2A Ethical Frameworks and Intertemporal Equity

2A.1 Ethical frameworks for climate change

The 'consequentialist' and 'welfarist' approach – the assessment of a policy in terms of its consequences for individual welfare – that is embodied in standard welfare economics is highly relevant to the ethics of climate change.

In Section 2.3, we described the standard approach to ethics in welfare economics i.e. the evaluation of actions in terms of their consequences for consumption by individuals of goods and services. We emphasised that 'goods and services' in consumption were multi-dimensional and should be interpreted broadly. In this appendix we examine that approach in a little more detail and compare it with different ethical perspectives of relevance to the economics of climate change.

For many applications of the standard theory, the community is defined as the nation-state and the decision-maker is interpreted as the government. Indeed this is often seen as sufficiently obvious as to go unstated. This is not, of course, intended to deny the complexities and pressures of political systems: the results of this approach should be seen as an ethical benchmark rather than a descriptive model of how political decisions are actually taken.

Nevertheless, questions such as 'what do individuals value', 'what should be their relation to decisions and decision-making', 'what is the decision-making process' and 'who are the decision-makers' arise immediately and strongly in the ethical analysis of climate change. These questions take us immediately to different perspectives on ethics.

Economics, together with the other social sciences, has in fact embraced a much broader perspective on the objectives of policy than that of standard welfare-economic analysis. Amartya Sen[1], for example, has focused on the capabilities and freedoms of individuals to live a life they have reason to value, rather than narrowly on the bundles of goods and services they consume. His focus is on opportunities and the processes that create them, rather than on outcomes only. Similar emphases come from discussions of equity[2] (with its focus on opportunity), empowerment[3], or social inclusion[4].

While such perspectives are indeed different, in practice many of the indicators arising from them would overlap strongly with the areas of focus in the Millennium Development Goals (MDGs) and other indicators commonly used by international institutions. Indeed, the MDGs were the outcome of analyses and discussions which themselves embraced a range of ethical approaches.

Impacts of climate change on future generations and other nations raise very firmly questions of rights. Protection from harm done by others lies at the heart of many philosophical approaches to liberty, freedom and justice.[5]

Protection from harm is also expressed in many legal structures round the world in terms of legal responsibility for damage to the property or well-being of others. This is often applied whether or not the individual or firm was knowingly doing harm. A clear example is asbestos, whose use was not prohibited[6] when it was placed in buildings with the worthy purpose of protecting against the spread of fire. Nevertheless insurance companies are still today paying large sums as compensation for its consequences.

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[1] Sen (1999).
[2] e.g. *World Development Report 2006*.
[3] e.g. Stern *et. al.* (2005).
[4] Atkinson and Hills (1998), Atkinson *et al*. (2002), Hills and Stewart (2005).
[5] See, for example, Shue (1999) on the 'no-harm principle' in the context of climate change and Gardiner (2004) for a link with John Rawls' theory of justice. From the point of view of jurisprudence, and for a discussion of links with notions of retribution, see Hart (1968).
[6] As Henry (2006) argued, the possibility of harmful effects had been discovered around 100 years go, but this would not necessarily be generally known by those whose used it.

This is a version of the 'polluter pays' principle that is derived from notions of rights, although, as we saw, for example, in the discussion of Fig. 2.1 above, it also arises from an efficiency perspective within the standard economic framework. If this interpretation of rights were applied to climate change, it would place at least a moral, if not a legal, responsibility on those groups or nations whose past consumption has led to climate change.

Looking at the moral responsibilities of this generation, many would argue that future generations have the right to enjoy a world whose climate has not been transformed in a way that makes human life much more difficult; or that current generations across the world have the right to be protected from environmental damage inflicted by the consumption and production patterns of others.

The notions of the right to climate protection or climate security of future generations and of shared responsibilities in a common world can be combined to assert that, collectively, we have the right only to emit some very small amount of GHGs, equal for all, and that no-one has the right to emit beyond that level without incurring the duty to compensate. We are therefore obliged to pay for the right to emit above that common level. This can be seen as one argument in favour of the 'contract and converge' proposition, whereby 'large emitters' should contract emissions and all individuals in the world should either converge to a common (low) level or pay for the excess (and those below that level could sell rights).

There are problems with this approach, however. One is that this right, while it might seem natural to some, is essentially asserted. It is not clear why a common humanity in a shared world automatically implies that there are equal rights to emit GHGs (however low). Equality of rights, for example to basic education and health, or to common treatment in voting, can be related to notions of capabilities, empowerment, or the ability to participate in a society. Further, they have very powerful consequences in terms of law, policy and structures of society. How does the 'right to emit' stand in relation to these rights? Rights are of great importance in ethics but they should be argued rather than merely asserted. More pragmatically, as we shall examine in Part VI of this report, action on climate change requires international agreement and this is not a proposition likely to gain the approval necessary for it to be widely adopted.

A concept related to the idea of the rights of future generations is that of sustainable development: future generations should have a right to a standard of living no lower than the current one.

In other words, the current generation does not have the right to consume or damage the environment and the planet in a way that gives its successor worse life chances than it itself enjoyed. The life chances of the next generation, it is understood here, are assessed assuming that it behaves in a sustainable way, as defined here, in relation to its own successor generation[7].

Expressed in this form, however, the principle need not imply that the whole natural environment and endowment of resources should be preserved by this generation for the next generation in a form exactly as received from the previous generation. The capital stock passed on to the next generation consists of many things, mostly in the form of stocks covering, for example, education, health, capital equipment, buildings, natural resources and the natural environment. The standard of living available to the next generation depends on this whole collection of stocks. A decline in one of them, say copper, might be compensated by another stock, say education or infrastructure, which has increased.

On the other hand, it seems quite clear that, at a basic level, the global environmental and ecological system, which provides us with life support functions such as stable and tolerable climatic conditions, cannot be substituted. The relation between emissions of GHGs and the risks to these functions is examined in detail in the Review, particularly Part II. The

[7] A valuable summary of the analytic background and foundations of sustainability is given by Anand and Sen (2000). See also Solow (1974).

commitment of Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) to 'achieve stabilisation of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic [i.e. human-induced] interference with the climate system' can be interpreted as just such a sustainability rule.

The notion of 'stewardship' can be seen as a special form of sustainability. It points to particular aspects of the world, which should themselves be passed on in a state at least as good as that inherited from the previous generation.

Examples might be historic buildings, particular pieces of countryside, such as National Parks, or even whole ecosystems such as tracts of primary tropical rainforest. This involves a particular interpretation of the responsibilities of the current generation in terms of a limit on its rights to property. Essentially, in this approach each generation has the responsibility of stewardship. Some would see the climate in this way, since it shapes so much of all the natural environment and is not straightforwardly substitutable with other capital. Others[8] might ask still more basic questions as to how we ought to live, particularly in relation to nature.

These different notions of ethics emphasise different aspects of the consequences of decisions for others and for the future. Nevertheless, the list of consequences on which they would focus for each generation are similar: above all consumption, education, health and environment.

And all the perspectives would take into account the distribution of outcomes within and across generations, together with the risks involved in different actions, now and over time. Hence in the Review we shall focus our analysis on the implications of action or inaction on climate change for these four dimensions.

How the implications on these four dimensions are assessed, will, of course, vary according to the ethical position adopted. How and whether, in making assessments, we attempt to aggregate over consequences (i) within generations, (ii) over time, and (iii) according to risk will be crucial to policy design and choice. When we do aggregate explicitly we have to be quantitative in comparing consequences of different kinds and for different people. We shall be paying special attention to all three forms of aggregation. Aggregation across dimensions poses different kinds of questions and problems, as was discussed in Section 2.3 above.

2A.2 Intertemporal appraisals and discounting[9]

Introduction: the underlying welfare framework for appraisal and cost-benefit analysis

Different strategies for climate change will yield different patterns of consumption over time. We assume that a choice between strategies will depend on their consequences for households now and in the future (see Chapter 2 and 2A.1 above, for a brief discussion of 'consequentialism'). The households to be included and examined in this weighting of consequences will depend on the perspective of those making the judgements: we assume here that the assessment is done from the perspective of the world as a whole. Narrower perspectives would include, for example, only those households associated with a particular country or region and would follow similar reasoning except that net benefits would be assessed for a narrower group. If all the perspectives are from narrow groups, one country, or just the next one or two generations, it is likely that little action would be taken on global warming. As is emphasised throughout this Review, this is a global and long-run issue.

An analysis of how to carry out an intertemporal assessment of consequences of strategies or actions is inevitable if somewhat formal: usually there would be first a modelling of the consequences, second an aggregation of the consequences into overall welfare indicators for households, and third an aggregation across households within generations, across

[8] Jamieson (1992).
[9] This section has benefited from discussions with Cameron Hepburn and Paul Klemperer, although they are not responsible for the views expressed here. See also Hepburn (2006).

generations and across uncertain outcomes. We focus here on the second and third elements, particularly the third.

We can compare the consequences of different strategies and actions by thinking of overall welfare, W, calculated across households (and generations) as a function of the welfare of these households, where we write welfare of household h as u^h. The joint specification of W and u^h constitutes a set of value judgements which will guide the assessment of consequences. We think of h as ranging across households now and in the future and can allow (via specification of W and u^h) for the possibility that a household does not live forever. Then, if we are comparing a strategy indexed by the number 1 with that indexed by zero we will prefer strategy 1 if

$$W^1 > W^0 \tag{1}$$

where W^1 is evaluated across the path 1 with its consequences for all households now and in the future, and similarly W^0.

In the above, the two strategies can yield very different patterns of outcomes across individuals and over time – they can differ in a non-marginal way. There is, however, a major part of economic theory that works in terms of a marginal change, for example an investment project. Then we can write, where W^1 is welfare in the world with the project and W^0 is welfare in the world without the project,

$$\Delta W \equiv W^1 - W^0 = \sum_h \frac{\partial W}{\partial u^h} \Delta u^h \tag{2}$$

where Δu^h is the change in household welfare for h as a result of the project. Calculating Δu^h will then depend on the structure of the economic model and the characteristics of the project. This is the theory of cost-benefit analysis set out clearly by James Meade (1955) and explored in some detail by Drèze and Stern (1987) and (1990) for imperfect economies.

As we have argued, strategies on climate change cannot be reduced to marginal comparisons, so we have to examine W^1 and W^0 (for different strategies) and, for many climate change questions, we must compare the two without using the very special case of marginal comparisons as in equation (2).

Nevertheless there will be investment projects that can be considered as small variations around a particular path e.g. a new technique in electricity generation. In this case marginal analysis can be appropriate. In this context we can think about comparing benefits occurring at different points in time, in terms of how we should value small changes around a particular path. This leads to the subject of discounting and how we value marginal benefits that are similar in nature but which occur at different points in time. We must emphasise very strongly that these valuations occur with respect to variations around a particular path. If the path is shifted, so too are the marginal valuations and thus, discount factors and rates (see below).

An investment carried out now may yield returns which are dependent on which strategy, and thus which growth paths, might be followed. If we are uncertain about these strategies, for example, we do not know whether the world would follow a strong mitigation strategy or not, then we should evaluate the project for each of the relevant scenarios arising from the strategies. Each of these evaluations would then be relative to a different growth path. The next step would not be straightforward. We could aggregate across the scenarios or growth paths using probabilities and relative values of social marginal utilities relevant for the different paths (i.e. we would have to compare the numeraire used for each path) but only if we are in a position to assign probabilities. Further, a related discussion over strategies may be going on at the same time as the projection evaluation.

Discounting: a very simple case

Discounting and discount rates have been controversial in environmental economics and the economics of climate change, because a high rate of discounting of the future will favour avoiding the costs of reducing emissions now, since the gains from a safer and better climate in the future are a long way off and heavily discounted (and vice versa for low discount rates). Our first and crucial point has been made already: discounting is in general a marginal approach where the evaluation of marginal changes depends on the path under consideration. If the two paths are very different, a marginal/discounting approach for comparing the two is unacceptable in logic – we have to go back to an evaluation of the underlying W for each path.

The discounting approach is, however, relevant for small changes around a given path and, since some of the literature has been somewhat confused on the issue and because it brings out some important issues relevant for this Review, we provide a brief description of the main principles here. To do this, we narrow down the relevant determinants of utility to just consumption at each point in time and take a very special additive form of W. Thus we think of the overall objective as the sum (or integral) across all households and all time of the utility of consumption. In order to establish principles as clearly as possible, we simplify still further to write

$$W = \int_0^{\infty} u(c) e^{-\delta t} dt \qquad (3)$$

We assume here that there is just one individual at each point in time (or a group of identical individuals) and that the utility or valuation function is unchanging over time. We introduce population and its change later in the discussion.

In Chapter 2 we argued, following distinguished economists from Frank Ramsey in the 1920s to Amartya Sen and Robert Solow more recently, the only sound ethical basis for placing less value on the utility (as opposed to consumption) of future generations was the uncertainty over whether or not the world will exist, or whether those generations will all be present. Thus we should interpret the factor $e^{-\delta t}$ in (3) as the probability that the world exists at that time. In fact this is exactly the probability of survival that would apply if the destruction of the world was the first event in a Poisson process with parameter δ (i.e. the probability of an event occurring in a small time interval Δt is δΔt). Of course, there are other possible stochastic processes that could be used to model this probability of survival, in which case the probability would take a different form. The probability reduces at rate δ. With or without the stochastic interpretation here, δ is sometimes called 'the pure time discount rate.' We discuss possible parameter values below.

The key concept for discounting is the marginal valuation of an extra unit of consumption at time t, or *discount factor*, which we denote by λ. We can normalise utility so that the value of λ at time 0 along the path under consideration is I. We are considering a project that perturbs consumption over time around this particular path. Then, following the basic criterion, equation 2, for marginal changes we have to sum the net incremental benefits accruing at each point in time, weighting those accruing at time t by λ. Thus, from the basic marginal criteria (2), in the special case (3), we accept the project if,

$$\Delta W = \int_0^{\infty} \lambda \Delta c dt > 0 \qquad (4)$$

where λ and c are each evaluated at time t, Δc is the perturbation to consumption at time t arising from the project and λ is the marginal utility of consumption where

$$\lambda = u'(c) e^{-\delta t} \qquad (5)$$

If, for example, we have to invest to gain benefits then Δc will be negative for early time periods and positive later.

The rate of fall of the discount factor is the *discount rate,* which we denote by ρ. These definitions and the special form of λ as in (5) are in the context of the very strong simplifications used. Under uncertainty or with many goods or with many individuals, there will be a number of relevant concepts of discount factors and discount rates.

The discount factors and rates depend on the numeraire that is chosen for the calculation. Here it is consumption and we examine how the present value of a unit of consumption changes over time. If there are many goods, households, or uses of revenue we must be explicit about choice of numeraire. There will, in principle, be different discount factors and rates associated with different choices of numeraire – see below.

Even in this very special case, there is no reason to assume the discount rate is constant. On the contrary, it will depend on the underlying pattern of consumption for the path being examined; remember that λ is essentially the discounted marginal utility of consumption along the path.

Let us simplify further and assume the very special 'isoelastic' function for utility

$$u(c) = \frac{c^{1-\eta}}{1-\eta} \qquad (6)$$

(where, for η=1, u(c) = log c). Then

$$\lambda = c^{-\eta} e^{-\delta t} \qquad (7)$$

and the discount rate ρ, defined as $-\dot{\lambda}/\lambda$, is given by

$$\rho = \eta \frac{\dot{c}}{c} + \delta \qquad (8)$$

To work out the discount rate in this very simple formulation we must consider three things. The *first is* η, which is the elasticity of the marginal utility of consumption.[10] In this context it is essentially a value judgement. If, for example η=1, then we would value an increment in consumption occurring when utility was 2c as half as valuable as if it occurred when consumption was c. The *second is* $\dot{c}/c$, the growth rate of consumption along the path: this is a specification of the path itself or the scenario or forecast of the path of consumption as we look to the future. The *third is* δ, the pure time discount rate, which generates, as discussed, a probability of existence of $e^{-\delta t}$ at time t (thus δ is the rate of fall of this probability).

The advantage of (8) as an expression for the discount rate is that it is very simple and we can discuss its value in terms of the three elements above. The Treasury's Green Book (2003) focuses on projects or programmes that have only a marginal effect relative to the overall growth path and thus uses the expression (8) for the discount rate. The disadvantage of (8) is that it depends on the very specific assumptions involved in simplifying the social welfare function into the form (3).

There is, however, one aspect of the argument that will be important for us in the analysis that follows in the Review and that is the appropriate pure time discount rate. We have argued that it should be present for a particular reason, i.e. uncertainty about existence of future generations arising from some possible shock which is exogenous to the issues and choices under examination (we used the metaphor of the meteorite).

But what then would be appropriate levels for δ? That is not an easy question, but the consequences for the probability for existence of different δs can illuminate – see Table 2A.1.

[10] See e.g. Stern (1977), Pearce and Ulph (1999) or HM Treasury (2003) for a discussion of some of the issues.

Table 2A.1				
	Probability of human race surviving 10 years	Not surviving 10 years	Probability of human race surviving 100 years	Not surviving 100 years
δ = 0.1	0.990	0.010	0.905	0.095
0.5	0.951	0.049	0.607	0.393
1.0	0.905	0.095	0.368	0.632
1.5	0.861	0.139	0.223	0.777

For δ=0.1 per cent, there is an almost 10% chance of extinction by the end of a century. That itself seems high – indeed if this were true, and had been true in the past, it would be remarkable that the human race had lasted this long. Nevertheless, that is the case we shall focus on later in the Review, arguing that there is a weak case for still higher levels.[11] Using δ=1.5 per cent, for example, i.e. 0.015, the probability of the human race being extinct by the end of a century would be as high as 78%, indeed there would be a probability of extinction in the next decade of 14%. That seems implausibly, indeed unacceptably high as a description of the chances of extinction.

However, we should examine other interpretations of 'extinction'. We have expressed survival or extinction of the human race as either one or the other and have used the metaphor of the devastating meteorite. There are also possibilities of partial extinction by some exogenous or man-made force that has little to do with climate change. Nuclear war would be one possibility or a devastating outbreak of some disease that 'took out' a significant fraction of the world's population.

In the context of *project uncertainty,* rather different issues arise. Individual projects can and do collapse for various reasons and in modelling this type of process we might indeed consider values of δ rather higher than shown in this table. This type of issue is relevant for the assessment of public sector projects, see, for example, HM Treasury (2003), the Green Book.

A different perspective on the pure time preference rate comes from Arrow (1995). He argues that one problem with the absence of pure time discounting is that it gives an implausibly high optimum saving rate using the utility functions as described above, in a particular model where output is proportional to capital. If δ=0 then one can show that the optimum savings rate in such a model[12] is 1/η; for η between 1 and 1.5 this looks very high. From a discussion of 'plausible' saving rates he suggests a δ of 1%. The problem with Arrow's argument is, first, that there are other aspects influencing optimum saving in possible models that could lower the optimum saving rate, and second, that his way of 'solving' the 'over-saving' complication is very ad hoc. Thus the argument is not convincing.

Arrow does in his article draw the very important distinction between the 'prescriptive' and the 'descriptive' approach to judgements of how to 'weigh the welfare' of future generations – a distinction due to Nordhaus (see Samuelson and Nordhaus, 2005). He, like the authors described in Chapter 2 on this issue, is very clear that this should be seen as a prescriptive or ethical issue rather than one which depends on the revealed preference of individuals in allocating their own consumption and wealth (the descriptive approach). The allocation an individual makes in her own lifetime may well reflect the possibility of her death and the probability that she will survive a hundred years may indeed be very small. But this intertemporal allocation by the individual has only limited relevance for the long-run ethical question associated with climate change.

[11] See also Hepburn (2006).
[12] This uses the optimality condition that the discount rate (as in (8)) should be equal to the marginal product of capital.

There is nevertheless an interesting question here of combining short-term and long-term discounting. If a project's costs and benefits affect only this generation then it is reasonable to argue that the revealed relative valuations across periods has strong relevance (as it does across goods). On the other hand, as we have emphasised allocation across generations and centuries is an ethical issue for which the arguments for low pure time discount rates are strong.

Further, we should emphasise that using a low δ does not imply a low discount rate. From (8) we see, e.g., that if η were, say, 1.5, and $\dot{c}/c$ were 2.5% the discount rate would be, for δ= 0, 3.75%. Growing consumption is a reason for discounting. Similarly if consumption were falling the discount rate would negative.

As the table shows the issue of pure time discounting is important. **If the ethical judgement were that future generations count very little *regardless of their consumption level* then investments with mainly long-run pay-offs would not be favoured. In other words, if you care little about future generations you will care little about climate change. As we have argued, that is not a position which has much foundation in ethics and which many would find unacceptable.**

Beyond the very simple case

We examine in summary form the key simplifying assumptions associated with the formulation giving equations (3) and (8) above, and ask how the form and time pattern of the various discount factors and discount rates might change when these assumptions are relaxed.

Case 1 Changing population

With population N at time t and total consumption of C, we may write the social welfare function to generalise (3) as

$$W = \int_0^\infty Nu(C/N)e^{-\delta t}dt \qquad (9)$$

In words, we add, over time, the utility of consumption per head times the number of people with that consumption: i.e. we simply add across people in this generation, just as in (3) we added across time; we abstract here from inequality within the generation (see below). Then the social marginal utility of an increment in *total* consumption at time t is again given by (5) where c is now C/N consumption per head. Thus the expression (8) for the discount rate is unchanged. We should emphasise here that expression (9) is the appropriate form for the welfare function where population is exogenous. In other words we know that there will be N people at time t. Where population is endogenous some difficult ethical issues arise – see, for example, Dasgupta (2001) and Broome (2004, 2005).

Case 2 Inequality within generations

Suppose group i has consumption C_i and population N_i. We write the utility of consumption at time t as

$$\sum_i N_i u(C_i/N_i)e^{-\delta t} \qquad (10)$$

and integrate this over time: in the same spirit as for (9), we are adding utility across sub-groups in this generation. Then we have, replacing (5), where c_i is consumption per head for group i,

$$\lambda_i = u'(c_i)e^{-\delta t} \qquad (11)$$

as the discount factor for weighting increments of consumption to group i. Note that in principle the probability of extinction could vary across groups, thus making δ_i dependent on i.

An increment in *aggregate consumption* can be evaluated only if we specify how it is distributed. Let us assume a unit increment is distributed across groups in proportions α_i. Then

$$\lambda = \sum_i \alpha_i u'(c_i) e^{-\delta t} \qquad (12)$$

For some cases α_i may depend on c_i, for example, if the increment were distributed just as total consumption, so that $\alpha_i = C_i/C$ where C is total consumption. In this case, the direction of movement of the discount rate will depend on the form of the utility function. For example, in this last case, if $\eta=1$, the discount rate would be unaffected by changing inequality.

If $\alpha_i = 1/N$ this is essentially 'expected utility' for a 'utility function' given by u′( ). Hence the Atkinson theorem (1970) tells us that if $\{c_i\}$ becomes more unequal[13] then λ will rise and the discount rate will fall if u′ is convex (and vice versa if it is concave). The convexity of u′ ( ) is essentially the condition that the third derivative of u is positive: all the isoelastic utility functions considered here satisfy this condition[14].

For α_i 'tilted' towards the bottom end of the income distribution, the rise is reinforced. Conversely, it is muted or reversed if α_i is 'tilted' towards the top end of the income distribution. For example, where α_i = 1 for the poorest subset of households, then λ will rise where rising inequality makes the poorest worse off. But where α_N = 1 for the richest household, λ will fall if rising income inequality makes the richest better off. Note that in the above specification the contribution of individual i to overall social welfare depends only on the consumption of that individual. Thus we are assuming away consumption externalities such as envy.

Case 3 Uncertainty over the growth path

We cannot forecast, for a given set of policies, future growth with certainty. In this case, we have to replace the right-hand side of (5) in the expression for λ by its expectation. This then gives us an expression similar to (12), where we can now interpret α_i as the probability of having consumption in period t, denoted as p_i in equation (13). We would expect uncertainty to grow over time in the sense that the dispersion would increase. Under the same assumptions, i.e. convexity of u′, as for the increasing inequality case, this increasing dispersion would reduce the discount rate over time. Increased uncertainty (see Rothschild and Stiglitz, 1976 and also Gollier, 2001) increases λ if u′ is convex since λ is essentially expected utility with u′ as the utility function.

$$\lambda = \sum_i p_i u'(c_i) e^{-\delta t} \qquad (13)$$

Figure 2A.1 shows a simple example of how the discount factor falls as consumption increases over time, when the utility function takes the simple form given in equation (6). The chart plots the discount factor along a range of growth paths for consumption; along each path, the growth rate of consumption is constant, ranging from 0 per cent to 6 per cent per year. The value of δ is taken to be 0.1 per cent and of *η* 1.05. The paths with the lowest growth rates of consumption are the ones towards the top of the chart, along which the discount factor declines at the slowest rate. Figure 2A.2 shows the average discount rate over time corresponding to the discount factor given by equation (13), assuming that all the paths

[13] This property can be defined via distribution functions and Lorenz curves. It is also called second-order stochastic domination or Lorenz-dominance: see e.g. Gollier (2001), Atkinson (1970) and Rothschild and Stiglitz (1970).
[14] Applying the same theory to the utility function shows that total utility will be lower under greater inequality for a concave utility function.

are equally likely. This falls over time. For further discussion of declining discount rates, see Hepburn (2006).

Figure 2A.1

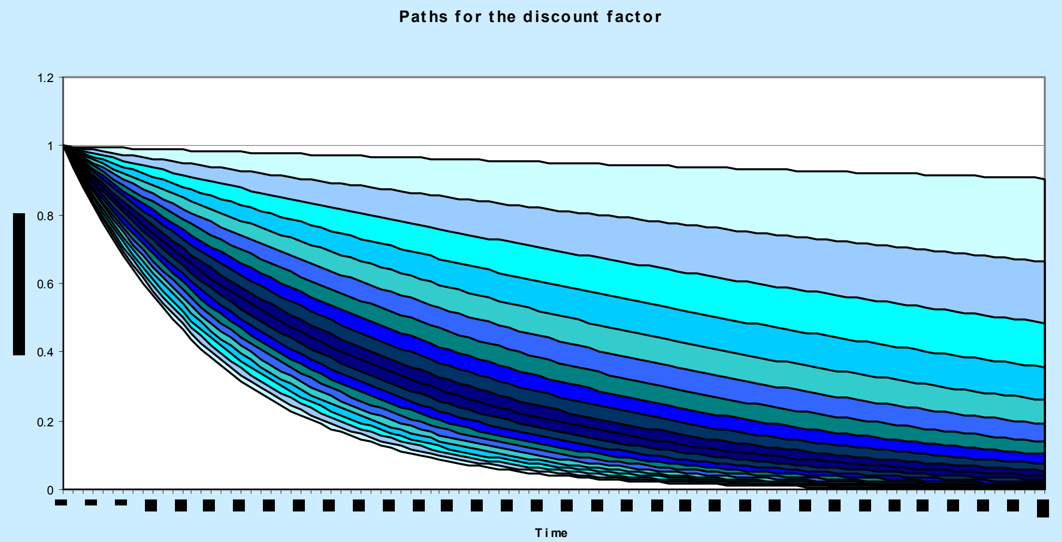
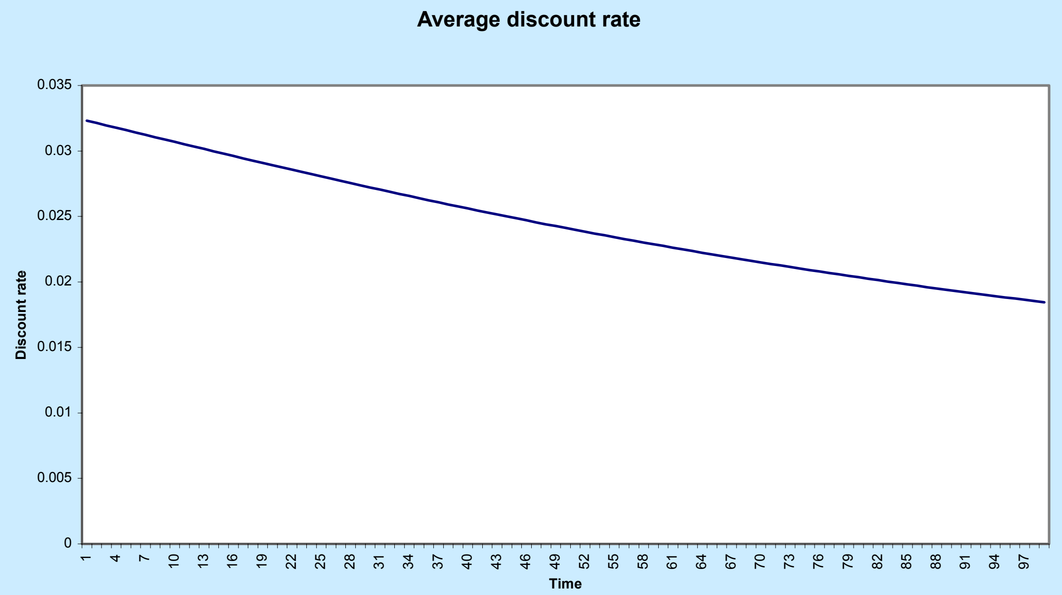


Figure 2A.2



Further complications

The above treatment has kept things very simple and focused on a case with one consumption good and one type of consumer, and says little about markets.

Where there are *many goods*, and *different types of household* and *market imperfections* we have to go back to the basic marginal criterion specified in (2) and evaluate Δu^h for each household taking into account these complications: for a discussion, see Drèze and Stern (1990). There will generally be a different discount rate for each good and for each consumer. One can, however, work in terms of a discount rate for aggregate (shadow) public revenue.

A case of particular relevance in this context would be where utility depended on both current consumption and the natural environment. Then it is highly likely that the relative 'price' of consumption and the environment (in terms of willingness-to-pay) will change over time. The changing price should be explicit and the discount rate used will differ according to whether consumption or the environment is numeraire (see below on Arrow (1966)).

Growing benefits in a growing economy: convergence of integrals.

We examine the special case (4) of the basic marginal criteria (2). The convergence of the integral requires λ to fall faster than the net benefits Δc are rising. Without convergence, it will appear from (4) that the project has infinite value. Suppose consumption grows at rate g and the net benefits at $\hat{g}$. From (8) and (4) we have that for convergence we need, in the limit into the distant future,

$$\eta g + \delta > \hat{g} \tag{14}$$

If, for example, g and $\hat{g}$ are the same (benefits are proportional to consumption) then for convergence we need, in the limit,

$$\delta > (1-\eta)g \tag{15}$$

Where $\eta \geq 1$ and $\delta > 0$, this will be satisfied. But for $\eta < 1$ there can be problems. Given that infinite aggregate net benefits are implausible this could be interpreted as an argument for a high η or more precisely a high limiting value of η. We have so far assumed that η is constant (the isoelastic case) but it could, however, in principle be higher for very high c. As we have indicated, arguments for a high δ should be conducted on a separate basis concerning the probability of existence, and we have, in this context, argued for a low value of δ.

Market rates, capital market imperfections and intergenerational welfare

Some may object that the discount rates that would arise from (8), e.g. 3-4% or lower, may not directly reflect market interest rates[15]. Further, it may be argued, market interest rates give the terms under which individuals actually do make intertemporal allocations and thus these market rates reflect individual marginal rates of substitution between goods now and in the future. Thus, in this argument, market rates should be used as discount rates.

There are a number of reasons why this argument may be misleading, including capital market imperfections and myopia. And the argument begs the question of which of the many different market rates of interest and return might be relevant. In this context, however, we would emphasise, as argued in Chapter 2, that the decisions at issue for the long-run analyses concern allocation *across generations* rather than within. One can confront these only by looking carefully at the ethical issues themselves. The intertemporal valuations of individuals over their own lifetimes, as we have argued, is not the same issue. They do not constitute a market-revealed preference of the trade-offs at stake here.

This is not the place for a detailed analysis of market imperfections, 'crowding out of investment' and discount rates. The reader may wish to consult Drèze and Stern (1987 and 1990) and some of the references therein, in particular Arrow (1966). An intuitive expression of the Arrow argument is as follows. The issue concerns the relative value of two forms of income, call this relative value μ. These different forms of income can be, for example, consumption, investment or government income. If μ is constant over time, then the discount rates, whether we work in terms of consumption, investment or government income, should be the same. The reason is that the difference between the two discount rates for the two

[15] However, these values are not far away from real long-run returns on government bonds.

forms of income is simply the rate of change of μ (since $\mu = \lambda^A / \lambda^B$ where λ are the discount factors for incomes type A and B respectively). The reason that μ is not unity arises from various market imperfections and constraints on the tax system (otherwise the government would shift resources so that λ^A is equal to λ^B). And if, the intensities of these imperfections and constraints are unchanged over time, then μ will be constant and the relevant discount rates will be equal.

2A.3 Conclusions

Discounting is a technique relevant for marginal perturbations around a given growth path. Where the strategies being compared involve very different paths, then discounting can be used only for assessing projects which involve perturbations around a path and not for comparing across paths. There will be important decisions for which marginal analysis is appropriate, including, for example, technological choices to sustain given paths of emission reduction. We must emphasise, however, that, as with any marginal analysis, the marginal valuations will depend on the paths under consideration. Which path or paths are relevant will depend on the overall strategies adopted.

Within the case of marginal perturbations, the key concept is the discount factor, i.e. the present value of the numeraire good: here the discount factor is the relative value of an increment in consumption at a time in the future relative to now. The discount factor will generally depend on the consumption level in the future relative to that now, i.e. on the growth path, and on the social utility or welfare function used to evaluate consumption. The discount rate is the rate of fall of the discount factor. It depends on the way in which consumption grows over time. If consumption falls along a path then the discount rate can be negative. There is no presumption that it is constant over time.

- If inequality rises over time then this would work to reduce the discount rate, for the welfare functions commonly used.

- If uncertainty rises as we go into the future, this would work to reduce the discount rate, for the welfare functions commonly used. Quantification of this effect requires specification of the form of uncertainty, and how it changes, and of the utility function.

- With many goods and many households there will be many discount rates. For example, if conventional consumption is growing but the environment is deteriorating, then the discount rate for consumption would be positive but for the environment it would be negative. Similarly, if the consumption of one group is rising but another is falling, then the discount rate would be positive for the former but negative for the latter.

Taken together with our discussion of ethics, we see that the standard welfare framework is highly relevant as a theoretical basis for assessing strategies and projects in the context of climate change. However, the implications of that theory are very different from those of the techniques often used in cost-benefit analysis. For example, a single constant discount rate would generally be unacceptable.

Whether we are considering marginal or non-marginal changes or strategies the ‘pure time discount rate’ is of great importance for a long-run challenge such as climate change. The argument in the chapter and in the appendix and that of many other economists and philosophers who have examined these long-run, ethical issues, is that ‘pure time discounting’ is relevant only to account for the exogenous possibility of extinction. From this perspective, it should be small. On the other hand, those who would put little weight on the future (regardless of how living standards develop) would similarly show little concern for the problem of climate change.

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