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Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns

This report was drafted by Dr. Cameron Hepburn (Vivid Economics and Oxford University), in the context of an OECD project dealing with the Costs of Policy Inaction.

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FOREWORD

This report was drafted by Dr. Cameron Hepburn (Vivid Economics and Oxford University), in the context of an OECD project dealing with the Costs of Policy Inaction. An earlier version of the report was reviewed by the OECD Working Party on National Environmental Policies (WPNEP) at its meeting in Rome on October 3-4, 2006. The paper has since been revised, based on comments received from that Working Party.

The report is published under the responsibility of the Secretary-General.

TABLE OF CONTENTS

1. Executive summary

Discounting is the practice of attaching a lower weight to future costs and benefits than to present costs and benefits. The use of high discount rates can appear to offend notions of sustainable development and the interests of future generations. However, not discounting — using a consumption discount rate of zero — is economically illogical and produces perverse results. Furthermore, although often promoted for environmental reasons, using low or zero consumption discount rates does not necessary lead to greater environmental protection. Zero discounting favours *any* project with large upfront costs and benefits further in the future, such as road building and investments in long-lived coal-fired power stations.

Discounting (and cost-benefit analysis) is intended to ensure that public funds are directed to the projects which yield the greatest social benefits, or which are "efficient". Recent developments in discounting theory, which incorporate the impact of long-term economic uncertainty, reduce the tension between efficiency and fairness between generations. Never has Keynes' (1936) dictum about practical men being slaves of "some defunct economist" been more inapt. The key economists are still alive, and impressively, these theoretical developments have been rapidly digested and incorporated into the government guidance of two OECD countries — France and the United Kingdom. Other OECD countries should consider following suit.

Within one country, different government departments should follow the same discounting guidance. Project-specific differences should not be accounted for by ad hoc adjustments to the discount rate. (For example, differences in project risk should be addressed by determining certainty-equivalent project cash flows, not by adjustments to the general discount rate.) When departments use different discount rates, public funds are not allocated efficiently. For instance, suppose an environmental ministry (incorrectly) fails to discount costs and benefits (that is, it employs a zero discount rate), and suppose another ministry applies a positive discount rate to the environmental impacts. The result is that the same environmental impacts would be valued differently, depending artificially on the relevant ministry. To avoid this state of affairs, countries should provide clear and uniform *central* guidance to all departments.

This paper reviewed current discounting practice in the OECD. It found a wide variance in guidance across countries (which may or may not be justifiable by different economic conditions), and significant differences in guidance within countries. Furthermore, even when discounting guidance is specified, it is not always followed in practice.

A clear conclusion from this study is the allocation of public funds would be substantially improved if OECD countries provided departments with a consistent set of guidance on discounting. This guidance should provide for the analysis of long-term projects, programmes and policies, which are increasingly important, particularly with respect to environmental concerns. Finally, guidance should incorporate advances in theory of discounting under long-term uncertainty. A recipe for determining the appropriate rate of decline in the discount rate is included in this paper.

2. Introduction

Discounting is crucially important to the analysis of long-term projects. For instance, a 100-year project, yielding benefits of €22,000 on completion, is worth around €8,000 today at a 1% discount rate. The same project is worth only €1 today at a 10% discount rate. Obviously, that is a, 8,000-fold difference in the present value of the project, depending upon the applicable discount rate.[1] It is hardly surprising that

[1] The example given is compounded in continuous time. In discrete time, the difference is over 5000-fold.

the discount rate is normally the most crucial factor in whether medium to long-term projects pass a cost-benefit analysis.[2]

This is hardly surprising. The example above reflects nothing more complicated than the power of compound interest, and it is obviously much more difficult for a 100-year project to yield a continuous 10% annual return than a 1% return. The discount rate matters.

The discount rate is not only important; it is also conceptually interesting. It reflects our most fundamental views about the future. Social discount rates, based on the "social rate of time preference" (discussed in section 3.1), reflect weighty ethical issues concerning how we treat future generations. As will be explained, the discount rate should also capture the deep uncertainty about the long-term state of the economy and the world at large.

Yet, despite its importance and interest, discounting remains poorly understood and inconsistently applied. This paper aims to provide a clear review discounting theory and practice. Section 3 presents an overview of recent developments in economic theory. Section 4 reports on current discounting guidance in selected OECD member states (with an overview of results at the end of the Introduction in section 2.2). Section 5 presents conclusions and recommendations. Much of the analysis and discussion is applicable to a range of policy areas, but the focus is upon discounting as it relates to environmental projects, programmes and policies. Special attention is given to impacts within the OECD strand of work on the costs of inaction, described in Box 1 below, and discussed in section 2.1 below.

Box 1: OECD research programme on the costs of inaction

There are significant information gaps with respect to environmental impacts which are long-term in nature and for which costs are borne unequally between generations or between and within countries. This complicates the policy-making process – politicians have to make difficult choices on whether to adopt potentially expensive policies in the short-term without the full information on the long-term benefits of the policies, or in other words, what it would cost society to not implement the policy.

While considerable work has been undertaken on the costs of implementing a policy in specific areas, in many cases there is an inadequate understanding of the consequences of inaction in a number of environment-related areas. Given the existence of such information gaps and the importance of this information to policymakers, there is a need to assess the 'costs of inaction' in the environmental sphere. Although there is no unanimously accepted definitions of the 'costs of inaction', Johnstone (2005) provides an overview of the issues.

The OECD Environment Directorate is pursuing different strands of work on this issue in three areas: biodiversity and ecosystem services; climate change; and health impacts from pollution.

2.1 The significance of discount rates to the costs of inaction

In several environmental policy areas — biodiversity and ecosystem services, climate change, and health impacts from pollution, for instance — the costs of inaction now accrue in the far distant future. The choice of social discount rate is extremely important to the valuation of these types of costs of inaction.

This section considers the impact of different discount rate frameworks on estimates of (i) the social cost of carbon, (ii) the valuation of forestry and of (iii) health impacts from pollution. Results are shown

[2] This is not to suggest that the discount rate is a choice variable that policy analysts can simply select according to their preference. The discount rate, as discussed at length below, is a function of expectations about the future state of the economy and some ethical parameters.

in Table 1. The difference in results can be several orders of magnitude, and make the difference between a project passing and failing cost-benefit analysis. Even apparently small changes, such as moving from a constant 3.5% discount rate to the gradually declining scheme beginning at 3.5% (HM Treasury, 2003) can make a substantial difference.

Table 1: Examples of the impact of the discount rate on the costs of inaction

Discounting scheme	**SCC estimate**[8]	**120-year Oak plantation**	**1% $PM_{2.5}$ reduction**
6% constant	2000 US$ 4/tC	-£1,300/ha	£31 billion
3.5% constant	2000 US$ 10/tC	-£320/ha	£82 billion
HM Treasury (2003)	2000 US$ 11/tC	£260/ha	£93 billion

2.1.1 Estimating the costs of inaction on climate change

The social cost of carbon ('SCC') is a monetary indicator of the global marginal damage done by the emission of one extra tonne of carbon dioxide today. It measures the net present financial value of the climate change damages avoided and as such is related to the cost of inaction on climate change.[3]

Estimating the SCC is an extraordinarily difficult exercise, requiring long-term forecasts of climate impacts and their monetary valuations, coupled with long-term forecasts of general economic conditions in the global economy. Clearly, there are extraordinarily levels of uncertainty in both endeavours. Nevertheless, some estimate of the social costs of inaction is helpful in the economic analysis of climate policy. The SCC is generally estimated by employing an integrated assessment model, which combines a scientific model of global warming with a socio-economic model of the underlying value of the impacts. Provided the change being evaluated is marginal, the present value of the damage done by emitting a tonne into the atmosphere can be determined by discounting the stream of expected future impacts. This stream of damages extends centuries into the future because carbon dioxide is resident for extremely long periods in the atmosphere.[4] Most integrated assessment models examine impacts over at least one century, many consider two or three centuries. The particular schedule of discounting rates (and hence discount factors) deemed appropriate for the calculation has a significant influence on the final estimate.

Differences in the discounting schemes assumed by different modellers are one of the major drivers of variability in the estimates of the SCC (Tol, 2005). Traditionally, constant discount rates have been employed, although modellers have more recently begun to consider declining discount rates as being more suitable for long-term problems such as estimating the marginal damage costs of greenhouse gas emissions (Pearce et al., 2003; Groom et al., 2005; Guo et al., 2006).

Based upon some relatively rough calculations, Pearce et al. (2003) find that shifting from a constant social discount rate of 6% to 4% roughly doubles the estimate of the social cost of carbon. Moving from 4% to the declining discount rate scheme proposed in Weitzman (2001) would roughly double the estimate again.[5] By way of illustration, some more estimates are provided in Table 1, including results under the

[3] The precise relationship between the 'social cost of carbon' and the 'costs of inaction' depends upon the particular definition of the latter. However, the purpose of this section is to illustrate the significance of the discount rate to long-term environmental problems, rather than engage in these definitional issues.

[4] Sometimes this notion is expressed in terms of a carbon half-life (the time taken for half the amount of carbon dioxide to be removed from the atmosphere by natural processes). However, the half-life concept is not appropriate for atmospheric carbon dioxide, due to the complexity of the carbon cycle and the possibility of feedbacks (Cox et al, 2000).

[5] See Section 1.4.2 below on the underlying reasons for the declining discount rate proposed by Weitzman (2001).

HM Treasury (2003) declining discount rate scheme.[6] Even these relatively small changes in the discount rate have extremely important implications for climate policy.

More sophisticated research confirms the sensitivity of climate policy to the discount rate, and indicates that the particular specification of the discount function is critical. Guo et al. (2006) conduct a sensitivity analysis on FUND (Climate Framework for Uncertainty, Negotiation and Distribution), one of the leading integrated assessment models. Testing a range of relatively plausible discounting schemes in the model produces variations in the social cost of carbon by up to a factor of 40, depending upon the particular scenario. Paying extremely close attention to discounting appears to pay important intellectual dividends in valuing the costs of inaction on climate change.

Finally, it is worth reemphasising an important caveat on the use of discounting with climate change damages. Conventional consumption discounting in cost-benefit analysis rests on the assumption that the project being evaluated is marginal — that is, it will not itself substantially alter economic conditions and the corresponding set of prevailing prices. This assumption is appropriate, for instance, when evaluating a particular wind farm or mitigation project. Indeed, almost all projects satisfy this condition. However, major shifts in climate change policy could change the structure of the economy, thus repudiating the assumption of marginality. Under these circumstances, the convenient “short cut” of applying a standard consumption discount rate in cost-benefit analysis is inappropriate, because the project itself alters the appropriate discount rate. Evaluation of the costs and benefits of large changes to global climate policy must rest upon a full comparison of different flows of welfare, using an integrated assessment model or a computable general equilibrium (CGE) model, in order to allowing for the fact that economic conditions are endogenous to non-marginal climate change.[7]

2.1.2 Valuation of forestry

Forestry is another important long-term environmental policy area. Forestry provides humans with a range of long-term benefits, including direct use values (e.g. timber products, extraction of genetic material, tourism), indirect use values (e.g. protection of watersheds, support of other ecosystems and carbon storage), option values and non-use values (i.e. existence or passive use values). Some of these services, especially those derived from genetic material and carbon storage, provide benefits to generations living well over 100 years in the future.

Hepburn and Koundouri (2006) examine the impact of applying constant and declining discount rate schemes to the economic viability of maintaining managed forests. The analysis accords entirely with intuition — high discount rates can imply that investing in forests for harvest in the far-distant future does not pass cost-benefit analysis.[8] On the other hand, forestry can comfortably pass a cost-benefit analysis with low and/or declining discount rates. For instance, discounted cash flow of a 120 year horizon investment in a plantation such as a Scottish Oak, the discounting scheme is critical. At both a constant 6% and 3.5% discount rates, the scheme fails cost-benefit analysis, while it passes when the declining

[6] Note that these estimates of the social cost of carbon are intended only to illustrate, very roughly, the significance of different discounting schemes. The estimates reflect a particular set of assumptions, do not reflect the full spectrum of uncertainty, and are certainly not advanced as accurate or robust estimates or the true social cost of carbon.

[7] See Hepburn (2006) for a brief explanation and Stern et al (2006) for a very detailed explanation and application of this approach to evaluating the costs of climate change under different climate policies.

[8] Pearce et al. (2002) state that ‘[h]igh discount rates in logging practice mean that there is little or no incentives to replant after one rotation, especially as there remains a substantial ‘frontier’ of unlogged forest to which the logging company can move’.

discount rate scheme adopted by HM Treasury (2003). Declining discount rate schemes are discussed further below.

2.1.3 Valuing the health impacts of pollution

The discount rate is also critical to valuing the health impacts from local air pollution when the impacts are felt in the distant future. Long time horizons can be relevant for two reasons. First, some pollutants are persistent, remaining in the local environment for years, if not decades. Second, some of the health impacts of pollution occur from long-term exposure or are only experienced decades after exposure. As such, any assessment of the costs and benefits of air pollution policies necessitates trading off the costs of reducing pollution now against the benefits of better health, and more life years, decades into the future.

Making sensible trade-offs is facilitated by economic valuation of the costs and benefits. Valuing the costs of inaction for future mortality risks from air pollution involves the following steps: predict future mortality risks (and life expectancy) in the absence of changes in air pollution for the population affected; create an alternative scenario where changes in air pollution lead to changes in mortality risk (according to available scientific evidence); compare predicted life expectancies between the scenario without pollution changes and the alternative scenario. After calculating the difference in life years between the two scenarios (in each separate year), and converting life years lost into monetary equivalents, the net present value is calculated by applying a particular discounting scheme. [9]

To provide a specific example, this approach might be employed to evaluate the health benefits of a policy that would reduce fine particulates ($PM_{2.5}$) in England and Wales by 10 $\mu g/m^3$ from 2010 through to 2109.[10] As Table 1 illustrates, the discount rates scheme adopted is enormously important to the final estimate of the health benefits of this policy. Moving from a 6% discount rate to the HM Treasury (2003) scheme triples the relevant valuation of the policy.

2.2 Current state of government guidance

Given the significance of the choice of discount rate, this paper investigated current discounting guidance in OECD countries. Section 4 reports the detailed findings that emerge from our information requests, described in Table 2. The findings are interesting. A significant, and perhaps troubling, finding is that many governments still do not appear to provide central guidance on discounting. Yet central guidance is important to ensure consistency between policies and between departmental evaluations, as was emphasised by OECD (1997) and re-emphasised by OECD (2004).

Where governments have taken the time to produce discounting guidance, it is generally appropriately based on the social rate of time preference. The specific discount rates adopted differ between OECD governments, although this may partially be due to different preferences and expectations about future economic growth. Two OECD governments — France and the United Kingdom — have implemented discounting schemes that reflect future uncertainty through a declining social discount rate.

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[9] There is a long-running debate about appropriate discounting practice for health benefits. There may be reasons to believe that the marginal utility of improved health is relatively independent to income, which would imply that discounting at the *utility* discount rate is an appropriate short-cut. However, the robust approach is to convert health effects into their monetary (i.e. consumption) equivalents, and then to discount at the consumption discount rate. There is further discussion of these issues in section 3.2.

[10] I am grateful to Brian Miller and Fintan Hurley at the Institute of Occupational Medicine, Emma Powell at UK Defra, Heather Walton at UK Department of Health, and Paul Watkiss for making available their data and research, which underpins the valuation process and results described above. Their more detailed analysis is expected to be available in April 2006 as part of the UK Government's Air Quality Strategy Review.

Table 2: Information obtained on current practice[11]

Country	OECD Response	Academic Response	Information contact/source	Summary of Guidance on Discounting
Australia		✓	Hollway.ben@finance.gov.au	Varies across the Australian States and depends on the type of project
Austria		✓	Andreas.Mayrbaeurl@bmf.gv.at	No standardised discount rate
Belgium			—	—
Canada	✓		luis.leigh@ec.gc.ca	TBS: 10% (sensitivity at 8% and 12%); Environment Canada: 7% (5% and 9%)
Czech Republic	✓		analyzy@env.cz	Ministry of Environment 1% (real, risk-free government borrowing rate)
Denmark	✓		lis@mst.dk	3% discount rate (SRTP), but ministry of finance employs 6%
European Commission	✓		Robin Miege	4% based on gilt yields and LIBOR rates, but 'reflects social time preference'
Finland	✓		timo.parkkinene@ymparisto.fi	Discounting not widely used; 5% (Ministry of transport and communications)
France	✓		elisabeth.langella@sgae.gouv.fr	4% for t < 30 years, 2% for t > 30 years since Jan 05 (reviewed on 5 year cycle)
Germany			—	—
Greece			—	—
Hungary		✓	marton.peresztegi@pm.gov.hu	Depends upon the shape of the HUF and Euro zero coupon yield curves
Iceland			—	—
Ireland	✓		Fiona_Quinn@environ.ie	5% for all public projects, as set by Department of Finance. Reviewed regularly.
Italy			—	—
Japan			—	—
Korea (South)			—	—
Luxembourg	✓		Eric.Debrabanter@mev.etat.lu	Cost benefit analysis is not employed by the Ministry of Environment
Mexico			—	—
Netherlands			—	—
New Zealand	✓		matthew.hickman@mfe.govt.nz	10% discount rate, with sensitivity analysis. Lower rates in some cases
Norway	✓		Bent.Arne.Sather@md.dep.no	
Poland			—	—
Portugal			—	—
Slovak Republic	✓		kolocany.frantisek@enviro.gov.sk	5% discount rate based on EU guidance
Spain	✓		mjfuente@mma.es	5% discount rate, except for water infrastructure (4%), based on EU guidance
Sweden		✓	ola.jornstedt@naturvardsverket.se	4% discount rate, to be reviewed in May 2006
Switzerland		✓	daniel.wachter@are.admin.ch	No standardised discount rate.
Turkey		✓	ykilic@dpt.gov.tr	The discount rate is the interest rate on debt finance for the specific project
United Kingdom		✓	HM Treasury (2003)	3.5% rate (SRTP) for first 30 years, then declining schedule
United States	✓	✓	OMB (2006)	3.0% or 7.0% depending upon type of cash flow, lower rates for longer-term.

[11] Complementary results from previous surveys are presented in Annexes 1-3.

3. The theoretical basis for discounting

This section provides an overview of the theory of discounting. First, we outline the concept of discounting, and explain why "not discounting" is inappropriate. Second, several common misconceptions about "adjusting" discount rates for environmental projects are clarified. Third, theoretical reasons for using declining discount rates are discussed. Problems of time-inconsistency are discussed, and conclusions are drawn on the merit of employing a time-varying discount rate. Guidance is provided on determining the appropriate time-varying discount rate for a particular country.

3.1 The case for positive discount rates

Projects, programmes and policies in all areas of government, including the environment, generally involve incurring costs now in return for benefits in the future. Evaluation therefore requires a mechanism to convert costs and benefits at different points in time into a common unit, which is normally the equivalent amount today (the "present value").

In social cost benefit analysis, a social discount factor, *D(t)*, is used for this purpose. The discount factor is normally set to unity for costs and benefits today, and is less than unity for costs and benefits in the future. The annual rate of decline in the social discount factor, *D(t)*, is given by the social discount rate, *s(t)*. The two are connected by the equation:

$$D(t) = \frac{1}{(1+s)^t} \qquad (1)$$

Using a constant and positive social discount rate implies that the discount factor declines approximately exponentially.[12] For instance, if the discount rate is 10% per annum, then the discount factor is 1.0 now, 0.62 in five years, and 0.38 in ten years, implying that a benefit of \$100 in ten years time is equivalent to \$38 today. Thus, employing a positive discount rate places a lower weight on cash flows in the future than cash flows today.

Using a positive discount rate is commonly justified by two reasons. First, people generally prefer to have good things earlier rather than later. Second, because capital is productive, savings yield positive returns that allow us higher consumption in the future than today.[13] If we expect consumption to increase over time (as it has done over the past century), diminishing marginal utility of consumption implies that additional consumption in the future is less valuable than it is today. These two reasons are reflected in the recommended approach to social discounting (Lind, 1982, p 89), which is to employ the *social rate of time preference*, so that the discount rate, *s*, is given by:

$$s = \delta + \eta g \qquad (2)$$

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[12] The continuous time analogue of the discount factor is the discount *function*, given by $D(t) = \exp\left[-\int_0^t s(\tau)d\tau\right]$, and if s is constant this is D(t) = $\exp(-st)$.

[13] Productive capital implies that current consumption is more expensive than future consumption. This being the case, there would be no current consumption (100% saving) if (1) people preferred earlier consumption to later consumption; or (2) it is expected that future consumption levels will be higher, so that future increments of consumption are less valuable.

where δ is the utility discount rate (or the rate of pure time preference), η is the elasticity of marginal utility and g is the rate of growth of consumption per capita.[14] In general, the appropriate social discount rate, s, in equation (2) is *not* constant over time, but is a function of the expected future rate of consumption growth, g. For instance, if it were known with certainty that future consumption growth will be cyclical, then the appropriate social discount rate should vary to reflect those cycles.

The approach described above — using the social rate of time preference — is conceptually distinct from using market interest rates.[15] There are at least four arguments why the social rate of time preference is to be preferred for social decision-making to market interest rates:[16]

1. *Market imperfections*. Market prices often give a misleading signal of value as a result of a sub-optimum distribution of income or because of other distortions in the economy, such as externalities, government taxation, imperfect information and the exercise of market power (Drèze and Stern, 1990). Under such conditions, market prices do not reflect the "shadow price", or the true social opportunity cost of the resource.

2. *Super-responsibility*. The government arguably has a responsibility to both current and future generations, and markets do not fully (if at all) reflect the preferences of generations in the distant future. Current markets, such as long-term bond markets, may reveal something about the preferences of the present generation towards future generations. However, even these markets do not (because they cannot) reflect the preferences of a generation which is not yet born.

3. *Dual-role*. The members of the present generation in their political role may be more concerned about future generations than their day-to-day activities on current markets would reveal.

4. *Isolation argument.* Finally, Sen (1982) argues that individuals may be willing to join in a collective savings contract, even though they are unwilling to save as much in isolation.

Although some of these positions generated heated argument, the overall view clearly emerged that simply using the real risk-free market rate of interest is inappropriate for social discounting.[17] This, of course, does not mean that market interest rates are irrelevant. When public investment simply crowds out private investment, the opportunity cost of that investment is the market interest rate. However, public expenditure displaces private expenditure to a different extent depending upon the particular investment, and Lind (1982) recommends accounting for crowding-out effects 'by directly analyzing the magnitude of these effects and the converting them to their consumption equivalents through the use of a shadow price on capital.'[18]

[14] Equation (2) is a short cut reflecting several assumptions: welfare is additive, the project being evaluated is marginal (see section 2.1.1), and that population is not dramatically changing over the course of the project.

[15] Although conceptually distinct, the results from the two different approaches turn out to be rather similar, as Arrow (1995) notes.

[16] See Sen (1982), who notes that this issue was debated vigorously in the late 1950s and 1960s, and cites 19 papers on the topic.

[17] See Lind (1982) for a clear statement of the consensus view emerging from the influential 1977 conference on the topic. See also Arrow (1995) expressing the same view.

[18] See also Feldstein (1964). This shadow pricing approach is not currently used in the UK (HM Treasury, 2003), reflecting a mix of practicability and the view that the real risk-free interest rate and the shadow discount rate are quite close in magnitude (Spackman, 1991; Pearce and Ulph 1999). See also Arrow (1995).

The discount rate, s, in equation (2), is the rate at which we discount future *cash* flows. It is referred to as a *consumption* discount rate. In contrast, δ is the rate at which future *utility* (or wellbeing) is discounted.[19] Notice that even if the utility discount rate δ is zero — so utility now and utility in the future is given equal weight — the social discount rate is still positive if $g > 0$ and η □0.

Over the last few centuries, OECD countries have, on average, experienced positive consumption growth (so $g > 0$) and many studies of human behaviour show that the marginal elasticity of utility is positive (so η □0), because people are risk averse and tend to smooth consumption. As such, unless there is a major structural break in the economy such that future consumption growth will be negative, it is difficult to argue against a positive consumption discount rate. Such an argument would probably rely on extreme pessimism about the possibility of future environmental degradation negatively impacting upon economic growth and wellbeing.

In contrast, a credible argument for employing a zero *utility* discount rate ($\delta = 0$) can be advanced, based upon the ethical position that the weight placed upon a person's utility should not be reduced simply because they live in the future. Indeed, a string of eminent scholars have famously supported this position, including Ramsey (1928), Pigou (1932), Harrod (1948) and Solow (1974), and even Koopmans (1965) expressed an `ethical preference for neutrality as between the welfare of different generations'. In a major review of climate change economics, Stern et al (2006) find these ethical arguments to be persuasive, and do not discount the future simply because it is the future.

This is not the only ethical view, however. Arrow (1999) argues that impartiality between generations is less appealing than 'agent-relative ethics'. Under agent-relative ethics, we owe special duties to those close to us, such as family and friends, and care less about the utility of those who are distant from us.[20] If accepted, this ethical position would require discounting the future with higher (positive) utility discount rates. While 'agent-relative ethics' is arguably easier to reconcile with actual behaviour, philosophers might question whether intergenerational ethics should be determined by reference to the revealed behaviour of the current generation.

Irrespective of such ethical debates, there is an additional credible argument for using a positive (but probably very small) utility discount rate.[21] First, at each moment in time, there is a small possibility that human civilisation will cease to exist (perhaps due to an asteroid striking Earth or a nuclear accident). A (probably very small) positive utility discount rate would account for these risks. Stern et al (2006) accepts this argument, and employs a discount rate of $\delta = 0.1$.

3.2 The use of 'special' environmental discount rates

The social discount factor at a given point in time reflects the weight placed on general *cash flows* (or their equivalent) at that point in time. If environmental impacts are monetized and incorporated into a cost benefit analysis, they should be discounted using the discount factors applied to other costs and benefits. Conceptually, this is because the discount rate reflects the *general* social rate of time preference, applying to the economy as a whole. Different discount rates should not be employed for different goods. Changes in the re*lative* prices of goods or services should, of course, be taken into account in the cost benefit analysis. But this should not be achieved through ad hoc adjustments to the discount rate.

[19] Utility is used roughly to refer to wellbeing.

[20] Schelling (1995) expresses a similar position.

[21] For a more detailed review, see Hepburn (2006).

Despite the fact that the social discount rate reflects general social preferences, there are several reasons that are occasionally advanced for using a 'special' discount rate for environmental benefits. We examine the merits of five arguments here.

3.2.1 Health and the environment are "different"

Some people argue that discounting non-monetary benefits, such as health or environmental benefits, is different to discounting monetary impacts. One version of this argument is advanced by Revesz (1999), who asserts that the justification for discounting money arises because (1) it can be invested; and (2) people are impatient. He notes that human lives cannot be invested, so the first rationale fails. He accepts the second rationale may provide a justification for discounting, but even then, it is argued, the discount rate should be extremely small.

While human lives cannot be invested, the resources used to save lives (or to reduce risk) can indeed be invested in a variety of ways, and the role of discounting in cost-benefit analysis is precisely to determine which of those investments is more efficient. As such, once health or environmental impacts have been translated into their monetary equivalents, there is no reason not to discount such impacts (Sunstein and Rowell, 2005).

Revesz's argument appears similar to the idea that health and environmental benefits should be discounted at the *utility* discount rate. This would be appropriate if the marginal utility of good health, safety and the environment is not a function of income. Effectively, this requires that the willingness to pay for health, safety and the environment increases precisely at rate $\eta.g.$[22] If this assumption holds, then it is an appropriate short cut is to discount health and environmental benefits at the utility discount rate.

Of course, this is an *assumption* about future valuations of a particular category of goods (health, safety and a pleasant environment). It appears to be a plausible assumption, but ideally it would be empirically investigated. Indeed, many of the arguments in this area actually reflect different assumptions about future *valuations* of particular goods, rather than the process of *discounting* the valuations derived. Many people have a sense that the value we place on health and environmental impacts will increase over time. Hoel and Sterner (2006) remind us that the relative price placed on environmental goods will increase as environmental goods become more scarce.[23] As we now discuss, this phenomenon (if correct) should certainly be accounted for in valuing health and environmental impacts, but not by adjusting the discount rate.

3.2.2 Heath and the environment will be valued more highly as incomes rise

A strong case can be made that the real value of many environmental assets, such as biodiversity and ecosystem services, will grow exponentially over time. This might be because environmental services are luxury goods in a world where incomes are increasing each year.[24] Alternatively, this may be because environmental assets are anticipated to become scarcer over time (Hoel and Sterner, 2006). These are

[22] If the monetary valuation of a health impact is a function of $e^{(\mu g)t}$ and is discounted at $e^{-(\delta + \mu g)t}$, then the net mathematical result of discounting an increasing valuation is $e^{(\mu g)t}.\ e^{-(\delta + \mu g)t} = e^{-(\delta)t}$, which reflects utility discounting.

[23] Hoel and Sterner (2006) also make the more sophisticated argument that factoring in the change in relative prices of environmental goods should affect the general discount rate for the whole economy. They examine a two sector economy, so that the applicable discount rate is a function of the growth rate in both sectors. If one sector produces the environmental good that becomes more scarce over time, then the appropriate discount rate is a function of the relative value share of the environmental sector and the elasticity of substitution.

[24] Luxury goods are goods on which we spend an increasing proportion of our income as we become more wealthy.

important considerations in determining the appropriate valuation of such environmental goods and services at each point in time, for use in social cost benefit analysis.

If the expected rate of growth in value of these assets is constant, then accounting for these considerations is mathematically equivalent to using a lower discount rate for those assets. However, it is not conceptually equivalent. Horowitz (2002) notes that using a lower 'net' environmental discount rate 'obscures the fundamental issues' and confusingly rolls two distinct concepts into one.[25] Expected changes in the valuation of environmental goods should be accounted for by increasing the benefits of environmental protection directly, before a *general* social discount rate is applied. This is because, as indicated above, the social discount rate reflects the general rate of time preference in society and expectations about future growth rates. As such, it is conceptually accurate to account for increasing valuations of environmental assets directly in the cost benefit analysis, then to discount every cost and benefit using the same framework.

3.2.3 The environment exhibits critical irreversibilities

Second, many ecosystems exhibit both non-linear behaviour and irreversibility, where crossing a natural thresholds results in permanent environmental damage (such as species loss). On a global scale, anthropogenic emissions of greenhouse gases are changing the climate in a way that might also turn out to be irreversible — significant damages are considered likely. In this context, investment in environmental protection provides a form of insurance, because the payoff from such investments shows a negative covariance with environmental and economic shocks.

The insurance value of such environmental investments is important, and must be accounted for in cost benefit analysis. However, there is a 'popular misconception that sometimes creeps even into professional discussions of risk and investment. It is that when evaluating an investment with uncertain returns over time, one can appropriately adjust for the riskiness of the investment…by simply adjusting the discount rate' (Lind, 1982). The risk and insurance features of an investment should be evaluated on the ledger of the cost benefit analysis, but should not be accounted for by adjusting the general social rate of time preference. For instance, as Nordhaus (1997) points out, the precautionary benefits of climate change mitigation 'does not lead to a different *time discount rate* but to a high *price of climate change*.'

3.2.4 Discounting for intergenerational problems

Why should a human life in 2100 be valued at a vast discount to a life today? There is certainly a good argument for the ethical irrelevance of one's date of birth. However, as discussed above, discounting allows us to determine whether the resources used to save lives are being used most efficiently. If the (undiscounted) cost of life saving is the same today and in 2100, discounting simply reflects the fact that if $X saves one life today, it could be invested and applied to save many more lives in 2100.

Clearly, discounting is useful in intergenerational problems. That said, there is an intuitive difference between intertemporal valuations by individuals within their own lifetimes, and valuations across different individuals, possibly over different generations. While individual impatience is a sound reason for discounting over the course of an individual life (partly because an individual cannot expect to live much beyond 100 years), individual impatience is less appropriate for social decision-making, where human society will hopefully continue to exist for at least several millennia into the future.

[25] Note that Horowitz (2002) appears to misinterpret Weitzman (1994) as arguing for a different discount rate to be employed for environmental benefits, on the basis that our willingness to pay for such benefits will increase over time.

Sunstein and Rowell (2005) argue that "the moral obligations of current generations should be uncoupled from the question of discounting, because neither discounting nor refusing to discount is an effective way of ensuring that those obligations are fulfilled." Unfortunately, it is simply not possible to uncouple ethical questions from discounting. Using market interest rates to set the social discount rate is inappropriate, as discussed above, because market rates simply aggregate the preferences of *current* individuals, about their *current* decisions. While market rates reflect a degree of altruism towards future generations (because savings partly reflect the bequest motive), market rates also reflect individual impatience, based on the normal human life span. They do not reflect the interests of future individuals (who do not participate in current markets), and nor do they necessarily fully reflect the preferences of current individuals about intergenerational matters. For the reasons advanced in section 3.1, while market rates may be a rough approximation, they are conceptually distinct to social discount rates. The social rate of time preference inevitably reflects ethical issues — sidestepping these issues is impossible.

Nevertheless, the second clause of Sunstein and Rowell's sentence is correct — using discounted cost-benefit analysis to achieve efficiency in no way guarantees that moral obligations are fulfilled. As such, Sunstein and Rowell make the sensible proposal that cost-benefit analysis with discounting should be employed for intergenerational problems, with the caveat that we should take any necessary extra measures to account for the fact that preferences revealed on current markets do not necessarily reflect social preferences towards intergenerational questions.

3.2.5 Different discount rates for different time horizons

In the past, governments have recommended employing different discount rates as a function of different time horizons. Such differential rates were probably motivated by concerns about intergenerational equity. While addressing such concerns by reducing the discount rate may have appeared to be, and in many cases was, entirely ad hoc, recent economic theory has provided a rigorous basis for a practice which appears quite similar. Section 3.5 outlines theory incorporating future economic uncertainty into discounting guidance, which leads to the recommendations that discount rates should decline (continuously) as time horizons increase.

The use of constant discount rates that fall with the time horizon is inferior to the use of a continuously declining discount rate, or at least a discount rate that is reduced *at the margin* in step changes as time passes. For instance, under the UK HM Treasury (2003) scheme, a discount rate of 3.5% is applied from years 0-30, then a 3% discount rate is applied subsequently from years 31-75.

3.2.6 Conclusion

In sum, there are no compelling arguments for using a different discount rate for environmental projects to other projects in the economy. While environmental projects often generate unusual and important benefits (such as protection of increasingly scarce assets and the provision of insurance), such benefits should be accounted for directly rather than by adjusting the general social rate of time preference.

3.3 Arguments for and against declining discount rates

In recent years, economic theorists have reemphasised that there is no particular requirement to employ constant discount rates. Indeed, we should not, generally speaking, expect the appropriate social discount to be constant over time (see section 3.1). The discount rate depends upon the expected future rate of consumption growth, $g(t)$, which will change as time passes. If consumption growth is expected to fall in the future, the consumption discount rate should fall as well, *ceteris parabis*.

This section presents recent economic theory suggesting that discount rates should gradually decline over the long run (Groom et al., 2005). The rationales for time-declining rates are varied, reflecting a somewhat confusing mix of positive and normative reasons, and are often complex. Probably the most important rationale concerns the efficient discount rate when the future is uncertain.

Two types of justification for declining social discount rates are examined. The first type is based upon determining the *efficient* social discount rate. Here we consider falling economic growth rates (1.4.1), heterogeneity in future preferences (1.4.2), and uncertainty about future economic conditions (1.4.3). The second type of justification is based upon intergenerational equity (1.4.4).[26]

3.3.1 Falling economic growth rates

If we knew for certain that future economic growth rates would gradually fall, perhaps due to increasing environmental problems, the appropriate social discount rate would also decline through time. If decreases in the *level* of consumption are expected — so that consumption growth is negative — the appropriate social rate of time preference could even be negative. However, for this to occur, either capital must be unproductive or a distortion, such as an environmental externality, must have driven a wedge between the market return to capital and the consumption rate of interest (Weitzman, 1994). This would seem unlikely given the economic performance in the OECD over the last century.

3.3.2 Changes to future preferences

Just as socially acceptable behaviour changes over time, so do individual and social preferences. How might the preferences of future generations be different from the current generation? Do we expect future generations to be more or less patient than we are? Greater patience would imply a falling utility discount rate, δ, and a declining discount rate.[27] However, there does not appear to be good basis for believing future generations to be more patient than we are.

Will we be prepared to accept larger risks, and be less susceptible to fluctuations in consumption as we become more wealthy? There is some cross-sectional evidence to suggest this. For instance, wealthy people invest a higher proportion of their capital in risky asset classes. In terms of equation (2) this means that the elasticity of marginal utility, η, falls as we become more wealthy. However, time series data would be needed to understand whether this is an absolute effect (η falls as wealth rises), or a purely relative effect (η falls as people become richer than others). If it is an absolute effect, and if consumption continues to grow ($g > 0$), the elasticity of marginal utility, η, will decline as time passes and, *ceteris paribus*, so would the social discount rate.

3.3.3 Heterogeneity in future preferences

If people have different preferences (which they do), and we aggregate these different preferences to produce a social preference, then the corresponding collective discount rate will decline over time under certain conditions. Gollier and Zeckhauser (2005) investigate this possibility, determining optimal

[26] For the argument for a declining social discount rate derived from heterogeneous preferences, see Gollier and Zeckhauser (2005).

[27] Recall that the social rate of time preference (see equation (2)) is a function of three variables: future consumption growth, g, the utility discount rate, δ, and the elasticity of marginal utility, μ. Consumption growth is easy to measure and forecast. The other two variables, δ and μ, reflect individual preferences, which are more difficult to measure. For the reasons expressed in section 1.1, even if these preferences can be measured, this information may not be appropriate for decision-making at a social level.

collective decision policy when individuals have heterogeneous (and constant) utility discount rates.[28] They find that provided individuals have "decreasing absolute risk aversion" the optimal collective policy is to employ a declining utility discount rate. Decreasing absolute risk aversion is roughly the same condition in section 3.5.2 above, requiring that the share of wealth invested in risky assets increases with income (Ogaki and Zhang, 2000). . It seems to be a plausible assumption.

This result is derived from two key insights. First, the efficient collective utility discount rate is a weighted average of the individual utility discount rates, where the weights are proportional to each individual's tolerance to consumption fluctuations. Second, the most impatient members of society should consume plenty at the beginning, with the patient members consuming more later. More patient individuals will therefore have a higher rate of consumption growth. Under plausible assumptions,[29] the tolerance to fluctuations of patient individuals increases over time, relative to impatient individuals.

So, the weights on discount rates are proportional to tolerance to fluctuations; and the tolerance of patient individuals increases over time. It follows that the weight placed on patient individuals increases as time passes, so the collective *utility* discount rate decreases with time.

Incidentally, analogous mathematical logic can be applied to *uncertainty* in future preferences, rather than *heterogeneity*. (This is because both issues require the aggregation over a distribution of preferences.) Just as in Gollier and Zeckhauser (2005) the argument can be made that if we are uncertain about future generations' preferences, over time, increasing weight would be placed on the scenario with the lowest social discount rate. The intuition behind this claim should become clearer in the following section.

3.3.4 Uncertainty about future economic conditions

Future economic conditions are perhaps even more uncertain than future preferences, and it is an understatement to say that we can have little confidence in economic forecasts several decades into the future. Ignoring this background uncertainty in social cost-benefit analysis can produce misleading results.

Suppose that the future comprises two equally likely states with social discount rate either 2% or 6%. Discount *factors* corresponding to these two *rates* are shown in Table 3. Recall that the discount *factor* is the weight placed on cash flows in future time periods, while the discount *rate* is the speed at which the discount factor declines from one to zero. The average of those discount factors is called the 'certainty-equivalent discount factor', and working backwards we can find the 'certainty-equivalent discount rate'. In the example in Table 3, the certainty-equivalent discount rate starts at 4% (the average of 2% and 6%) and declines gradually to 2% as time passes.[30]

Table 3: Numerical example of a declining certainty-equivalent discount rate

Time (years from present)	**1**	**10**	**50**	**100**	**200**	**400**
Discount factor for 2% rate	0.98	0.82	0.37	0.14	0.02	0.00
Discount factor for 6% rate	0.94	0.56	0.05	0.00	0.00	0.00
Certainty-equivalent discount factor	0.96	0.69	0.21	0.07	0.01	0.00
Certainty-equivalent (average) discount rate	4.0%	3.8%	3.1%	2.7%	2.4%	2.2%

[28] There is plenty of empirical evidence supporting the claim that different people have different rates of time preference. Warner and Pleeter (2001), for instance, found that individual discount rates can vary between 0% and 30%.

[29] Namely the assumption of increasing absolute tolerance to consumption fluctuations. This means that people with higher level of consumption are more tolerant to fluctuations.

[30] The certainty-equivalent average discount rate is given by $s_c(t) = (1/D_c(t))^{1/t} - 1$, where $D_c(t)$ is the certainty-equivalent discount factor. See section 3.5 for more guidance on applying the theory.

The two key assumptions in this example are that the discount rate is uncertain and *persistent* (Weitzman 1998, 2001). Persistence means that periods of low (high) rates will tend to be followed by further periods of low (high) rates. The particular rate of decline in the discount rate depends upon how uncertain the future looks. Newell and Pizer (2003) try to model future uncertainty by using data on past US interest rates. They find a high degree of persistence in interest rates, which implies that we should employ rapidly declining certainty-equivalent discount rates. This has significant policy implications.

Along related lines, Gollier (2001, 2002a, b) analyses an optimal growth model, where a utility function is specified, and demonstrates that a similar result can hold. Under uncertainty, the social discount rate in equation (2) needs to be modified to account for an additional prudence effect:

$$s = \delta + \mu g - \frac{1}{2}\mu P \operatorname{var}(g) \qquad (3)$$

where P is the measure of relative prudence introduced by Kimball (1990). An individual is prudent if her willingness to save increases with increases in future income risk.[31] As such, prudence leads to `precautionary saving' when economic conditions are uncertain. Gollier (2002b) notes that a prudent society should care more about the future when it is more uncertain, and this is achieved by reducing the discount rate, so that more investment (favouring the future) becomes profitable.

The size of the prudence effect increases with uncertainty. Now because uncertainty increases with the time horizon, the precautionary argument applies even more strongly for more distant futures, implying a declining discount rate.

These two sets of results (Weitzman, 1998; Gollier 2002a, b) show that declining social discount rates are necessary for intergenerational efficiency and also for intergenerational optimality under relatively plausible utility functions.

3.3.5 Intergenerational equity and potential compensation

The previous sections have examined how using declining social discount rates is efficient, maximising the expected benefits to society. Incidentally, it happens that this places a greater weight on the future, reducing the apparent tension between efficiency and intergenerational equity.

Another set of papers directly confronts the issue of intergenerational equity. Chichilnisky (1996, 1997) introduces two axioms for sustainable development. These axioms demand that the level of consumption now and also in the very long run is considered. This leads to a very specific criterion which society should aim to maximise. Unfortunately, the Chichilnisky criterion does not have a solution under standard exponential discounting. Interestingly, however, it does have a solution when the utility discount rate, δ, declines over time, asymptotically approaching zero. So a declining utility discount rate is necessary to satisfy Chichilnisky's axioms of sustainable development.

Li and Löfgren (2000) propose a similar model which examines a society of two individuals, a utilitarian and a conservationist. The two individuals are assumed to discount the future at different rates — the conservationist employs a zero utility discount rate, while the utilitarian uses a standard positive discount rate. As with the model of Weitzman (1998), the result is that the long-run discount rate for society must tend towards the lowest discount rate, which in this case is the conservationist.

[31] Formally, an individual is prudent if the third derivative of her utility function is positive.

3.3.6 Conclusions

Arguments for declining discount rates are predominantly based upon efficiency under uncertainty/heterogeneity and intergenerational equity. In particular, uncertainty about future economic conditions is a very strong basis for using a declining social discount rate. [32] In addition to achieving efficiency, declining discount rates also reduce the conflict with considerations of intergenerational equity.

3.4 Time inconsistency problems

Employing a declining *utility* discount rate can give rise to problems of time inconsistency (Strotz, 1956).[33] Time inconsistency (or 'dynamic inconsistency') arises when a plan determined to be optimal at one date is no longer optimal when considered at a later date. In other words, the optimal plan depends upon the evaluation date. As such, unless a planner can commit future planners to the original plan, it will eventually be abandoned. Solow (1999) comments that this 'sounds like a poor way to run a railroad.'[34] Note that the problem of time inconsistency arises from time-varying utility discount rates – it does not arise for time-varying *consumption* discount rates when the underlying *utility* discount rate is constant.[35]

Faced with potential time inconsistency, a government without a commitment mechanism can formulate policy in a 'naïve' or 'sophisticated' manner. Neither situation is satisfactory. The sophisticated government takes into account the fact that future governments will have an incentive to deviate from its optimal (committed) policy. The situation may be modelled as an intertemporal game played with its successors. The government makes policy as the best response to successive government's best responses, retaining credibility and, as Barro (1999) and Karp (2005) illustrate, time-consistency.[36] The result, however, is not Pareto optimal. In contrast, the 'naïve' government presses ahead with dynamically inconsistent policy, ignoring the fact that future governments will find its policies to be sub-optimal. This is also clearly sub-optimal.[37] From the perspective of the current 'naïve' government, its optimal policy will not be adhered to.

Despite these results, several commentators do not consider time inconsistency to be a serious problem. Heal (1998) argues that time consistency is a 'most unnatural requirement' given that social decisions generally satisfy weaker rationality conditions than individuals do. Henderson and Bateman (1995) present a similar view. Spackman (2002) states that 'it is hard to see any serious philosophical or policy objection to [time inconsistency], if it reflects the considered preferences of people at the time that each decision is made.'

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[32] It was on this basis that the United Kingdom government has incorporated declining social discount rates in its most recent HM Treasury (2003) Green Book, which contains the official guidance on government project and policy appraisal.

[33] Heal (1998) proves that almost all types of declining utility discount rates generate time inconsistency problems.

[34] Hyperbolic discounting has been so successful precisely because this time inconsistency allows it to explain phenomena such as procrastination and addiction, where well-being is not maximised.

[35] The reason for the difference is that a changing *utility* discount rate reflects changing preferences. A changing consumption discount rate may reflect (fully anticipated) changes in material situation, which do not give any cause to adjust a well-designed plan.

[36] Interestingly, under certain conditions discussed by Barro (1999) this Nash equilibrium policy ends up being equivalent to a policy that would have been constructed using a conventional exponentially declining discount rate.

[37] Hepburn (2003), for instance, shows that a naïve government employing a hyperbolic *utility* discount rate in the management of a renewable resource can unwittingly manage the resource into extinction.

More importantly, it is worth reemphasising that the problem only arises when the *utility* discount rate is time-varying.[38] This is because a changing *utility* discount rate reflects changing preferences (and potential time-inconsistency). In contrast, a changing *consumption* discount rate may reflect (fully anticipated) changes in flows of wealth, which do not give any cause to adjust a well-designed plan. In contrast, incorporating uncertainty in economic growth rates, which is a more substantial issue, generates declining *consumption* discount rates. When the *consumption* discount rate is declining, although policy decisions are likely to suboptimal *ex post*, this does not make them time-inconsistent. Newell and Pizer (2003) remind us that in an uncertain world, decisions that are sensible *ex ante* often turn out to be regrettable *ex post*.

Finally, even if time inconsistency problems are produced by declining discount rates, as a practical matter it seems likely that such problems are likely to be substantially less worrying than policy reversals prompted by political or external shocks.

3.5 Applying the theory

3.5.1 Overview

Determining the applicable social discount rates for a country can be done in several different ways. The ideal approach is to estimate the future social rate of time preference. This involves three main steps: (i) develop a series of scenarios with different forecast pathways for δ, η and g; (ii) attach a probability to each scenario; and (iii) determine the corresponding certainty-equivalent discount rate. Remember that, generally speaking, the discount rate in each scenario will vary according to changes in the expected future growth rates.

Forecasting pathways for δ, η and g is a difficult exercise, especially since δ, η reflect social preferences. A good place to start with these variables is revealed individual preference, although the caveat that individual preferences do not necessarily represent social preferences should be borne in mind.[39]

3.5.2 Revealed preference evidence

Pearce and Ulph (1999) summarise various estimates and derive their own estimate of the social rate of time preference, which they find by looking at the evidence for the individual components. They divide the utility discount rate into two components — impatience and life chances. They conclude that the

[38] And even with declining *utility* discount rates, one might speculate, given the results in Gollier and Zeckhauser (2005), that there could be a way around the problem. There, although the collective policy shows a declining discount rate, it is not time-inconsistent. This is because each individual agent, with a constant utility discount rate, adopts a time-consistent consumption plan. As such, even though the social planner may be inclined to adjust the plan as time passes, each individual agent has no incentive to do so. So, in theory, decentralisation may effectively create a commitment mechanism that resolves the time inconsistency problem. How this would be implemented in practice is unclear. Perhaps different (but constant) δ could be employed for projects of different lengths?

[39] For instance, individual lifespans are generally under 100 years, yet the future lifespan of human civilisation will hopefully be substantially longer; see section 3.1. Even after accounting for individual's preferences for bequests to their children, there are arguably important differences between individual's private preferences (as revealed by current markets) and optimal social decision making.

component for impatience (the 'rate of pure time preference') lies between zero and 0.5% (best guess 0.3%), although they note that there is 'no clear view what the rate of pure time preference should be.'[40]

Interestingly, evidence from experiments suggests that humans use a declining utility discount rate, in the form of a `hyperbolic discounting' function.[41] For instance, although receiving a bonus in five years or five years and one day seem essentially equivalent, the difference between receiving it today or tomorrow is more tangible. While there are other interpretations of this evidence, such as similarity relations (Rubinstein, 2003) and sub-additive discounting (Read 2001), are possible, the evidence for hyperbolic discounting is relatively strong.

Pearce et al. (2003) present the argument that if people's preferences count, and these behavioural results reveal underlying preferences, then declining discount rates ought to be integrated into social policy formulation. Pearce et al. recognise, however, that the assumptions in this chain of reasoning might be disputed. First, as hyperbolic discounting provides an explanation for procrastination, drug addiction, undersaving, and organisational failure, the argument that behaviour reflects preferences is weakened. Second, Hume would resist concluding that the government *should* discount the future hyperbolically because individual citizens *do*. The recent literature on `optimal paternalism' suggests, amongst other things, that governments may be justified in intervening not only to correct externalities, but also to correct `internalities' — behaviour that is damaging to the actor.[42] Whether or not one supports a paternalistic role for government, one might question the wisdom of adopting a schedule of discount rates that explains procrastination, addiction and potentially the unforeseen collapses in renewable resource stocks (Hepburn, 2003).

The second component of the utility discount rate — 'life chances' — has been defined in different ways. For an individual, the definition is clear: 'life chances' reflect the background risk of death which justifies discounting future streams of consumption. For society, however, definitions vary. Pearce and Ulph (1999) correctly reject the view that it is simply an aggregation of the risk of death for individuals. Instead, they focus upon the 'life chances of whole generations' and calculate the proportion of a generation which will die each year. But for social decision-making spanning several generations, this may also be misguided. The relevant risk, for social decision-making, appears to be the risk of catastrophe eliminating society. As Dasgupta and Heal (1979) argue, `one might find it ethically feasible to discount future utilities as positive rates, not because one is myopic, but because there is a positive chance that future generations will not exist'.[43]

[40] Their estimate is based on Scott (1989), which has been derived from UK savings data. They also argue independently that equity reasons ague against a zero rate of pure time preference, but this does not appear to play a role in the estimation of δ. We discuss equity considerations in section 4 below.

[41] The shape of the discount function can be constructed by asking people to choose between a set of delayed rewards, such as money, durable goods, sweets or relief from noise: see, for instance, Thaler (1981), Cropper et al. (1994), Kirby (1997), Harris and Laibson (2001) and the reviews by Frederick et al. (2002) and Ainslie (1992). Evidence suggests that some animals do likewise: Green and Myerson (1996) and Mazur (1987) provide summaries of evidence on the behaviour of birds.

[42] Recent work on sin taxes by O'Donoghue and Rabin (2003) provides an example of this type of approach. See also Feldstein (1964), who asks whether the government should act in the best interests of the public, or do what the public wants.

[43] Conceptually, there is merit in the view expressed by Broome (1992) that such risks, while 'in a sense…undoubtedly a reason for discounting the wellbeing of future generations', should be accounted for separately, presumably on the ledger. There are good practical reasons, however, for including exogenous risks of calamity that do not vary from project to project in the discount rate, just as an individual would include a component for their personal 'life chances'. Such risks could theoretically be factored into estimates of future growth rates, but it is, in my

3.5.3 Employing proxies: past real interest rates

Although forecasting the future values of the components of the social rate of time preference is the 'ideal' approach, it is also rather difficult. An alternative is to assume that that future uncertainty in discount rates is reflected by the uncertainty in past interest rates. Based upon this assumption, there is a relatively straightforward recipe for determining the appropriate pathway of discount rates through time. Hepburn et al. (2006) employ such a recipe to estimate certainty-equivalent discount rates for Australia, Canada, Germany and the UK. The approach is to:

1. Obtain a long time series of past interest rates.

2. If necessary, adjust nominal interest rates for inflation to produce a series of real interest rates.

3. Remove crises or extreme events from the data series.

4. Smooth short-term fluctuations by determining a 3-year moving average of the real interest rates.

5. Take natural logarithms of the series to avoid negative interest rates.

6. Specify and estimate an appropriate econometric model (such as an autoregressive or regime switching model).

7. Test the model for misspecification etc

8. Derive the certainty-equivalent interest rate from the econometric model

Results for Australia, Canada, Germany and the UK are shown in Table 8 in Annex 4. Of course, there is little point in conducting this analysis if it expected that future discount rate uncertainty will not reflect past uncertainty, in which case society would be better served by the 'ideal' approach of constructing future scenarios, however imperfectly implemented this may be.

3.5.4 Three other issues: crowding out, opportunity cost and sensitivity analyses

Although we have focussed on determining the social rate of time preference (using proxies or otherwise), this does not mean that market interest rates are irrelevant. As noted early, if public investment crowds out private investment, the opportunity cost of that investment is the market interest rate. The impact of public spending crowding out private spending should be addressed, probably by converting any impacts into their consumption equivalents through the use of a shadow price on capital.[44]

An important function of social cost benefit analysis is to ensure that government invests in projects, policies and programmes that yield the highest public returns. Applying the social rate of time preference indicates whether a project, policy or programme would yield net social benefits. But within the set of projects that pass social cost benefit analysis, some projects will no doubt yield more benefits than others. When public resources are constrained, it is important that government implements the set of projects that yield the greatest benefits. This is, however, probably better achieved by examining measures of social

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view, neater to include them as a component in δ. Ultimately, wherever such risks are accounted for, the mathematical effect is identical to discounting the future.

[44] See also Feldstein (1964). This shadow pricing approach is not currently used in the UK (HM Treasury, 2003), reflecting a mix of practicability and the view that the real risk-free interest rate and the shadow discount rate are quite close in magnitude (Spackman, 1991; Pearce and Ulph 1999). See also Arrow (1995).

profitability (net present value, benefit cost ratio etc), rather than making ad hoc adjustments to the "hurdle rate" required before projects are accepted.

Finally, given the importance of the discount rate in social cost benefit analysis, some government guidance recommends conducting a sensitivity analysis on the discount rate. This can be a useful and informative process. The only caveat is that sensitivity analysis should not provide a justification for "choosing" the discount rate to allow politically favoured projects to pass social cost benefit analysis.

The next section looks at how OECD countries have actually determined their discount rates, examines current practice and asks whether different discount rates are employed for environmental or long term problems.

4. A review of government practice

This section reviews current discounting practice of OECD governments. This objective of this survey was to complement and update previous attempts to compile information on discounting practice, described in Annexes 1-3. Information requests were sent to all OECD 30 countries and the European Commission, through official and academic channels. Table 2 in the Introduction provides a summary of the responses, which numbered only 17 in total.

4.1 Information requests

Country delegates were asked the following questions.

1. What discount rates *are currently used* in your country? Since when have these discount rates been used? Do they apply across the entire country? What discount rates *were previously used*?
2. What is the *theoretical basis* for determining discount rates *(present and past)*?
3. What discount rates do your Ministries use for the evaluation of *environmental projects/policies?*
4. How are these environmental discount rates determined?
5. Are there circumstances in which you *discount costs and benefits differently* (or environmental costs and benefits differently to direct financial costs and benefits)?
6. Do you use special discount rates for projects/policies with *very long-run* costs or benefits?
7. Do you use *time-varying* discount rates? If *yes,* under what conditions?
8. Any other comments about discount rates, their application or implementation in your country?

4.2 Overview of country responses

4.2.1 Central guidance

Of the 31 entities contacted (30 countries and the European Commission) through both OECD and academic channels, only 17 responded with information on their discounting practice. Results are summarised in Table 2 in the Introduction. Guidance ranges widely throughout OECD countries, from some countries not employing cost-benefit analysis at all, to other countries with clear central guidance on discounting.[45]

4.2.2 Inconsistencies across departments

Furthermore, even when consistent guidance is in place, this does not necessarily imply that it is followed by the relevant departments. In most OECD countries central guidance is just that — guidance — and is not mandatory. For instance, in the United States agencies are not bound by OMB guidelines, and as such their practice has recently ranged from 10% at the EPA to 3% at the Food and Drug Administration (Sunstein and Rowell, 2005).[46] Similarly, discounting practice in Australia varied across different states. Informally, through academic channels it was suggested that such variation is likely in several other countries.

4.2.3 Inconsistencies within departments

Moreover, the discount rate used in practice is not necessarily consistent even *within* a particular ministries, departments and agencies. Previously, according to Sunstein and Rowell (2005), the United States, EPA had used three different discount rates for three different policies — 10% for emissions from locomotives, 7% for drinking water regulation and 3% for regulations of lead-based paint. There is anecdotal evidence that similar patterns of practice occur even in the United Kingdom, where there is a clear, central source of guidance in the HM Treasury (2003) Green Book. It would not be unreasonable to expect a similar, or perhaps even greater, degree of inconsistency in countries without central guidance on discounting.

4.3 Results

4.3.1 Conceptual foundation

A majority of the countries who responded to the survey used the social rate of time preference as the conceptual foundation for their discount rate. This was frequently estimated by reference to market rates. This probably reflects the resolution of the vigorous debates about the 'correct' discount rate by Lind (1982, p 89), who concluded that the recommended approach was to `equate the social rate of discount with the social rate of time preference as determined by consumption rates of interest and *estimated on the basis of the returns on market instruments that are available to investors*'.

In other words, the use of real interest rates may be an appropriate approximation to the social rate of time preference. As noted above, the differences between estimation based upon the social rate of time preference and risk-free interest rates may be relatively small. All the same, the conceptual distinction is important, and most countries recognised that market interest rates do not fully reflect appropriate individual intertemporal preferences (because of imperfections in the economy), nor can they reflect the appropriate ethical dimensions of intergenerational decisions.

[45] It is reasonable to assume a degree of self-selection among respondent countries. Those with central guidance on the evaluation of projects, policies and programmes are also likely to have a designated contact (or department) to assist with enquires about evaluation, and are probably more likely to reply to information requests. It is a corollary that the 14 countries which did not respond are less likely to have centrally coordinated guidance on discounting informed by recent economic theory.

[46] At least this inconsistency is not new — Bazelon and Smetters (1999) discuss the variety of discount rates that are actually used by United States policymakers.

4.3.2 Consistency

As noted in section 4.2, discounting practice is highly inconsistent. One might expect (small) differences between national governments, because the appropriate discount rate is a function of future economic conditions and preferences (and uncertainty therein), which may differ between countries. That said, the differences between OECD countries are surprisingly large, from as low as 3% in Denmark up to 8-12% in Australia and 10% in New Zealand. It is highly unlikely that differentials in expected future growth rates can fully justify this difference.

Within Europe, many member states are adopting Commission guidance on discounting. With continued integration of European economies (such that convergence in future economic conditions might be expected), this trend is likely to be sensible.[47]

4.3.3 Accounting for uncertainty

A central and robust conclusion from the theoretical literature is that long-term social discount rates should be declining. At present, however, only two OECD countries have implemented this in their discounting guidance — France and the United Kingdom. This should change as the gradual process of 'intellectual technology transfer' occurs, and as other countries review their discounting guidance over the coming years.

4.4 Detailed country responses

Australia

The Australian Government uses different discount rates depending on the circumstances:

1. For property ownership and divestment decisions, a three tiered methodology is used depending on risk, currently discount rates at the three tiers are 12%, 10% and 8%, based on the CAPM approach.[48]

2. For public private partnerships (PPP) value for money assessments the current policy is to use the risk-free rate (Australian Government 10 year bond rate).

3. For capital proposals a flat 10% discount rate is used.

The State and Territory Governments in Australia use various discount rates for their own spending.[49] There are no specific discount rates for environmental projects, which is typically the responsibility of State and Territory Governments. Time varying discount rates are not currently employed.

The Australian Government has recently issued a handbook to its departments and agencies on cost benefit analysis (Commonwealth of Australia, 2006). This guidance reviews the social rate of time preference and social opportunity cost views, and concludes that the social opportunity cost approach is appropriate because it is roughly similar to the application of the social rate of time preference with the

[47] There is a relationship between the appropriate discount rate and the currency area, given that currency areas ought to (i) include nation-states with similar economic conditions, and (ii) membership of the Euro should have been encouraging convergence in member economies.

[48] See http://www.defence.gov.au/im/disposal/australian_government_property_ownership_framework.pdf.

[49] Departments can be contacted at www.finance.gov.au/GBPFAU/Private_Financing/private_financing_links.html

adjustment for the shadow value of capital.[50] The review does not mention the arguments for declining discount rates under uncertainty.

Austria

According to the Federal Ministry of Finance, the Kommunalkredit Austria AG has the mandate to administer federal support to environmental programmes. The Kommunalkredit apparently do not make use of social discount rates for the evaluation of environmental projects or policies.

The Federal Ministry of Finance indicated that there is no standardised social discount rate in Austria. This is because changes in the interest rate in recent decades made the use of discounting 'not very feasible'.

Canada

The Treasury Board of Canada Secretariat (TBS) published a Cost Benefit Analysis Guide in 1976 (updated in 1998) which recommends a 10% real discount rate. Sensitivity analysis is recommended using 8% and 12% real discount rates. This rate reflects both (i) the opportunity cost of capital in the private sector; and (ii) a social rate of time preference for consumption of 4%, adjusted for the shadow price of investment funds deemed to be $2.50. The discount rate does not vary over time.

However, discounting guidance has not been used lately, in recognition that the discount rate proposed seems high. The TBS is currently reviewing the guidelines, and it is likely that a new standard will be adopted. Recently, Environment Canada has been using a real discount rate of 7% with sensitivity analyses at 5% and 9%.

Czech Republic

At present there is no central guidance on the use of discount rates in assessment procedures for projects financed from public budgets. This is because there has been only little use of cost benefit analysis in policy making.

For long-term environmental projects, the Ministry of the Environment has recently adopted a real discount rate of 1%, based on the real interest rates of long-term government borrowing (a nominal rate of 4% less 3% assumed inflation). The rational is based on opportunity cost.

When the project costs are shared between the public and the private sectors, a weighted average discount rate is applied (where the weights are the shares of public and private capital respectively). When the private company is larger than 100 employees, the private rate is assumed to be 7% nominal (currently 4% real).

The Ministry of the Environment has submitted these recommendations to the Office of the Government of the Czech Republic for potential wider application across government. However guidance on cost benefit analysis is now the responsibility of the Ministry of the Interior, and no response has been forthcoming thus far.

[50] See section 1.1 above.

Denmark

The Danish Ministry of Environment recommends combining the consumption discount rate with the shadow price of capital in order to take into consideration the opportunity costs from foregone investments. The consumption discount rate is based on the social time preference rate and set to 3%. The shadow price of capital is based on an alternative rate of return of 6% and a consumption discount rate on 3%.

In contrast to the Ministry of Environment, the Danish Ministry of Finance recommends a 6% discount rate, reflecting opportunity cost from other projects before tax, and after depreciation.[51] Given the different guidance between ministries, a sensitivity analysis is usually conducted to consider the impact of using both discount rate schemes.

Apparently, the trend in the Ministry of Environment is increasingly towards using the Ministry of Finance number (6%) and supplementing this with a sensitivity analysis using 3% combined with the return on investment factor. This trend is especially evident in analyses where the Ministry of Finance is involved. All other institutions (e.g. The Danish Energy Agency, Ministry of Transport etc.) use the recommendations from the Ministry of Finance.

There are no specific recommendations for projects with very long-run impacts and time-varying discount rates are not applied. The Danish Ministry of Environment will revise its guidelines for cost benefit analysis from 2000. Also The Ministry of Finance will update their guidelines from 1999. Both revisions are expected to be finalised in 2007.

European Commission

The European Commission Guidelines for Impact Assessment[52] recommend a discount rate of 4%, which 'broadly corresponds to the average real yield on longer-term government debt in the EU over a period since the 1980s'.[53] This is intended to reflect social time preference.[54] Prior to the introduction of this guidance, a variety of discount rates were employed without any systematic difference in theoretical underpinning. Importantly, Annex 12 of the European Commission Guidelines states that 'for some cases involving very long horizons – such as the effects of climate change – it may be appropriate to use a lower discount rate. This might be justified by the longer-term implications of sustainable development and in particular, the need to take proper account of the preferences of future generations (for more on this see 'Discounting and sustainability: Issues on the choice of discount rate for long-term environmental policy', background paper prepared for ENVECO meeting, 2-3 June 1999).'

For projects financed from EU Structural Funds, the Commission draws a distinction between the *financial* discount rate for 'financial analysis' and the *economic* discount rate which is employed in socio-economic cost benefit analysis. The financial discount rate is 'limited to' 6% in real terms for all projects, although it may be increased to 8% in new member states or current candidate countries where they would have difficulty obtaining finance at a lower rate. The United Kingdom employs a financial discount rate of 3.5%, while the Czech Republic employs 6%.

[51] Vejledning i udarbejdelse af samfundsøkonomiske konsekvensvurderinger, Finansministeriet, 1999.

[52] See http://europa.eu.int/comm/secretariat_general/impact/docs/SEC2005_791_IA%20guidelines_annexes.pdf.

[53] Annex 12, p 39, footnote 90.

[54] European Commission communication to OECD Environment Directorate, 21 December 2005.

The economic discount rate is chosen by the beneficiary state, and must be consistent across all projects in that state. The Guide to Cost-Benefit Analysis advises using a rate of 5% for all projects whatever the sector.[55]

Finland

The role of discounting in evaluating environmental projects in Finland is 'relatively minor', although in a recent example on noise abatement a 5% discount rate was employed. The Ministry of Transport and Communications also recommend 5% including for environmental considerations. Time-varying discount rates do not appear to be applied.

France

Environmental projects in France are evaluated according to the general approach for public projects, for which le Commissariat Général du Plan takes responsibility.[56] A constant discount rate of 8% was employed until a recent revision in January 2005. Since then, the official discount rate has been 4% for costs and benefits accruing within 30 years, falling to 2% for costs and benefits beyond 30 years.[57] Review of official discounting guidance is intended over a five year cycle.

Hungary

The zero-coupon yield curve derived from government bonds is employed to evaluate public projects and policies in Hungary. This yield curve is reviewed and published quarterly by the Government Debt Management Agency.

By law all projects exceeding HUF 50 billion (€ 200 million) in net present value have to be approved by the Parliament, and the discounting method for this is set by a Government decree. Currently, the Government Debt Management Agency is using the zero coupon method. Since October 2005, maturity has been extended to 35 years where yields over the longest maturity Hungarian Government Bond (15 years) are approximated by the appropriate Euro yield plus a risk premium. As such, the shape of the discounting factors depends on the shape of the HUF and Euro denominated zero coupon yield curves.

Ireland

The same basic discount rate (called the 'test discount rate') is used in all cost-benefit and cost-effectiveness analyses of public sector projects. The recommended TDR is 5% in real terms, although this is intended to be adjusted from time to time when there are significant changes in real interest rates and in the rate of return on investments in Ireland.[58]

Luxembourg

The Luxembourg Ministry of Environment does not currently evaluate the costs of policies, projects or of inaction using discount rates, and doing so in house is currently not considered to be feasible.

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[55] It is unclear why this is inconsistent with the 4% guidance for impact assessment.

[56] Further information is available on their website at www.plan.gouv.fr.

[57] Prior to the legal implementation of this change, sensitivity analysis was commonly conducted at both an 8% and a 4% discount rate.

[58] See Irish Department of Finance (1994).

New Zealand

The Ministry for the Environment[59] uses the general public sector discount rate of 10% for the evaluation of projects and policies. Sensitivity analysis is usually run to determine the effects of lower and higher rates. In cases where officials and analysts consider the 10% rate too high, then agreement has been reached with Treasury officials to present the results of an alternative discount rate alongside the agreed rate. For example, 7.5% was employed in the case of the Project Aqua cost-benefit analysis.[60]

Special discount rates are not applied, as standard practice, for projects or policies with very long-run impacts, although a case may be made to Treasury for a special exemption. Treasury state that "it is anticipated that, in New Zealand, lower discount rates would be used only in exceptional circumstances" in their guidance material.

The Ministry is unaware of any case of time-varying rates being used. There is no specific guidance on the application of discount rates in the evaluation of environment-related projects and policies. There is guidance available on cost-benefit analysis, regulatory impact statements and Section 32 of the Resource Management Act (essentially the cost-benefit criterion of the Act, which the Ministry administers).

The New Zealand Treasury recently reviewed the conceptual basis for the discount rate, along with the calculation method (Young, 2002).

Norway

The recommended discount rate is 4 % in real terms, consisting of a risk-free rate and a risk premium of both 2%. The standard rate is intended to be adjusted from time to time when there are significant changes in real interest rates and in the rate of return on investments in Norway.

In projects with significant systematic risk a risk premium of more than 2 % is recommended, for example 4 %, which is in line with the average return in the stock market.

The transportation sector employs a standard discount rate of 4.5 % in real terms.

Special discount rates are not applied for projects and policies with very long term impacts.

Slovak Republic

The Slovak Republic Ministry of the Environment employs a 5% discount rate for the evaluation of environmental impacts, as indeed it is for other impacts on society. This discount rate was set according to recommendation of the European Commission.

No special discount rates are employed for projects or policies with very long-run impacts. Many projects (e.g. water supply and treatment, flood prevention) have time horizons set to 30 years. This is usually the maximum horizon for which economic benefits and costs are considered. For all projects 5% discount rate is used.

No time-varying discount rates are applied — a discount rate of 5% is applied throughout the time horizon of analysis.

[59] With input from the Treasury and the Ministry for Economic Development.

[60] See http://www.med.govt.nz/ers/environment/cba-waitaki/final/index.html.

Spain

The Spanish Ministry of Environment uses a 5% discount rate for the evaluation of environmental projects, except for water infrastructure projects in which a 4% discount rate is used. The basis for this latter discount rate is the European Commission rules.

Sweden

Sweden currently employs a constant 4% discount rate, which will be reviewed in May 2006.

Switzerland

No standardised discount rate is employed in Switzerland.

Turkey

The discount rate is the interest rate on debt finance for the specific project.

United Kingdom

In the United Kingdom general guidance on discounting across all departments is centralised and contained in the HM Treasury (2003) Green Book. The discount rate is based upon the social rate of time preference, and is currently set at 3.5% for projects under 30 years. For longer horizon projects, the schedule of declining discount rates in Table 4 is employed.

Table 4: Declining discount rates in the United Kingdom

Period of years	**0-30**	**31-75**	**76-125**	**126-200**	**201-300**	**301+**
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

The rationale for this schedule of declining discount rates was uncertainty in future economic conditions (see section 3.5.3 above).

United States

The U.S. Office of Management and Budget issued "Circular A-4" in September 2003 to provide guidance to federal agencies for regulatory analyses. It applies to "economically significant" regulations (Executive Order 12866 on Regulatory Planning) which may have an annual effect on the economy of over $100 million.[61]

Circular A-4 requires the use of both 3% and 7% for conventional discounting. The 7% rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. The 3% rate is based on the social rate of time preference, and is described as being "appropriate when regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services)." The social rate of time preference is approximated by the real rate of return on long-term government debt.

[61] Also included are regulations which adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities.

If the policy at issue is expected to have substantial long term impacts, then in addition to discounting at 3% and 7%, the U.S. Environmental Protection Agency[62] and the Office of Management and Budget recommend conducting the standard discounting using a range of discount rates between 1% and 3% (e.g. 1%, 1.5%, 2% and 2.5%). The challenge is in defining "long term". Usually, long term is considered beyond a generation. For example, 50 years would probably require a sensitivity analysis of this nature. The guidelines note that there is little consensus in the economic literature on the appropriate treatment of such long term effects, but directs EPA analysts to include a "no discounting" scenario, displaying the non-discounted streams of benefits and costs over time.

Time-varying discount rates are virtually never applied in the U.S.

5. Recommendations for policy makers

5.1 Procedures for using cost-benefit analysis and discounting

The survey of discounting practice conducted for this paper yielded some important findings. The central policy recommendations following from those findings are that:

- Policy in OECD countries would be more likely to maximise social benefits if discounting (and cost-benefit analysis) were consistently employed;

- To facilitate this, central rules on discounting (and conducting cost-benefit analyses more generally) should be provided in each country;

- The rules should be mandatory, rather than just "guidelines", for investments over a particular threshold; and

- The rules should apply across all government departments to ensure consistency in policy making.

It was noted that although economic differences between countries might justify small differences in the appropriate social discount rate, the variance between country guidance appeared to go well beyond what could be justified.

Finally, because the discount rate is such a central variable in social cost benefit analysis, government guidance might recommend a procedure for sensitivity analysis, for instance by recommending analysis at several different discount rates.

5.2 Discounting schedules

The review of recent developments in discounting theory has produced insights that have already been rapidly incorporated into guidance in two OCED countries. The central policy recommendations from the theoretical survey are that:

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[62] The Environmental Protection Agency provides its own guidance for preparing economic analyses, available at http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html, which contains a discussion of different discounting methodologies but does not recommend a specific discount rate.

- Social discount rates should be estimated according to social rate of time preference;
- Risk-free market interest rates might serve as a rough proxy, although it is preferable to estimate the social rate of time preference from first principles, according to equation (2);
- The social discount rate should explicitly account for uncertainty in future macroeconomic conditions (as distinct from project-level uncertainty); and
- As such, in practice the appropriate discounting schedule for most, if not all, OECD countries will involve a discount rate that eventually declines with time.

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ANNEX 1: SURVEY BY COMMISSARIAT GENERAL DU PLAN (2005)

In their most recent revision of the French discount rate, le Commissariat Général du Plan (2005) provides a valuable summary of discounting practice in other countries, replicated in Table 5.

Table 5: Discount rates as listed by Commissariat Général du Plan (2005)

Country	Discount rate	Time horizon (years)
South Africa	8%	20-40
Germany	3%	Variable
Australia	6-7%	20-30
Canada	5-10%	20-50
Denmark	6-7%	30
United States	3-7%	Variable
Italy	5%	
France	8%	30
Hungary	6%	30
Japan	4%	40
Mexico	12%	30
Norway[63]	5%	25
New Zealand	10%	25
Netherlands	4%	30
Portugal	3%	20-30
Czech Republic	7%	20-30
United Kingdom	3.5%	30
Sweden	4%	15-60
European commission	5%	
World Bank	10-12%	

[63] According to a communication from Norway, the survey above should have reported a discount rate of 4% with a variable time horizon.

ANNEX 2: STUDY OF RIAS BY OECD (2004)

In a recent study of Regulatory Impact Assessment by the OECD, information was obtained on the social discount rate, presented in Table 6 below.

Table 6: Discount rates as listed by OECD (2004)

Country	Social Discount rate
Australia	While no social discount rate is specified in the RIS Guide, the ORR recommends, where applicable, the social discount rate endorsed by the Australian Government Department of Finance and Administration.
Austria	n.a.
Belgium	n.a.
Canada	Departments are encouraged to follow Treasury Board Secretariat's (TBS) guidelines on benefit-cost analysis. For long-term time horizons, TBS suggests using specialists to estimate discount rates and the suggested social discount rate is described as robust around 10%, with a range from 7.5 to 12%. A review of practices in Canada in 2002 suggests that practices in applying social discount rates in Canada are similar to practices in OECD and the US – generally, financial investment analyses use 7.5 to 12% discount rates whereas health/ environment studies use lower discount rates than the suggested 10%. Very short-term impact analyses, where discount rate would have little impact, may not be discounted at all.
Czech Republic	No common guidance is given concerning the discount rate
Denmark	The Danish discount rate is set to 6 percent (cf. the Danish manual to social economic analysis). The discount rate is thought to be in a reasonable interval of the theoretical concept: consumer's time preference (approx. to the interest rates the consumers must pay after taxes) and of the alternative payoffs of the capital. However it is recommended that the risk assessment also includes other discount rates to show the strength of the estimated results. Projects that are financed through public taxes are also estimated to have a 20 percent tax wrench on the net cost.
European Union	The discount rate is expressed in real terms (4.5%), taking account of inflation. This rate approximately corresponds to the average real yield on longer term government debt in the EU over a period since the early 1980s.
Finland	No
France	n.a.
Germany	Discount rates are applied when formal cost-benefit analysis are undertaken. The RIA Handbook offers methodological assistance.
Greece	No unified guideline on social discount rate
Hungary	A forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions from the most appropriate source (e.g.: rates of annual budget in case of short-term analyses, official assumptions of the National Bank of Hungary concerning mid- or long-term studies).
Iceland	n.a.
Ireland	No.
Italy	A Social discount rate is not officially defined. As a consequence the surveys regularly made by public bodies are considered as benchmarks.
Japan	n.a.
Korea (South)	The guideline recommends the price increase rate of recent several years, but the ministries do not use the same rate.
Luxembourg	n.a.
Mexico	Agencies select discount rates. However, due to the uncertainty regarding the estimates of quantitative costs and benefits, this is not a great concern. Collection of adequate data is a much more pressing concern.
Netherlands	n.a.
New Zealand	Discount rates usually only considered when formal cost/benefit analysis undertaken and costs expressed as Net Present Value – usually only in respect of moderately high to high impact proposals. Guidance from RIA Unit in MED suggests a range of discount rates (e.g., 5 – 7% pa for value of avoiding death or serious injury, government bond rate for proposals on government expenditure, a lower (unspecified) rate for environmental values).
Norway	Social discount rate is determined as risk-free discount rate plus addition for estimated social risk of each project. The risk-free discount rate equals pre-tax real returns on risk-free long-term capital investments (3.5 % from 2000).[64]
Poland	n.a.
Portugal	n.a.
Slovak Republic	n.a.

[64] According to a communication from Norway, the updated value is 2 % from 2005.

Spain	No.
Sweden	n.a.
Switzerland	n.a.
Turkey	No.
United Kingdom	The discount rate (3.5%) is determined by the formula R = p + e.g, where R is the discount rate; p is time preference of individuals; e is elasticity of marginal utility of consumption; g is annual growth in per Capita consumption. For more details on the discount rate, see "HMT Green Book" in web address: http://greenbook.treasury.gov.uk/annex06.htm
United States	The discount rate is based on the marginal pre-tax rate of return on an average investment in the private sector in recent years. This rate is usually the same rate as the interest rate on Treasury Notes and Bonds. Significant changes in this rate are updated by the OMB Circular which is updated around the time of the president's budget submission to Congress. It is recommended that the sensitivity analysis using other discount rate should be added if the use of such an alternative rate can be justified. For more details on the discount rate, see the web page: http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html

ANNEX 3: SURVEY BY SPACKMAN (2002)

Spackman (2002) provides a very helpful summary of data of discounting practice in some OECD countries, mostly collected by HM Treasury, summarised in Table 7 below.

Table 7: Discount rates in OECD countries at or before 2002

Country	Central guidance on appraisal and evaluation	Standardisation across government	Discount rate	Theoretical basis
Canada	Treasury Board Secretary issues 'benefit-cost analysis guide'.	Applied throughout national government.	Social discount rate of 10% real. Treasury guide of 1976 suggested range of 5-15%, but later revised to 8-12%.	Based on opportunity cost of foreign borrowing, foregone investment in the private sector, or foregone consumption.
France	No general guidance. Expert committee for *Commissariat General du Plan* prepared recommendation in 1995 for transport	Each sector draws up its own methodology, using the specified discount rate.	A real discount rate has been set since 1960. It was last examined in 1985 and set at 8% real.	1985 working group estimated cost of capital at 6%, but discount rate was set at 8% to keep a balance between public and private sector investment
Germany	Federal Finance Ministry publishes guidance.	Applied at federal level.	4% real	Average federal government refinancing rate over the past 5 years was 6% nominal. Average GDP deflator (2%) is subtracted, giving 4% real.
New Zealand	Finance ministry issues handbook on 'Estimating the cost of capital for crown entities and state owned enterprises', including capital budgeting and costing public services.	Project appraisal on departmental basis, following central broad methodology.	Varies with cost or benefit being discounted, following financial textbook conventions for private sector investment.	Based on Capital Asset Pricing Model (CAPM), using private sector comparators to estimate project betas.
Norway	Government wide recommendations	Departmental interpretations of central guidance	Set in 1978 at 7% real.	New proposal to use world prices as shadow prices (opportunity cost) for traded goods, with 3.5% real as the discount rate.
United Kingdom	Finance ministry issues guidance to all central government.	Central guidance, plus departmental guidance adapted to departmental needs.	6% real in most cases since 1989. Consideration being given to reducing rate(s) to around 4%, perhaps with shadow price of public spending.	Time preference and cost of capital both derived in 1989 as in range of 4%-6&%. 6% chosen from top of range, mainly because of belief that this would better motivate public enterprises.
USA	Office of Management and the Budget (OMB) issues a Capital Programming Guide (1997) and OMB Circular A-94.	Departments take note of OMB guidance but also have their own standards and guidelines.	7% real since 1992. For some purposes a shadow price (opportunity cost) of capital also recommended.	Based on average private return to capital in US in 1970s and 1980s. Before 1992 rate had been 10% real, based on private return to capital in 1960s.

ANNEX 4: EXAMPLE CERTAINTY-EQUIVALENT DISCOUNT RATES

Table 8 reports the certainty-equivalent discount rates for Australia, Canada, Germany and UK derived in Hepburn et al. (2006). The table shows each country commencing with a discount rate of 3.5% for comparison. In fact, there is no reason to artificially impose this particular initial discount rate — a recent mean appropriate to each country would suffice.

Table 8: Certainty-equivalent discount rates using a regime-switching model

Year	**Australia**	**Canada**	**Germany**	**UK**
1	3.50	3.50	3.50	3.50
20	2.98	3.13	3.46	3.34
40	2.98	2.99	3.41	3.31
60	2.95	2.84	3.35	3.29
80	2.91	2.75	3.28	3.25
100	2.88	2.67	3.20	3.22
150	2.79	2.45	2.99	3.13
200	2.68	2.26	2.68	3.03
250	2.52	2.07	2.31	2.91
300	2.28	1.93	1.84	2.97