade-offs should reflect the intertemporal preferences of those affected. Thus, social discounting should seek to mimic the discounting practices of the affected individuals. Simultaneously, social discounting must reflect social trade-offs in consumption over time, which may differ from trade-offs from a private, individual perspective.

The literature on discounting often uses a variety of terms to describe identical or very similar key concepts. For the purposes of the *Guidelines*, the following fundamental concepts are used in defining a social discount rate:

- The **social rate of time preference** is the discount rate at which society is willing to trade consumption in one period (usually year) for consumption in the next period.
- **Consumption rate of interest** is the rate at which an individual is willing to trade consumption in one period for consumption in the next period. This rate reflects the individual's rate of time preference and, following the potential Pareto principle, the social rate of time preference should be based on this individual rate.
- The **social opportunity cost of capital** is the consumption allowed in the next period due to private investment in the prior period. This is the rate at which society can trade consumption over time due to productive capital. Benefits and costs should account for future consumption changes due to changes in private investment.
- **Market interest rates** are what we observe in markets for loanable funds. There are several real market interest rates which, to varying extents and accounting for tax distortions, can be taken as estimates for the individual rates of time preferences and the social opportunity cost of capital.

Social discounting is primarily concerned with the relationships among these concepts and how they are measured.

6.2.1 Consumption Rate of Interest and Social Opportunity Cost of Capital

If capital markets were perfect and complete with no distortions or uncertainties, the market interest rate would equal both the consumption rate of interest and the social opportunity cost of capital since it reflects both how individuals value present versus future consumption and how productive capital can be transformed into future consumption. Following the potential Pareto principle and valuing future costs and benefits in the same way as the affected individuals, this market rate would be the appropriate social discount rate.

However, perfect and complete markets do not exist. Private sector returns are taxed (often at multiple levels), capital markets are not perfect, and capital investments often involve private (and not necessarily social) risks. These factors cause a divergence in the consumption rate of interest

9 The term consumption is broadly defined to include both the use of both private and public goods and services by households in BCA and includes the intergenerational nature of this change in consumption.

and the social opportunity cost of capital. That is, there is a divergence between the rates at which *individuals* and *society* can trade consumption over time. Text Box 6.2 illustrates how these rates can differ.

A large body of economic literature analyzes the implications for social discounting of divergences between the consumption rate of interest and the social opportunity cost of capital. Most of this literature is based on the evaluation of public projects, but many of the insights still apply to regulatory BCA, and the dominant approaches from the literature are briefly outlined here. More complete recent reviews can be found in Spackman (2004), Burgess and Zerbe (2011a), Moore et al. (2013a, 2013b), and Harberger and Jenkins (2015). Section 6.2.2 discusses social discounting using the consumption rate of interest as the social rate of time preference, whereas Sections 6.2.3 and 6.2.4 discuss methods for discounting when investment changes.

6.2.2 Social Rate of Time Preference as the Social Discount Rate

If costs and benefits can be represented as changes in consumption profiles over time, then discounting should be based on the rate at which society is willing to postpone consumption today for consumption in the future. Thus, the rate at which society is willing to trade current for future consumption, or the social rate of time preference, is the appropriate discounting concept for evaluating public policy decisions.

But the social rate of time preference differs from individual rates of time preference. An individual rate of time preference includes factors such as the probability of death, whereas society can be presumed to have a longer planning horizon. Additionally, individuals are routinely observed to have several different types of savings, each possibly yielding different returns, while simultaneously borrowing at different market interest rates. For these and other reasons, the social rate of time preference is not directly observable and may not equal any particular market interest rate. Generally, there are two primary approaches to deriving the social rate of time preference.

6.2.2.1 Estimating a Social Rate of Time Preference Using Risk-Free Assets

One common approach to estimate the social rate of time preference is to use the market rate of interest from long-term, risk-free assets such as government bonds. The rationale behind this approach is that this market rate reflects how individuals discount future consumption, and the government should value policy-related consumption changes as individuals do. In this approach, the social discount rate should equal the consumption rate of interest found in the market**.**

In principle, estimates of the consumption rate of interest could be based on after-tax interest rates consumers face for either saving (i.e., lending) or borrowing. Because individuals have different marginal tax brackets, different levels of assets, and different opportunities to borrow and invest, the type of market interest rate that best reflects the consumption rate of interest will differ among individuals. However, the fact that, on net, individuals generally accumulate assets over their working lives suggests that the after-tax returns on savings instruments available to the public will provide a reasonable estimate of the consumption rate of interest for society.

The historical rate of return on long-term government bonds, after-tax and in real terms, is a useful measure as it is relatively risk-free, maintaining the distinction between risk and social discounting described in Section 6.1.6. Also, as long-term instruments, they provide more information on how individuals value future benefits over time frames more relevant for environmental policy analysis.

Text Box 6.2 - Social and Consumption Rates of Interest

The following example illustrates how the return on private sector investments may differ from the consumption rate of interest. Suppose a private sector investment for one period is returned as consumption, the real pre-tax market rate of return on those investments is 5% and that taxes on capital income amount to 40% of the rate of return. In this case, the private investment yields a 5% return, 2% is paid in taxes to the government and individuals receive the remaining 3%. From a social perspective, current consumption - if it were instead invested in capital - can be traded for future consumption at a rate of 5%, with 3% going to individuals and 2% going to the government. But from the individuals' perspective, they are effectively trading consumption through time at a rate of 3%. Therefore, the consumption rate of interest is 3% and the social rate of return on private sector investments (also known as the social opportunity cost of capital) is 5%.

6.2.2.2 Estimating a Social Rate of Time Preference Using the Ramsey Framework

A second option is to construct the consumption rate of interest as the social rate of time preference in a framework attributed to Ramsey (1928), which explicitly reflects: (1) preferences for utility in one period relative to utility in a later period; and (2) the value of additional consumption as income changes. These factors are combined in the equation:

$$r = \rho + \eta g \qquad (16)$$

where

r = the consumption rate of interest,

ρ = the pure rate of time preference,

η = the elasticity of marginal utility with respect to consumption, and

g = the consumption growth rate.

The pure rate of time preference, ρ, is the rate at which the representative individual discounts utility in future periods due to a preference for utility sooner rather than later. The elasticity of marginal utility with respect to consumption, η, defines the rate at which the well-being from an additional dollar of consumption declines with the total level of consumption. The consumption growth rate, g, defines how consumption is expected to grow over time. For example, it may be expected to increase because incomes are expected to increase over time. Estimating a social rate of time preference in this framework requires information on each of these arguments. While η and g can be derived from data, ρ is unobservable and must be assumed or calibrated.[10] Text Box 6.3 provides a more detailed discussion of the Ramsey equation, and Section 6.3.1 discusses using the Ramsey framework to guide intergenerational discounting.

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10 The Science Advisory Board defined discounting based on a Ramsey equation as the "demand-side" approach, noting that the value judgments required for the pure rate of time preference make it an inherently subjective concept (U.S. EPA 2004). However, recent research has developed methodologies to calibrate the pure rate of time preference using a descriptive approach (Newell et al., 2022).

Text Box 6.3 – The Ramsey Discounting Framework

The Ramsey discounting framework provides an intuitive approach to thinking about, and potentially calibrating, the social discount rate. It can be derived by considering a representative individual with utility $u(c_t)$ in period t, where c_t denotes consumption. The agent is assumed to make choices to maximize lifetime welfare, $\int_0^T e^{-\rho t} u(c_t) dt$, where ρ is the pure rate of time preference (i.e., the rate at which the agent discounts utility) and $e^{-\rho t}$ is the discount factor. Suppose the agent is considering a one period investment of one dollar in consumption at time t for additional consumption at time $t + 1$. The minimum investment rate of return, r, required for the individual to find the investment desirable is defined by the equation:

$$\frac{du}{dc_t} = e^{-\rho}\left(e^r \frac{du}{dc_{t+1}}\right) = e^{r-\rho} \frac{du}{dc_{t+1}} \qquad (6.3.1)$$

That is, to be worthwhile the increased utility of consumption in the second period, $\left(e^r \frac{du}{dc_{t+1}}\right)$, discounted back at the pure rate of time preference, ρ, must be at least equal to the forgone utility of consumption forgone in the first period to fund the investment, which could be induced by a regulatory action. The rate r defines the additional return, beyond recovering the initial investment, required for the agent to be just as well off as before. So, r represents the discount rate appropriate for comparing a future change in consumption with a change in present consumption.

If it is assumed, as is common, that the utility function has an iso-elastic form, such that $u(c_t) = \frac{c_t^{1-\eta}}{1-\eta}$, where η is the absolute value of the elasticity of marginal utility, the Ramsey formula can be recovered. Substituting this utility function into equation (6.3.1), taking the natural log of both sides of the equation, applying the relationships $ln(a) - ln(b) = ln(a/b)$ and $ln(a^m) = m\, ln(a)$, and solving for r produces:

$$r = \rho + \eta\, ln\left(\frac{c_{t+1}}{c_t}\right) = \rho + \eta g \qquad (6.3.2)$$

where g is the rate of growth of consumption between t and $t + 1$.

This definition highlights two reasons that future changes in consumption should be discounted (as described in section 6.2.2.2).

1. The pure rate of time preference, ρ, captures the general preference by individuals for utlity sooner rather than later and measures the rate at which individuals discount their own future utility.
2. The term, ηg represents that a marginal change in consumption in the future may not have the same value as a marginal change in consumption today. For example, if consumption increases over time, the marginal utility of consumption will decrease over time, implying that a marginal change in future consumption is valued less (and discounted more) than a marginal change in current consumption.

As shown by Ramsey (1928), in an economy with no taxes, market failures or other distortions, the social discount rate r, as defined in equation (6.3.2), would be expected to equal the market interest rate. The market interest rate, in turn, would be equal to the social rate of return on private investments and the consumption rate of interest. However, distortions and market failures cause these rates to diverge in practice. As such, r represents the consumption rate of interest.

6.2.3 Social Opportunity Cost of Capital as the Social Discount Rate

The social opportunity cost of capital recognizes that the social return to private investments may exceed the private returns. Therefore, if funding for government projects or capital investments required to comply with government regulations displace total private investment in the economy the opportunity cost of those forgone investments may exceed the private returns. In other words, if a regulation displaces private investments, society will lose the total returns from those forgone investments, including the tax revenues generated.

Private capital investments might be displaced if public projects are financed with government debt and government borrowing crowds out private investment. In a regulatory context, private investment might be displaced if regulated firms cannot pass through capital expenses to households and the supply of investment capital is relatively fixed. In these cases, demand pressure in the investment market will tend to raise market interest rates and reduce private investments that would otherwise have been made.[11] A BCA should account for the full social cost of any declines in private capital investments due the policy being evaluated (and similarly the social benefits of any increase in private capital investments induced by the policy), as appropriate.

In principle, the social opportunity cost of capital can be estimated by a pre-tax, marginal, risk-free rate of return on private investments, but this rate is not observed in the marketplace. As a result, these values are sometimes derived by using National Accounts data to estimate rates of return on reproducible capital (e.g., Burgess and Zerbe 2011b; Harberger and Jenkins 2015), though there are some differences in the exact accounts included and their relative weights across these analyses. In practice, average returns that are likely to be higher than the marginal returns are typically observed, given that firms will make the most profitable investments first. This leads to uncertainty as to how marginal returns can be estimated. Observed rates also reflect an unknown risk premium faced in the private sector, which causes them to be higher than a risk-free rate.

In very specific circumstances using the social opportunity cost of capital as the social discount rate in a BCA for an environmental policy can account for the social costs of displaced capital investments. In particular, it requires that the policy costs fully crowd out private investments.[12] Harberger (1972) recognized this is unlikely to be the case and derived a generalized version of this approach, assuming that policies displace a mix of consumption and investment. In this case, the social discount rate is a weighted sum of the net pre-tax marginal return to capital (i.e., the social opportunity cost of capital) and the after-tax marginal return to capital (i.e., the consumption rate of interest). Sandmo and Drèze (1971), Drèze (1974), and Burgess (1988) extended this approach to include the marginal cost of foreign financing in an open economy. In practice, this weighted sum is likely to be closer to the consumption rate of interest than the opportunity cost capital for a number of reasons. First, the United States is a large, open economy with a high capital mobility.

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11 Another justification for using the social opportunity cost of capital argues that the government should not invest (or compel investment through its policies) in any project that offers a rate of return less than the social rate of return on private investments. While it is true that social welfare will be improved if the government invests in projects that have higher values rather than lower ones, it does not follow that rates of return offered by these alternative projects define the level of the social discount rate. If individuals discount future benefits using the consumption rate of interest, the correct way to describe a project with a rate of return greater than the consumption rate is to say that it offers substantial present value net benefits.

12 The terms "displacement" and "crowding out" refers to how total private investment in the economy is reduced due to new investment in response to the environmental policy. That is, how compliance costs in response to the policy displace investment that would have occurred without the policy. An environmental policy has fully crowded out private investment if private investment is reduced by the full compliance cost of policy.

Most regulatory costs are not expected to result in a substantial displacement of capital investment, which can be funded through an increase in financing by foreign lenders. Second, the benefits of regulation could induce capital investment (e.g., by increasing productivity or reducing depreciation), which is unaccounted for in the social opportunity cost of capital approach.[13] As such, the shadow price of capital approach is the analytically preferred approach to account for the full social cost of any changes in private capital investment expected in response to the policy being analyzed.

6.2.4 Shadow Price of Capital Approach

As noted above, because capital markets are taxed and experience other market distortions, the consumption rate of interest and the social opportunity cost of capital are not equal. This means that while individuals are indifferent between consumption and the returns to risk-free private investment on the margin, society is not. The shadow price of capital approach accounts for this by adjusting the costs and benefits that affect investment into equivalent consumption impacts (i.e., their shadow values) that reflect the social value of altered private investments.[14] All impacts—the costs and benefits that affect consumption and the shadow costs and benefits of affected investments—are then discounted using the social rate of time preference that represents how society trades and values consumption over time.[15] Many sources recognize this method as the preferred analytic approach to social discounting for public projects and policies.[16]

The shadow price (or social value) of private capital investment captures the perspective that a unit of private capital produces a stream of social returns at a rate greater than that at which individuals discount them due to distortions in the capital market noted in the discussion of the social opportunity cost of capital. This is because a capital investment produces a rate of return for its owners equal to the consumption rate of interest (post-tax) plus a stream of tax revenues for the government (generally considered to be used for consumption). Text Box 6.4 illustrates this idea of the shadow price of capital.

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13 This approach has been used by the Federal government for many years and was recommended in previous EPA Guidelines (2016) and OMB Circular A-4 (2003), but it is technically incorrect and can produce NPV results substantially different from the shadow price of capital approach. For an example of these potential differences, see Spackman (2004).

14 A "shadow price" can be viewed as a good's true opportunity cost, which may not equal the market price. Adjusting the cost and benefits of investment to reflect their consumption equivalent impact is, essentially, reporting their shadow values. Lind (1982a) remains the seminal source for this approach in the social discounting literature.

15 Because the consumption rate of interest is often used as a proxy for the social rate of time preference, this method is sometimes known as the "consumption rate of interest – shadow price of capital" approach. However, as Lind (1982b) notes, what is really needed is the social rate of time preference, so more general terminology is used. Discounting based on the shadow price of capital is referred to as a "supply side" approach by the EPA's Science Advisory Board (U.S. EPA 2004).

16 See OMB Circular A-4 (2023), Freeman (2003) and the report of the EPA's Advisory Council on Clean Air Compliance Analysis (U.S. EPA 2004).

Text Box 6.4 – Calculating and Applying the Shadow Price of Capital

A highly stylized example illustrates the shadow price of capital concept. Suppose that the real pre-tax annual rate of return on private investments (i.e., the social opportunity cost of capital) is 3.5% and the post-tax consumption rate of interest is 2%. Under these conditions, $1 in private investment will produce a stream of private consumption of $.02 per year, and tax revenues of $.015 per year. Further assume that the $1 investment does not depreciate (i.e., it exists in perpetuity), the annual $0.02 net-of-tax earnings from this investment are consumed each year and the $.015 annual tax-revenue is also used for consumption in each year. The present value of the perpetual stream of constant investment income to individuals is the stream of income divided by the discount rate (Equation (10)), $0.02 / 2% = $1. The present value of the $0.015 per year stream of tax revenues discounted at 2% is $0.015/0.02 = $0.75. This is the present value of the additional benefits to society (via the government). Thus, the full social value of this $1 private investment – the shadow price of capital – is $1.75, greater than the $1 private value that individuals place on it.

This example is a highly stylized case where changes in the productive capital stock persist in perpetuity and all income from capital assets funds only consumption. A more complete derivation of the shadow price of capital, as given by Li and Pizer (2021), takes into account depreciation and the savings rate (i.e., the rate at which individuals invest income):

$$Shadow\ price\ of\ capital = \frac{(1 - savings\ rate)(gross\ rate\ of\ return\ on\ capital)}{[consumption\ rate\ of\ interest + depreciation\ rate - (savings\ rate)(gross\ rate\ of\ return\ on\ capital)]}$$

The gross rate of return on capital is the net rate of return on investments before depreciation (i.e., the social opportunity cost of capital plus the depreciation rate). Maintaining the assumptions of a 3.5% social opportunity cost of capital and a 2% consumption rate of interest, and assuming a depreciation rate of 10% and an equilibrium savings rate of 25% would yield an estimate of 1.17 for the shadow price of capital.

To apply the shadow price of capital estimate in a BCA, one needs additional information about how much investment is displaced and induced. For example, assume a large public project is financed with 75% as additional government debt and 25% through increased taxes. Further supposed that the increase in government debt displaces an equal amount of private investments and the increase in taxes reduces individuals' current consumption by an equal amount.

The shadow price of capital approach would be applied to the cost estimate in the following steps:

1. Separate the costs that displace capital investment from the costs that displace consumption.
    a. $0.75 of every $1 in costs financed through debt displaces investment.
    b. $0.25 of every $1 in costs financed through taxes displaces consumption.
2. Apply the shadow price of capital (1.17 from the example above) to the $0.75 of costs that displace private investment. This yields a shadow cost of $0.88 which accounts for the impact of these costs on investments.
3. Add to this the remaining current cost ($.25) that displaces current consumption, which is not adjusted for the shadow price of capital.
4. The total social cost of this public project is $1.13 for every $1 spent.

The same steps should be followed for the benefits estimate, separating the benefits that induce capital investment from those that directly increase consumption, to determine the total social benefits. The total social cost would then be compared to the social benefits of the project.

When compliance with environmental policies displaces private capital investments (e.g., machinery and equipment), the shadow price of capital approach adjusts any capital-displacing project or policy cost upward by the shadow price of capital (i.e., the effect of displacing capital on consumption society-wide). This calculation effectively converts changes in private investment into consumption equivalents, such that all costs and benefits can then be discounted using a social discount rate equal to the consumption rate of interest. The most complete frameworks for the shadow price of capital also recognize that while the costs of regulation might displace private capital, the benefits could induce additional private investments in capital. In principle, a complete analysis using the shadow price of capital would treat capital adjustments from costs and benefits in the same fashion.

Policies analyzed in a general equilibrium framework (Chapter 8) will implicitly apply a shadow price of capital approach. In the case of partial equilibrium analyses, additional steps are necessary to apply the shadow price of capital approach. The first step is determining whether a policy will alter private investment flows. Next, the altered private investment flows (positive and negative) are multiplied by the shadow price of capital to convert them into consumption-equivalent units. All flows of consumption and consumption equivalents are then discounted using the consumption rate of interest. A simple illustration of this method applied to the costs of a public project is shown in Text Box 6.4.

6.2.4.1 Estimating the Shadow Price of Capital

While the shadow price of capital approach provides a theoretically sound method for measuring the impact of changes in private capital investment, it is challenging to implement in practice. The Li and Pizer (2021) specification described in Text Box 6.4, requires estimates of the social rate of time preference, the social opportunity cost of capital, a depreciation rate, a savings rate, and, in particular, the extent to which regulatory costs displace private capital investment and benefits stimulate private capital investment. The first two components can be estimated as described earlier, and the depreciation rate and savings rate can be estimated from empirical data, but information on how regulation affects capital formation is more difficult to obtain, making the approach difficult to implement.[17]

How policies affect capital investment depends on whether the economy is assumed to be open or closed to trade and capital flows, and on the magnitude of the policy intervention relative to the flow of investment capital from abroad. Some argue that early analyses implicitly assumed that capital flows into the nation were either nonexistent or very insensitive to market interest rates, known as the "closed economy" assumption.[18] However, if an economy has highly mobile capital flows, including from international sources, that are sensitive to market interest rate changes (the "open economy" assumption), then total investment in private capital is likely to be less sensitive to regulatory policy interventions, and there will be little, if any, crowding out.[19] If there is no

17 In addition to Li and Pizer (2021), Lyon (1990) and Moore et al. (2004) provide reviews of how to calculate the shadow price of capital and possible settings for the various parameters that determine its magnitude. Boardman et al. (2011) contains a textbook explanation as well as empirical examples. Depending on the magnitudes of the various factors, shadow prices from 1 to infinity can result according to Lyon (1990), but the ratio of the social opportunity cost of capital to the social rate of time preference is an upper bound in the Li and Pizer (2021) specification.

18 See Lind (1990) for this revision of the shadow price of capital approach.

19 See, for example, Warnock and Warnock (2009).

crowding out of private investment, then no adjustments using the shadow price of capital are necessary; benefits and costs should be discounted using the consumption rate of interest alone. The economic literature is not conclusive on the degree of crowding out and there is limited empirical evidence of a relationship between the nature and size of projects and capital displacement. This presents challenges to implementing the shadow price of capital approach outside of a general equilibrium framework.

6.2.5 Evaluating Alternative Social Discount Rate Estimates

The empirical literature for choosing a social discount rate focuses on estimating the consumption rate of interest at which individuals trade off consumption through time. Historical real rates of return on “safe” assets (post-tax), such as U.S. Treasury securities, are normally used to estimate the consumption rate of interest. Some studies and reports have found government borrowing rates range between 1.5-4%, with long-term interest rates declining for the last two decades.[20] Other studies have expanded this portfolio to include other bonds, stocks and even housing. This generally raises the range of rates slightly. It should be noted that these rates are *realized* rates of return, not anticipated, and they are somewhat sensitive to the choice of time period and the class of assets considered.[21]

Other economists have constructed a social discount rate by estimating the individual parameters in the Ramsey equation. These estimates necessarily require judgments about the pure rate of time preference. Moore et al. (2013a) and Boardman et al. (2011) estimate the social discount rate to be 3.5% under this approach. The Ramsey equation has been used more frequently for intergenerational discounting, which is addressed in the next section.

Using the social opportunity cost of capital as the social discount rate requires a situation where private investment is fully crowded out by the costs of environmental policies. This is an unlikely outcome, but it can be useful for sensitivity analysis and special cases. Estimates of the social opportunity cost of capital typically range from 4.5% to 8%, depending upon the type of data used.[22]

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20 Newell and Pizer (2003) find a 200-year average (1798-1999) rate of 4% for long-term (30-year) U.S. government bonds. According to the U.S. Congressional Budget Office (CBO) (2005), funds continuously reinvested in 10-year U.S. Treasury notes from 1789 to 2004 would have earned an average inflation-adjusted return of slightly more than 3% a year. OMB (2003) reported a 30-year average (1973-2002) pre-tax rate for 10-year U.S. Treasury notes of 3.1%. U.S. CBO (2016) estimated that the average real rate for 10-year Treasury notes was 2.9% between 1990 and 2007. Boardman et al. (2011) suggests 2.71% as the 1953-2001 average real rate of return on 10-year U.S. Treasury notes. However, the Council of Economic Advisers (CEA 2017) notes a decades-long downward trend in real rate of return for U.S. Treasury notes. Bauer and Rudebusch (2020, 2023) found that the decline in real interest rates reflects a reduction in the equilibrium real interest rate, suggesting that lower real interest rates are expected to persist. OMB Circular A-4 (2023) states that the more recent 30-year average (2003-2022) rate for 10-year Treasury marketable securities was 2.0%. U.S. EPA (2023) reported a 1991-2020 average real rate of return on 10-year Treasury securities of 1.5 to 2.0%, based on the inflation measure used. U.S. CBO (2023) projects a real interest rate on 10-year Treasury notes of 1.5% in 2033, rising to 2.2% by 2053.

21 Ibbotson and Sinquefield (1984 and annual updates) provide historical rates of return for various assets and for different holding periods.

22 OMB (2003) estimated a real, pre-tax opportunity cost of capital of 7%. Harberger and Jenkins (2015) estimate an average rate of 8% for "advanced countries." Burgess and Zerbe (2011a) estimate a rate of 6% to

The utility of the shadow price of capital approach hinges on the magnitude of altered capital flows from the environmental policy. If the policy will substantially displace or induce private investment, then a shadow price of capital adjustment is necessary before discounting consumption and consumption equivalents using the consumption rate of interest. Estimates of the shadow price of capital in the academic literature range from 1.1 to 2.2 (Boardman et al. 2011, Moore et al. 2013a, Li and Pizer 2021). The economic literature does not provide clear guidance on the likely scale of this displacement, but it has been suggested that if a policy is relatively small and capital markets fit an "open economy" model, there is probably little displaced investment.[23] Changes in yearly U.S. government borrowing during the past several decades have been in the many billions of dollars. It may be reasonable to conclude that EPA programs and policies costing a fraction of these amounts will not likely result in significant crowding out of U.S. private investments. For these reasons, some argue that for most environmental regulations, it is sufficient to discount costs and benefits with an estimate of the consumption rate of interest with sensitivity analysis as appropriate.[24]

6.3 Intergenerational Social Discounting

Policies designed to address long-term environmental problems such as global climate change, radioactive waste disposal, groundwater pollution, or biodiversity present unique challenges because they can involve significant economic effects across generations. Often, costs are imposed mainly on the current generation to achieve benefits that will accrue primarily to unborn, future generations. Discounting in this context is generally referred to as intergenerational discounting.

This section discusses the main issues associated with intergenerational social discounting using the Ramsey discounting framework as a convenient structure for considering how the "conventional" discounting procedures might need to be modified for policy analysis with very long, multi-generational time horizons. This discussion presents alternative modeling approaches to estimate the term structure, or the sequence of discount rates over time, along with important caveats when using these approaches.

Intergenerational discounting is complicated by at least three factors: (1) the "investment horizon" is longer than what is reflected in observed market interest rates representative of intertemporal consumption trade-offs made by the current generation; (2) intergenerational investment horizons involve greater uncertainty than intragenerational time horizons; and (3) future generations without a voice in the current policy process are affected. These complications limit the utility of using observed market rates to evaluate long-term public investments. The leading alternative is to use model-based approaches to forecast a discount rate representative of expected household preferences. These models suggest using a social discount rate lower than one based on recently observed market rates and conditions, especially when uncertainty over the future state of the world is taken into consideration.

The problem of comparing benefits borne by future generations to costs experienced by the current generation involves both economic and ethical questions. Therefore, the normative choice of how a

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8%, and Moore et al. (2013b) estimate a rate of approximately 5% using the same model but with different inputs. Using an approach similar to OMB (2003), CEA (2017) estimated real rates of return to capital to be around 7% based on National Accounts data but noted that approach may be subject to measurement error leading to an overestimate.

23 Lind (1990) first suggested this.

24 See Lesser and Zerbe (1994), Moore et al. (2004), and OMB (2023).

decision maker should weigh the welfare of present and future generations, along with the preferences of the current generation regarding future generations, cannot be made on economic grounds alone. Nevertheless, economics offers important insights concerning intergenerational discounting, the implications and consequences of alternative discounting methods, and the systematic consideration of uncertainty.

6.3.1 The Ramsey Framework in an Intergenerational Context

The Ramsey framework introduced in Section 6.2.2 is one of the most commonly used approaches for modeling consumption discount rates.[25] It is based on fundamental economic theory and provides an intuitive organizing framework for thinking about consumption discount rates over long time horizons. If per capita consumption grows over time — as it has since the Industrial Revolution (Valdés 1999) — then future generations will be richer than the current generation. Due to the diminishing marginal utility of consumption, increases in consumption will be valued less in future periods than they are today. In a growing economy, changes in future consumption would be given a lower weight (i.e., discounted at a higher rate) than changes in present consumption in the Ramsey framework, even setting aside discounting due to the pure rate of time preference, ρ.

This framework can be viewed in positive terms as a description (or first-order approximation) of how the economy works in practice. It can also be considered in normative terms to define how individuals should optimally consume and reinvest economic output over time. As a result, the individual parameters of the Ramsey equation can be specified using two approaches: the descriptive (or positive) approach and the prescriptive (or normative) approach.

- **The descriptive (positive) approach** attempts to calibrate the parameters of the Ramsey equation by using estimates from observed behavior. The resulting consumption discount rate reflects society's observed preferences for trading off consumption over time and the best available information on the future growth rate of consumption. Advocates of the descriptive approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision-makers [individuals] actually use" (Arrow et al. 1996). However, this can be difficult to do in practice.
- **The prescriptive (normative) approach** is based on defining a social welfare function that formalizes the normative judgments that the decision-maker wants to explicitly incorporate into the policy evaluation. In the case of the Ramsey equation, parameters would then be chosen to match these desired normative judgments.[26,27] The main argument against the prescriptive approach is that it may not be consistent with individuals' preferences for inter-temporal trade-offs revealed by their market behavior.

While the Ramsey framework is commonly used and is based on an intuitive description of the general problem of trading off current and future consumption, it has limitations. Arrow (1996)

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25 Text Box 6.3 provides a derivation of the Ramsey framework. Key literature on this topic includes Arrow et al. (1996), Lind (1994), Schelling (1995), Solow (1992), Manne (1994), Toth (1994), Sen (1982), Dasgupta (1982), Pearce and Ulph (1994), Gollier (2010), and Arrow et al. (2013).

26 Arrow et al. (1996).

27 For instance, there has been a long debate, starting with Ramsey himself, on whether the pure rate of time preference, which shows a general preference for consumption by the current as opposed to future generations, should be greater than zero when evaluating public policy decisions.

contains a detailed discussion of descriptive and prescriptive approaches to discounting over long time horizons, including examples of rates that emerge under various assumptions about components of the Ramsey equation.

6.3.2 Efficiency and Intergenerational Equity

A principal concern when policies span long time horizons is that future generations affected by the policy are not yet alive. Therefore, they cannot participate in the decision-making process and their preferences are uncertain. This is not always a severe problem for practical policy analysis. Many policies impose relatively modest costs and benefits, or have costs and benefits that begin immediately or occur in the not-too-distant future. In most cases, it suffices to assume future generations will have preferences like those of present generations. However, for policies where the costs and benefits are large and distributed asymmetrically over large expanses of time, the choice of discount rate may involve both efficiency and ethical considerations.

6.3.2.1 Efficiency Considerations

As discussed in Chapter 1 and Appendix A, the BCA efficiency test is grounded in the notion of a potential Pareto improvement, whereby those who benefit from a policy, on net, could potentially compensate those who experience costs, on net, such that everyone is at least as well off as they were before. The potential for this compensation to occur across generations hinges on the interest rate at which society can transfer wealth across long time horizons. The choice of social discount rate, therefore, contains an implicit assumption about whether, and at what price, the distribution of wealth across generations could be adjusted to compensate those who bear costs, on net. Some have argued that in the U.S. context, the federal government's borrowing rate is a good candidate for this rate, while others have argued that practical difficulties associated with implementing intergenerational transfers suggest that the Kaldor-Hicks potential compensation test is limited in its ability to assess policies affecting multiple generations.[28,29] Still others argue that the discount rate should be below market rates to correct for market distortions, and uncertainties or inefficiencies in intergenerational transfers of wealth.[30] The role of uncertainty is discussed in more detail below.

6.3.2.2 Equity Considerations

Because future generations cannot participate in decisions made by current generations, social discounting may raise ethical issues regarding the intertemporal distribution of wealth. This concern does not suggest forgoing the use of a positive discount rate but has led to suggestions that the discount rate used in intergenerational contexts should be below market rates to ensure that generations are treated equally based on ethical principles (e.g., Arrow et al. 1996, Portney and Weyant 1999).[31] One interpretation of this idea is to forgo discounting the utility of future

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28 See Lind (1990) and a summary by Freeman (2003).

29 For more information and theoretical foundations of the Kaldor-Hicks test for potential Pareto improvements, see Appendix A.

30 Arrow et al. (1996); Weitzman (1998).

31 Another issue is that there are no market rates for intergenerational time periods.

generations by setting the pure rate of time preference in the Ramsey framework to zero. These suggestions are for using a prescriptive (i.e., normative) approach for discounting.

6.3.3 Declining Discount Rates

Theoretical and empirical support is growing for discount rates that decline over time for intergenerational discounting (Arrow et al. 2014). That is, the appropriate rate to use in discounting effects in year 101 to year 100 will be lower than the appropriate rate to use in discounting effects in year 2 to year 1. Multiple rationales support a declining discount rate, most notably slowing consumption growth rates and uncertainty about economic growth.

6.3.3.1 Rationales for Declining Discount Rates

A slowing of consumption growth rates leads to declining discounting, as is evident from the Ramsey framework. Using a constant discount rate in BCA is technically correct only if the rate of economic growth per capita remains fixed over the time horizon of the analysis. In principle, any changes to income growth, the elasticity of marginal utility of consumption, or the pure rate of time preference will lead to a discount rate that changes accordingly. If economic growth per capita changes over time, the discount rate will also fluctuate. In particular, an assumption that the growth rate is declining systematically over time (perhaps to reflect some physical resource limits) will lead to a declining discount rate. This is the approach taken in some models of climate change.[32]

Uncertainty about future consumption growth can also lead to a declining discount rate. The longer time horizon in an intergenerational policy context implies greater uncertainty about the investment environment and economic growth over time, and a greater potential for environmental feedbacks to economic growth (and consumption and welfare). These feedbacks further increase uncertainty when attempting to estimate the social discount rate. This additional uncertainty implies effective discount rates lower than those based on observed average market interest rates (Weitzman 1998, 2001; Newell and Pizer 2003; Arrow et al. 2013; Cropper et al. 2014). [33,34]

The effect of uncertainty on discount rates is a result of the fact that discounting is a non-linear operation, such that the average discount factor (i.e., $E[e^{-rt}]$) is not equal to the discount factor calculated at the average discount rate (i.e., $e^{-E[r]t}$). As an alternative to estimating the average discount factor, one can calculate the certainty equivalent discount rate schedule, which is the discount rate schedule that yields the same discount factor in any time period as the average discount factor across the possible discount rates. Uncertainty about future consumption growth will cause this certainty equivalent discount rate schedule to decline over time as the potential for low discount rates will increasingly dominate the expected NPV calculations for benefits and costs

32 See, for example, U.S. EPA (2023).

33 This holds regardless of whether or not the estimated investment effects are predominantly measured in terms of private capital or consumption.

34 Gollier and Zeckhauser (2005) reach a similar result using a model with decreasing absolute risk aversion.

far in the future (Weitzman 1998). Text Box 6.5 provides a simple example highlighting how declining discount rates arise in this fashion.[35]

6.3.3.2 Approaches to Estimate Declining Discount Rates under Uncertainty

Declining discount rate schedules can be derived from specifications of the Ramsey formula or from historically estimated stochastic models of interest rates.

If there is uncertainty in the consumption growth rate, then the standard Ramsey formula may need to be adjusted. Incorporating uncertainty in consumption growth results in a third term being subtracted from the Ramsey formula to account for the potential of low growth futures (Gollier 2002; Arrow et al. 2014). If the shocks to consumption growth are independent and identically distributed, then the precautionary term will cause the discount rate to be lower but not decline. However, if the shocks are positively correlated over time, then the precautionary term will grow over time and cause the discount rate to decline (Goiller 2014). If there is parametric uncertainty regarding the process underlying consumption growth or the other values in the Ramsey formula, this can also lead to a declining discount rate. However, if the uncertainty in the growth rate is endogenously incorporated in the benefits or costs calculations using Monte Carlo simulations, this adjustment is unnecessary.[36]

The use of historical data to estimate a declining discount rate schedule is shown by Newell and Pizer (2003). They use historical data on U.S. interest rates and assumptions regarding their future path to characterize uncertainty and compute a certainty equivalent rate. In this case, uncertainty in the individual components of the Ramsey equation is not being modeled explicitly. This is attractive as a descriptive approach because it does not require specifying uncertainty over the consumption growth rate and parameters of the Ramsey formula, but its results are sensitive to the selection of a model to represent the stochastic interest rate process (Groom et al. 2007).

Some modelers and government bodies have used fixed step functions for the discount rate term structure to approximate more rigorously-derived declining discount rate schedules and to reflect non-constant economic growth, intergeneration equity concerns, and heterogeneity in future preferences.[37] This method acknowledges that a constant discount rate does not adequately reflect the reality of fluctuating and uncertain growth rates over long time horizons. However, no empirical evidence suggests the point(s) at which the discount rate declines, so any year selected for a change in the discount rate will be ad-hoc.

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35 While this explanation is motivated by uncertainty over long-term consumption growth, a similar result arises when there is persistent uncertainty about preferences or heterogeneity in preferences. See Heal and Millner (2014).

36 For example, see the approach taken in Newell et al. (2022).

37 For instance, in the United Kingdom, the Treasury recommends the use of a 3.5% discount rate for the first 30 years followed by a declining rate over future time periods until it reaches 1% for 301 years and beyond. The guidance also requires a lower schedule of rates, starting with 3% for zero to 30 years, where the pure rate of time preference in the Ramsey framework (the parameter r in our formulation) is set to zero. For details, see Lowe (2008). Additionally, Weitzman (2001) presents a novel approach to calibrating a fixed step discount rate schedule based on uncertainty using survey data.

Text Box 6.5 – Declining Discount Rates from Uncertainty

The term structure for the certainty equivalent discount rate may decline over time due to uncertainty about future economic conditions or social preferences. Consider a simple example where one is attempting to evaluate the net present value of a policy that yields $1 in net benefits every year, and there is uncertainty as to whether the discount rate is 2% or 4%, with each rate equally likely. Because discounting is a nonlinear operation, using the average discount rate of 3% will not provide the same result as calculating the expected net present value of the two equally likely rates. Figure 6.1a presents the present value of this stream of net benefits for time horizons from 1 year to 300 years. Using the average discount rate of 3% underestimates the average present value of the payments for long time horizons. However, the plot shows that, the difference is relatively small over short time horizons.

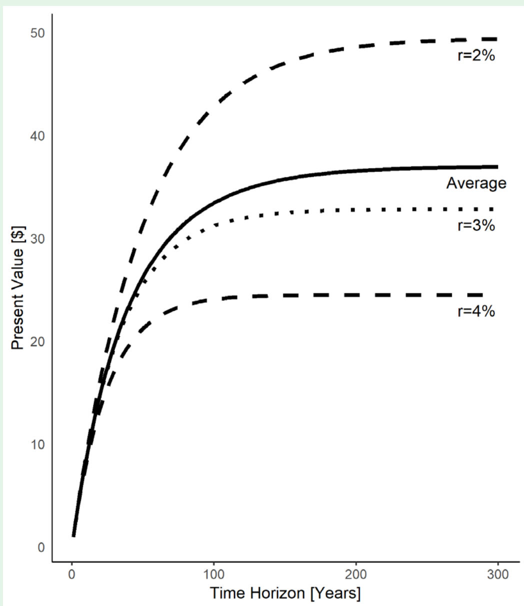

Figure 6.1a: Net Present Value

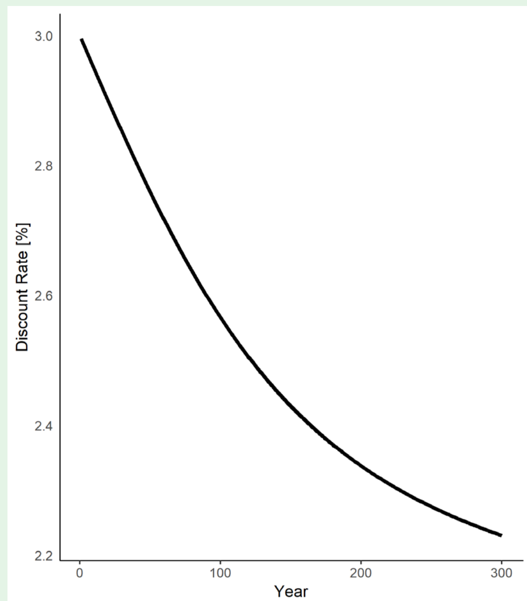

Figure 6.1b: Certainty Equivalent Discount Rate

As opposed to calculating the average net present value, one could solve for the discount rate schedule that, when applied to the problem as if there were certainty about the discount rate, yields the same present value for a particular time horizon as when explicitly accounting for uncertainty. This discount rate schedule is referred to as the certainty equivalent discount rate. Figure 6.1b presents the certainty equivalent discount rate for this example. The discount rate schedule begins close to, but below, the average discount rate of 3% and so for short time horizons the 3% and certainty equivalent discount rates have approximately equal impact on the present value. However, as one moves further out in time, the certainty equivalent discount rate declines and becomes much lower. This effect may be seen in Figure 6.1a. At the 4% discount rate, after approximately 100 years, future payments do not appreciably affect present value. However, at the 2% discount rate, extending the time horizon past 100 years appreciably increases the present value. Therefore, in terms of calculating the average present value it is the possibility of the discount rate being 2% that matters more (i.e., it dominates). This is the general effect that causes the certainty equivalent discount rate in Figure 6.1b to decline.

6.3.3.3 Consistency Issues and Declining Discount Rates

Another concern regarding declining discount rates is the potential for time inconsistency in policy recommendations over time (Arrow et al. 2014). Time inconsistency means that a net-beneficial policy today may not be net-beneficial if evaluated in the future, even when nothing has changed except for the date of the evaluation. The use of fixed step functions can exacerbate the problem. Therefore, whether an analysis shows the policy to be net-beneficial will be sensitive to the point in time the analysis is conducted. Text Box 6.6 provides an illustration of this time consistency problem.

If the analyst obtains new information between the time the original and updated analysis are conducted, the results of the analysis may have changed. However, if a fixed declining discount rate schedule is adopted and not updated between analyses to reflect the arrival of new information, that could lead to a potential time inconsistency problem (Arrow et al. 2014).

6.3.3.4 Calibration and Challenges

A wide range of potential approaches for calibrating a discount rate or a schedule of declining discount rates is available for discounting intergenerational costs and benefits. More complex analysis is justified when the proportion of costs and benefits occurring far out on the time horizon and the temporal separation of costs and benefits is large. While strong theoretical and empirical evidence shows that a declining discount rate schedule is appropriate when considering effects over long time horizons, calibration complications and concerns with time inconsistency remain notable challenges.

One possible response to such challenges is to select a constant but slightly lower discount rate when discounting costs and benefits expected to occur far out in the time horizon, reflecting a certainty equivalent discount rate. Independent of the approach or rate selected, the same discount rate should be applied to all benefits and costs that occur in the same year for both intra- or intergenerational consequences to ensure consistency in the analysis (Arrow et al. 2013).

6.4 The Role of Private Discounting in Economic Analysis

This chapter focuses on social discounting, which is discounting from the broad society-as-a-whole perspective embodied in BCA. By contrast, private discounting is the discounting of expected future benefits or costs (e.g., revenues or expenditures) from the perspective of private individuals or firms. Private discount rates reflect the preferences of specific individuals for consumption over time, as well as the prices that individuals and firms pay to borrow and lend money. These rates vary among firms, industries, and individuals due to differences in preferences, tax treatments, and costs of borrowing. Section 6.2.1 describes why market interest rates differ from the consumption rates of interest.

As previously stated, private discount rates should not be used to estimate the NPV of the social net benefits of policies and projects because the intertemporal preferences of society as a whole (as measured by the social rate of time preference) are not likely to be equal to private market lending rates or individual or firm preferences.

Text Box 6.6 – Time Inconsistency and Declining Discount Rates

Time inconsistency means that a net-beneficial policy today may not be net-beneficial if evaluated in the future, even when the only change is the date of the evaluation.

Consider the following stylized example of a declining discount rate used to analyze a policy. The discount rate schedule is a step function with 3% for benefits and costs that occur one period in the future and 0% in each period thereafter. The policy will cost $1,000 in the second period from today and will provide benefits of $1,003 in the third period. If evaluated today, the policy has positive net benefits of $e^{-0.03}$ ($e^{-0.00}$$1,003 - $1000) = $3.

However, a reevaluation of the policy in the second period would have negative net benefits of $e^{-0.03}$ $1,003 - $1000) = $-27, because costs are not discounted while the benefits in period three are discounted to period two at 3%. Therefore, whether an analysis shows the policy to be net-beneficial will be sensitive to the point in time the analysis is conducted. This is a time-inconsistent approach to discounting.

6.4.1 Predicting Private Behaviors and Choices

Private discounting should be used to predict behaviors and choices of individuals and firms in response to policy, and how investment in the economy and consumption (broadly defined) are expected to change as a result.[38] Individuals and firms can be expected to make decisions based on their own opportunity costs rather than those of society as a whole. For example, from the viewpoint of a private firm, the change in a stream of future profits due to the adoption of a pollution abatement project would be evaluated at the rate at which the firm can borrow. Similarly, the expected consumption behavior of individuals and households should be modeled consistently with how they make purchasing decisions. To predict the purchase of durable goods, for example, private evaluation and perception of the consumer's benefits and costs from using these goods over time should be used. Failure to account for choices based on appropriate private discount rates will lead to inconsistencies between the behavior of individuals and firms in the analysis and their expected behavior in the real world.[39] Therefore, private discount rates should be used to evaluate how firms and individuals will respond to policy.

6.4.2 Treatment of Interest Payments

Any changes in the amount of interest paid for borrowing (e.g., loans) resulting from a potential regulation should not be included in the calculation of its estimated social benefit or cost. Interest payments do not reflect the use of real resources such as labor, capital, and materials in an economy. Rather, the interest payment is a transfer between the borrower and lender and would net out of a social benefit-cost analysis. Private interest rates, in part, reflect the opportunity cost to society of any changes in the timing of consumption as a result of a regulation, but this opportunity

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38 This guidance applies both the regulated sources and any individuals and firms meaningfully affected by the behavior of the regulated sources.

39 For this same reason, using a social discount rate to model how firms and individuals evaluate private benefits and costs can lead to misspecification of the baseline over time and/or a mistaken projection of their responses to a policy.

cost is already accounted for in social discounting, as discussed above.[40] However, interest payments should be accounted for when evaluating the incidence and economic impacts of a regulation. For example, if a firm must take out a loan to comply with a regulation, the interest payment on that loan should be accounted for when estimating the effect of the regulation on the firm's profits.[41] See Chapter 9 for further discussion of how to determine the incidence of a regulation.

6.4.3 Selecting Private Discount Rates

Selecting which discount rate best represents household or firm behavior is a challenge. An appropriate discount rate may be observed from market behavior, but different households and firms borrow at different interest rates, and even within a household or firm, borrowing (and lending) occurs at different rates.[42] For example, firms may borrow at different rates depending on whether they are financing investments through debt or equity. Therefore, the choice of discount rate used to represent private behavior should be explained and, if necessary, sensitivity analyses using different rates should be considered.

6.5 Recommendations and Guidance

The following recommendations are intended as practical and plausible default assumptions rather than comprehensive and precise estimates of social discount rates that apply in all situations. In some analyses, there may be compelling reasons to gather data and develop a realistic model with precise empirical estimates for the factors most relevant to the specific circumstances. In such cases, these estimates should be presented along with the rationale in the description of the

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40 Administrative charges on a loan (e.g., origination fees) may include the cost of preparing and administering any loans. Changes in these costs, if they can be determined, should be accounted for in a benefit-cost analysis.

41 When evaluating the incidence of a regulation over time, it may also be important to recognize the annualization of any capital investment. However, when estimating net-benefits, costs should be discounted from the period they are realized and not necessarily when they are paid for by the regulated source (or other economic actor). The private amortization schedule of financed costs should not be used.

42 As discussed in the behavioral economics literature, individual behavior is not always consistent with the conventional discounting framework. For example, households may consume and save different sources of wealth differently, and therefore are applying different discount rates to those sources of wealth, even when the sources of wealth are fungible (Thaler 1990). There is also evidence that discount rates for individuals decline over time, are lower the larger the magnitude of the future value, are higher for gains than for loses and that individuals may prefer a stream of benefits that increase over time over one that is constant over time despite each having the same nominal values (Fredrick et al. 2002). Alternative behavioral frameworks have been proposed that are consistent with these observed patterns of discounting (e.g., Loewenstein and Prelec 1992; Laibson 1998). Conventional discounting should be used to represent individual, household or firm behavior in the economic analysis, although alternative discounting frameworks to represent the behavior of individuals or households may be provided in a sensitivity analysis, provided the alternative framework is well-studied in the literature in settings comparable to that of the regulation. Care should be taken when applying alternative discounting models to predict behavior, as observed behavior that at first appears inconsistent with the conventional framework may actually be consistent with the perceived inconsistency due to omitted considerations. For example, an individual's discount rate may appear to change over time due to perceived uncertainty about future outcomes being valued, even though their strict rate of time preference may not be changing (Fredrick et al. 2002).

methods and any appropriate peer review. Results based on default assumptions should also be included for comparison purposes and consistency with OMB guidance, as appropriate. With this caveat in mind, recommendations for discounting are below.

- Display the full time paths of benefits and costs as they are projected to occur over the time horizon of analysis both without discounting and appropriately discounted.
- When determining the net benefits of a regulation, the analysis should compare the discounted value of the entire time horizon of benefits and costs. It is inappropriate to characterize the effect of a regulation with only the costs or benefits for a limited period of time, e.g., a single year, when benefits and costs may occur during other periods. Similarly, it is inappropriate to compare an annual value to an annualized value.
- Calculate the present or annualized value of social benefits and costs using the consumption rate of interest. This is appropriate for situations where all costs and benefits occur as changes in consumption flows rather than changes in capital stocks (i.e., capital displacement and inducement effects are negligible). OMB (2023) recommends a real consumption rate of discount of 2% based on empirical estimates.
- To the extent that a regulation is expected to displace or induce short-term or long-term capital investment, then the shadow price of capital should be applied to the components of benefits and costs impacting this investment to convert all effects into consumption equivalents.
    - In general, there is uncertainty as to the extent to which private capital is displaced or induced by regulatory requirements. If the shadow price of capital approach is not applied explicitly or implicitly using a general equilibrium framework, then analysts should consider a sensitivity analysis consistent with OMB (2023) to understand the potential effect of capital investment changes on the discounted benefits and costs. OMB recommends considering a range of 1.0 to 1.2 as the shadow cost of capital. The sensitivity analysis should be presented separately and not part of the primary estimates of benefits, costs, or net benefits, and should be considered as a check on the robustness of the relative net benefits of the analyzed options.
- If the policy has costs or benefits that extend over a long time horizon (e.g., most benefits accrue to one generation and most costs accrue to another), then a constant consumption rate of interest may not be appropriate. The analysis should also present the net benefits under an additional approach whose rationale is clearly explained. These approaches may include:
    - Calculating the expected present value using a Monte Carlo simulation which explicitly accounts for uncertainty in the growth rate of consumption and the correlation between the growth rate and the benefits and costs.[43]
    - Calculating the expected present value of net benefits using a schedule of declining discount factors (Newell and Pizer 2003, Groom et al. 2007, Hepburn et al. 2009, OMB 2023).
- Regardless of the approach or rate selected, the same discount rate should be applied to *all* benefits and costs that occur in the same year to ensure consistency in the analysis, and

43 For example, see Newell et al. (2023).

benefits and costs should be discounted to the same year when calculating net benefits. In addition, assumptions that may influence the discount rate (e.g., the gross domestic product (GDP) growth rate) should be consistent with assumptions made elsewhere in the analysis when feasible. In cases where this is not possible (e.g., because a valuation estimate has a discounting assumption embedded in it that cannot be disentangled), the analysis should clearly explain the limitation, why it cannot be resolved, and its implications for the analysis.

When discounting future benefits and costs, the following principles should be kept in mind:

- Private discount rates should be used to predict the behavior of individuals and firms and to evaluate economic impacts and incidence, but they should not be used in place of the social discount rate to assess the social benefits and costs of a policy.
- The discount rate should reflect marginal rates of substitution between consumption in different time periods. It should not be confounded with factors such as uncertainty in benefits and costs or the value of environmental goods or other commodities in the future (i.e., the "current price" in future years).
- The economic analysis should account for the lag time between a change in regulation and the resulting welfare impacts. This includes accounting for expected changes in human health, environmental conditions, ecosystem services, and other related factors.

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