“Just Give Me a Number!” Practical Values for the Social Discount Rate*

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Abstract

A major reason the quality of cost-benefit analysis (CBA) varies widely is inconsistent use of the social discount rate (SDR). This paper provides guidance about the choice of the SDR. First, we review the theory of social discounting in both intra- and intergenerational settings and discuss alternative discounting methods. Second, we suggest observable proxy variables and provide empirical estimates of these proxies using recent and historical US data. Third, we recommend the following procedures: if the project is intragenerational (does not have impacts beyond 50 years) and there is no crowding out of private investment, then discount all flows at 3.5 percent; if the project is intragenerational and there is some crowding out of investment, then weight investment flows by the shadow price of capital of 1.1 and then discount at 3.5 percent; if the project is intergenerational and there is no crowding out of investment, then use a time-declining scale of discount rates; if the project is intergenerational and investment is crowded out, then convert investment flows during the first 50 years to consumption equivalents using a shadow price of 1.1, and then discount all of these flows at 3.5 percent, and discount all flows after the 50th year using time-declining rates. Fourth, we review current discounting practices of U.S. federal agencies and compare them to our estimates. Consistent use of the recommended rates would eliminate arbitrary choices of discount rates and would lead to better public sector decision-making.

Key Words: Social Discount Rate, Cost-Benefit Analysis, Shadow Price of Capital, Consumption Rate of Interest, Optimal Growth Rate Method, Time-Declining Discount Rates,

INTRODUCTION

What is the appropriate social discount rate (SDR), or rates, for government use? Most cost-benefit analysts simply require a theoretically sound number: "Just give me a number!" Analysts need a theoretically appropriate number more than ever because both the federal government and many state governments now mandate the use of cost-benefit analysis (CBA) for major physical and social investments, as well as for regulatory initiatives (Whisnant and Cherry, 1996; Hahn, 2000).

There is abundant evidence that the quality of governmental CBAs vary widely, and that a major reason for this variability is lack of consistency in the use of the SDR (De Alessi, 1996; GAO, 1998; Hahn et al., 2000). Many governmental CBAs employ SDRs without any well-specified rationale (Morrison, 1998; Hahn et al., 2000). Some governments, especially at the sub-state level, do not discount at all (Zerbe and Dively, 1990). This lack of consistency weakens CBA as an aid to decision making for a number of reasons. First, lack of consensus on the SDR reduces the intellectual coherence and, therefore, the emerging legitimacy of CBA (Frank and Sunstein, 2001). Second, CBA recommendations about the desirability of specific projects, programs and regulations vary depending on the choice of the SDR; projects with significant initial costs and subsequent benefit flows may yield a positive net present value (NPV) with a low discount rate, but a negative NPV with a high discount rate. Third, use of different SDRs by different agencies potentially skews assessment of projects: they may be accepted or rejected solely on the basis of which agency does the analysis.

There are two major issues to be faced in designing an appropriate SDR: the conceptual choice of the discounting parameter (or discounting method), and the specification of the value of that parameter. The latter requires both determining the best available proxy for the parameter and estimating its numerical value in intragenerational and intergenerational settings.

There is a widespread view that discounting should be done using a rate at which individuals are willing to trade present consumption for future consumption flows. Aggregate social preferences are usually inferred from the marginal return to individual savings, specifically an individual consumer/saver's after-tax return to savings. However, if the project affects investment, these flows should first be valued in terms of their consumption equivalents using a shadow price that reflects the greater social value of investment relative to consumption (the shadow price of capital, SPC). We refer to this method as the consumption rate of interest *cum* shadow price of capital (CRI-SPC) method. Specific values of the SDR based on this and closely related methods are based on individuals' behavior.

Using individuals' behavior as revealed by market interest rates to construct and estimate a SDR is problematic, however. There is convincing evidence that individuals do not behave according to the standard postulates of microeconomic theory, weakening the normative argument for basing social choices on market behavior. Further, when the effects of projects span generations, individuals may not fully take into account the effects of their spending and saving behavior on future generations. An alternative method prescribes a SDR directly using an optimal growth rate (OGR) model. This method does not rely on individual choices and so segues around these issues by prescribing the SDR based on the trend growth rate in per capita consumption. Again, investment flows can first be weighted by the shadow price of capital and then discounted at the rate derived from an OGR model. We refer to this method as the OGR-SPC method.

A separate issue arises with very long-term, intergenerational choices: market interest rates and growth rates vary over time. As such, society faces considerable uncertainty as to the SDR parameters in the future. Acknowledging this uncertainty implies that time-declining discount rates should be used; i.e., consumption flows that occur further and further in the future should be discounted at lower and lower rates.

The basic outline of this assessment of the SDR is as follows. First, we review social discounting theory and discuss alternative discounting methods. Second, we suggest observable proxies that correspond to the parameters of the major alternative methods and provide empirical estimates of the proxies using recent and historical U.S. data. Third, we summarize our recommendations concerning the appropriate discount rate (or rates under a few, well-specified circumstances). Fourth, we compare our recommendations to the discounting practices of U.S. federal agencies.

The main conclusions are summarized in Figure 1. If the project is intragenerational (does not have impacts beyond 50 years) and there is no crowding out of private investment, then analysts can simply proceed to discount at our central estimate for the SDR based on the OGR method, 3.5 percent (Box A). If the project is intragenerational and there is reason to believe that it will crowd out investment, then investment flows should be converted to consumption equivalents using a shadow price of 1.1, and then all flows should be discounted at 3.5 percent

(Box B). If the project is intergenerational (i.e., has impacts beyond 50 years) and there is no crowding out of investment, then we recommend using the following time-declining scale of discount rates: 3.5 percent from year 0 to year 50, 2.5 percent from year 50 to year 100, 1.5 percent from year 100 to year 200, 0.5 percent from year 200 to year 300, and 0 percent thereafter (Box C). If the project is intergenerational and there is reason to believe that it will crowd out investment, then investment flows during the first 50 years should be converted to consumption equivalents using a shadow price of 1.1, and then all of these flows should be discounted at 3.5 percent, and investment flows after the 50^{th} year should be discounted using the above time-declining rates (Box D).

SOCIAL DISCOUNT RATE THEORY

The key issue in determining the *real* social discount rate[1] is deciding on the weights that society should apply to costs and benefits that occur in future time periods relative to the current period. We first consider projects whose effects mainly occur within the lifetimes of those currently alive.

Intragenerational Discounting: The Consumption Rate of Interest *cum* Shadow Price of Capital (CRI-SPC) Method

It is widely accepted that society's choices should reflect the preferences of the individuals making up that society. Accordingly, the level of public investment should be based on individual preference for present consumption versus future consumption (the marginal rate of time preference), because investment is simply a means of using resources that are potentially available for consumption now in order to increase consumption later.

Individuals typically have a positive rate of time preference, i.e., they demand compensation when forgoing present for future consumption. The CRI-SPC approach posits that the SDR should equal this rate. If the future increase in net benefits is more than sufficient to compensate for the present costs, using the marginal rate at which individuals are willing to save (the consumption rate of interest, CRI), then the project passes a potential compensation test – it

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[1] Throughout we focus on the *real* SDR, but, for convenience, omit the word “real.” The flows of benefits and costs should also be expressed in real dollars. To account for risk, these flows should be converted into certainty equivalents, and then discounted using a risk-free rate (Boardman et al., 2001).

would be possible for the winners (net beneficiaries) to compensate the losers and still have sufficient gains to allow some to be made better off without making anyone else worse off.

For example, suppose that the net return available to individual savers is 2 percent per year and that a project would cost taxpayers $1 million this year and deliver a net benefit of $3.2 million in 50 years. Because forgoing current consumption of $1 million and lending at 2 percent would produce a return of approximately $2.72 million in 50 years, individuals would prefer to have the $3.2 million benefit.[2] Inevitably though, the taxpayers who fund the project and the net beneficiaries will not be exactly the same individuals. However, if we are willing to use the potential compensation criterion and ignore intragenerational redistributions, then we can plausibly suggest that this project would improve social welfare.

If individuals seek to maximize their own well being consistent with economic theory, then they will equate their marginal rate of time preference and the rate at which they can trade present for future consumption (or vice versa) in the market. In a world with no taxes or transaction costs, borrowing and lending rates would be the same. Then the CRI would also equal the marginal rate of return on private investment (ROI) and both would equal the market interest rate. But, in practice, there is a wedge between the CRI and the ROI.[3] As a consequence, even though consumers/savers may be willing to rank the future returns versus the present costs at the rate they can earn after-tax by saving, society actually forgoes the opportunity to earn an even higher return: the before-tax return to investment. In other words, from a societal perspective, resources that go into investment are worth more than those that are currently consumed.

For example, suppose that $1 million is saved and invested today, that the after-tax marginal return to savings is 2 percent, but the before-tax marginal return to private investment is 4 percent. Further, assume (for simplicity) that the entire net-of-tax return is consumed during the period in which it is generated, that the original $1 million is reinvested and that there is no depreciation. A $1 million investment thus produces private consumption of $20,000 a year and

[2] In this and all other examples, we compound or discount continuously, using the exponential function. For more details, see Boardman et al., (2001, p. 150).

[3] Boardman et al., (2001, 231-6); this wedge is largely due to capital taxes on returns to investment (such as corporate income taxes), to income taxes on the returns earned by savers, and to transactions costs. We ignore transactions costs in the examples that follow.

taxes of $20,000 a year in perpetuity. Discounting at 2 percent, the streams of private consumption and public taxes are each worth $1 million today. In this example, $1 million of investment is worth $2 million from a social perspective. Put another way, the shadow price of capital (SPC, the value of forgone investment in terms of the equivalent amount of consumption) is 2.

The accepted solution is to first weight the displaced investment by a SPC that reflects the greater opportunity costs of displaced investment, thereby converting it to consumption equivalents, and then to discount the consumption and consumption equivalent flows at the consumption rate of interest (Eckstein, 1958; Bradford, 1975; Lind, 1990; Lyon, 1990).[4]

In the above simple example, the SPC is measured as the ratio of the rate of return on investment, $\boldsymbol{i}$, to the consumption rate of interest, $\boldsymbol{c}$. We denote this version of the SPC as $\boldsymbol{s}$:

$$s = i/c \tag{1}$$

More likely, some of the project's returns are consumed and some are reinvested. Allowing for these possibilities leads to the following formula for the SPC, denoted $\boldsymbol{s'}$:

$$s' = \frac{(i + f)(1 - a)}{c - ia + f(1 - a)} \tag{2}$$

Here $\boldsymbol{i}$ is the net rate of return on capital after depreciation, $\boldsymbol{f}$ is the depreciation rate of capital, $\boldsymbol{a}$ is the fraction of the gross return that is reinvested and $\boldsymbol{c}$ is the consumption rate of interest.[5] Note that in the absence of reinvestment and depreciation (that is, if $\boldsymbol{a} = 0$ and $\boldsymbol{f} = 0$), this formula reduces to the initial expression for $\boldsymbol{s}$, equation (1).

Suppose a project yields constant perpetual annual net benefits (after year zero) that are consumed in the year they arise, and all of the costs that occur in year zero are raised from consumption, then discounting can proceed using a CRI without regard to the SPC. Alternatively, if the percentage of costs and the percentage of benefits that come from investment are the same in every period, then using the CRI-SPC will not affect whether a project has a positive present value or not, so again discounting can proceed without regard to the SPC (Lesser and Zerbe, 1994).[6]

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[4] If the project produces benefits in the form of increased investment, these should also be converted to consumption equivalents before discounting.

[5] For proof of equation (2) see Lyon (1990) or Boardman et al. (2001).

To apply the CRI-SPC method, one must first determine when and by how much investment is likely to be displaced or augmented. As a general rule, deficit financed projects in a closed economy are most likely to displace investment, as the increased demand for loanable funds raises interest rates, given the supply of savings, and crowds out private investment. Consumption is much less likely to be reduced because the balance of the evidence suggests it is not very responsive to changes in the market interest rate (Harberger, 1969; Hall, 1988; Muelbauer and Lattimore, 1995). On the other hand, tax financing is much less likely to displace investment. Taxes reduce consumers' disposable incomes and most disposable income is consumed rather than saved.[7]

How can one determine the financing source? At least up until the last couple of years, Congress and the public have usually viewed new federal expenditures as necessitating additional taxes, while reductions in expenditures have been passed on as tax reductions. Almost all state and local governments are subject to requirements that they run balanced budgets. Thus, it seems appropriate in most circumstances to assume that a project is tax financed (Havemann, 1969). Because the project's funding would therefore come almost entirely at the expense of private consumption, the analyst may proceed by discounting at the CRI without using the SPC. However, if a specific state or municipal bond issue finances a project, then obviously debt financing should be assumed. If a closed economy is assumed (no possibility of foreign borrowing), then we may assume that the initial costs of the project are raised at the expense of domestic investment, and these should be valued in consumption equivalents using the SPC before discounting at the CRI.

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[6] Let B denote the annual net benefits and K denote the initial costs. Let $\boldsymbol{c}$ be the (after-tax) consumption rate of interest, $\boldsymbol{i}$ be the (before-tax) return to investment and $\boldsymbol{s}$ be the shadow price of capital in equation (1). The NPV of this perpetual consumption flow discounted at $\boldsymbol{c}$ is $B/\boldsymbol{c}$. If all of K were at the expense of consumption, the SPC method would approve the project if $B/\boldsymbol{c} > K$. If the same fraction ($\boldsymbol{w}$) of K and B came from investment, then this method would approve the project if $(\boldsymbol{sw}B + (1\text{-}\boldsymbol{w})\ B)/\boldsymbol{c} > \boldsymbol{sw}K + (1\text{-}\boldsymbol{w})\ K$; i.e. if $(\boldsymbol{sw} + 1 - \boldsymbol{w})\ B/\boldsymbol{c} > K\ (\boldsymbol{sw} + 1 - \boldsymbol{w})$, or simplifying if $B/\boldsymbol{c} > K$.

[7] Dynan et al. (2000) find that marginal propensities to save out of disposable income vary between 2.4 and 11 percent in the US. Souleles (2002) finds that the Reagan tax cuts of the 1980s had very strong effects on current consumption when enacted (rather than when announced), inducing marginal propensities to consume out of nondurables of between 0.6 and 0.9. Even predictable tax refunds are largely spent when received (Souleles, 1999), indicating that consumption is very responsive to the actual, rather than the predictable, permanent level of income, contrary to standard economic theory.

Even if there is deficit financing, in an open economy the government can borrow from abroad at the market interest rate. Increased borrowing may raise interest rates, but this in turn appreciates the exchange rate (under a flexible exchange rate regime) and thus crowds out net exports as well as investment. If the supply of loanable funds from abroad is very responsive to the interest rate, then very little domestic investment is crowded out (Lind, 1990). Unfortunately, there is very little evidence on how responsive the supply of foreign funds is to the interest rate. For a small project, the analyst can reasonably assume that the effect on interest rates, the exchange rate and the trade deficit is quite small, and hence discounting in an open economy can proceed at the CRI without using the SPC (U.S. Environmental Protection Agency, 2000, 43-46).

In summary, if a project is strictly tax-financed, if supply of foreign funds is extremely responsive to the interest rate or the project is quite small, or if the percentage of costs and benefits that comes from investment is the same in every period, then the analyst may simply discount at the CRI. If the project is deficit financed, and the supply of savings and of foreign funds are both assumed to be very unresponsive to the interest rate, then the displaced (or augmented) investment flows should be converted to their consumption equivalents using a SPC before discounting at the CRI.

Alternative Intragenerational Discounting Methods: Discounting at the ROI or the Weighted Social Opportunity Cost (WSOC) Method

Many analysts argue for discounting all flows of costs and benefits at the before-tax marginal return on investment (ROI) (Harberger, 1969; Lind, 1995, 1997; Manne, 1995; Schelling, 1995; Nordhaus, 1997, 1999). The basic motivation is that the opportunity cost of doing a public project is the forgone return on the marginal private project. Note that if all the resources for the project displace private investment and the SPC can be calculated using (1), then the CRI-SPC method gives an identical result to discounting at the ROI.[8] However, as discussed above, typically some (if not all) costs will displace consumption; thus, this method is generally invalid.

Another generally invalid method based on market rates is to construct the social discount rate as a weighted average of the CRI and the ROI. This method is known as the

[8] Consider the example in footnote 6 again. If all of K were at the expense of investment, the CRI-SPC method would approve the project if $B/\boldsymbol{c} > \boldsymbol{s}\, K = (\boldsymbol{i}/\boldsymbol{c})\, K$, or, equivalently, if $B/\boldsymbol{i} > K$. This is equivalent to discounting at the ROI.

weighted social opportunity cost (WSOC) method.[9] However, it will not give the same NPV as using the CRI-SPC method. To see this, return to the example above of the project that costs $1 million this year and delivers a single net benefit of $3.2 million in 50 years. The after-tax return to savings is 2 percent, but the before-tax marginal return to private investment is 4 percent. Assuming no depreciation or reinvestment of earnings, the SPC is 2. Further, assume that 17 percent of the initial funding comes at the expense of investment, and 83 percent at the expense of consumption, and that the net benefit is all in the form of increased consumption. Using the CRI-SPC method, we first take 17 percent of the $1 million and multiply by 2 to get a consumption equivalent of $340,000, which is added to the $830,000 that comes from current consumption, giving a present cost in consumption units of $1.17 million. We then calculate the present value of $3.2 million of consumption in 50 years using the consumption rate of interest of 2 percent as $1,177,200 (rounded), giving an approximate NPV to the project of $7,200 and leading to project acceptance.

Using the WSOC method, we construct a discount rate as the weighted average of 2 percent and 4 percent, where the weights are the percentages of the initial cost that displace consumption and investment: 0.83∗2 percent + 0.17∗4 percent = 2.34 percent. We then use this discount rate to find the present value of $3.2 million in 50 years, and subtract the $1 million cost today. The NPV thus calculated is –$6,825, which would lead to rejection of the project.

Discounting Using the Optimal Growth Rate (OGR) Method

The OGR method rejects the notion that social choices should reflect individual preferences as inferred from market interest rates. One reason for rejection is that capital markets are not perfect and individual consumers do not behave as assumed by the standard economic model of intertemporal choice. There are four strands of evidence to support these assertions. First, not only do borrowing and lending rates differ due to taxes and transactions costs, but some individuals are screened out of legitimate credit markets altogether due to informational asymmetries**.** Hence, individuals differ in both their rates of time preference and in their

[9] This approach, which assumes that all funds come from borrowing, also allows for borrowing from abroad at the government bond rate, and includes that rate in the weighted average. For example, see Jenkins (1977; 1981).

opportunities: while some are saving at low rates, others are borrowing at higher rates, and still others are borrowing from loan sharks.

Second, many individuals simultaneously borrow and lend: they pay down mortgages, buy government and corporate bonds and stocks for retirement, and even borrow on their credit cards (Lind, 1990). Given such behavior, it is unreasonable to assume that individual savers/consumers are equating their marginal rates of time preference with a single market interest rate.[10]

Third, individual preferences do not appear to be time consistent. For example, individual rates of time preference and implied discount rates appear to decline over the horizon to which they are applied (Cropper et al, 1992; Loewenstein and Prelec, 1992; Laibson, 1997), implying that choices made at one point in time may be overturned later even if no new information becomes available, a phenomenon known as time inconsistency. This is problematic, as projects that appear socially valuable at one point in time may suddenly appear to be a mistake, even though nothing has changed except the passage of time.

Fourth, there is a strand of evidence demonstrating that the framing of intertemporal choice affects individuals' implicit rates of time preference. Thus, individuals use different rates to discount large versus small amounts, losses versus gains (loss aversion), choices involving the near future as against choices further out in time, and choices between speeding-up versus delaying consumption (Loewenstein and Prelec, 1992). Depending on the choice being made, and the individual making it, one can infer CRIs anywhere from 0 to 30 percent (Warner and Pleeter, 2001).

These four strands of behavioral evidence severely weaken the case for deriving a CRI from observations on individual intertemporal choices in markets. A second reason for rejecting the CRI-SPC approach is that while there may be markets in which one can trade private consumption over time, there are no markets on which one can trade public goods over time. So market interest rates tell us little about individual preferences for the time-distribution of public goods.[11]

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[10] Laibson (1997) argues that individuals may have pre-committed themselves to saving a certain amount of their income in an illiquid asset, while borrowing for current consumption from ready sources of credit. However, they are still not equating their marginal rates of time preference to a single market rate.

[11] We thank Doug MacArthur for this point.

Even if individual behavior does not indicate consistent, well-behaved intertemporal choices over public and private goods subject to resource constraints, society may wish to make its public investments as though it does. The OGR method assumes that policy makers use a well-behaved social welfare function, which describes the values society places on different amounts of per-capita consumption, both public and private, over time. Policy maker chooses the amount of public investment in order to maximize the well being of society now and in the future. Society discounts the future for two possible reasons – one is that it simply prefers to consume more now; the other is that it will be richer in the future and wants to reduce inequality in consumption flows over time. Using this OGR method, the social discount rate, denoted $\boldsymbol{o}$, is the sum of two elements (Ramsey, 1928):

$$\boldsymbol{o} = \boldsymbol{d} + \boldsymbol{ge} \tag{3}$$

The first term, $\boldsymbol{d}$**,** the utility discount rate, measures the rate at which society discounts the well-being or utility of its future per capita consumption. It reflects purely a preference for well being in the present over the future, regardless of economic growth ("impatience"). The second term reflects consumption discounting – a preference for more equality in per capita consumption over time than would otherwise occur. It is the product of two parameters: the growth rate of per capita consumption, $\boldsymbol{g}$, and the absolute value of the rate at which the marginal value of that consumption decreases as per capita consumption increases, $\boldsymbol{e}$.[12]

Note that if $\boldsymbol{o}$ is less than the private, marginal return on investment, society is under-investing relative to the socially best outcome. If a public investment produces a one-period, real return greater than $\boldsymbol{o}$, then society should make this investment because it improves social welfare adopting the value judgments used in calculating $\boldsymbol{o}$. However, if the ROI of an

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[12] This second parameter, the absolute value of the elasticity of the social marginal utility of consumption with respect to per capita consumption, varies between zero and infinity. Setting the parameter equal to zero implies no discounting of future consumption: society treats each unit of consumption received in the future as identical to a unit of consumption in the present, signifying a complete lack of concern for intergenerational inequality. As it approaches infinity, society completely discounts each unit of consumption received in the (richer) future, signifying an overwhelming desire to equalize per capita consumption over time. When it equals one, the relative weight on society's consumption in each time period equals the inverse of its relative per-capita consumption. Thus, a 10 percent reduction in consumption today, for example from $40,000 to $36,000, is an acceptable trade-off for a 10 percent increase in consumption at a richer, future time, for example from $80,000 to $88,000. Society weighs the loss of $1of consumption today as twice as important as a gain of $1 to its future self, because the future society is initially twice as rich.

alternative private sector project exceeds the return on the public project, then the private project would increase social welfare even more. So, as in the CRI-SPC method, investment flows should be converted to consumption equivalents by the shadow price of capital (replacing ***c*** in equation (1) or (2) with ***o***) before discounting at ***o***. We label this variant the OGR-SPC method.

A third reason for rejecting the CRI-SPC method is that market interest rates only reflect the preferences of individuals currently alive. This is especially problematic when a project's effects span generations. Many critics of CRI-SPC argue that members of the current generation fail to account appropriately for the effects of long-term projects on the welfare of future generations (Ramsey, 1928; Eckstein, 1958; Phelps, 1961; Marglin, 1963; Arrow et al., 1995; Dasgupta et al, 1999). So the OGR method may be recommended when a project's effects are likely to be intergenerational. However, very long-term investments also raise other concerns to which we now turn.

Intergenerational Discounting Using Time-Declining Discount Rates

There is no obvious way to decide when a project is intragenerational or intergenerational. In many circumstances, those as yet unborn when a project is initiated will live to be affected by it, whether as beneficiaries or taxpayers or both. Those alive bear some of the startup costs, but may not live to reap the benefits. Nonetheless, as we discuss below, both the serious ethical dilemmas and the practical differences that occur when considering long-term projects do not begin before a span of about 50 years. For our purposes, we will define intragenerational projects as those whose main effects are contained within a 50-year horizon.[13] Projects with significant effects beyond 50 years are considered intergenerational.

Intergenerational issues often pertain to projects with environmental impacts, including efforts to mitigate global warming by greenhouse gas (GHG) abatement, preserving biodiversity through the protection of unique ecosystems, and the storage of radioactive waste. Discounting at a constant discount rate can pose an ethical dilemma – the use of constant discount rates much

[13] One rationale for this 50-year cutoff is that most equipment, structures and buildings will not last much longer than 50 years. Depreciation rates appear to range between 3.4 and 13.3 percent per year, implying that between 80 percent and virtually everything has depreciated after 50 years (Hulten and Wykoff, 1981; Nadiri and Prucha, 1996). Thus, there are likely to be few public investments that are intergenerational in our sense. Another argument is that 50 years corresponds approximately to two generations – our generation and our children's – and that events beyond this time period truly belong to future generations. A third rationale is provided by Newell and Pizer (2001), which we discuss later.

in excess of 1 percent implies that it is not efficient for society to spend even a small amount today in order to avert a very costly environmental disaster, provided that the disaster occurs sufficiently far into the future. For example, if GHG build up imposes a net cost of $1 trillion in 400 years time (approximately 1/10th of current U.S. GDP), this has an NPV of less than $336 million today at a discount rate of 2 percent, and an NPV of less than $113,000 at a rate of 4 percent. CBA using a discount rate of more than 2 percent would result in the conclusion that we should do little GHG abatement today, even if the future effects on the climate are catastrophic (Portney and Weyant, 1999).

The standard compensation logic behind CBA fails when impacts are intergenerational. For example, the argument for discounting using the ROI is that the alternative to a particular public project is to invest in a marginal private sector project. If the public project yields a lower rate of return than the private project, then the future potential beneficiaries of the public project would be better off if society invested in the private project and gave them these proceeds instead. However, if those who are hurt are alive 400 years in the future, there is no plausible mechanism to "give them the cash instead." Even if the current generation set up a fund to compensate those who bear the costs of not reducing global warming, there are no viable 400-year investments, and intervening generations may rob the fund.

Using the OGR method permits an explicit consideration of the welfare of future generations. However, the most common social welfare function used with this method treats society as a single, representative individual (whose well being is equal to the discounted sum of the utility derived from present and future per capita consumption). This may make sense for evaluating 50-year investments. But it loses much of its relevance for evaluating 400-year or 10,000-year investments, such as for GHG abatement or the storage of radioactive waste.

There have been a variety of responses to the issue of intergenerational equity arising from very long-term environmental projects. Some argue that the costs and benefits of all projects should be discounted using a constant discount rate, based on the ROI, even when they occur far in the future (Lind, 1995, 1997; Manne, 1995; Nordhaus, 1997). Others suggest treating intergenerational equity issues directly, rather than adjusting the SDR (Lesser and Zerbe, 1995; Schelling, 1995), or discuss reformulating the social welfare function so that each generation puts some weight on its own utility and a (discounted) weight on the utility of future generations, but treats all future generations alike (Heal, 1997; Arrow, 1999). Page (1997) puts forward a somewhat similar ethical goal: that the resource base of the planet, broadly defined, be kept intact over time, thus treating each future generation the same. CBA can then be used to choose the means of achieving this goal and also to make shorter-term decisions within this overall ethical framework.

Notwithstanding these ethical considerations, there is one practical difference between intra- and intergenerational discounting that matters a great deal. The inherent uncertainty as to the future growth rate of the economy, the return on investment, and the CRI all increase, the further we look into the future. More formally, the confidence interval surrounding any forecast widens with the length of the forecast. Furthermore, allowing for this uncertainty means that lower and lower discount rates should be used to discount consumption flows that occur further and further in the future (Weitzman, 2001; Newell and Pizer, 2001).

To see why discount rates decline as they apply to flows that occur further out in time, consider the following example. Suppose a project delivers a single benefit of $1 billion in 400 years. Suppose further that there is a 50 percent chance that the appropriate (constant) discount rate over this period will be 7 percent and a 50 percent chance that it will be 1 percent. One might imagine that we should average these two rates to obtain the expected discount rate, 4 percent, and then use this averaged rate to compute the expected NPV of the future benefit as $1 billion $* e^{-(0.04)*400}$, which is approximately $110. However, this is incorrect. The discount factors of $e^{-(0.07)*400}$ and $e^{-(0.01)*400}$ should be averaged, yielding an expected NPV equal to $1 billion $* [(0.5 e^{-(0.07)*400}) + (0.5 e^{-(0.01)*400})]$, which is approximately $9,157,800. This is equivalent to using a single, certain discount rate of approximately 1.17 percent. In effect, the larger discount rate almost completely discounts itself out of the average. This effect grows over longer and longer time horizons, resulting in a time-declining schedule of discount rates. In the distant future, only the very lowest possible rate matters; all the higher rates result in discount factors that approach zero. Note that this motivation for time-declining rates is due solely to uncertainty and so does not imply time inconsistency in social choices (Azfar, 1999; Newell and Pizer, 2001, 10).

To see how time-declining rates would be used, consider the following schedule: 3.5 percent for years 0 to 50; 2.5 percent for years 50 to 100; 1.5 percent for years 100 to 200; 0.5 percent for years 200 to 300; and 0 percent thereafter. Thus if a project has a single benefit of $1 billion delivered in year 400, and an initial cost of $1 million today, the NPV would be –$1 million + \$1 billion ∗ [($e^{-(0.035) * 50}$) ∗ ($e^{-(0.025) * (100-50)}$) ∗ ($e^{-(0.015) * (200-100)}$) ∗ ($e^{-(0.005) * (300-200)}$) ∗ ($e^{-(0) * (400-300)}$)], which is approximately \$5,737,00. Note that we discount at 0 percent from year 400 to 300; then we discount the year 300 value back to year 200 at 0.5 percent, take the resulting value in year 200 and discount it back to year 100 at 1.5 percent, and so on. In this example, this is equivalent to applying a single, constant rate of approximately 1.25 percent from year 400 to the present.

This method allows the effects on far future generations to be given more weight than alternative methods. After a given period of time, all future generations are essentially treated alike. As only the lowest possible rates apply to the far distant future, the choice of the specific rate for discounting intragenerational projects turns out not to matter very much for the evaluation of very long-term, intergenerational projects (Newell and Pizer, 2001).

SOCIAL DISCOUNT RATE PROXIES AND ESTIMATES

For each of the three major discounting methods, the consumption rate of interest *cum* shadow price of capital method, the optimal growth rate method, and the time-declining discount rate method, we first identify a reasonable proxy or set of proxies that correspond to the parameters in question, and then we provide historical or recent estimates for these proxies. In principle, one should use the expected future values for each future period in the analysis. As we do not know what these are, we will use our best estimate based on recent data for intragenerational discounting. For long-term projects with intergenerational discounting, we explicitly account for uncertainty about future rates.

Estimating the Consumption Rate of Interest (CRI)

The most widely used proxy for the rate that consumer/savers can earn by postponing present for future consumption is the real, after-tax return on savings. This provides a potential way to estimate the CRI. For this and other market-based measures, one must grapple with three issues: What is the most appropriate asset for which to compute a nominal yield? How should expected inflation be measured?[14] Over what time period should the expected, real yield be estimated?

[14] With a nominal interest rate $\boldsymbol{n}$ and an expected inflation rate of $\boldsymbol{m}$ during the year, \$(1+$\boldsymbol{n}$) one year from now is expected to buy only as much as \$(1+$\boldsymbol{n}$)/(1+$\boldsymbol{m}$) does today. The expected, real interest rate, $\boldsymbol{r}$, is

For the CRI measure, one also requires an estimate of the effective, marginal tax rate paid on the nominal return on savings.

There are two arguments suggesting that the CRI should be measured by the return on a riskless asset. The first argument is that the government can effectively reduce the non-systematic risk that individual citizens bear to zero by pooling risks across the entire population (Arrow and Lind, 1970).[15] The second argument is that it is appropriate to separate the issues of risk and discounting by converting net benefit flows to certainty equivalents prior to discounting at a risk-free rate (Boardman et al., 2001). An obvious candidate for the CRI is the return to holding government bonds, the class of assets considered to have the lowest risk.

We consider two possible candidates for the CRI proxy: the average monthly yield on one-year US government Treasury notes, and that on 10-year Treasury bonds. Historical monthly series on these are available from 1953 through 2002.[16] The return on long bonds generally exceeds that on the one-year notes. One-year notes are better matched to available measures of expected inflation, but long-term bonds may give a better idea of the rates at which consumer/savers are willing to postpone consumption for future net benefits.

The nominal, pre-tax average monthly yields on bonds must be converted to real, after-tax rates by adjusting for taxes and inflation. In practice, it is difficult to know exactly what effective tax rate faces the marginal saver. Shoven and Topper (1992) argue that the personal tax rate on savings in the U.S. is 30 percent, which we use in our calculations.[17]

To measure the rate of inflation that consumer/savers expected while holding these assets, we use the implicit forecasts for one-year ahead inflation in the Livingston survey, available bi-annually from 1947 through 2002 (Croushore, 1997; Thomas, 1999).[18] We assume

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therefore defined by $(1+\boldsymbol{r}) = (1+\boldsymbol{n})/(1+\boldsymbol{m})$. Rearranging, this converts a nominal interest rate, $\boldsymbol{n}$, to an expected, real interest rate, $\boldsymbol{r}$, when the expected inflation rate is $\boldsymbol{m}$: $\boldsymbol{r} = \frac{\boldsymbol{n} - \boldsymbol{m}}{\boldsymbol{1} + \boldsymbol{m}}$.

[15] Grant and Quiggin (2003) argue that if the equity risk premium results from information asymmetries in insurance and credit markets governments should use its risk-free rate when evaluating investments.

[16] Unless otherwise cited, all data are from the DRI Basic Economics macroeconomic database, formerly known as CITIBASE, viewed June 20, 2003.

[17] As high-income individuals do most of the personal saving, their rates are likely the most appropriate.

[18] These data are available at the Federal Reserve Bank of Philadelphia's website: www.phil.frb.org/econ/liv/index.html. We use the average forecast for each June and December.

that forecasters had the March and October CPI numbers available while making their June and December forecasts, respectively, and we use these and their CPI forecasts for the following June and December to calculate implicit one-year ahead inflation forecasts. We also use the explicit ten-year ahead inflation forecasts available in the bi-annual survey from June 1991.

We match the monthly yields on one-year and ten-year Treasuries (for each June and December from 1953 to 2002) to the implicit one-year ahead inflation forecasts, and we match the June and December returns on ten-year Treasuries with the explicit ten-year ahead inflation forecasts from 1991 to 2002. Using an effective marginal tax rate of 30 percent, we calculate three sets of bi-annual estimates (for June and December) of the real, after-tax return to savings, our proxy for the CRI – one for the one-year notes, one for the ten-year bonds using the one-year ahead inflation forecasts, and one for the ten-year bonds using the ten-year ahead inflation forecasts.

The historical series for ten-year Treasuries, using the one-year ahead forecasts for inflation, results in real, expected after-tax savings rates that typically fluctuate between 1 and 2 percent, although there were periods (when inflation was poorly forecast as it rose in the 1970s and fell in the 1980s) during which these rates actually became negative (the 1970s) and then rose dramatically to over 4 percent (the early 1980s). The average rate for the period 1953 through 2002 is 1.3 percent with a standard deviation of 1.15 percent. The series for one-year Treasuries exhibits a similar pattern, with real, after-tax returns about 50 basis points lower. The most recent five-year, moving averages for these two series are 1.3 percent and 0.6 percent, respectively. Using ten-year bonds and the explicit, ten-year ahead inflation forecasts for the period 1991 through 2002, we find that real, after-tax returns averaged 1.2 percent, with a standard deviation of 45 basis points and a range between 0.26 and 2 percent. The most recent five-year, moving average is 1.1 percent.

These estimates of the CRI are not that far apart. The real, after-tax returns to ten-year Treasury bonds, which employ recent, explicit ten-year ahead inflation forecasts, probably provide the best estimate. Given this estimate, tempered with the longer-term historical results, we recommend currently estimating the CRI at 1.5 percent, with sensitivity analysis at 1 percent and 2 percent (approximately plus or minus one standard deviation, given the most recent measures of volatility).

Estimating the Shadow Price of Capital (SPC)

Estimating the SPC from equation (2) requires a measure of the marginal, pre-tax return to private investment, the depreciation rate of capital, and of the fraction of the gross return on capital that is reinvested. The ROI is probably best proxied by the real, before-tax rate on corporate bonds. There are four reasons for using a bond rate rather than a measure of the average return on equities. The first is that doing so avoids the problem of having to estimate the effective marginal corporate tax rate. Because a firm can deduct the interest it pays to its bondholders before calculating its taxable income, it will equate (on the margin) its expected before-tax return on an investment with the before-tax rate it must pay on its bonds. So the bond yield is a good direct proxy for the ROI. Second, analysts seek a measure of the marginal pre-tax return on private investment. Using a measure based on average returns to equities would lead to too high a rate, as the marginal investment yield is lower than the average. In the bond market, the interest rate represents the marginal borrower's willingness to pay, and this should proxy the return on the marginal investment. Third, bond yields are available contemporaneously, while the average return to equity must be calculated by looking back over a historical period (and will vary greatly according to the period chosen). Finally, returns to equity investments contain a premium for bearing the extra risk of holding equities, typically measured as the difference between the observed, *ex post* real return to a diversified equity portfolio and the return to a (default-risk free) government bond. Historical studies using U.S. data over the last century find this risk premium to be in the neighborhood of 6 to 7 percent (Mehra and Prescott, 1985). However, most researchers consider this to be too high to be compatible with the standard economic model of risk bearing, a result known as the equity premium puzzle (Kocherlakota, 1996).

We consider two possible candidates for the ROI proxy: the monthly average of the real yields on Moody's AAA-rated corporate bonds and the real, average monthly yield on all Moody's rated corporate bonds. The latter series, weighted by outstanding debt, contains some bonds with default risk ratings below AAA. Historical monthly series on these are available from 1947 through 2002. As for the CRI, we match the monthly nominal bond yields for each June and December from 1947 to 2002 to the implicit one-year ahead inflation forecasts from the Livingston survey. We also match the June and December returns with the explicit ten-year ahead inflation forecasts from 1991 to 2002.

The expected, real yield on Moody's AAA bonds using the one-year ahead inflation forecasts fluctuated between 3 and 4 percent for much of the post-war period, with a similar pattern in the Treasuries' series: a sharp decline during the 1970s as inflation rose unexpectedly, followed by a very large increase as disinflation occurred in the early 1980s. Since then it has varied between 4 and 5 percent. The average for 1947-2002 is 3.9 percent with a standard deviation of 1.7 percent. The series for all-rated corporate bonds exhibits a similar pattern, with real returns about 40 basis points higher than the AAA bonds. The most recent five-year, moving averages for these two series are 4.5 and 4.9 percent, respectively. Using the explicit, ten-year ahead inflation forecasts for 1991-2002, the real pre-tax returns averaged 4.15 percent for the AAA bonds, with a standard deviation of 47 basis points and a range between 3.2 and 4.9 percent. For all corporate bonds, the corresponding estimates are similar but again about 40 basis points higher. The most recent five-year, moving averages are 4.24 and 4.72 for the two series, respectively. There are only small differences among these estimates. On balance, we prefer the most recent evidence based on a weighted average of all Moody's rated corporate bonds, thus estimating the current ROI at 4.5 percent, with sensitivity analysis at 4 percent and 5 percent (approximately plus or minus one standard deviation, given the most recent measures of volatility).[19]

To obtain a value for ***f***, the depreciation rate of capital, we rely on Hulten and Wykoff (1981) who found that the annual depreciation rate for manufacturing equipment was 13.3 percent and for structures used in manufacturing was 3.4 percent. Weighting these rates by the relative proportions of equipment (67 percent) and structures (33 percent) in the U.S. capital stock (figures that are available from the *United States Statistical Abstracts*) gives an average annual depreciation rate of $[0.67 * 0.133 + 0.33 * 0.034] = 10$ percent.

The gross investment rate (the ratio of real gross fixed investment to real GDP) provides a rough estimate of ***a***, the fraction of the gross return that is reinvested. It averages 13 percent for 1947-2002, based on quarterly real GDP data with a range between 10.6 and 18.5 percent and a standard deviation of 1.8. Over the last economic cycle (roughly 1991-2001) the gross

[19] Nordhaus (1999) argues that the post-tax rate of return on private investments must be at least 6 percent. Using a corporate tax rate of 38 percent this implies a pre-tax return of $[0.06/(1 – 0.38)] = 9.67$ percent (Shoven and Topper, 1992). Cline’s (1992) survey suggests a central estimate of 7 percent for the ROI. Many contributors in Portney and Weyant (1999) argue that a rate between 5 percent and 8 percent is appropriate. Our central estimate is below the lower bound of these estimates, because we prefer a measure from the bond market rather than an average return to holding equities, for the above reasons.

investment rate averaged 15.5 percent, while the most recent five-year average was 17.6 percent. The ratio peaked in the second quarter of 2000, but still remains above the long run historical average (16.7 percent in 2002). This suggests that an average rate of approximately 17 percent is likely in the future, and we choose it as our central estimate.

We can now estimate the SPC using equation (2). Our central estimates of the CRI, $\boldsymbol{c}$ = 1.5 percent; the ROI, $\boldsymbol{i}$ = 4.5 percent; depreciation, $\boldsymbol{f}$ = 10 percent; and the reinvestment rate, $\boldsymbol{a}$ = 17 percent yield a measure of the SPC, $\boldsymbol{s'}$ of 1.33, implying that one dollar of private sector investment would produce a stream of consumption benefits with a NPV equal to $1.33. Using equation (1) our estimate of the SPC would be $\boldsymbol{s}$ = 3.

Sensitivity analysis with respect to $\boldsymbol{c}$ yields estimates of $\boldsymbol{s'}$ equal to 1.41 with $\boldsymbol{c}$ = 1 percent and 1.26 with $\boldsymbol{c}$ = 2 percent. A low value of $\boldsymbol{c}$ implies a high value of $\boldsymbol{s'}$ and vice versa. Estimates of $\boldsymbol{s'}$ range from1.27 with $\boldsymbol{i}$ = 4 percent and to 1.39 with $\boldsymbol{i}$ = 5 percent (holding $\boldsymbol{c}$ = 1.5 percent). Because $\boldsymbol{c}$ and $\boldsymbol{i}$ are likely to be strongly, positively correlated,[20] we recommend $\boldsymbol{s'}$ = 1.33 as a central estimate, and performing sensitivity analysis at 1.32 and 1.35, based on varying $\boldsymbol{c}$ between 2 and 1 percent (and simultaneously varying $\boldsymbol{i}$ between 5 and 4 percent).

Estimating the Social Discount Rate (SDR) Based on the Optimal Growth Rate (OGR) Model

To estimate the SDR using an OGR model, we need estimates of the elasticity of the social marginal utility of consumption with respect to per capita consumption, $\boldsymbol{e}$, the utility discount rate, $\boldsymbol{d}$, and the growth rate in per capita consumption, $\boldsymbol{g}$.

One way to estimate $\boldsymbol{g}$ is to regress the natural logarithm of real per capita aggregate consumption on time and use the slope coefficient. Using annualized per capita quarterly data on real consumption expenditures for1947-2002, we estimate the average growth rate of consumption per head in the U.S. was 2.3 percent per annum with a standard error of 0.025 percent.[21] It is difficult to predict the future long run growth rate especially as recent historical growth rates have varied substantially. Given this, we recommend using $\boldsymbol{g}$ = 2.3 percent, with sensitivity analysis at 2 and 2.5 percent.

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[20] The simple correlation coefficient between these two measures is 0.77.

[21] Comparably, Prescott (2002, p. 5) argues for a real growth rate of 2 percent as this is the secular growth rate of the U.S. economy in the 20th Century.

Brent (1994) suggests that ***e*** should be between 0 and 1, with 0.5 as a benchmark. Arrow et al. (1995) argue that individuals reveal their own ***e***'s by their risk taking and intertemporal choice behavior; they suggest that individual elasticities of marginal utility of consumption lie between 1 and 2. Thus, the recently proposed values for ***e*** vary between zero and two, with ***e*** = 1 a reasonable compromise. We recommend setting ***e*** = 1, with sensitivity analysis at 0.5 and 1.5.

There has been considerable debate about the value of ***d*** since Ramsey (1928). He argues that it is ethically indefensible to use a positive value, as this would discount future generations' well being relative to the present one's. However, Arrow (1995) shows that weighting all generations' welfare equally results in very high rates of savings being required of the current (or even of every) generation. He demonstrates that, under reasonable parameter values, the current generation could be required to save approximately two-thirds of its income! To avoid this result, a positive pure rate of time preference should be employed. Arrow suggests a figure of around 1 percent for ***d***, which we use in our calculations below.

With an estimate of ***g*** = 2.3 percent, ***e*** = 1, and ***d*** = 1 percent, we obtain ***o*** = 3.3 percent, or rounding, 3.5 percent. Sensitivity analysis with ***e*** ranging between 0.5 and 1.5 and with ***g*** varying between 2 and 2.5 percent implies ***o*** ranges from 2 percent to 4.75 percent, or rounding, between 2 percent and 5 percent. Thus, we recommend using a central estimate of ***o*** equal to 3.5 percent with sensitivity analysis at 2.5 percent and 4.5 percent.[22]

The OGR-SPC method weights investment flows at the SPC, but replaces ***c*** with ***o*** in equation (2), and discounts the resulting consumption equivalents and consumption flows at ***o***. Using ***o*** = 3.5 percent with our central estimates for the marginal return on investment, ***i*** = 4.5 percent, for the depreciation rate of capital, ***f*** = 10 percent, and for the fraction of the gross return on capital that is reinvested, ***a*** = 17 percent, yields a measure of ***s′*** = 1.09, which we round to 1.1.[23] Sensitivity analysis yields estimates of ***s′*** that vary from 1 (***o*** = ***i*** = 4.5 percent) to 1.25

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[22] Kula (1984) estimates the average annual growth rate in U.S. per capita consumption between 1946 and 1975 as 2.3 percent. He treats ***e*** as representing the preferences of average individuals, and estimates it from an aggregate demand equation for food, arriving at 1.89. He views ***d*** as representing an average individual's expected annual mortality rate. He assumes this equals the average death rate in the population as a whole, which he estimates is 0.9 percent per year. Therefore, he estimates ***o*** = (0.023)(1.89) + 0.009 = 5.2 percent. Cline (1992), assuming the likely future world growth rate is 1 percent, ***d*** = 0 and ***e*** = 1.5, estimates ***o*** = 1.5 percent.

[23] Cline (1992) proposes using a value of ***s′*** equal to 1.56 and then discounting using ***o*** measured at 1.5 percent for all CBAs, including GHG abatement projects. His estimate of ***s′*** uses ***i*** = 8 percent, assumes

(***o*** = 2.5 percent, ***i*** = 5 percent). Again, since ***o*** and ***i*** are likely to be highly correlated, we recommend using the central estimates of ***o*** = 3.5 percent and ***s′*** = 1.1, with sensitivity analysis at ***o*** = 2.5 percent (and ***i*** = 4 percent) and ***s′*** = 1.15, and at ***o*** = 4.5 percent (and ***i*** = 5 percent) and ***s′*** = 1.04 or, rounding, 1.05.

Estimating the SDR for Intergenerational Discounting[24]

Regardless of whether analysts believe they should use the CRI-SPC, the OGR method or the OGR-SPC variant, they face a problem: the parameter values in 50, 100 or 300 years are unknown. As argued above, allowing for this uncertainty means that lower rates should be used to discount consumption flows that occur further in the future.

Weitzman (2001) uses this rationale to derive a scale of time-declining SDRs. He surveyed almost 2,200 economists, asked each to provide a single, real rate to use in discounting the costs and benefits of global climate change, and found that the frequency distribution of the respondents' rates approximated a gamma distribution. His main finding is that even if every respondent believes in a constant discount rate, the wide spread of opinion results in the SDR declining significantly over time. Based on the distribution of his respondents' preferred discount rates, Weitzman suggests a scale for SDRs that approach zero after 200 years.

Newell and Pizer (2001) follow a different approach based on the historical behavior of interest rates. Their model captures the uncertainty in forecasting the rates that will prevail in the far future. They examine the U.S. government's real, long-term bond rate over the past 200 years and find the data do not clearly distinguish between a random-walk and a mean-reversion model. They prefer the random-walk version and use it to simulate the future path of the bond rate, from both a 4 percent and a 2 percent initial value. They generate thousands of different time paths and use these to construct expected discount factors. This results in a time-declining scale of effective discount rates, which we think is superior to the Weitzman method.

For practical purposes, it is useful to provide a single rate over a reasonably long time period. Based on Newell and Pizer's rate schedule that starts at 4 percent, we suggest the following blocks: 3.5 percent from year 0 to year 50; 2.5 percent from year 50 to year 100; 1.5 percent from year 100 to year 200; 0.5 percent from year 200 to year 300; 0 percent thereafter.

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that all investments have 15-year lives, and that ***a*** = 0.2.

[24] We would like to thank an anonymous referee for providing significant guidance in this section.

These rates are generally higher Weitzman's rates and fall more slowly, with the declining rate kicking-in after about 50 years. For a single benefit in year 300, this is equivalent to applying a single, constant rate of 1.67 percent.

RECOMMENDED SOCIAL DISCOUNT RATE

There is wide agreement that investment flows should be treated differently from consumption flows and multiplied by the shadow price of capital before discounting. This view is incorporated into our recommended SDR. There is also some support for the view that market rates can serve as a basis for the SDR. However, we do not believe that market interest rates can serve as the basis for an appropriate parameter to represent the SDR because there are too many inconsistencies in observed individual consumer/saver behaviour. Given observed individual intertemporal choices and the implied rates of individual time preference, there would be a wide range of possible discount rates and no obvious way to choose among them. For this reason, we prefer to specify a parameter for the SDR directly, based on an OGR model of intertemporal choice, using the expected growth rate in per capita consumption as well as explicit social values.

There are legitimate grounds for some disagreement about what to do for projects with long-term, intergenerational effects. However, we believe that the logic of explicitly incorporating uncertainty as to the future path of interest and growth rates is compelling. The key implication is that there are legitimate grounds for using a time-declining schedule of discount rates.

Figure 1 presents a flow chart that summarizes how to determine the most appropriate discounting method and rate. There are two critical questions: does the project have intergenerational costs or benefits that occur after 50 years time ($T > 50$) and is there a reason to believe that the project will crowd out private investment?

*****Insert Figure 1 about here*****

If the project does not have intergenerational impacts ($T < 50$) and there is no reason to believe that the project will crowd out private investment, then analysts can simply discount at our central estimate based on the OGR method, 3.5 percent (Box A). If the project does not have intergenerational impacts, but there is a reason to believe that the project will crowd out private investment, then analysts should convert investment flows to consumption equivalents by multiplying them by our central estimate for the SPC of 1.1, and then discounting consumption equivalents and consumption flows at 3.5 percent (Box B). Sensitivity analysis can be conducted using the lower bound for the discount rate of 2.5 percent and the SPC = 1.15, and the upper bound at 4.5 percent and the SPC = 1.05. In practice, there will be few situations where shadow pricing will be necessary. Crowding out of private investment is likely only if the project is debt financed, the supply of foreign funds and savings are unresponsive to interest rates, and if the project is large enough to affect bond yields. If a project-specific bond issue finances the project, then it is obviously debt financed; otherwise, analysts should assume that it is tax financed.

If the project has intergenerational impacts and there is no reason to believe that the project will crowd out private investment, then we recommend using the time-declining scale of discount rates in Box C. The final situation pertains to projects that have intergenerational impacts and there is likely to be significant crowding out of private investment. In this case, we propose that analysts use a hybrid method: Box B for the first 50 years and then Box C for the remainder of the project. Even if there are likely to be significant investment effects in the far future (T > 50), the effect of uncertainty as to the return on investment implies that the expected value for the ROI that applies after 100 or 200 years will converge to the expected value of the discount rate parameter, as both converge to their lowest possible values. In practice, this implies a SPC very close or equal to one for such long-term effects.

There is a widespread view that the correct discounting method is to use a parameter for the SDR that represents the weights that society places on consumption flows in different periods. Some analysts may wish to infer this parameter from historical market interest rates and the implied behaviour of individual consumer/savers. If they do so based on recent data, then they will derive rates that are in the neighbourhood of 1 to 2 percent. Note that these are lower than our recommended rates. Analysts who feel that government should use an SDR based on the return to the marginal private investment should recognize that this is only equivalent to the conceptually correct method of first weighting investment flows by the SPC and then discounting at a CRI under very special circumstances. There are several reasons to believe that using an average of observed, historical returns to private equities is not a good proxy for the ROI. Our estimate of the SDR based on the OGR method is in fact fairly close to our estimate of the ROI, where the latter is based on the real, expected return to a weighted average of Moody's-rated corporate bonds

COMPARISONS TO U.S. DISCOUNTING PRACTICES

How do these proposed guidelines compare to current practice in the United States? As we point out in the introduction, practice is quite variable in government. The prescribed rates in the U.S. Federal government have tended to be fairly high, but they have been trending lower. For example, in the 1970s and 1980s, OMB required most agencies to use a real discount rate of 10 percent (OMB, 1972). This rate was intended to approximate the opportunity cost of capital, measured as the real, marginal, before-tax rate of return on private investment. More recently, the OMB (1996) has revised this rate downward to 7 percent. This new rate was based on low yielding forms of capital (e.g. housing), as well as high yielding corporate capital. It advises agencies that wish to use either the consumption rate of interest *cum* shadow price of capital or optimal growth rate methods to consult with the OMB prior to conducting their analyses. Even assuming that discounting at the marginal rate of return on private investment is valid, our estimates suggest that the appropriate rate is only 4.5 percent with sensitivity analysis at 4 and 5 percent.

Both the General Accounting Office (GAO) and the Congressional Budget Office (CBO) use a lower rate that the OMB. The CBO has estimated the real historical yield on U.S. government securities at 2 percent, and uses this rate, plus or minus 2 percentage points. The GAO uses the average nominal yield on Treasury debt maturing between one year and the life of the project, less the forecast rate of inflation.[25] GAO uses the same rate for all applications, while the CBO and OMB have a number of exceptions.[26]

A recent proposal by the U.S. Panel on Cost-Effectiveness in Health and Medicine recommends the use of a 3 percent discount rate for cost-effectiveness studies, with sensitivity analysis at rates between 0 percent and 7 percent (Weinstein et al., 1996).

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[25] Using the U.S. Government's 10-year, constant-maturity bond rate and the explicit 10-year-ahead inflation forecasts in the Livingston survey, we calculate that the expected real, rate on long-term bonds has varied between 1.6 and 4.3 percent since 1991, with an average of 2.9 percent and a standard deviation of 0.67 percent. The latest 5-year moving average is 2.7 percent.

[26] Both the OMB and CBO use private sector rates for asset divestitures. If they did not, they would be using a lower discount rate than the private sector, implying that the NPV of assets is higher in the public than in the private sector. Assuming no efficiency differences between public and private ownership, this would imply that the government should never divest any assets (Hartman, 1990).

Guidelines published by the U.S. Environmental Protection Agency (EPA, 2000) recommend using the CRI-SPC method, and propose an estimate of the CRI measured at 2 to 3 percent. Because of their view that capital is relatively mobile and most environmental projects are likely to be marginal, they do not suggest applying the shadow price of capital very often. However, correspondence with the EPA indicates that it has been common to annualize the capital costs of an environmental rule using the marginal rate of return on private investment, and then to discount this flow using the CRI. This is equivalent to using the SPC method under very simple assumptions, as per equation (1), and follows the procedure suggested by Kolb and Scheraga (1990). Using our point estimates to do this would give values for SPC of 1.33; in contrast, we recommend an SPC of 1.1, based on the OGR method.

CONCLUSION

There has been considerable debate as to the appropriate method of discounting, as well as the best way to estimate the SDR. In this paper we propose an explicit SDR—we "give 'em a number." We also present our reasoning and calculations.

Our specific recommendations are summarized in Figure 1. For most projects – those whose main impacts occur within 50 years and whose financing does not crowd out investment – we recommend a discount rate of 3.5 percent. With appropriate sensitivity analysis, we find that the range of likely values for the SDR is not that large – no matter which method one chooses, the estimates for the SDR vary between 1.5 and 4.5 percent for intragenerational projects, and between 0 and 3.5 percent for projects with intergenerational impacts.

Some theorists may disagree with our analysis and, therefore, our number. However, if they feel strongly we would urge such critics to follow through and explicitly compute, and present, their own recommended discount rate or rates for use by analysts.

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Figure 1. Best Estimated Values for the Social Discount Rate(s)
(Lower and upper bounds appear in brackets)