ENVIRONMENTAL ECONOMICS

Determining Benefits and Costs for Future Generations

The United States and others should consider adopting a different approach to estimating costs and benefits in light of uncertainty.

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In economic project analysis, the rate at which future benefits and costs are discounted relative to current values often determines whether a project passes the benefit-cost test. This is especially true of projects with long time horizons, such as those to reduce greenhouse gas (GHG) emissions. Whether the benefits of climate policies, which can last for centuries, outweigh the costs, many of which are borne today, is especially sensitive to the rate at which future benefits are discounted. This is also true of other policies, e.g., affecting nuclear waste disposal or the construction of long-lived infrastructure.

A declining discount rate (DDR) schedule, as used by the governments of France and the United Kingdom (*1*, *2*), means that all benefits and costs occurring in a given year are discounted at the same rate, but this rate declines over time. In contrast, the United States and other countries use discount rates that are constant over time; a lower constant discount rate is sometimes used to evaluate projects that affect future generations. We summarize the arguments in favor of using a DDR schedule and discuss the problems in using different constant discount rates to evaluate inter- and intragenerational benefits. The use of a DDR schedule would avoid these problems.

What Does the Discount Rate Represent?

There are two rationales for discounting future benefits, one consumption- and the other investment-based. The consumption rate of discount reflects the rate at which society is willing to trade consumption in the future for consumption today. Basically, we place a lower value on the consumption of future generations, because we assume that future generations will be wealthier than we are and that the utility people receive from an extra dollar of consumption declines as their level of consumption increases. To illustrate, if per capita consumption grows at 1.3% per year, in 200 years it will be more than13 times today's value. So a dollar of consumption received 200 years from now will therefore be "worth" less than it is today (*3*).

The investment approach says that, as long as the rate of return to investment is positive, we need to invest less than a dollar today to obtain a dollar of benefits in the future. Under the investment approach, the discount rate is the rate of return on investment. If there were no distortions (e.g., taxes) or inefficiencies in markets, the consumption rate of discount would equal the rate of return on investment. There are, however, many reasons why the two may differ (*4*), which is why the U.S. Office of Management and Budget (OMB) requires projects involving intragenerational benefits and costs to be evaluated twice, once by using a constant discount rate of 3% to approximate the consumption rate of discount and, separately, by using a discount rate of 7%—the real, pretax average return on private investment. For regulations with important intergenerational benefits or costs, OMB advises analysts to consider an additional lower but positive discount rate (*5*).

Using a constant discount rate for intergenerational benefits and costs that is lower than the rate used to evaluate intragenerational benefits and costs can lead to inconsistencies in decision-making. In a recent regulatory impact analysis of Corporate Average Fuel Economy standards for motor vehicles (*6*), benefits associated with reduced GHG emissions were discounted at a lower rate than fuel savings associated with the proposed standards. This resulted in benefits occurring in the same year being discounted at different rates. This is clearly inappropriate (*7*). Consistency in decision-making requires that the same discount rate must be applied to all certain benefits and costs that occur in the same year, irrespective of whether the project has intra- or intergenerational consequences. With a DDR schedule, benefits and costs in a given year are discounted at the same rate, but the rate declines over time.

PRESENT VALUE OF A CASH FLOW OF $1000 RECEIVED AFTER *T* YEARS

t	Value ($) of $1000 at a discount rate of				Certainty equivalent (%)
	1%	4%	7%	Equally likely 1% or 7% expected value	
1	990.05	960.79	932.39	961.22	3.94
10	904.84	670.32	496.59	700.71	3.13
50	606.53	135.34	30.20	318.36	1.28
100	367.88	18.32	0.91	184.40	1.02
150	223.13	2.48	0.03	111.58	1.01
200	135.34	0.34	0.00	67.67	1.01
300	49.79	0.01	0.00	24.89	1.01
400	18.32	0.00	0.00	9.16	1.01

Present value of a cash flow of $1000 received after *t* years. Expected value is the average of values from the 1% and 7% columns.

Why Might the Discount Rate Decline?

Uncertainty about future discount rates leads to a DDR schedule (*8*). This can be illustrated by a simple example. Suppose we wish to discount $1000 received *t* years from now to the present. The net present value (NPV) of $1000 = $1000*exp(–*rt*), where *r* is the discount rate. If the discount rate is 4%, the NPV of $1000 received in 100 years is $18.32 (see the table).

But future discount rates are inherently uncertain. Suppose that we think the interest rate is equally likely to be 1% or 7% in 100 years. We evaluate the NPV using its expected value (*9*), averaging the

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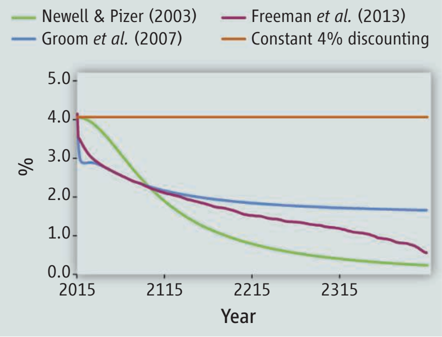
results obtained using the 1% and 7% rates [$184.40 = (367.88 + 0.91)/2]. The fact that the expected NPV of $1000—$184.40—is much larger than the NPV of $18.32 computed using the mean interest rate (mean of 1% and 7% = 4%), follows from the shape of the discounting function. As the table illustrates, uncertainty about the discount rate, combined with constant exponential discounting, will always yield a higher expected NPV than using the mean discount rate with 100% certainty. This effect is magnified as *t* increases.

Despite the uncertainty in discount rates, the relation between the expected NPV in any two adjacent years can be expressed in terms of a certainty-equivalent discount rate (the single rate, which, when applied with 100% certainty, results in the same NPV as when multiple rates are applied with less than 100% certainty). Using equally likely 1% and 7% discount rates, the expected NPV of $1000 received in year 101 is $182.53, and in year 100 is $184.40, which is $182.53 (1.0102). This 1.02% change is the certainty-equivalent discount rate used to discount benefits from year 101 to 100. As the table illustrates, the certainty-equivalent discount rate is less than the mean discount rate and declines over time, as the present values at 1% dominate the expected NPV (*10*).

The decline in the certainty-equivalent discount rate over time follows from the assumption that the discount rate is uncertain. In the more general case, in which future discount rates are uncertain and may vary from one year to the next, the change in certainty-equivalent discount rates over time depends on the joint probability distribution of the yearly discount rates. If the yearly discount rates are independent and identically distributed, then the certainty-equivalent discount rate is constant; low rates in one year, uncorrelated over time, tend to be offset by high rates in another. If there is correlation among the forecasted discount rates, there is a high chance of long periods of persistently low discount rates and an associated high present value of benefits, thus certainty-equivalent discount rates will decline over time (*11*, *12*).

Estimation and Impacts of a DDR

Future discount rates are inherently uncertain because of uncertainty in the rates of growth in consumption and return to investment. They must be predicted using a combination of empirical models and judgment. Whether future predicted discount rates are correlated is an empirical issue. Various models of per capita consumption growth for the United States (*13*, *14*) suggest that the rate of growth in consumption is stochastic and that deviations from long-term trends are positively correlated.



Estimated declining discount rate schedules. From (*11*, *16*, *17*).

Other literature has estimated certainty-equivalent discount rates based on historical time series of interest rates (*15*). Models estimated from two centuries of data on long-term, high-quality government bonds (primarily U.S. Treasury bonds) suggest correlation in uncertainty about bond yields (*11*, *16*, *17*), which implies that the certainty-equivalent discount rate declines over time. DDR schedules estimated by fitting different statistical models to these data are shown in the figure.

Does the use of a DDR make a difference? The DDR schedules shown in the figure make a considerable difference to estimates of the social cost of carbon (SCC) (i.e., the present value of damages from emitting a ton of carbon dioxide), compared with using a constant exponential discount rate. In these studies, estimates of the social cost of carbon are increased by as much as two- to threefold by using a DDR, compared with using a constant discount rate of 4%, the historic mean return on U.S. Treasury bonds. For example, if we hold the path of damages constant, the SCC in 2000 increases from $10.70 per ton of CO_2 (in 2013 U.S. dollars), using a constant discount rate of 4%, to $19.50 using the DDR in (*11*), $26.10 using (*17*), and $27.00 using the DDR in (*16*).

There are compelling arguments for using a DDR schedule. For simplicity, we have focused on uncertainty in the discount rate, but a DDR can also be obtained using an approach that looks at underlying uncertainty in consumption (*12*, *18*, *19*). Implicit in using a model based on future discount rate uncertainty is the need to update the DDR as future information is observed.

An important practical question is how a DDR schedule should be determined if it is to be used for project analysis. As the figure illustrates, estimates of the DDR vary considerably depending on the underlying statistical model. As with choosing a constant exponential discount rate, empirical estimates of a DDR using an investment- or a consumption-based approach will require human judgment about the appropriate models to use to capture uncertainty about future discount rates.

References and Notes

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