Social Discount Rates for Canada

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Abstract

This paper proposes an appropriate real social discount rate (SDR) for the evaluation of projects by all levels of government in Canada. Since 1976, the Treasury Board of Canada Secretariat required that federal cost-benefit analysts use an annual, real SDR of 10%. Recent interim guidelines of the Treasury Board Secretariat (2007) now recommend a discount rate of 8% with sensitivity rates of 3% and 10%. These values are based on the weighted social opportunity cost of capital (WSOC) method. We argue that this is an inappropriate methodology and, even if it were not, the 8% rate is too high. In contrast, we recommend deriving the SDR as a solution to an optimal growth rate (OGR) model. We estimate the future growth rate in consumption and prescribe values of two key ethical parameters. If the project is intragenerational (does not have impacts beyond 50 years) and there is no crowding out of private investment, then analysts should discount future impacts at 3.5%. If the project is intragenerational and it will crowd out (or add to) private-sector investment, then these flows should first be converted to consumption equivalents using a shadow price of capital of 1.1. If the project has intragenerational impacts (beyond 50 years), such as those affecting climate change, we recommend a schedule of time-declining SDRs.

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

1. INTRODUCTION

Many proposed government projects and regulations have impacts that occur over time. While some projects have immediate and short-term impacts, many projects have impacts that occur many years later. For example, infrastructure projects, such as dams or airports, have impacts that occur over decades. Some projects, such as those that seek to avert climate change, could have impacts that occur over centuries.

There is general agreement in the policy analysis community that future impacts should be discounted at the social discount rate (SDR) – the rate at which society discounts future costs and benefits and converts them into present values.[1] There is, however, less agreement over what this rate should be. Until recently, the Treasury Board Secretariat (TBS) in Canada required that cost-benefit analysts at the federal level use an annual, real SDR of 10% (TBS, 1976; TBS, 1998: Ch. 5). However, current "interim" guidelines (Treasury Board Secretariat, 2007) now recommend a discount rate of 8 %, with sensitivity rates of 3% and 10%. These guidelines even suggest that 3% might be appropriate in some intergenerational circumstances.

This downward revision in the value of the SDR in Canada at least partially reflects research and policy trends in other countries. Recently, Moore et al. (2004) derive SDR estimates for the US, using US data and propose an SDR of 3.5% in many circumstances. Both governmental and scholarly sources are also now providing more theoretically grounded estimates of the appropriate SDR for other countries (Evans and Sezer, 2004, 2005). In 2003, the United Kingdom government switched from a 6% real rate to a 3.5% real rate and also recommended the use of declining discount rates for evaluating intergenerational projects (HM Treasury, 2003). In France, a group of experts commissioned by the Ministry of Finance has recommended a reduction in the SDR from 8% to 4% for most public sector projects (Lebegue et al., 2005). Valentim and Prado (2008) have recently proposed a rate of approximately 5% for Brazil.

These factors present a rationale for updating the Canadian SDR. The specific purpose of this study is to derive up-to-date estimates of the SDR for Canada using Canadian data and to recommend SDRs for use in specific circumstances. Prior to Moore, Boardman, and Greenberg

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[1] Throughout, we are concerned with the choice of the *real* SDR. For consistency, we treat all benefits and costs in real (constant, inflation adjusted) dollars.

(2001), one has to go back over twenty years to find published extended theoretical discussion of the social discount rate in Canada (Burgess, 1981; Jenkins, 1981).

The importance of the appropriate value of the SDR has recently been driven home in the debate over the *Stern Review on the Economics of Climate Change* (Stern, 2006). In this widely reported study, Sir Nicholas Stern argues that current policies could lead to the cost of climate change amounting to 5% of world output, as measured by global gross domestic product (GDP), each year — beginning in 100 years and lasting, essentially, forever. According to Stern's analysis, this justifies an immediate current sacrifice of 1% of global GDP (see the discussion in Weitzman, 2007). However, Nordhaus (2007: 689) has responded that the *Review's* conclusions are largely based on "an extreme assumption about discounting" and that if instead "we substitute more conventional discount rates used in other global-warming analyses…the *Review's* dramatic results disappear". Weitzman (2007) and Dasgupta (2007) generally concur with Nordhaus' conclusions. Although the SDR rate does not have as dramatic an impact on most policy questions as it does on global warning, it nearly always plays an important role in determining the net benefits of public investments and, therefore, on the recommended policy alternative.

The paper is organized as follows. Section 2 discusses the current federal practice in Canada; specifically, we argue that the current TBS recommendation concerning the level of the SDR is not supported by theory or evidence. Section 3 proposes values for the SDR in Canada based on four project categories: Intragenerational projects with no crowding out of private investment; intragenerational projects with some crowding out of investment; intergenerational projects with no crowding out of private investment, and intergenerational projects with some crowding out of investment. Section 4 provides a brief conclusion.

2. WHY THE CURRENTLY RECOMMENDED SDR IN CANADA IS INCORRECT

TBS's recommended SDR of 8% is based on the weighted social opportunity cost of capital (WSOC) method. The WSOC method computes the weighted average of: the real, before-tax marginal return on private investment (ROI), the real, after-tax return to savings – a measure of the consumption rate of interest (CRI), and the marginal cost of foreign borrowing. In supporting this approach, the TBS guidelines drew extensively on Jenkins (1973), following Harberger (1972) and Sandmo and Dreze (1971). Jenkins initially estimated the WSOC as approximately 9.5%, based on data from 1965-1969 and subsequently reaffirmed this estimate using 1965-1974 data (Jenkins, 1973, 1977). There are, however, six major reasons not to use the 8% rate.

The rate overestimates the private sector ROI

Even if one accepts the WSOC approach in principle, the private sector does not earn a high enough return in practice to justify using an SDR of 8%. As mentioned, Jenkins' estimate is based on a weighted average of the ROI, the CRI and the marginal cost of foreign funds. Since CRI estimates are typically around 1 or 2% and the marginal cost of foreign funds is unlikely to exceed 4%, the ROI must exceed 9.5% (using Jenkins' (1976, 1981) original weights) or 13.6% (using Kuo and Jenkins' (2007) more recent weights) to yield a WSOC of 8%. However, the private sector does not yield pre-tax returns on investment of 9.5% to 13.6% on average.

Let us suppose that a project yields a post-tax return equal to its financing costs. Also, suppose that this project is financed by a 50/50 ratio of debt-to-equity. Burgess (2005) reports that the nominal, compound annual rate of return to the TSX index for the 15 years from 1990 through 2004 was 8.2%, and that the average, annual rate of inflation measured by the CPI over the same period was 2.2%. This yields an estimated average real cost of equity for a typical firm (with a beta of 1) of approximately 5.9%. Later, we estimate that the real cost of debt averaged about 5.2% in Canada during a similar period. Using an effective marginal corporate tax rate of 36.7% (Chen and Mintz, 2006) and taking into account the tax advantage of debt financing, this would yield an average, real weighted cost of capital of around 4.6%, implying an average pre-tax return on investment of around 7.2%, which is much less than 9.5%. [2,3]

Furthermore, such calculations over-estimate the average ROI for two reasons. First, they are based partially on long-term estimates of equity returns, which suffer from "survivor bias" (failed firms disappear from the sample). Second, the cost of equity includes a risk or equity premium. This premium is the difference between the observed, long-term returns to holding equity as against holding short-term government debt. The equity premium is estimated

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[2] $\boldsymbol{WACC = 0.5 \times k^e + 0.5 \times (1-t) \times k^d = i \times (1-t)}$, where $\boldsymbol{WACC}$ is the weighted average cost of capital, $\boldsymbol{k^e}$ is the real cost of equity, $\boldsymbol{k^d}$ is the real cost of debt, $\boldsymbol{t}$ is the corporate tax rate, $\boldsymbol{i}$ is the pre-tax ROI, and we are assuming a debt-to-equity ratio of 1.

[3] This contrasts with Jenkins and Yuo's (2007) recent ROI estimate of 11.5% and Burgess' (2005) estimate of 10.3%.

to be somewhere around 6%, based on very long-term U.S. data (Mehra and Prescott, 1985). However, the size of the premium implies a degree of risk aversion that is inconsistent with other observed measures using the standard economic model of risk bearing, a result known as the "equity premium puzzle" (Kocherlakota, 1996; Campbell, 2003).[4]

ROI should be measured at the margin

Even if one accepts the WSOC approach in principle, it is clear that the ROI should be based on the *marginal* ROI, not the *average* ROI. But, actual estimates of the WSOC compute the average return on investment, not the marginal return. The marginal return is the correct measure because if public sector investments displace private sector investments at all, they only displace the marginal private sector investment. The marginal ROI is lower than the average ROI— one would certainly expect that firms make their best (highest return) investments first. We believe that the most appropriate way to estimate the marginal ROI is by the real, expected bond yield. Because a firm can deduct the interest it pays to bondholders before calculating its taxable income, on the margin it will equate its expected before-tax return on an investment with the before-tax return it pays on its bonds. As noted, given our recent data, we estimate that the real, expected bond yield is about 5.2%.

The rate is too high as it assumes public sector investments mostly displace private sector investments

Even if one accepts the WSOC approach, 8% is too high because the weights are not applicable to most projects. The 8% figure assumes that public sector investments mostly displace private sector investments. Jenkins (1976, 1981) assumes that 75% of the funds for a public sector investment come at the expense of private sector investments with the remaining 25% coming from foreign funds (20%) and from consumption (5%). WSOC advocates have recently applied lower weights to private investment, resulting in lower SDRs. Jenkins and Kuo (2007) now put approximately 45% weight on ROI, 40% on foreign funds and 15% on CRI, leading to a SDR of 8.2%. Burgess (1981) places around 30% on ROI, 60% on foreign funds and 10% on CRI, depending on the elasticity of supply of foreign funds. More recently, Burgess (2005) prefers 50% on ROI, 40% on foreign funds and 10% on CRI, leading to a recommended SDR of 7.3%.

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[4] Weitzman (2007) suggests that, in order to explain observed ROI, this premium should be as little as 0.1%, using a standard model, instead of the observed premium of some 6%.

However, neither theory nor evidence supports this view. Suppose that the project is financed from taxes. Taxes reduce consumers' disposable incomes and most disposable income is consumed rather than saved.[5] Thus, projects financed from taxes will mainly reduce consumption rather than investment. In an open economy with the availability of deficit financing, 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 funds from abroad is very responsive to the interest rate, then very little domestic investment would be crowded out (Lind, 1990). Unfortunately, there is little evidence on the supply elasticity of foreign funds to the interest rate. However, for all projects except very large ones, the effect on interest rates, the exchange rate, and the trade deficit is quite small, and hence one can assume that government projects displace consumption, not investment.

It is only in a closed economy with deficit-financed projects that public sector investment is likely to displace private-sector investment. Here, 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 as the balance of the evidence suggests it is not very responsive to changes in market interest rates (Harberger, 1969; Muellbauer and Lattimore, 1995). The elimination of federal deficits in the 1990s, and the emergence of surpluses since 2000, means that new federal expenditures are unlikely to be deficit-financed, at least for the near-term. Thus, it seems appropriate in most circumstances to assume that projects are financed from taxes (Havemann, 1969) and, consequently, that the costs of a public sector investment displace consumption rather than investment.

The WSOC method discounts both costs and benefits at the same SDR. Implicitly, WSOC assumes that public sector projects yield benefits that generate more private-sector investment rather than more consumption. However, while some benefits might impact investment, non-monetary benefits probably do not. For example, the lives saved, time saved or

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[5] Dynan et al. (2000) find that marginal propensities to save from disposable income vary between 2.4% and 11% in the US. Souleles (2002) finds that the Reagan tax cuts of the 1980s had 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 responsive to the current, rather than the permanent, level of income, contrary to standard theory.

pollution reduced by a new transportation project will probably impact consumption rather than investment. The extent to which impacts displace consumption or investment will vary from project to project and will be considered in more detail later.

The rate estimate uses market-based interest rates as proxies in computing the SDR

The WSOC estimates uses observed market interest rates to estimate the ROI, the CRI and the cost of foreign funds. This approach is also sometimes called the descriptive or revealed preference approach, in contrast to the prescriptive approach which we discuss later. Earlier we explained that market-based estimates of the ROI are problematic. Here, we discuss the problems that arise from using market-based interest rates to estimate the CRI.

First, when estimating the CRI using market-based interest rates, one must confront the fact that borrowing and lending rates differ due to taxes and transactions costs. As a result, individuals differ in both their rates of time preference and in their circumstances: while some are saving at low rates, others are borrowing at higher rates, and still others are borrowing from loan sharks! It is unclear how to aggregate the many observed rates.

Second, market-based interest rates are based on individuals currently participating in the market. Some individuals are screened out of legitimate credit markets altogether due to informational asymmetries or the inability to borrow against their human capital**.** Also, of concern for projects with very long-term impacts, methods based on market interest rates only reflect the preferences of individuals currently alive.

Third, there is a growing body of evidence that individuals do not behave according to the standard postulates of microeconomic theory in intertemporal contexts. This weakens the normative argument for basing social choices on market behaviour (Frederick et al., 2002). There are three strands of evidence to support this assertion. First, 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 behaviour, it is unreasonable to assume that individual savers/consumers are equating their marginal rates of time preference with a single market interest rate. Second, 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 time may be overturned later even if no new information becomes available; a phenomenon known as time inconsistency.[6] This is problematic, as projects that appear socially valuable at the time of an initial decision may suddenly appear to be a mistake, even though nothing has changed except the passage of time. Third, there is evidence demonstrating that the framing of intertemporal choices 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% (Warner and Pleeter, 2001). Caplin and Leahy (2004) have argued that the view that social choices should be based on individuals' revealed preferences is far less compelling when choices are made over time than it is for choices at any given moment in time, and that this implies that the SDR should be less than the CRI.

The WSOC method is not the correct method for computing the SDR

Welfare economics frames policy choices as an attempt to maximize social welfare – an aggregation of the well-being of the individuals that make up the society – and generally assumes that individual well-being depends directly on consumption (broadly defined to include privately consumed goods and services, including health and education, as well as public goods such as environmental goods). Cost-benefit analysis discounts future net benefits because consumption that occurs in the future is generally worth less in present value terms than consumption that occurs today. Thus, from a broad normative perspective, the SDR should reflect society's willingness to trade-off future consumption for present consumption. According to this approach, the level of public investment should reflect society's aggregate preferences for present versus future consumption. Investments are simply a means of using resources that are potentially available for consumption now in order to increase consumption later. However, if the SDR is less than the private, marginal ROI, society is under-investing relative to the socially best outcome. Failure to account for this might mean that society would undertake a low-yielding public project at the expense of a higher-yielding private project. To reflect the greater opportunity cost of displaced private sector investment, any impacts (crowding out or crowding in) on investment flows should be converted to consumption equivalents by multiplying them by

[6] Individuals who recognize that they are likely to make time inconsistent choices may choose to use various commitment devices, e.g., to ensure that they save enough for retirement. This may explain the observation that individuals simultaneously borrow and lend.

the shadow price of capital (SPC). Then, the consumption flows and the consumption equivalent flows are discounted at the SDR (Lind, 1990; Lyon, 1990). This approach is not equivalent to the WSOC approach.

The ethical treatment of future generations and the presence of long-term uncertainty suggest that 8% is too high

The present value of $1 received 50 years in the future and discounted at 8% is less than 2 cents. Adopting this approach means that benefits received by our children or grand-children are worth less than 2% of the same benefit received by this generation. CBA using a discount rate of more than 2% would result in the conclusion that we should do little greenhouse gas (GHG) abatement today, even if its future effect on climate is catastrophic (Portney and Weyant, 1999). Consequently, many economists argue that members of the current generation (who determine current market interest rates) fail to account appropriately for the effects of long-term projects on the welfare of future generations (Ramsey, 1928; Phelps, 1961; Arrow et al., 1995; Dasgupta et al., 1999).

A separate issue concerns future market interest rates and growth rates. These rates can vary considerably over time, and society faces considerable uncertainty as to their values, especially far 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 (Azfar, 1999; Weitzman, 2001; Newell and Pizer, 2003). These rates go some way to resolving the ethical dilemma posed by the use of constant SDRs to evaluate very long-lived projects.

3. THE RECOMMENDED SDR IN CANADA

Figure 1 summarizes our recommendations for the real SDRs in Canada. If the project does not have impacts beyond 50 years and there is no crowding out of private investment, then analysts should discount at our central estimate for the SDR which is 3.5% (Box A). If the project does have impacts beyond 50 years 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% (Box B). If the project has impacts that stretch beyond 50 years and there is no crowding out of investment, the following time-declining scale of discount rates should be used: 3.5% from year 0 to year 50, 2.5% from year 51 to year 100, 2.0% from year 101 to year 200, 1.5% from year 201 on (Box C). If the project has impacts beyond 50 years 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%, and investment flows after the 50th year should be discounted using the above time-declining rates (Box D).

*** Insert Figure 1 about here***

In the rest of this section, we explain in detail the rationale for each of the parameters in the four situations: Box A: Intragenerational projects with no crowding out of investment; Box B: Intragenerational projects with some crowding out of investment; Box C: Intergenerational projects with no crowding out of investment, and Box D: Intergenerational projects with some crowding out of investment.

Intragenerational projects with no crowding out of investment (Box A)

If the project does not have intergenerational impacts ($T < 50$) and the benefits and costs affect consumption, not investment, then analysts can simply discount impacts at 3.5%. This is appropriate for a project whose benefits are non-pecuniary and whose costs are financed by taxes or are relatively small. Some transportation projects would fit at least partially. The costs are up-front and are likely funded by taxes. Major benefits of such projects can include lives saved, injuries avoided and time saved. Public health projects such as immunization or DNA testing are also likely to fit here. Social policies that provide benefits to disadvantaged groups would also fall into this category.

The approach we take to calculating the SDR is the standard one in modern welfare economics. We propose estimating the SDR directly using an optimal growth rate (OGR) model (Ramsey, 1928). This approach does not rely on individual preferences as inferred from market interest rates, which are problematic as we discussed above. Nevertheless, even if individuals do not always make consistent intertemporal choices over public and private goods, society should make its public investments as though they do. Thus, this method is sometimes referred to as a prescriptive approach.

The OGR method assumes that policy-makers maximize a well-behaved social welfare function that describes the values society places on different amounts of per-capita consumption, both public and private, over time. They choose the level of public investment in order to maximize the net present value of well-being of society, where well-being depends on the aggregate per capita consumption. Policy-makers discount the future for two reasons. First, members of society simply prefer to consume more now. Second, society will be richer in the future and wants to reduce inequality in consumption across time. Using this OGR method, the SDR, denoted ***o***, is the sum of two elements:

$$\boldsymbol{o} = \boldsymbol{d} + \boldsymbol{g} \times \boldsymbol{e} \quad (1)$$

The first term, ***d*,** the utility discount rate, measures the rate at which society discounts the utility of present versus future (per capita) consumption (or impatience), regardless of economic growth. The second term reflects consumption discounting – a preference for more equality in per capita consumption over time than would otherwise occur. Consumption discounting is the product of two parameters: the growth rate of per capita consumption, ***g***, and the absolute value of the rate at which the marginal value of that consumption decreases as per capita consumption increases, ***e***.

The most plausible way to decide on a value of ***g***, the future growth rate, is to estimate it based on past data. The most natural option is to regress the natural logarithm of real per capita aggregate consumption on time and use the slope coefficient. An alternative approach is to regress the natural logarithm of real GDP per capita on time and use this slope coefficient. Moore et al. (2001) found that this growth rate was 2.6 percent for 1926-72, but only 1.58% for 1973-95. Using annual per capita data on real consumption expenditures for 1971-2006, we estimate that the average growth rate of consumption per head in Canada was 1.7% per annum with a standard error of 0.056%.[7] It is very difficult to predict the future long run growth rate for Canada. Estimates of historical Canadian consumption growth rates vary by as much as 0.7 percentage points depending on the data period.[8] Long-run global growth rates have varied considerably over time. For example, based on Lucas (1998), Jones (2001, 15-6) computes global growth rates of GDP per capita as 0.17% between 1750-1850, 0.88% from 1850-1950, and 2.2% from 1950-1990. Researchers appear to favour the use of approximately around 2% for

[7] Data on real consumption expenditure are from CANSIM series v41707176; population data are from CANSIM series v466668. One reason why we did not go back beyond 1971 is that the available CANSIM population data is “broken” into pre 1971 and post 1971 data, and they do not appear to match up well.

[8] Kula (1984) estimates the annual Canadian growth rate of consumption per capita between 1946 and 1975 at 2.8%. More recently, Moore et al. (2001) estimate the annual growth rate in consumption using 1926-1995 data as 2.23%. Fitting a line to the last 10 years of annual data gives an estimate of 2.4% annual growth, although this was a period with increasing commodity prices and low interest rates.

future growth rate for the US (Prescott, 2002; Moore et al., 2004; Evans and Sezer, 2004; Nordhaus, 2007: Weitzman, 2007).[9] Although historical rates have varied considerably, we recommend using ***g*** = 1.7% for Canada, with sensitivity analysis at 1.5 and 2.0%.

The parameter ***e*** represents social preferences for equality or inequality across generations. It equals the absolute value of the elasticity of the social marginal utility of consumption with respect to per capita consumption, and 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.

One approach to estimating ***e*** recognises that it is equivalent to a preference for avoidance of risk (coefficient of relative risk aversion) and consequently bases ***e*** on observed individual behaviour for risk avoidance. However, there are many problems inherent in trying to calibrate the OGR-derived SDR with observed growth rates and values for ***e*** based on individuals' revealed preferences for risk avoidance (Weitzman, 2007). These problems seem to arise from the same sources as the equity premium puzzle, and imply either severe market failure or that our standard economic model of choice under uncertainty is fundamentally flawed. Weitzman suggests ***e*** equals 2, with a range of 1 to 4 being reasonable. Arrow et al. (1995) argue that the evidence supports estimates of individual elasticities of marginal utility of consumption between 1 and 2. Kula (1984) infers ***e*** from the ratio of estimates for income elasticity to compensated price elasticity of food demand, using aggregate data from 1956-1976, and finds ***e*** equals 1.56. A recent update using a similar methodology estimates ***e*** as 1.3 (TBS, 2007).

An alternative approach to estimating ***e*** is to look at the progressivity of the income tax schedule, and to infer social choices about inequality from this. Adopting this approach, Evans and Sezer (2004) calculate values for ***e*** ranging from 1.3 to 1.7 for six major countries. We have replicated their approach for Canada, using the most recent OECD data (www.oecd.

[9] On the other hand, Cline (1992) uses a 1% rate.

org/taxation; accessed February 27, 2008). For a single individual without children, earning the average wage, the data on the marginal and average tax rates (adding together income and social security taxes) imply estimates for ***e*** ranging from 1.7 for 2000 to 1.56 for 2006. A simple average of the calculated values for individuals at 67%, 100% and 167% of the average wage yields estimates for ***e*** ranging from 1.57 (2000) to 1.43 (2006). Evans (2005) presents estimates for 20 OECD countries at "high" or "low" income levels in 2002, and finds ***e*** for Canada equal to 1.3 or 1.25.

A final method of choosing ***e*** is simply to prescribe it based on an ethical perspective. Brent (1994), Cline (1992) and Stern (2006) do so, and suggest values for ***e*** that range between 0 and 1.5. Brent suggests that ***e*** should be between 0 and 1, with 0.5 as a benchmark. Stern (2006) recommends an ***e*** value of 1, and Cline chooses ***e*** equal to 1.5. Nordhaus (2007) criticizes this approach as paternalistic, and notes that the values often prescribed for ***d*** and ***e*** are incompatible with observed market interest rates and savings ratios. Dasgupta (2007) has also criticized the Stern report for its choice, pointing out that in simple growth models such a low value for ***e*** implies that the current generation should save approximately 97.5% of its income in order to increase the consumption of future, wealthier generations.[10] Accordingly, he argues that reasonable attitudes towards inequality of consumption imply that ***e*** would fall in the range of 2 to 4. Our view is that attempting to calibrate the parameters of the OGR model with observed behaviour is subject to the same criticisms that we applied to market-based (descriptive) interest rates discussed above. We conclude that one should use prescribed rates. However, empirical observations do provide an order of magnitude check on the choice of ***e***. With prescribed rates in the range of 0.5 to 4, and empirical estimates somewhere between 1 and 2, we believe a central estimate of 1.5 is reasonable, with sensitivity analysis at 1 and 2.

There has been considerable debate about the value of ***d*** since Ramsey (1928) who argues that it is ethically indefensible to use a positive value, as this would discount future generations' utility relative to the present generation. Similarly, Dasgupta (2007) argues that ***d*** should be zero. Alternatively, ***d*** may be interpreted as the probability of non-survival for either an individual or a society. Under the first interpretation, ***d*** would represent the fact that individuals prefer consumption now to consumption later, as they may not be around later. It could be

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[10] This result follows in the Ramsey (1928) model where capital is proportional to output, ***d*** = 0, ***e*** = 1, ***g*** = 1.3 as in Stern (2006), and the ROI = 4%.

estimated as the instantaneous probability of death, measured by the average population death rate. Kula (1984) following this approach estimates ***d*** to be 0.8% a year. Recent data suggests it is close to 1% (TBS, 2007). This approach, however, cannot be easily extended to long-term social choice, as society's probability of total extinction is clearly much lower than an individual's instantaneous probability of death. For this reason, and for ethical reasons, Stern (2006) suggests that ***d*** should not exceed 0.1%. However, Arrow (1995) demonstrates that setting ***d*** close to or equal to zero—essentially weighting all generations' welfare equally—results in very high rates of savings being required of the current (or even of every) generation. He shows that under reasonable parameter values the current generation would 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 around 1% for ***d***, which we use below.[11]

With an estimate of ***g*** = 1.7%, ***e*** = 1.5, and ***d*** = 1%, we obtain ***o*** approximately = 3.5%. Sensitivity analysis with ***e*** ranging between 1 and 2 and with ***g*** varying between 1.5 and 2.0% implies ***o*** ranges from 2.5% and 5.0%. Thus, we recommend using a central estimate of ***o*** equal to 3.5% with sensitivity analysis at 2.0% and 5.0%.[12]

Intragenerational projects with some crowding out of investment (Box B)

If the project does not have intergenerational impacts (<50 years), but some project impacts crowd out private investment, then analysts should convert the investment flows to consumption equivalents by multiplying them by 1.1, and then discounting consumption equivalents and consumption flows at 3.5%. Sensitivity analysis can be conducted using the lower bound for the

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[11] Nordhaus (2007) chooses a value of 3, to make the SDR equal to an estimated return on (risky) capital of 6%, given a chosen value for ***e*** of 1.5 and an estimated growth rate of 2%. This is equivalent to the descriptive approach with the SDR estimated by the ROI.

[12] Kula (1984) and Moore et al. (2001) provide earlier estimates for Canada. Kula (1984) estimates ***g*** = 2.8%, using the average annual growth rate in Canadian per capita consumption between 1946 and 1975. He treats ***e*** as representing the preferences of average individuals, and estimates it from an aggregate demand equation for food, arriving at 1.56. He views ***d*** as representing an average individual's expected annual mortality rate, which he assumes equals the average death rate in the population as a whole, equal to 0.8% per year. Therefore, he estimates ***o*** = 5.2%. Moore et al. (2001) use prescriptive estimates of ***d*** = ***e*** = 1 and estimate ***g*** = 2.2 to estimate ***o*** = 3.2 for Canada. For the U.S., Moore et al. (2004) set ***d*** = ***e*** = 1 and estimate ***g*** = 2.3 to find ***o*** = 3.3. Cline (1992), assuming the likely future world growth rate is 1%, ***d*** = 0 and ***e*** = 1.5, estimates ***o*** = 1.5%. Stern (2006) projects growth at 1.3%, sets ***d*** = 0.1% and ***e*** equal to 1 to get ***o*** = 1.4%. Weitzman (2007) suggests a "trio of twos" giving ***o*** = 6%. The UK government recently set ***e*** =1, ***d*** = 1.5 and forecasting ***g*** = 2%. This replaced previous estimates based on the opportunity cost of capital.

discount rate of 2.0% and the SPC = 1.2, and the upper bound at 5.0% and the SPC = 1.0.

In practice, there are only a few situations where shadow pricing will be necessary. Shadow pricing should be applied to the costs of only a very large project that is financed via deficits or if a specific bond issue finances the project. Benefits should also be shadow priced where they would plausibly increase private sector investment. For example, operating cost savings that accrue to trucking firms from improvements in the Trans-Canada highway might be expected to increase private sector investment. However, there is still considerable controversy over the size, if any, of the spillovers (Gramlich, 1994; Garcia-Mila, McGuire and Porter, 1996).

Lyon (1990) shows that an estimate of the SPC, which is denoted ***s***, can be obtained using:

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

where ***i*** is the net rate of return on capital after depreciation (the ROI), ***f*** is the depreciation rate of capital, ***a*** is the fraction of the gross return that is reinvested, and ***o*** is the SDR.[13] An estimate of the SPC requires a measure of the marginal, pre-tax ROI, the depreciation rate of capital, and of the fraction of the gross return on capital that is reinvested.

For the reasons given above, the most appropriate proxy for the marginal, pre-tax ROI is the expected pre-tax interest rate on corporate bonds. There are two possible candidates for the ROI proxy: the average expected real yield on long term Canadian corporate bonds in the Scotia Capital Inc. series, and the weighted average expected real yield on medium term bonds from the same source.[14] Historical nominal yield data are available on a monthly basis. However, in order to calculate the expected real yield, we require a measure of expected inflation. We use the Consensus Economics mean forecast (average of all forecasts) for the year-over-year change in the Canadian CPI, both for the current and for the next year.[15] In order to have annual rates of

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[13] In the absence of reinvestment and depreciation (that is, if ***a*** = 0 and ***f*** = 0), this formula reduces to: $s' = i/o$, the ratio of the rate of return on investment, ***i***, to the social discount rate, ***o***. Using our preferred estimates for the SDR of 3.5% and for the ROI of 5.2%, this would yield $s' = 1.5$.

[14] Source: CANSIM series v122518, and v122519; annual January 1 observations, 1990-2008.

[15] Source: DataStream, *Consensus Economics* consumer prices (% year-over-year, mean) – geometric average of current and next-year forecasts, annual January 15 observations, from 1990 through 2008. The average, annual expected inflation rate over this period is 2.3%.

expected inflation that match with annual bond yields, we choose the January 15 observation of expected inflation for the current and next calendar year, and the January 1 observation for the bond yield. The expected inflation data are available from January 1990 through January 2008, so this allows for 19 annual observations. Based on the nominal interest rates paid on Canadian corporate bonds (Scotia Capital Inc. Time Series "Average Weighted Yield: All Corporations Long-Term,") and on the average two-year ahead forecast for Canadian Consumer Price Index (CPI) inflation, we calculate that the estimated real, expected cost of debt for Canadian corporations from January 1990 to January 2008 averages 5.2%, with a standard deviation of 1.3% for long term bonds, and averages 4.6% for medium term bonds, with a standard deviation of 1.5%. We prefer the long-term bond data, and thus we estimate the current ROI at 5.2%, with sensitivity analysis at 4.0% and 6.5% (plus or minus approximately one standard deviation, given the most recent measures of volatility).[16]

To obtain a value for *f*, the depreciation rate of capital, we rely on Patry (2007), who offers new empirical evidence on the rates of economic depreciation for a comprehensive set of Canadian assets. Using a micro database on the purchase and disposal of capital goods from Statistics Canada's Capital Expenditure Survey, he estimates depreciation rates for 36 asset categories, which represent over 45% of the Canadian business capital stock. Depreciation rates for the remaining assets are calibrated using the average age-price relationship from the estimation and surveyed service lives obtained from the Capital Expenditure Survey. His estimates for the weighted average depreciation rate of capital for which he has micro-data is 16.4%, and calibrating rates for the remainder of the capital stock results in an overall weighted average depreciation rate of 13.5%. Thus, we estimate that ***f*** = 13.5%.

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 14.3% for 1961-2006, based on annual real GDP data, with a range between 10.3 and 20.7% and a standard deviation of 2.6. Over the last 20 years (1987-2006) the gross investment rate averaged 16.7%,

[16] Jenkins and Yuo (2007) estimate a Canadian pre-tax return on investment of 11.5%, while Burgess (2005) measures it at 10.3%. Nordhaus (1999) argues that the post-tax rate of return on private investments must be at least 6%. Using a corporate tax rate of 38% (Shoven and Topper, 1992), this implies a pre-tax return of [0.06/(1 – 0.38)] = 9.7%. Cline's (1992) survey suggests a central estimate of 7% for the ROI. Many contributors in Portney and Weyant (1999) argue for a rate between 5% and 8%. Our central estimate is below the lower bound of these estimates because we prefer a measure from the bond market, rather than equities, for the reasons discussed above.

while the most recent five-year average was 18.8%. The largest annual observation was for 2006, and rates below 15% have not been observed in the last two decades. This suggests that an average rate of approximately 17% is likely in the future, and we choose it as our central estimate.

We can now estimate the SPC using equation (1). Our central estimates of the SDR, $\boldsymbol{o}$, equals 3.5%; the ROI, $\boldsymbol{i}$, equals 5.2%; depreciation, $\boldsymbol{f}$, equals 13.5%; and the reinvestment rate, $\boldsymbol{a}$, equals 17%, which yields a measure of the SPC, $\boldsymbol{s}$ equal to 1.12, implying that one dollar of private sector investment would produce a stream of consumption benefits with a NPV equal to \$1.12. Given this, we recommend using $\boldsymbol{o}$ = 3.5% with $\boldsymbol{s}$ = 1.1 as a best estimate.[17]

Based on Moore et al. (2004), we recommend using $\boldsymbol{o}$ = 2.0% with $\boldsymbol{s}$ = 1.2, and $\boldsymbol{o}$ = 5.0% with $\boldsymbol{s}$ = 1.0 for purposes of sensitivity analysis. Note that displaced investment has at most a 20% premium relative to displaced consumption. It would be useful to have specific Canadian estimates of the sensitivity of the SPC to uncertainty about the parameters, but we do not think this is critical. Although Moore et al. (2004) found that the SPC is fairly sensitive to the parameters used in its estimation, the NPV of a project will not be very sensitive to the precise value of the SPC unless a substantial share of the project's benefits augment domestic investment or a large proportion of the costs displace domestic investment, which as we discussed earlier in some detail, will not be the case for most projects.

Intergenerational projects with no crowding out of investment (Box C)

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: 3.5% from year 0 to year 50; 2.5% from year 51 to year 100; 2.0% from year 101 to year 200; 1.5% from year 201 on.

To see how these rates work, consider a project that has a single benefit of \$1 billion delivered in year 400, and an initial cost of \$1 million today. The PV of the benefits would \$1 billion $* [(e^{-0.035*50}) * (e^{-0.025*(100-50)}) * (e^{-0.020*(200-100)}) * (e^{-0.015*(400-200)})]$, which is approximately \$335,462, yielding a project NPV of -\$664,537. Note that we discount at 1.5% from year 400 to 200, then take the resulting value in year 200 and discount it back to year 100 at 2.0%, and so on.

[17] Cline (1992) proposes a value of $\boldsymbol{s}$ equal to 1.56 and then discounting using $\boldsymbol{o}$ measured at 1.5% for all CBAs, including GHG abatement projects. His estimate of $\boldsymbol{s}$ uses $\boldsymbol{i}$ = 8.0%, assumes that all investments have 15-year lives, and that $\boldsymbol{a}$ = 0.2.

In this example, this is equivalent to applying a single, constant rate of 2% from year 400 to the present.

There is no obvious way to decide when a project is intragenerational or intergenerational. In some circumstances, those as yet unborn when a project is initiated will live to be affected by it, as beneficiaries or taxpayers or both. Those alive at the start bear some of the start-up costs, but may not live to reap the benefits. Nonetheless, 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. Therefore, we consider projects with significant effects beyond 50 years to be intergenerational. Somewhat fortunately, though, this issue is moot given our recommended SDR values. One can think about Box A as simply a special case of Box C. Nonetheless, it should be clear that Box C pertains to projects with environmental impacts, especially climate change impacts. For example, it includes efforts to mitigate global warming by greenhouse gas abatement, preserving biodiversity through the protection of unique ecosystems, and the storage of radioactive waste.

There have been a number of responses to the issue of intergenerational equity arising from very long-term environmental projects. One response has been to suggest the use of rates that decline into the future, or declining discount rates. Both Pearce et al. (2003) and Groom et al. (2005) review the rationales for the use of declining rates. In our view, the most plausible reason stems from the fact that the inherent uncertainty as to the future growth rate of the economy, the return on investment, and the SDR all increase, the further we look into the future. Or, more formally, the confidence interval surrounding any forecast widens with the length of the forecast. Allowing for this increasing uncertainty means that lower discount rates over time should be used to discount consumption flows, essentially because one must average discount factors, not discount rates.[18]

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[18] To see why discount rates decline as they apply to flows that occur further out in time consider a project that delivers a single benefit of $1 billion in 400 years. There is a 50% chance that the appropriate (constant) discount rate over this period will be 7% and a 50% chance that it will be 1%. One might simply average these two rates to obtain an expected discount rate, 4%, 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. It is the discount factors of $e^{-0.07*400}$ and $e^{-0.01*400}$ which should be averaged, yielding an expected NPV equal to $1 billion $* [(0.5\ e^{-0.07*400}) + (0.5\ e^{-0.01*400})]$, approximately $9,157,800. This is equivalent to using a single, certain discount rate of approximately 1.2%. The larger discount rate almost completely discounts itself out of the average – an effect that grows over longer time horizons, resulting in a time-declining schedule of discount rates (Azfar, 1999; Weitzman, 2001; Newell

Weitzman (2001) uses this rationale to derive a scale of time-declining SDRs. He surveyed almost 2,200 economists and asked each to provide a single, real rate to use in discounting the costs and benefits of global climate change. He found that the frequency distribution of the respondents' rates approximated a gamma distribution. He then showed 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 (the lowest rate suggested) after 200 years.

Newell and Pizer (2003) follow a different approach based on the historical behaviour 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 initial values of 4% and 2%. They generate thousands of different time paths and use these to construct expected discount factors, which also result in a time-declining scale of effective discount rates. We think this method is superior to the Weitzman method because it captures the future uncertainty with respect to the SDR, as proxied by uncertainty in interest rates, rather than simply disagreement as to the appropriate SDR to use.

Recently, Hepburn et al. (2007) have applied the Newell and Pizer approach to data from four countries, including Canada. They use a government bond rate as a proxy for uncertainty in the SDR—data from 1844-2004 on the real, before-tax yield on bonds with maturities in excess of 10 years for their Canadian study. They measure inflation by the 10-year moving average for the CPI, and include a dummy variable for inflation to eliminate the effects of extreme events that make the real interest rate negative. They then smooth the data by taking three-year moving averages of the real rates. They find that, for all countries, the mean-reversion model fits better than a random walk – for Canada, a simple autoregressive model (AR(1)) fits the data best. However, they then allow for time-varying coefficients in their estimation, and find that this model is preferred for all countries, with switching between a low-volatility and a high-volatility regime. Both are highly persistent in the data, with the stable regime lasting an average of 37 years, and the unstable regime lasting 9 years.

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and Pizer, 2003; Groom et al., 2005).

Having estimated their model for Canada, Hepburn et al. simulate 100,000 possible future paths for the real interest rate, starting it at 3.5% (serendipitously, our preferred estimate for the SDR!) They then calculate the certainty equivalent rates that would apply at various times into the next 400 years. There are substantial differences among the four countries, with Canada having the lowest certainty equivalent rates for a horizon over 100 years. However, because Hepburn et al. use a mean-reversion model, with interest rates tending to return to their central values, they don't find that rates decline asymptotically to the lowest possible rate in the very long run, as Newell and Pizer (2003) do.

For practical purposes, it is useful to suggest a single rate for the SDR over a reasonably long time period. Based on Hepburn et al. whose rate schedule starts at 3.5%, we suggest the following blocks: 3.5% from year 0 to year 50; 2.5% from year 51 to year 100; 2.0% from year 100 to year 200; 1.5% from year 200 on. These rates are chosen to approximate the same pattern as Hepburn et al. data for Canada, but are not identical (for example, the rates for Hepburn et al. are: 3.46% for year 20, 2.84% for year 60, 2.67% for year 100, 2.26% for year 200, 1.93% for year 300, 1.61% for year 400.

Intergenerational projects with some crowding out of investment (Box D)

The final situation pertains to projects that have intergenerational impacts and there is some crowding out of private investment. We recommend a combination of the computations from other boxes. For the first 50 years, Box B applies if some project flows affect investment, and Box A applies if flows do not. Thereafter, investment flows are treated the same as consumption flows and Box C applies. There are two main reasons. First, after 50 years it is usually difficult to determine the proportion of flows that affect private-sector investment. Second, it seems unnecessarily complicated. Even if there are significant investment effects in the far future ($T > 50$ years), 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 to one for such long-term effects.

4. CONCLUSIONS

There has been considerable debate as to the appropriate method of discounting, as well as the best way to estimate the SDR. There is widespread agreement that the correct conceptual method of social discounting is to shadow price investment flows and to discount the resulting consumption equivalents and consumption flows using a consumption-based social discount rate. The main disagreements centre on the choice of the consumption-based SDR, the estimates of the parameters, especially the ROI, and on how to deal with intergenerational issues. Inevitably, we have made several important judgment calls. Specifically, we believe that the most appropriate SDR is based on the OGR-SPC method. We suggest estimating the ROI using real, before-tax bond rates. We recognize that others prefer to estimate the ROI based at least partially on returns to equities, but we reject this approach because of the numerous problems that one encounters in its implementation and the conceptual problem of dealing with the equity risk premium incorporated in returns on equities. We suggest the use of time-declining discount rates in projects with significant intergenerational impacts. Others may make different judgment calls and arrive at different estimates.

This paper suggests that Canada should use an SDR that varies between 2.0 and 5.0% for intragenerational projects, and between 1.5% and 3.5% for projects with intergenerational impacts. These estimates are lower than the TBS's current recommendations. As we mentioned in the introduction, other governments have recently lowered their prescribed SDRs (Evans and Sezer, 2004, 2005).

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